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CATALYSTS OF CHANGE: ANALYZING POPULATION DYNAMICS AND URBAN BOOM OF "AHMEDABAD – A METROPOLITAN CITY"

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ABSTRACT
Ahmedabad, a bustling metropolis with a population of 7,692,000 (7.6 million). Rapid industrialization, coupled with favourable economic policies has attracted a significant influx of migrants seeking employment opportunities resulting India's 7th largest urban agglomeration. Its urban sprawl, mainly along the SP Ring Road, covers 76 km. Analysing span of year 2005 to 2023 using LULC provided by Landsat and ortho rectified IRS LISS-III satellite imagery further corrected by Resourcesat-2 reveals a direct correlation between population and built-up areas. Statistical study and spatio-temporal analysis of the data in QGIS shows meteoric changes and the challenges faced such as strained transportation networks, environmental degradation, overcrowding and traffic congestion. The traffic congestion is compounded by presence of various government transit systems like AMTS, BRTS, Metro and other person vehicles which creates a complex web of routes and schedules resulting in overlapping, inefficient use of road space and increased accidents. The heatmap of Ahmedabad city shows the increased rate of accident and their hotspots. Also, the effect of this vehicles on environment along with other factors are graphically represented by NO_2 and CO_2 emission rate and its consequences. The findings of this study would be useful for systematic urban planning, traffic control and establishment of sustainable development of Ahmedabad.

Keywords: Urban agglomeration, QGIS, LULC, population, traffic congestion, pollution, Ahmedabad.

1. INTRODUCTION
Ahmedabad is the largest city of Gujarat having area over 1866 km^2 and 8th largest city of India. It was founded in the 15th century by Sultan Ahmed Shah, the city has a history dating back over 600 years. The city was gifted with many architectural marvels in the Mughal period. The British period saw the emergence of Ahmedabad as an industrial centre for textile mills. Their policies encouraged industrial and economical growth of city and its reputation of "Manchester of India". City also played significant role in independence movement, being a site of mahatma Gandhi's Sabarmati ashram. Post independence, the city experienced the boom over industrialization and urbanisation becoming one of India's major

economic hubs. But as we know big power comes with big responsibilities, Ahmedabad is facing the dilemma of overcrowding. Against India's swift urbanization, several urban areas exhibit the coexistence of escalating populace and expansion in developed regions alongside extensive spatial heterogeneity. (Gajender Kumar Sharma, 2024) The economic hub attracted the rural for the opportunities and hope for better livelihood. To make room for the offices and to develop residential accommodation, new constructions began in the outskirts of old Ahmedabad. This grown area was spread over the ring road. This phenomenon has completely changed the demographic, social, physical and cultural landscape.

In 2010, Ahmedabad was ranked 3rd in Forbes's list of fastest growing city. Consequently, the study identified the major causes of urban sprawl as rapid population increase, high level of urban development pressure, provision of housing, changes in living standard, as well as technological changes among others. (Festus, 2020) The urban perimeters of municipalities have been used increasingly in favour agents of the reproduction of unequal urban space, aggravating the process of socio-spatial segregation, the formation of urban gaps and real estate

speculation. (Maurício Polidoro, 2012) Urban sprawl is characterized by the dispersion of urban occupation, which rapidly reaches rural areas and is qualified mainly by the low population density of these areas, which extend beyond the consolidated city center. (Mukhjerji, 2003)

To monitor and analyze urban sprawl, some researchers propose using sprawl indicators whereas other researchers emphasize the use of geospatial techniques such as remoting sensing and GIS in addition to statistical techniques. (Y. Yang, 2018) The built-ups over the year from 2005 to 2023 is analysed with help of QGIS. Quantum GIS, or QGIS, is a free, open-source GIS software package created by the QGIS Development Team in 2002. (Jeffry M. Flenniken, 2020) The data was collected from land use land cover mapping on 1:50000 scale using 3 season (kharif, rabi and Zaid) and terrain corrected Resourcesat_2 LISS-III data. This has increased the number of urban dwellers and resulted in the conversion of different and Land Use /Land Cover (LULC) forms into urban or built-up areas. (Ernest Biney, 2021)The monitoring with GIS processes is done by the multi spectral imaging, image processing with interpretation of temporal changes, sensors and many other tools which tend to make the analysing process easier. Assessing the quality of results after classification is performed from satellite images is very important for change detection analysis. (O.O. Othow, 2017) The result achieved through the classification suggests a need of implication of effective land use planning and monitoring of the environmental issues for their sustainable use. (Sukanya Ghosh, 2014)

