RNI: MAHENG/2016/68030 **VOLUME 8 (2023), ISSUE 1 : 1-8** **ISSN: 2456-5342 (print)**

MGMUNIVERSITY
JAWAHARLAL NEHRU
ENGINEERING COLLEGE

VISTA INTERNATIONAL JOURNAL ON ENERGY, ENVIRONMENT & ENGINEERING

VISTA

Regenerative architecture : A step ahead of sustainability

Rutuja Jadhav* and Sheetal Bagde
Department of Architecture, Jawaharlal Nehru Engineering College,
MGM University, Chhatrapati Sambhajinagar

***Corresponding Author's E-mail:** jadhavrutuja17@gmail.com **Mob.:** +91-8999880467

A B S T R A C T

A serious impact on the environment because of the increase in the demand of natural resources causes an increase in the ecological footprint and decrease in the biocapacity of the earth. There is need to fulfill the increasing demand of resources without causing any harm to the environment, there is a requirement of system which will constantly evolve and regenerate the natural resources. This research paper is investigated that the concept of regenerative architecture as a more advanced and effective approach to addressing environmental challenges compared to traditional sustainability practices.

The research paper begins by examining the limitations of sustainability, emphasizing its tendency to focus on reducing harm rather than actively promoting regeneration. It further discusses the urgent need for a paradigm shift in architectural practices towards regenerative design, which views buildings as integrated components of larger ecological systems.

Keywords : *Regenerative Architecture, Energy Regeneration, Circularity in Resources*

1. Introduction :

In 2020 global alliance for building and construction reported that, 36% of global energy is consumed by construction industry.[1] Also this is responsible for several amount of greenhouse gases emissions and huge amount of resources consumption. This amount of energy consumption creating non-negotiable negative impact on environment and human health. Sustainability is widely used concept in architecture, which majorly focused on fulfilling present need without hampering future, reducing consumption and minimizing waste. But sustainability comes with some limitation that, it is just a "less bad approach". Because of that regenerative, a new paradigm emerged. The regenerative architecture not only minimizes the negative impact, but also helps to restore the natural resource, helps in regenerate the system and creates positive impact.[2]

1.1. Need for Regenerative Design :

The population is increasing, and the growth rate of the population is 0.88% in 2022.[3] The demand for

resources increases as the growth rate increases. As result of the ecological footprint is increasing. The Biological capacity of the earth is decreasing over the years. India's biological capacity is 0.43 hectors which is low as compare to other countries.[4] Thus the earth overshoot dates are falling earlier as compared to the previous year. need 1.75 earth to fulfill the resource demand of the year 2022 depicted in Fig 1. [5] Another major reason of understanding regenerative design and regenerative energy is to understand the importance of on-site renewable energy. Most of the energy supply is dependent on non-renewable energy, in result of that environment is degrading, climate change such as global warming, acid rain, pollution, greenhouse gas emissions, carbon emission is occurred.[6] There is a need of a system which will incorporate the environment to fulfill resources demand and give positive impact on nature to overcome the negative environmental impacts.

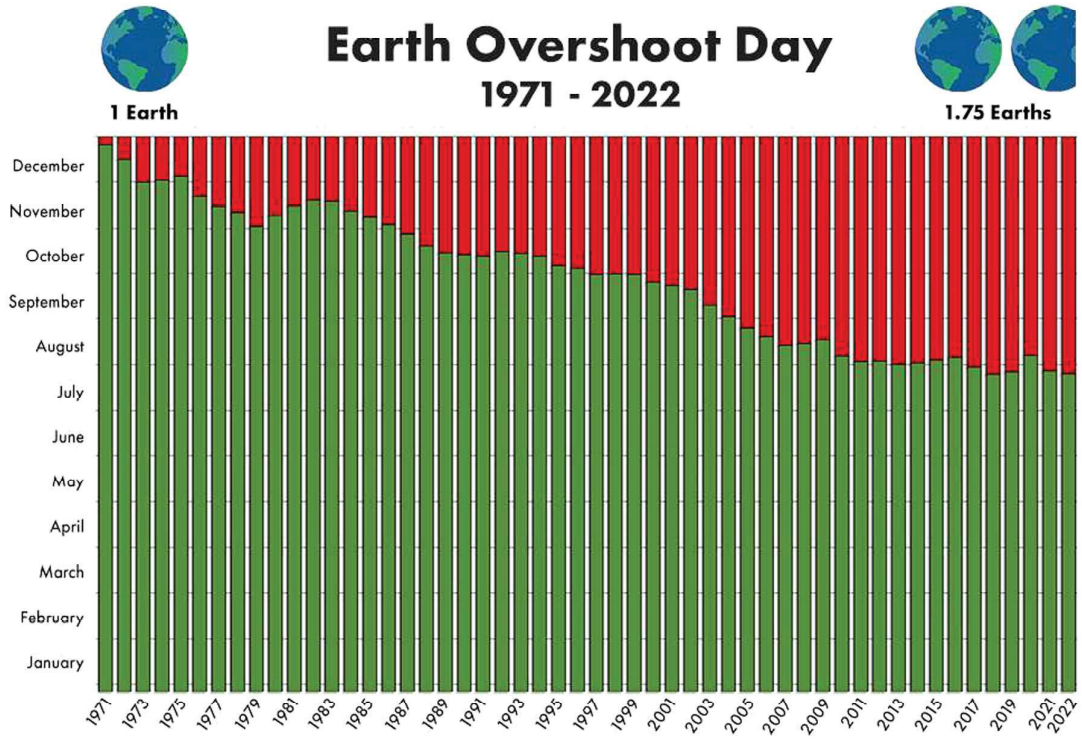

Fig. 1 Earth Overshoot Day 1971-2022[5]

1.2. Literature review :

There is a wide range of theories regarding regenerative architecture, there is no universal definition of it. The renowned architect s states nine principles in research paper named regenerative architecture: a pathway beyond sustainability.[2] The nine principles are whole design integration, integration into the landscape, intelligent limit, concentration, intelligent construction, bold ecology, community, and experience of place and culture.[2] The regenerative architecture was introduced by John T. Lyle in 1976 [7]

1.3. Background Study :

In 1994, Architect John Tillman Lyle first introduced the concept of regenerative architecture in his book "Regenerative design for sustainable development." Its starts more emerging in early 2000s. in 2002 William McDonough co-author of book "cradle to cradle: Remarking the way we make things" written about importance of Closed-loop system.[8] And most recent example is "Living Building Challenge "certification launched in 2006 by international Living Future Institute, Focused on restorative and regenerative buildings in architecture. There are number of annual summits and conferences are organized by academic institutes, for example

Regenerative Summit by Boston Architectural College, this summit covers topics such as, Circular economy and waste reduction, Net-zero energy and water system and urban resilience and climate change adaption.

2. Difference between Sustainability and Regenerative Architecture :

Sustainability and regenerative architecture both have same aims to reduce the adverse effect on environment. Sustainability has some limitations; it only focuses on reducing consumption of resources as well as waste and increase efficiency. While incase of regenerative architecture there is focus on restoring resources, minimize resources use, mainly contribute in natural resources regeneration and creates a closed-loop system which is nature-to-nature as shown in Fig 2.[9] Sustainability Reduce, Reuse and Recycle where, regenerative is Restore, Renew and Replenish as shown in fig 3.

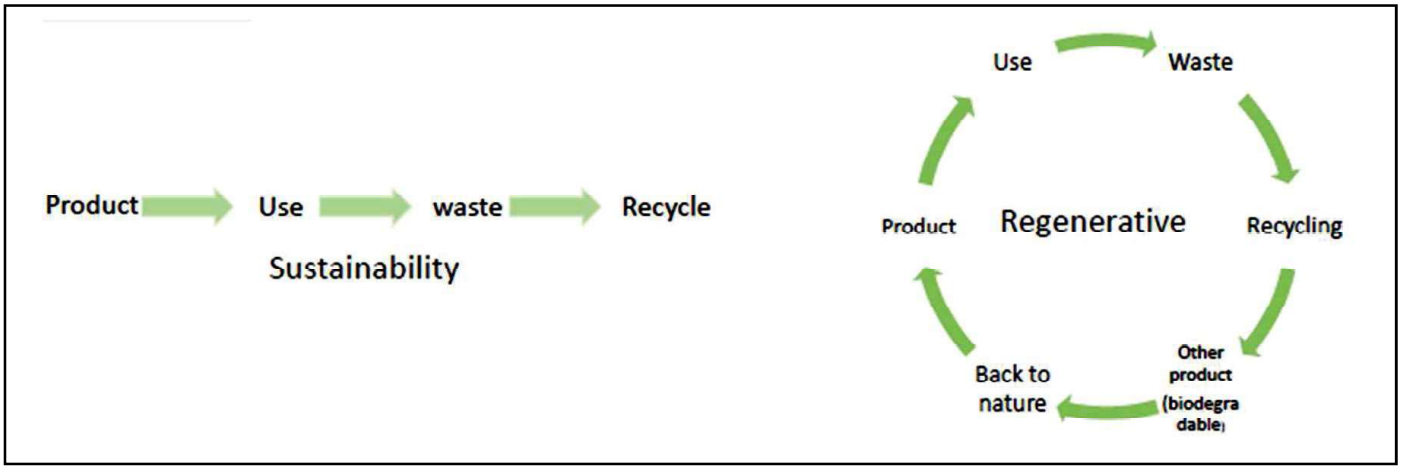

Fig.2 Difference between substantiality and regenerative approaches

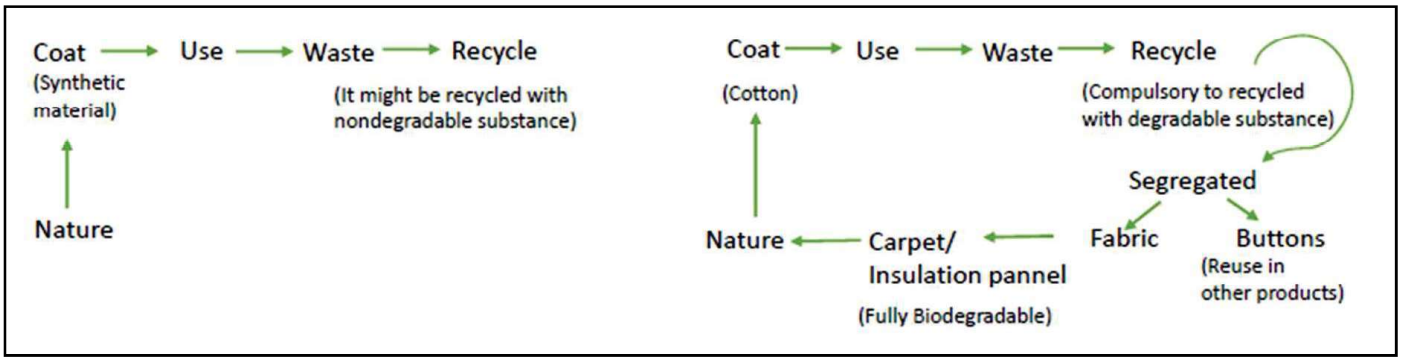

Fig.3 Example of substantiality and regenerative approaches

2.1. Shift from Sustainability to Regenerative Architecture :

A shift from sustainability to regenerative architecture is needed because sustainability addresses minimizing the consumption of resources and adverse effects on the environment which is not enough to address the issue we are facing currently. Regenerative architecture goes beyond reducing environmental impact, creating a built space that actively contributes to the health and well-being of the surrounding ecosystem. As shown in Fig. 4. conventional buildings deplete resources, and they are considered degenerative. Whereas practicing green buildings and net zero buildings helps to conserve resources. But practicing regenerative architecture helps to conserve resources at their full potential.

One example of regenerative design is the Bullitt Center in Seattle, Washington. The Bullitt Center is a six-story office building that is designed to be self-sustaining and regenerative. The building produces all of its own energy through a combination of solar panels and a geothermal system, and it also captures and treats its own water.[10]

The shift from sustainability to regenerative architecture is necessary because it offers a more comprehensive and proactive approach to addressing environmental and social challenges, and helps to create a more resilient and sustainable future for all. [11]

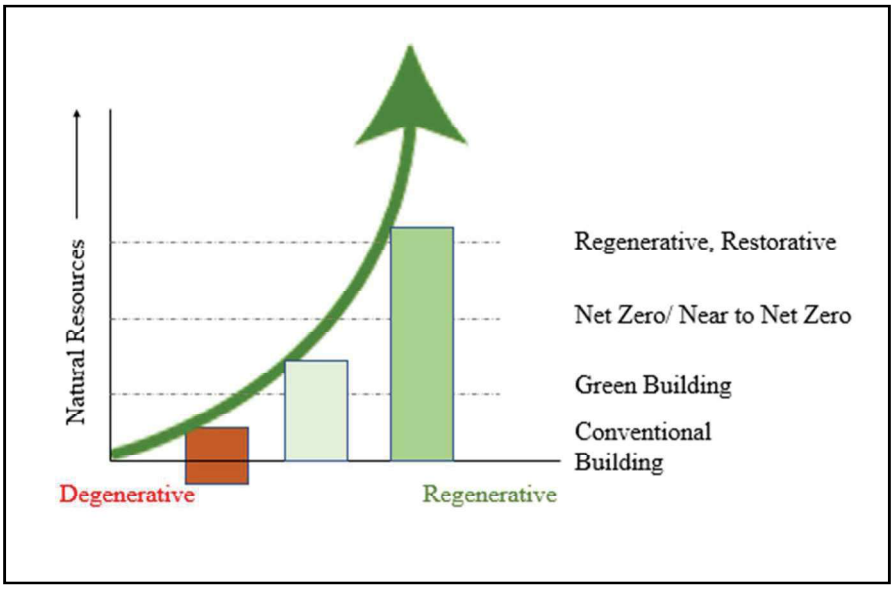

Fig.4 Bridge between Degenerative to Regenerative approaches

2.2. Neighborhood with regenerative energy system :

The building industry accounts for 40% of the total energy demand worldwide,[1]The migration causes and exponential increase in population of neighborhood. City including neighborhood creates major effect on environment because of high energy demand. Most of the energy demand of neighborhood is fulfill by non-renewable resources. , leading to an increase in carbon emission, greenhouse gases and eventually global warming and depletion of natural resources. At present most of the neighborhood is focused on net zero, but to achieve the aim, it is supposed to be net positive, which in turn will give back to the natural resources and the process will be closed-looped.