The interpreted data is analysed for increased challenges like the traffic congestion, accelerating pollution rate, transportation systems chaos, major accident rates and sustainability. Following the overview, we focus on four issues that raise clear efficiency and equity concerns: unproductive congestion on roads, high levels of metropolitan car pollution, the loss of open space amenities, and unequal provision of public goods and services across sprawling metropolitan suburbs that give rise to residential segregation and pockets of poverty. (Nechyba, 2004) The ground data are also compared to bring accuracy. The presence of multiple transit system for a particular route creates a tanged networks in city. The AMTS buses, BRTS buses, Metro rails and GSRTC buses overlaps the schedules and decrease the space on road. Also, Ahmedabad has 48 lakh registered vehicles which works out to just 0.54m of road per vehicle only, resulting in blockage. The heatmap of Ahmedabad is created using QGIS for analysing accident rate and hotspots. Accident reports are prepared in form of textual format in Varanasi and it is very difficult to analyze accident and identify hot spots. (Jayvant Choudhary, 2015) The method used is to create a density map to calculate complexity in certain areas using Quantum GIS. This study uses the Kernel Density Estimation (KDE) method with a search bandwidth in an area of 300 meters. The results of the study are accident heat maps for the study area and related to the inputted attributes. (Ronal Watrianthos, 2020) The conclusive goal is to identify and analyze accident black spots using QGIS, compare it with the most vulnerable segments. (Harsh Naik, 2016)

The pollution in the city increases due to the consumption of fossil fuels in vehicles and to power heating systems in winter season. Based on geospatial mapping, data on residential environmental exposure was added using annual average air pollutant concentrations from local air quality monitoring network, including particulate matter, nitrogen dioxide (NO_2), and road-traffic noise measurements at different component frequencies. (Wisdom adza, 2022) Rate of toxic gases like NO_2 and CO are graphically represented in context to measure seasonal change in rate in mol/m^2. The Ahmedabad is one of the targeted smart city initiative projects and its development can be enhanced by rectifying these challenges.

2. DATABASE

Secondary and tertiary data have been used for the present study. However, field observations were also undertaken for verification of ground level realities. The following is the list of data sources employed in this study:

- Census of India
- Bhuvan- ISRO

- Earth data
- AMC (Ahmedabad Municipal Corporation)
- Ahmedabad Police Records
- The Gujarat government Gazette
- Tropomi Explorer
- Kaggle datasets
- GMRC (Gujarat Metro Rail Project)
- Landsat 5 TM 2005, 2010 & 2023 and ortho rectified IRS LISS-III satellite imagery
- Google Earth Imagery

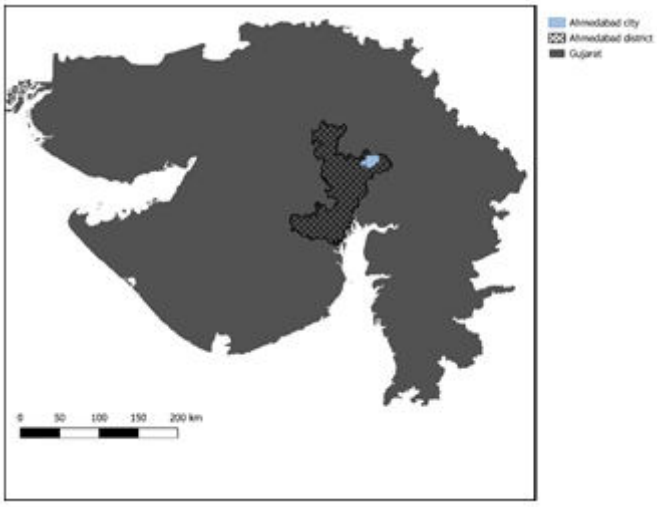


Figure 1: Location Map of Ahmedabad city

3. STUDY AREA

Ahmedabad city is situated along 23.0225 °N and 72.5714 °E. It lies in western India at 53 metres above sea level on the banks of Sabarmati River, in north-central Gujarat covering 505 km^2 and having buffer zone of 3.95 km^2. The old Ahmedabad is known for its historical structures like Jama-e-masjid, rani no Hajiro, Sabarmati ashram, Lal Darwaja, etc but the city has been explored to its modern initiatives also like Sabarmati riverfront, Ellis bridge and other multiplexes and residential high raised buildings. Aside from monsoon, the climate is extreme dry and in summer season it also peaks to 48 °C. The city is the centre node for many connecting towns and corridor for multiple highways, indicating its pivotal road in connecting and facilitating transportation networks.