The study can be done on only building scale but to understand overall impact and energy exchange, the design principles of regenerative architecture should be applied on neighborhood level, to understand the major impacts which cannot be created by single building. In terms of infrastructure and services, mobility and public space.[12]

3. Case study :

Aim of the case studies is to understand the diverse ways in which regenerative architecture can be implemented at the neighborhood level. The case studies exemplify how these approaches go beyond mere sustainability by actively regenerating resources and systems, contributing to a more resilient and self-sustaining built environment.

The first case study selected is Magarpatta, a neighborhood known for its innovative waste management

system. In this case, energy is generated from waste through the process of biogas production. This method not only helps in waste reduction but also regenerates energy from the organic matter that would otherwise go to landfill. Magarpatta's use of biogas aligns with the regenerative approach by turning waste into a valuable resource for energy generation.

The second case study featured in the research paper is the Energy Vault, which exemplifies regenerative architecture through the utilization of wind power. This innovative application of wind power not only harnesses renewable energy but also demonstrates a regenerative process that recycles and reuses energy.

3.1. Case 1: Magarpatta City, Pune :

Magarpatta city, Pune is an integrated township spread over 400 acres, including commercial, residential and institutional areas with 30% of open space for landscape. Planted 25000 tress, one tree for 80 sq.m. it has Asia's largest solar water heater water treatment plants treat 4.5-million-liter water per day reuses as for landscape and keeping the IT building cool.

The energy demand of Magarpatta city is fulfilled by solar panel and biogas plant. The biogas has 8 Ton capacity, generates 400-450 cubic meter gas per day, which is equivalent to 20 LPG gas cylinders. By using both the system it is 70% self-resilience.[13] This township use circular approach in resources. The organic waste is converting into energy and that energy is used to fulfill on site energy demand. Also, use of fly ash to replace cement and fine aggregate. As result of that carbon emission by 130000 tones as shown in Figs. (5-6).

Fig.5 Biogas plant at Magarpatta city[14]

Fig.6 Solar panels at Magarpatta city[14]

3.2. Case 2: Energy Vault, Switzerland :

Energy vault is a 100m tall tower at the base of it there is 35 metric ton concrete blocks. When excess amount of energy is available by renewable resources, the crane at the center lifts concrete block at the top height of the crane using potential energy in blocks. When the energy is required crane lower down the blocks and the potential energy is converted into kinetic energy as shown in Fig.7.

The energy vault at Castione-Arbedo is prototype design to understand the efficiency and effectiveness of energy storage system. It stated that this system is scalable and potential to power thousands of homes, in controlled environment. i.e., it demands upon several parameters such as size, storage capacity and energy demand of local community.

This technology have more benefits compare to other energy storage solutions.[15] Recyclable material used to make the concrete bock, hence resources circularity in resources is taken into consideration.

Fig.7 Energy Vault Testing Tower in Castione-Arbedo[15]

3.3. Comparative analysis of case studies:

Parameters are used to conduct a comparative analysis of the case study Magarpatta and Energy Vault in terms of regenerative architecture. Each parameter helps to evaluate and compare the two projects based on specific aspects related to regeneration and sustainability.

Table.1 Comparative analysis of case studies

Parameter	Magarpatta township	Energy Vault
Energy Generation	Utilizes solar panels, wind turbines, and biogas to generate electricity on-site.	Stores excess energy generated from renewable sources
Regeneration	Incorporates green spaces, rainwater harvesting, and wastewater treatment systems	Utilizes gravity-based energy regeneration technology to store and release energy efficiently.
Scale	A sustainable township with a land area of around 430 acres.	A scalable solution that can be implemented at various scales, depending on energy storage needs.
Material Usage	Focuses on sustainable materials, such as Fly ash, bamboo, recycled materials, and low VOC	Utilizes concrete and recycled materials in the construction of the energy storage units.

While both regenerative and sustainability approaches aim to address environmental concerns, regenerative practices offer several advantages over traditional sustainability practices.

a. Holistic Approach: Regenerative practices take a holistic approach to design and development by actively working to restore and enhance ecosystems. As in Magarpatta township, Pays very close attention to every issue.

b. Emphasis on Regeneration and Replenishment: Regenerative practices prioritize replenishing and regenerating natural resources rather than solely conserving or using resources more efficiently.
c. Long-Term Resilience: Regenerative practices promote long-term resilience by creating systems that can adapt and thrive in the face of changing environmental conditions. In energy vault, the investment is high but it gives long term resilience.

4. Limitations :

There are several limitations to consider when exploring the concept of regenerative architecture in the context of energy-efficient neighborhoods.

a. Lack of Standards - A major limitation is limited research, there is no universal definition or principles in this paradigm. That makes this new paradigm more challenging to practice. There are no codes, regulations or standards to comply and make the deign regenerative.
b. Adaptability - Adaption of regenerative technology are bit difficult because, there is no much research about regenerative strategies also these strategies are not suitable for changing climatic patterns.
c. Cost - Some regenerative materials or technologies may require a large investment, which will make it less accessible in some region.
d. Site Limitation – Regenerative architecture is very site specific, parameters such as climate, topography, ecology, etc. Also regenerative is not applicable for all site because of lack of space, climatic conditions.

5. Conclusions :

The study draws the following key conclusions as follows:

1) Regenerative architecture has the potential to create a more sustainable and resilient future for our communities. By actively regenerating the natural systems upon which it depends, regenerative architecture goes beyond sustainability, creating buildings and communities that actively contribute to the health and well-being of the environment.
2) The case studies presented in this paper demonstrate the potential for positive shifts in sustainability and energy efficiency in the built environment. Both case studies used regenerative technologies to cater to environmental and climate crises.
3) Living building challenge and LEED also indulging restorative and regenerative principles in certification to make the world more resilient but those principles are not yet approved.

References :

[1] Globalabc, 2021 Global Status Report for Buildings and Construction https://globalabc.org/resources/publications/2021-global-status-report-buildings-and-construction accessed Dec. 09, 2022.

[2] J. A. Littman, Regenerative Architecture: A Pathway Beyond Sustainability, p. 74.

[3] World Population Growth Rate 1950-2023. www.macrotrends.net/countries/WLD/world/population-growth-rate accessed Mar. 17, 2023.

[4] Ecological Footprint by Country 2023, https://worldpopulationreview.com/country-rankings/ecological-footprint-by-country accessed Mar. 17, 2023.

[5] Earth Overshoot Day 2022 MoveTheDate, www.overshootday.org/ accessed Mar. 18, 2023.

[6] T. Wang, T. Khangaonkar, W. Long, and G. Gill, “Development of a Kelp-Type Structure Module in a

Coastal Ocean Model to Assess the Hydrodynamic Impact of Seawater Uranium Extraction Technology, 2014 J. Mar. Sci. Eng., vol. 2, no. 1, pp. 81–92.

[7] The Design Gesture, Regenerative Architecture: An Innovative Step Beyond Sustainability, https://thedesigngesture.com/regenerative-architecture/ accessed Dec. 09, 2022.

[8] S. Attia, Towards regenerative and positive impact architecture: A comparison of two net zero energy buildings,2016 Sustain. Cities Soc., vol. 26, pp. 393–406.

[9] ArchDaily, What is Regenerative Architecture? Limits of Sustainable Design, System Thinking Approach and the Future, Dec. 05, 2022. www.archdaily.com/993206/what-is-regenerative-architecture-limits-of-sustainable-design-system-thinking-approach-and-the-future accessed Dec. 10, 2022.

[10] Archello, Bullitt Center | The Miller Hull Partnership, Vitro Architectural Glass, Teknion, https://archello.com/project/bullitt-center-2 accessed Mar. 30, 2023.

[11] Replacing Sustainability With Regenerative Design, Apr. 07, 2022. https://urbandesignlab.in/replacing-sustainability-with-regenerative-design/ accessed Dec. 04, 2022.

[12] D. Waldron, A. Cayuela, and D. Miller, Regenerative Neighborhoods – scaling up from net positive buildings, p. 14, 2013.

[13] TERI Report on Sustainability Report 2017-18 www.magarpattacity.com/mp_sustainability_report_17-18.html accessed Feb. 04, 2023.

[14] Dilip, Eco Friendly Practices at Magarpatta City, Hadapsar Pune, Jun. 14, 2010. www.bharatestates.com/blog/eco-friendly-practices-at-magarpatta-city-hadapsar-pune, accessed Apr. 04, 2023.

[15] Energy Vault. www.energyvault.com/ev1 accessed Mar. 31, 2023.

RNI: MAHENG/2016/68030 **VOLUME 8 (2023), ISSUE 2 : 9-19** **ISSN: 2456-5342 (print)**

MGMUNIVERSITY
JAWAHARLAL NEHRU ENGINEERING COLLEGE

VISTA INTERNATIONAL JOURNAL ON ENERGY, ENVIRONMENT & ENGINEERING

VISTA

Analyzing the factors driving towards the implementation of Transit Oriented Development in Chh. Sambhajinagar (Aurangabad)

Sailee Dangre and Sheetal Bagde*
Department of Architecture, Jawaharlal Nehru Engineering College,
MGM University, Chhatrapati Sambhajinagar

***Corresponding Author's E-mail:** ar.sheetalbagde@gmail.com **Mob.:** +91-9168792599

A B S T R A C T

Rapidly growing industries and tourism in Chhatrapati Sambhajinagar (Aurangabad) and the constant rise in the population has brought about higher rate of motorization in the city. This is leading to various problems for the people like congestion, improper parking, etc. Constant increase in the number of private vehicles is observed in the city due to the lower waiting time and shortfall of public transport. A sustainable approach to diminish these problems is required urgently. A transit-oriented development is thus an approach that focuses on mixed land use that minimizes trips, increases accessibility of public transport and encourages walkability by the improvement of pedestrian network.

Some of the other cities in India like Delhi and Ahmedabad where massive investments are done to implement Transit Oriented Development (TOD) achieved some advancement which led to the adoption of mass transit reducing the use of private vehicles. This paper checks the need of transit-oriented development in Aurangabad by analyzing the factors that urge towards the implementation of TOD by comparing the current stateof transit in Aurangabad with the current conditions of Delhi and Ahmedabad. Comparison is done with respect to various factors and in some of them drawbacks of the system is also seen. In Ahmedabad and Delhi TOD regulated the traffic condition to certain extent.Likewise, the paper analyses the factors that drive towards the need of TOD in Aurangabad to regulate the traffic and fix the issues.

Keywords : *Transit oriented development (TOD), public transport, walkability, connectivity, private vehicles, traffic congestion*

1. Introduction :

In recent years, the population of India has increased tremendously. With that the need of connectivity also increased due to migration and employment opportunities. Figure 1 shows the relation between the population and motorization.

Aurangabad is the largest city in the Marathwada region with the population of 3,701,282 as per census 2011 and the total area 10,100 sq.km. [1]. The city being densely populated has 1365936 two wheelers 83533

cars with the total of 1748969 vehicles.Vehicles per thousand population in the city is 320 and the number of vehicles per km road length is 117 as of 2016-17.

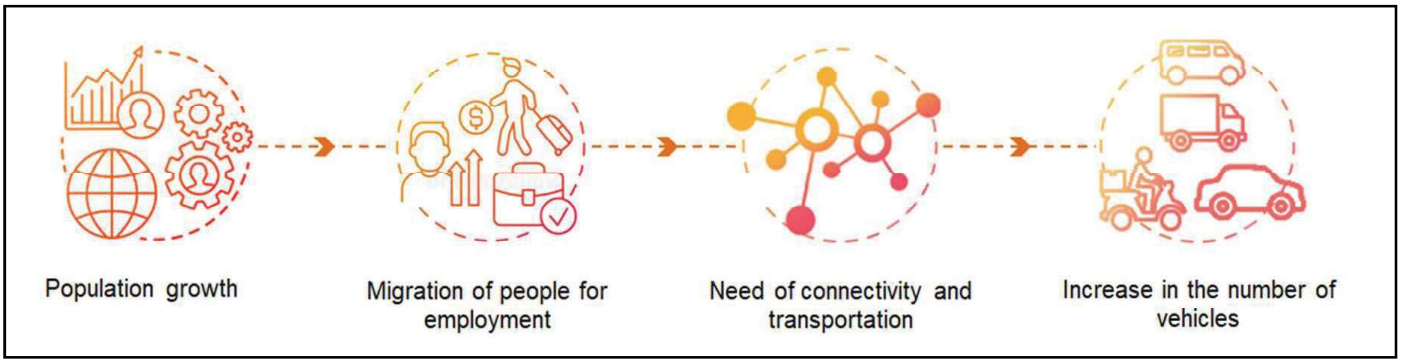

Fig.1 Relationship between Population growth and motorisation

Rise in the number of vehicles has led to many issues in the city like the deteriorating air quality due to the rise in motor vehicles and industries, traffic congestion due to the increased number of private vehicles, road side parking due to absence of parking space, smaller road widths due to encroachments of shops in old city area and bad road conditionas seen in Fig. 2.Some areas don't have footpaths for pedestrians so people walk on roads and no pedestrian signals on squaresare seen as shown in Fig. 3 and non-functioning traffic signals at some places as seen in Fig. 4. As the population in the city is rising the need of connectivity is also rising. But the use of public transport is decreased over the years leading to the increase in the private vehicles adding on to the pollution. Very less people in the city use public transport due to longer waiting time and the shortfall of it. The stipulated need of buses in a city of 14 lakh people is 560 buses but Aurangabad has less than 30 running.[2]

Fig.2 Bad Road Conditions

Fig.3 No pedestrian Signals

Fig.4 Absence of Traffic Signal

In the historical city where tourism is a forte and the four MIDC's providing employment to the local people, improving connectivity through sustainable Transit Oriented Developmentand boosting the number of public vehiclesto abbreviate the waiting time is foremost to encourage people to use public transport.