4. METHODOLOGY

The geo spatial study of Ahmedabad city is spread over the 18 years from 2005 to 2023. The QGIS (Quantum GIS) software is free and open source which supports editing, interpretation and designing of geospatial data. The software supports the vector, raster and mesh layers and the plugins are written in python and C++ language. The base map of OSM along with the shape files of roadways and roadways enabled for the reference. The geoprocessing of Land cover- Land use data is prompted from the ISRO's Bhuvan web from thematic data over the period of decade. The data is taken on 1:500000 scale using temporal resourcesat-2 terrain corrected LISS-III data carried out by ISRO under NRC project of National Natural Resources Repository programme. Images were then pre-processed including Image Rectification, Image Enhancement, Atmospheric Error correction and Image

Destriping. The supervised classification of LULC used in research was Built-up area spread out i.e. the area of human habitation developed due to the non-agricultural use and that has a cover of buildings, transport and communication, utilities in association with water, and vacant land. Web LULC map consist of 3 built-up classes viz., urban, rural and mining. The earth data and google imagery is used to double check the source data of study. The urban growth of city over the years is further quantized by the ratio of population to the built-ups.

$$\therefore \frac{\text{Total population}}{\text{Built} - \text{up area}}$$

The population data is carried out from survey of India (Census 2001, 2011). Then the result is further used for analyse of traffic congestion and pollution in the city. The real time data analysis of the single destination through different routes and different transit systems, brought out to be different and overlapping for each other.

5. RESULT AND REPERCUSSIONS

5.1 Statistical Analysis

The GIS and remote sensing brought the world to our pocket. The spectral data of LULC with supervised classification provides us the brief to urban built-up growth of Ahmedabad city. The sprawl is influenced by population in the city. And the noticeable reasons for population growth are industrialization, business opportunities, migration and better education. The Ahmedabad Municipal Corporation (AMC), the governing and administrative body of Ahmedabad brought Parivartan project in 1990s to accumulate the accommodation for slum people and migrants. Ahmedabad city is divided into types of residential areas, R1, R2 and R3. These three development zones are indicated as Residential 1, Residential 2 and Residential 3. In lexinon zoning language the primary difference between them is density. R3 zone is with higher density with bungalows and farm houses, R2 zone is semi-detached flats or houses, and R1 zone is signified for flats. The zoning study helps to signify the density if population over the area in the city. The old Ahmedabad is known as pol consist of raw houses have lower density that the built ups in the outskirt of modern Ahmedabad areas like Sindhu bhavan, C.G. Road, Bopal, Sola, Gota, Sarkhej, Vastral, Nikol, Narol, etc along the border line of Ring Road. The high-tech areas like Satellite, Science city road, and C.G. Road have posh neighbourhood zoned as R3. But the other areas consist of High raised flats and buildings zoned under R1 and R2. Many of them are used for industrial and business purposes like Sarkhej. The planning of city is very systematic yet the overcrowding can cause the challenges. The increase of population from census 2001 to 2011 is 23.4% but the urban boom and agglomeration developments like Bopal, S.G. Highway, iscon, etc on the outskirts higher the rate of increment to 47% in 2023. According to new urban planning, AMC overtook numerous towns under its control for sustainable growth. Quantification of sprawl is done by calculating the ratio of total population to the total built-up of the area under study, in a defined time zone.

DESCRIPTION		2005-06	2011-12	2015-16
BUILT-UP AREA (sq.km.)	MINING	0.00	0.19	0.19
	RURAL	58.54	125.90	129.62
	URBAN	277.21	433.53	445.98
TOTAL BUILT-UP AREA (sq.km.)		335.75	559.62	575.76
TOTAL POPULATION (Estimated)		5,494,000	6,413,000	7,109,000
Cumulative Increment of Urban Sprawl (%)		163.63	114.59	123.47

Table 1: Change in Built-up area and Population of Ahmedabad City (2005-2015)

This study is specifically shown and calculated in the Table 1. The rate of built-ups is increasing over the period of time with population increment. The given exponential graphical representation made an ease to statically prove that similar point. In year 2005, the estimated population through census 2001 is given to be 5,494,000 with

the new built ups of 335.75 sq. km. The year of 2011 is appeared to have an urban expansion of 559.62 sq.km. which brings out that the population difference between the years is 918999 and the percentage change of 11.7% with new urban spread out of 223.87 sq.km. Similarly, the significant noticeable growth between 2011 to 2015 is carried out as the percentage of population change is 11.08% with the resulting new built ups of 16.14 sq. km. this study clearly proves the growth of built ups is exponentially increasing with the population rate over the time.