1.1 Transit Oriented Development (TOD):

Cities can grow in two ways scattered where distance between the work and home will be more and dense where it will be near and easily connected. TODis the planning strategy which increases the accessibility of

the transit stations by creating pedestrian and Non-Motorised Transport (NMT) friendly infrastructure that benefits large number of people thereby increasing the ridership of the transit facility lessens the impacts on environment and improving the economic and financial viability of the system.TOD focuses on the development of the areas near the transit, improve the transit network and access to transit stations by improving the pedestrian and non-motorised infrastructure in the city.

The Urban Development Department of the state has drafted and published the Maharashtra Urban Mobility Policy in June 2017 to counter the transportation issues. With sustainability at its core, the policy looks to develop transport systems in accordance which reduces burden on resources and most importantly, offers an equal space to every commuter. Hence, facilitating walking, cycling and usage of public transport."Every rupee spent by a city on public transport boosts its economy by four rupees!" said Mr Khatua, Director of Mumbai Technical Support Unit, at a workshop on the Maharashtra State Urban Transport Policy.[3] Like most of the other cities in India Aurangabad has also adopted the Smart City Mission where in TOD plays a crucial role. Metro is proposed in the city which will connect Waluj to Shendra and Bidkin to Harsul MIDC. No Mass Rapid Transit System (MRTS) connectivity between the city and MIDC is planned. So the condition of traffic in the city will remain the same.

Massive investments are done in urban transport in the Indian cities like Delhi and Ahmedabad. By this infrastructural and transit development advancement has been achieved which led to the adoption of mass transit to some extent. In the paper further both of these cases will be studied and compared with Aurangabad with respect to population and density, diversity of the area, design of transit, etc. The objective behind the study is to check the need of TOD in Aurangabad by comparing the conditions of these cities and explore the feasibility of TOD in Aurangabad.

1.2 Factors affecting TOD:

Transit-oriented development (TOD) is influenced by various factors that can have a significant impact on its success and effectiveness. The key factors affecting transit-oriented development are:

i) **Proximity to Transit:** The TOD's location within a short walking distance of transit infrastructure such as train stations or bus stops.

ii) **Land Use and Zoning:** The regulations and policies that determine the types of development allowed and their density, promoting mixed-use and reduced parking requirements.

iii) **Transportation Infrastructure:** The quality and availability of transportation networks, including roads, sidewalks, and bike lanes, that facilitate easy movement within and around the TOD.

iv) **Walkability and Pedestrian-friendly Design:** The design and layout of streets, sidewalks, and amenities that encourage walking and cycling and make the TOD attractive for pedestrians.

v) **Affordable Housing:** The provision of housing options that are affordable for people with various income levels, promoting socioeconomic diversity within the TOD.

vi) **Community Engagement and Stakeholder Collaboration:** The active involvement of community members and stakeholders in the planning and decision-making processes of the TOD.

vii) **Economic Viability and Market Demand:** The market conditions, availability of jobs, retail opportunities, and amenities that make the TOD financially sustainable and attractive to potential residents and investors.

viii) **Sustainability and Environmental Considerations:** The integration of environmentally friendly

practices, such as energy efficiency and reduced reliance on private vehicles, to promote a greener and more sustainable TOD.

ix) **Government Policies and Incentives:** Supportive policies, regulations, and financial incentives provided by the government to encourage and facilitate TOD development.

2. Analysis of current scenario of transit in Ahmedabad and Delhi

2.1. Current scenario of Transit in Ahmedabad:

River Sabarmati divides Ahmedabad, a growing metropolitan city in two regions. The old city area which is in the eastern region is a congested area comprising railway station, market, old buildings and temples. Another is the new city area on the western bank which comprises of new residential, institutional and commercial area. Like any other city with tremendous population Ahmedabad also faces the problems like congestion and more travel time which is the result of low use of public transport, more dependency on cars, more public vehicle ownership, etc. Newly metro inauguration in the city has taken place in order to increase the use of public transport in the city. The land use and social planning of the transit zones 200m on both sides of the metro stations is in the main focus now.In Ahmedabad the condition of bus rapid transit system (BRTS) is quite well but very little impact on development around the transit stations is observed.

Fig. 5 Ahmedabad BRTS Janmarg

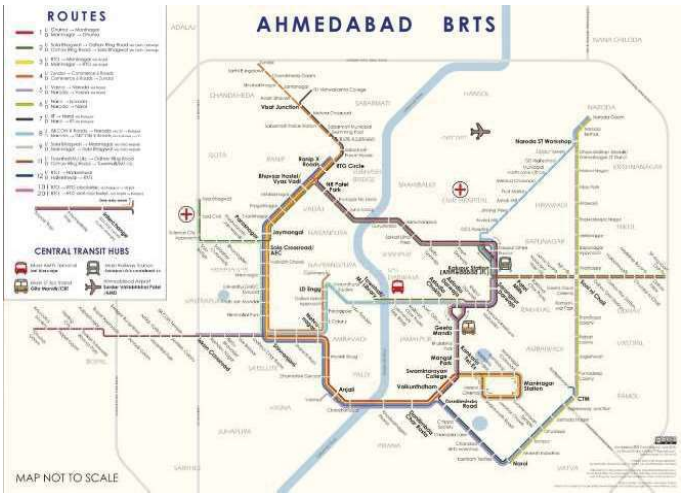

Fig. 6 Ahmedabad BRTS

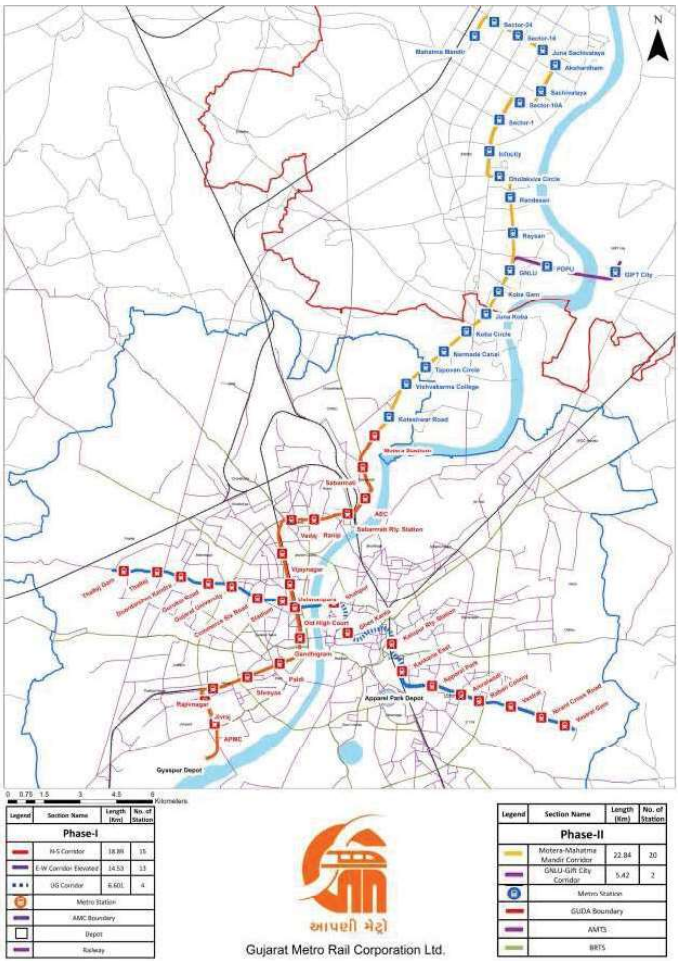

Fig. 7 Ahmedabad metro rail map

In the Fig.7, metro station plan of Ahmedabad which connects the east- west and north-south part is shown of which phase 1 is completed and phase 2 is expected to complete till 2024. In Ahmedabad 2 lines of metro connecting the important places of the city of which one line is along the river.

The above Fig.6is the BRTS map of Ahmedabad in which the stations are highlighted on every route. The BRTS of Ahmedabad is widely used mostly by the people but the development around the transit zones is yet to be improved.

2.2.Current scenario of Transit in Delhi

Delhi, the capital of India is divided into two parts, the old Delhi in the north and the New Delhiin the south. The road network of the city was originally designed for smaller population. With the rise of population due to migration the system became overloaded and redevelopment of the network started to manage the traffic by the construction of overpasses and underpasses for pedestrians, flyovers, widening of roads, etc.Like any other city with tremendous population Delhi also faces the problems like congestion and more travel time which is the result of low use of public transport, more dependency on cars, more public vehicle ownership, etc. To counter this problem DDA introduced metro in Dec, 2002.

The map in Fig. 8 shows the last mile connectivity of BRTS. The BRTS road network is strong in Delhi than MRTS but the longer waiting time and lesser number of buses than has encouraged the use of MRTS and lessen the use of BRTS.

Delhi metro is the largest metro system in India and has 10 metro lines operational in the city. MRTS is the widely used public transport in the city by the people due to the longer travelling time required due to traffic congestions in Delhi. Fig. 8 shows the metro lines in Delhi in different colours.

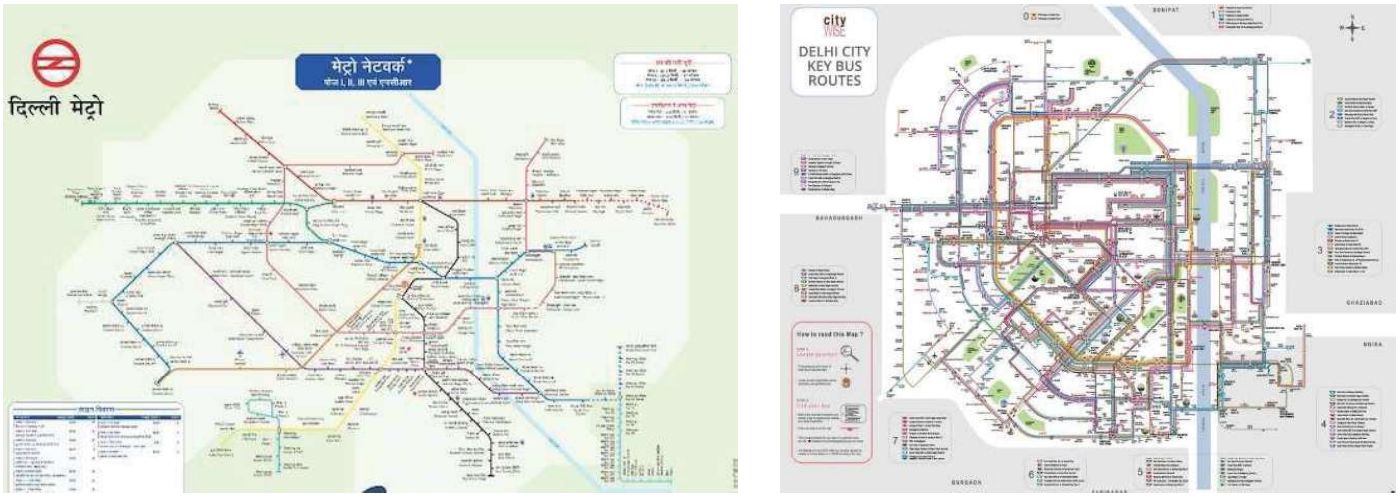

Fig.8 Metro network and City bus network of Delhi

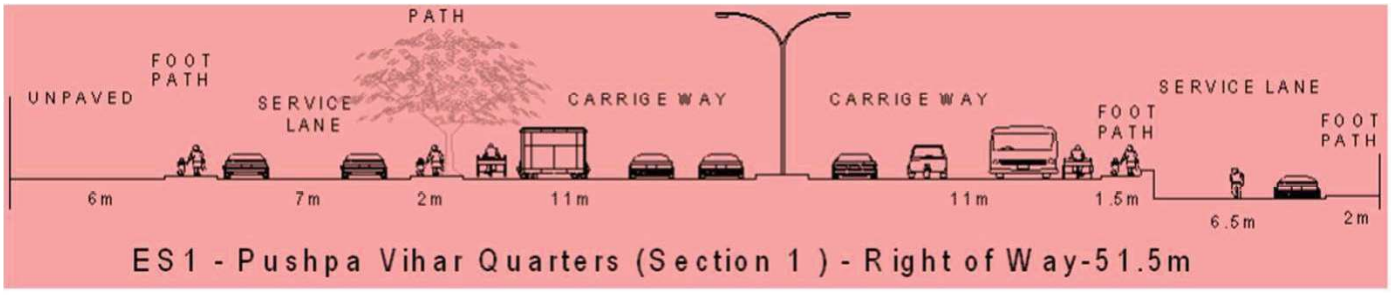

Fig.9a Before BRT road cross section

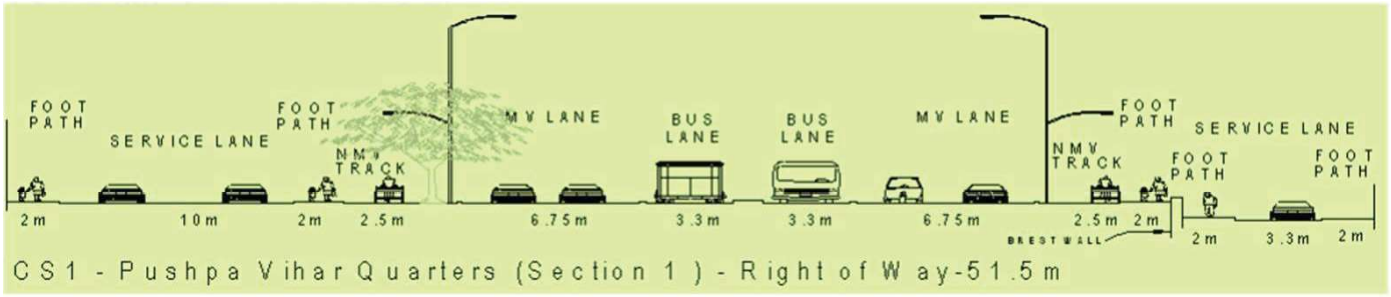

Fig. 9b After BRT road cross section

The Figs. 9 a,b shows the cross section of the road before and after the implementation of TOD. There were no specific lanes for buses before which was dangerous for the people with non-motorized vehicles. There were no footpaths on the service lane on the right side. Unpaved area on the left side as seen in before BRT cross section of road is the waste space. After BRT modifications are done to solve the issues and the road widths are increased. Specific lane is allotted for the bus near the bus station, service lane is designed properly with footpaths and space is allotted for non-motorized vehicles to avoid accidents. Footpaths are properly designed where needed keeping in mind the safety of the people. Provision of street lights on both the sides and proper utilization of the unused land by extending and providing more space for service lane is observed here.