A linear graph has been drawn for the effectual understanding of the built-up and demographic dynamics of Ahmedabad in spatio-temporal context. Above stated factors are further supported by these graphs. The given graph shows the exponential change of urban expansion with respect to years. The measured slope of the assumed time period is 13.87 with is not linear but exponential. The slope is not constant for every decade because the factors affecting the influx of population can affect the need for built ups. The given graph states the urban sprawl of Ahmedabad city over the period of time.

5.2 Geo-Spatial Analysis from LULC

The above study was based on the data and calculation with graphical analysis. Now the Urban sprawl is characterized by change in spatio-temporal characteristics of the area. Population trends in the city and urban sprawl refer to the area expansion of urban concentration beyond what they have been. This rise in population in turn demands more residential land and hence affects land cover within and around the urban area including forest cover, green cover, agricultural land, waste land, water bodies etc. The Figure 3 of LULC comparative study shows the Radical concentration change of built-up area.

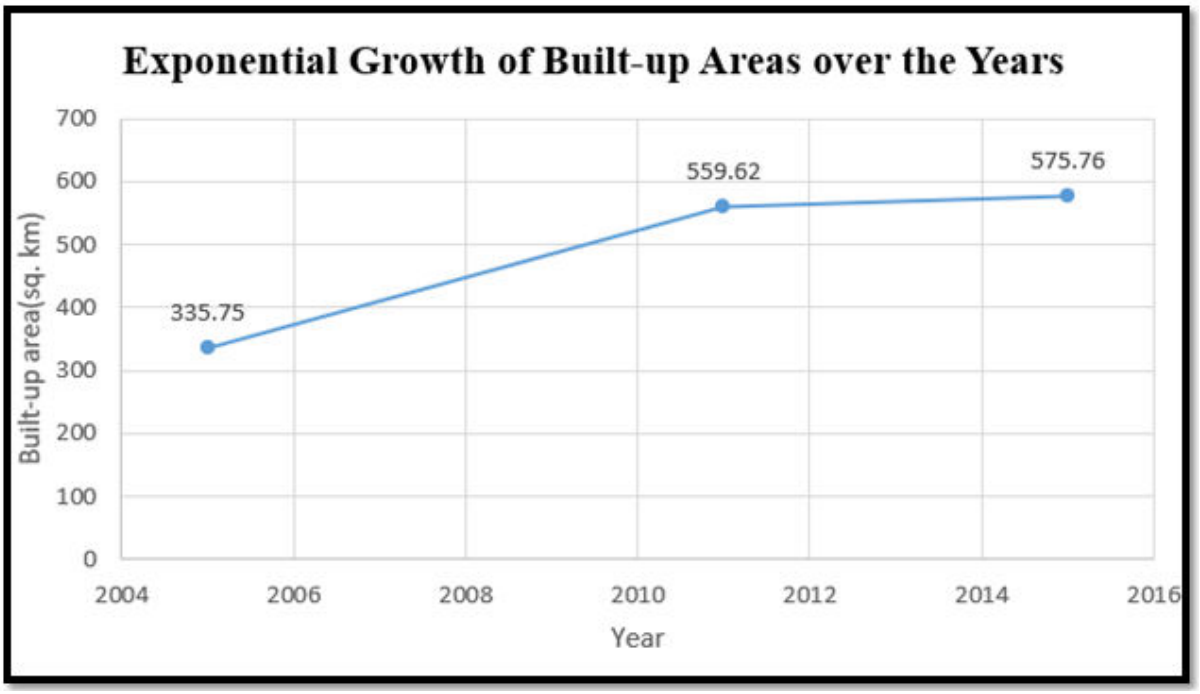


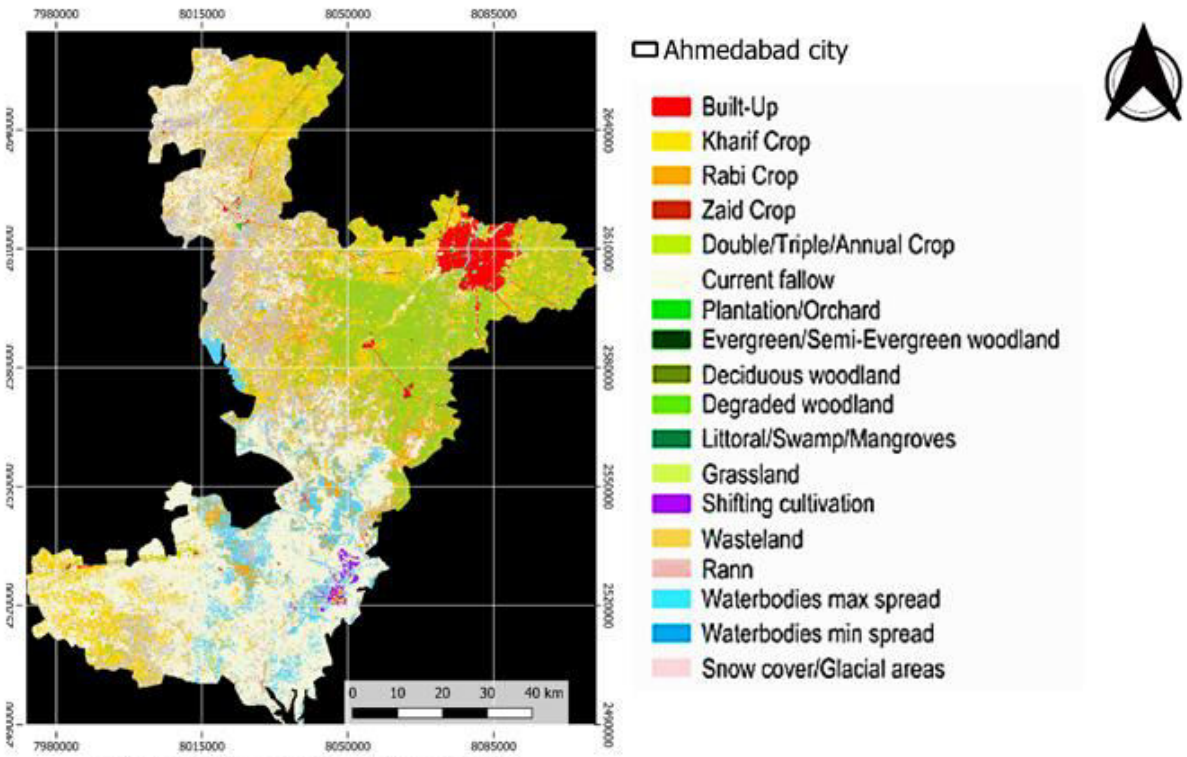
Figure 2: Comparative trend of built-up area and Years

The Border line of Ahmedabad city is surrounded by the Sardar Patel Ring Road, where the new construction is noticeable. The job of accommodating the growing population and making enough space for all is carried out by the department of town planning and in this case AMC. The team based on GIS data and Remote Sensing images, prepares a future map to deal with the future needs, and this involves study of spatial and temporal structures in morphology of the city. Area with the high density is defined as CBD (Central Business District).

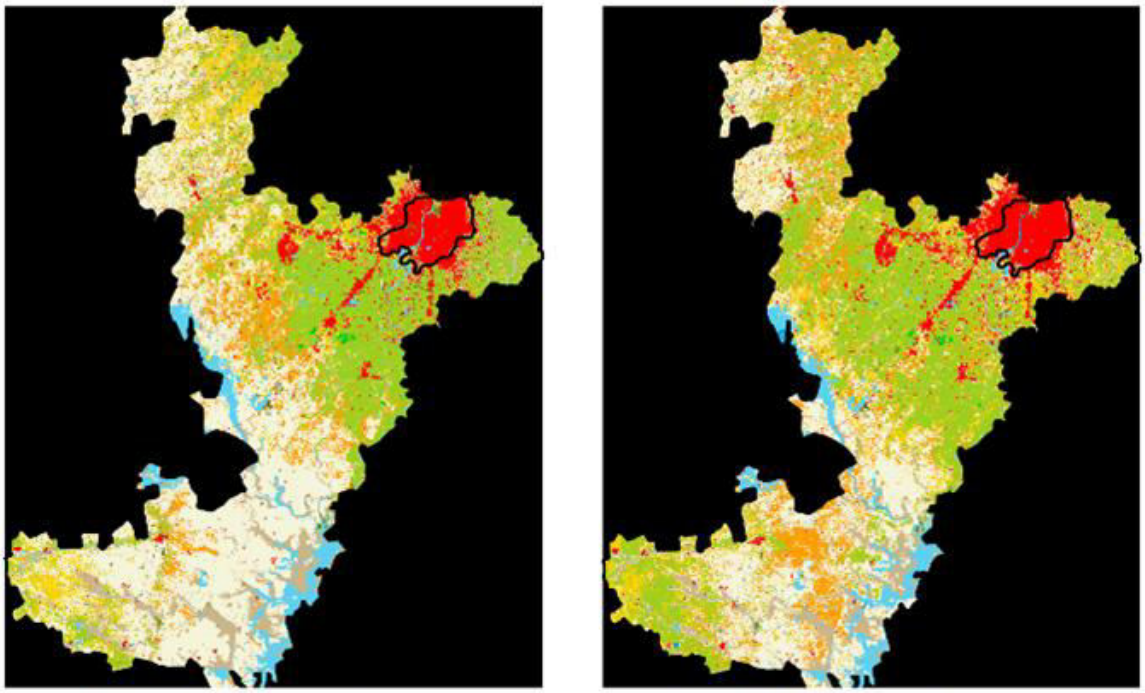
Around the year of 2005, the CBD was old Ahmedabad but with overcrowding and construction of the city, the vast area of Ahmedabad city can be stated as CBD. In Ahmedabad city, farming area can be stated negligible and