3. Comparative analysis of TOD implementation :

Below is the comparative analysis of the current TOD scenario of Ahmadabad and Delhi compared with Aurangabad's current scenario with respect to the location and planning, TOD planning and design, transportation and infrastructure, users and community narrated in Tables 1-4.

Table 1. Location and planning

Factors	Ahmedabad	Delhi	Aurangabad	Analysis
1. Area	Eighth largest city in India with an area of 505 sq.km	Largest city in India with an area of 1397.3 sq.km.	City has an area of 138.5 sq.km	Area wise Aurangabad is a smaller city.
2. Population and density/ km2	2011 - 5,577,940. Urban / metropolitan- 6,361,084 Density- 11000/ km2. [4]	2011 - 11,034,555 Its urban / metropolitan population is 16,349,831. Density – 11320/ km2.[5]	2011 - 1,175,116; Its urban / metropolitan population- 1,193,167 Density- 8500/km2. [6]	TOD conditions vary due to higher population in Ahmedabad and Delhi necessitating more transportation infrastructure .
3. Planning Authority	AUDA (Ahmedabad Urban Development Authority)[7]	DDA (Delhi Development Authority)	AMC (Aurangabad Municipal Corporation)	Due to the population variation both the cities have specific authority allotted whereas Aurangabad still runs on MC.

Table 2.TOD planning and design

Factors	Ahmedabad	Delhi	Aurangabad	Analysis
1. Nature of TOD plans	TOD regulation prepared	TOD regulation prepared	TOD regulation prepared but not implemented.	TOD needs to be implemented in Aurangabad.
2. Increasing density along the transit stations	Encourage High densities along BRTS- 200m area on both sides – intensedevelopment zones with higher FSI of 4 will be allowed along 41km stretch. [9]	Encourage High densities along MRTS- 500m area on both sides FAR of 4 will be allowed. Compulsion is made for the projects within the influence zone to use minimum 20% FAR or residential and 30% for commercial. 20% area for green space.[12]	Density is seen more in the old city area. There are no transit nodes fixed here.	Increasing density and along the transit stations enables less trips and encourage walkability and provide accessibility to transit stations.
3. Land use diversity	Commissioned planning firms to prepare local area plan for TOZ. Mixed use is made compulsory in the TOD zone but the land use is kept flexible so that the market shall decide and not demarcated.	Mixed use, mixed income development near stations as desirable along the corridor. Development without onsite parking and mixed use is not permitted in the influence zones.	Mixed land use is seen at various places which can be demarcated as transit nodes.	With the development of transit stations the development around the stations also takes place slowly with varying landuses.
4. Design	Front margins increased with increased active frontage to encourage walkability. New pedestrian walkways are allowed within the block. The current scenario does not show much change in the frontages of the building even after the BRT launch.	Compulsion is made that the main façade of the building shall face the public street without setback to ensure active frontage. Transparency of minimum 50% should be made on the ground floor of a commercial shop. The current scenario is minimal active frontage along the streets.	Cycle tracks designed in some areas are not in use for cycling but used by the pedestrians and sometimes vehicles. Poor NMT connectivity is seen.	Improvement needs to be done in Aurangabad to encourage people to use the facilities that are made available to them.
5. Accessibility	Last mile connectivity is not addressed. Cycle tracks are very well designed at some places. Pathways are well designed but at some places obstacles are seen. Underground parking (public) is encouraged. Mixed use in the areas reduces the need to travel longer distances.	Additional parking other than the mandatory can be designed only as paid. 20% area of the plot in TODIS of 4Ha and above shall be designed for green open space for all the public. Less availability of cycling paths along the stations but considerable availability of shaded footpaths around the stations for accessibility at few stations.	No parking facility in the old city market area. On road parking is seen which lead to congestion of traffic. Some transit stations are away from the residential area.	Easy accessibility of transit stations – frequent use.

Table 3. Transportation and infrastructure

Factors	Ahmedabad	Delhi	Aurangabad	Analysis
1. Registered motor vehicles	2007 - 1.5 million total registered vehicles, which increased to more than twice its initial value in 2019. [10] Since the mid-2000s the number of two-wheelers have increased tremendously. 2019 - 70 per cent of the registered vehicles across the city, are two-wheelers.	In fiscal year 1997, the city had a total of around 2.84 million registered vehicles, which increased to 11.39 million in 2019 more than 10.68 million in 2018. [11]	In the year 2017 1.18 million total number of vehicles in the city were there which rose to 1.72 million total number of vehicles in 2022 with 1.35 million two wheelers. 5000 new vehicles are registered in the city in every month.	Private vehicles are rising in all the three cities. As the public vehicles are not accessible and less than required in Aurangabad the registration of new vehicles is on the rise.
2. Impact of MRTS	Recently on 6th oct 2022 the metro is inaugurated. The metro covers north south and east west corridor and consist of 32 metro stations.	Implementation of metro has reduced the use of private vehicles resulting in reduction of environmental pollution and reduced traffic congestion to some extent.	No impact is seen as MRTS isproposed but not implemented.	MRTS is advantageous as less waiting time, safe and saviour from the congestion also sustainable.
3. BRTS and its impact	“Janmarg.” Has 101km operational route. Frequency is 2,3 and 4 minutes in peak hours and 6, 8, 10, 15 minutes in off peak hours with the total 228 buses. 1.6 lakh average passengers per day use buses in the city. Planning to bring more electric buses to promote sustainable transport. [13.]	Buses make 27% of all trips in Delhi The bus system has a greater connectivity unlike metro and provides access to areas outside of Delhi. Required fleet size- 10,000 buses Existing fleet - 6,088 buses on 773 routes. Average waiting time 70 minutes, poor maintenance and the congestion on the streets make bus the less preferred means than metro. [12.][13]	The public transport system of the city is relying on less than 50 buses against the normal requirement of 560 and 77 bus stands with bad shape.MRTS is also proposed in Aurangabad which will connect the MIDC’s. [14.]	Comparing three cities the BRTS of Ahmedabad is well designed than the other two. Aurangabad is in urgent need of BRTS development as the public transport is rarely used here.

Table 4. Users and community

Factors	Ahmedabad	Delhi	Aurangabad	Analysis
Pedestrians	Pathways are in good conditions, but occasional obstacles are present. Some parts of the old city have poor pathway conditions and interruptions in the pathways.	Delhi has sidewalks along major roads and commercial areas, but their condition varies. Footbridges, subways, and pedestrian signals are available. Challenges are infrastructure, encroachments, and accessibility.	Several areas lack pathways for walking, existing footpaths are often in poor condition with obstacles. No pedestrian signals, posing a significant life-threatening risk to its citizens.[15.]	To encourage walkability pathways should be well designed with no obstacles. In Aurangabad few areas have pathwaysin good condition.

2.4. Discussion of TOD implementation :

2.4.1 Scenario of Ahmedabad:

It has been more than a decade since BRT is running but very less development is observed in the TOD zones. The city is focusing on the densification and development of areas around the transit stations and improving accessibility by providing footpaths and cycle tracks for better connectivity as shown in Fig. 10. Many of the areas in the old city have improper pedestrian paths and no cycle tracks. Proper connectivity is established between the old city and the new city through the over bridges above the river at many places. Pedestrian safety is established at some places. BRT is used by many people and the stations are well designed. Inauguration of electric bus was done as shown in Fig. 11. The policy permits for more FSI still the density is comparatively lower along the stations. The roads are properly designed and are in good condition at most of the places. Some areas like Manik chowk which is active till 1am has no parking provision but it is managed properly as other gold shops nearby are closed after 10am.Minimal problems are faced by the people here as proper planning is done. The construction of MRTS is completed in some areas and is used which has reduce traffic to some extent.

Fig. 10 Cycle tracks

Fig. 11 Ahmedabad BRTS

Fig. 12 Ahmedabad MRTS

2.4.2 Scenario of Delhi :

In Delhi parking ECS for TOD plots is comparatively lesser even though policy permits more so parking is made too costlier.More transit hubs are planned to enhance connectivity and encourage the use of public transport. DDA's flagship TOD projects are already started spreading over 37.4 hectares which is provided with Rs. 1,168-crore which comprises of high-rise residential complexes, commercial and office spaces, public utilities andmulti-modal public transport facilities and 30% green area. The MRTS of Delhi is mostly used due to the shorter waiting time and is a saviour from traffic congestion as seen in Fig. 13. The BRTS needs to be improved and the required amount of buses should be made running in a good condition so that traffic congestion is reduced with the improvement of the Transit corridors to encourage people to use buses.Traffic congestion is seen in Fig. 14 and BRTS route is very less occupied. Even after MRTS and BRTS available and used by the people most of the areas have constant traffic congestions due to private vehicles and constantly rising population.

Fig. 13 Delhi MRTS view

Fig. 14 Delhi BRTS

2.4.3 Scenario of Aurangabad :

Aurangabad is smaller with respect to area than both the cities. Being one of the industrial city with 4 MIDC's and the city with historical importance, population and density in the city is on a rise due to employment opportunities leading to migration. People are facing various problems due to the rise in number of vehicles in the city every year. Mixed land use is seen in most of the parts of the city. If the development of public transportation in the city is not taken into notice it won't take much time for the situation here to become like Delhi.Even though metro is proposed in Aurangabad to encourage the use of public transport and contended connectivity to the MIDC areas, there will be certain limitations in the connectivity due to the shorter road widths and congested areas. Road infrastructure, development of transit stations, proper parking facilities improvement of BRTS, pedestrian friendly environment and safer walkways with active streets will only take place when there will be implementation of TOD.

5. Conclusions:

Aurangabad is facing numerous traffic issues in certain areas, and the population growth and motorization rate indicate that these problems will likely worsen in the future. This study has following key conclusions:

1. The implementation of the TOD policy in Aurangabad is necessary to manage traffic and improve connectivity.
2. The city's mixed land use and encroachments in the market area have reduced road width and worsened traffic conditions.
3. The implementation of BRTS, along with footpaths and other non-motorized transport options, will improve last mile connectivity and reduce private vehicle usage in the city.
4. The proposed metro in the MIDC areas will improve connectivity, but it is not sufficient to address the city's traffic issues.
5. Considering the above factors, the implementation of TOD in Aurangabad is essential to address the future rise in traffic problems, improve bus connectivity, enhance last-mile connectivity, and promote sustainable and efficient transportation options.

References:

[1] District Profile | District Aurangabad | India. https://aurangabad.gov.in/en/district-profile/ (accessed Dec. 09, 2022).

[2] Public transport system far from smart, The Times of India, Jun. 05, 2016. Accessed: Dec. 09, 2022. [Online]. Available: https://timesofindia.indiatimes.com/city/aurangabad/Public-transport-system-far-from-smart/articleshow/52596821.cms

[3] Aurangabad Archives, ITDP India. https://www.itdp.in/tag/aurangabad/ (accessed Nov. 24, 2022).

[4] Ahmedabad City Population Census 2011-2022 | Gujarat. https://www.census2011.co.in/census/city/314-ahmedabad.html (accessed Nov. 26, 2022).

[5] NDMC City Population Census 2011-2022 | Delhi. https://www.census2011.co.in/census/city/50-ndmc.html (accessed Nov. 26, 2022).

[6] Aurangabad City Population Census 2011-2022 | Maharashtra. https://www.census2011.co.in/census/city/360-aurangabad.html (accessed Nov. 26, 2022).

[7] Y. Jariwala, Study on Transit Oriented Development, vol. 06, no. 12, Art. no. 12, 2019.

[8] Transit Oriented Development For Indian Smart Cities. https://niua.org/tod/todfisc/book.php?book=1&section=5 (accessed Nov. 25, 2022).

[9] Delhi Metro: A Solution For The Transit-Oriented Development In Delhi | The Design Gesture, Oct. 21, 2021. https://thedesigngesture.com/delhi-metro/ (accessed Nov. 26, 2022).

[10] Registered Motor Vehicles: City: Ahmedabad | Economic Indicators | CEIC. https://www.ceicdata.com/en/india/number-of-registered-motor-vehicles-by-cities/registered-motor-vehicles-city-ahmedabad (accessed Nov. 27, 2022).

[11] Registered Motor Vehicles: UT: Delhi | Economic Indicators | CEIC. https://www.ceicdata.com/en/india/number-of-registered-motor-vehicles-by-cities/registered-motor-vehicles-ut-delhi (accessed Nov. 27, 2022).

[12] BRTS Ahmedabad Municipal Corporation. https://ahmedabadcity.gov.in/portal/jsp/Static_pages/citizen_brts.jsp (accessed Dec. 15, 2022).

[13] BRT in Delhi, BRT Route, Delhi Bus Rapid Transit System. https://www.delhionline.in/city-guide/brt-in-delhi (accessed Dec. 15, 2022).

[14] Signals keep motorists guessing at most junctions, The Times of India, Jan. 21, 2017. Accessed: Nov. 27, 2022. [Online]. Available: https://timesofindia.indiatimes.com/city/aurangabad/signals-keep-motorists-guessing-at-most-junctions/articleshow/56709013.cms

[15] Complete TOD project before its deadline, says Delhi lieutenant governor VK Saxena, The Times of India, Jun. 26, 2022. Accessed: Nov. 27, 2022. [Online]. Available: https://timesofindia.indiatimes.com/city/delhi/complete-tod-project-before-its-deadline-says-lg/articleshow/92462363.cms