the expansion of areas can give adverse effect on future generation. By analysing the spectral changes of Figure 2, we can say that the concentration of urban expansion is noticed on the outskirts over the period of time with increase in population.

The use of GIS and remote sensing techniques made it easy for town planners to accommodate or restrict the development on any area. The geo-spectral distribution shows the growth of urban area and their spread. Analyzing historical maps and spatial data can inform infrastructure planning and development projects. This includes identifying suitable locations for roads, bridges, pipelines, and utilities based on factors like population growth, transportation needs, and environmental considerations.



Year 2005 Landcover/Land-use



Year 2010 Landcover/ Land-use Year 2023 Landcover/ Land-use

Figure 3: Landcover/ Land-use of Ahmedabad district in year 2005, 2010 and 2023

5.3 Detailed Comparison of year 2005 & 2023 LULC

The study of spatial distribution of year 2005 and 2023 gives the steady comparison of 18 years of dynamic alteration. The Ahmedabad city is divided into two physical parts, eastern and western by Sabarmati River as seen in the Figure. Eastern old city consists of the areas like Bapunagar, Dariyapur, Khanpur, Kalupur, etc and the western new constructed areas are Vastrapur, Ranip, Gota, etc. in the Figure 4 and 5, the LULC of year 2005 and 2023 is shown. The legends are same as Figure 4. By analysing the 2005 map, we can see the red area (urban built-up) is around the old city and the outskirt areas have rabi and kharif cropping. In the year 2004, S P Ring Road is constructed by Ahmedabad Urban Development Authority (AUDA) with budged of 3.55 billion rupees which encircles the Ahmedabad city. The major junctions are Sarkhej, Narol, Zundal, Naroda, etc for substituting the tolls. Over the significant period of time, alongside development of ring road is accompanied with the major growth of industries and rapid increment in population. Therefore, in 2023, the red coverage seems to expanded along the ring road. And the cultivation area seems to be negligible. As observed from LULC, also the area along the National highways and state highways seems to be growing as new industries and companies are established for job occupancies generation and business exposure of the city. The business hub areas for Ahmedabad city are Sarkhej, Adalaj highway, etc. With increasing the construction boundaries, AMC tend to include the several Towns within the Ahmedabad city and develop it for residential purpose. The urban expansion over the 18 years is visible by the given LULC and the challenges can be brought out by this study.

5.4 Traffic Analysis

The above study shows us the increasing population rate over the long period of time. With a greater number of people and diverse occupations, the need of transportation for a person is basic. It can be fulfilled by various ways and routes which can be further classified as public transport and private transportation. For Ahmedabad city, the public transit systems are BRTS (Bus Rapid Transit System), AMTS (Amdavad Municipal Transport Service), METRO Rail, GSRTC (Gujarat State Road Transport Corporation) and many private vehicular are owned by people. The rate of personal vehicle increased with increase in population. The graph shown in Figure 7 shows the increment of personal vehicle with respect to year. The bar graph is exponentially increasing in millions. Also,

data according to march, 2023 states the daily ridership of BRTS is 3,49,000 passengers and daily ridership of AMTS is 2,20,000. And as metro is installed only a year ago, its daily ridership is on average 90,000 passengers. Therefore, we can say that the transportation system is basic need for metropolitan city in this fast-moving world. But the presence of several means of transport for single route can be the reason for congestion in the city. The traffic congestion is a daily problem for Ahmedabad city.

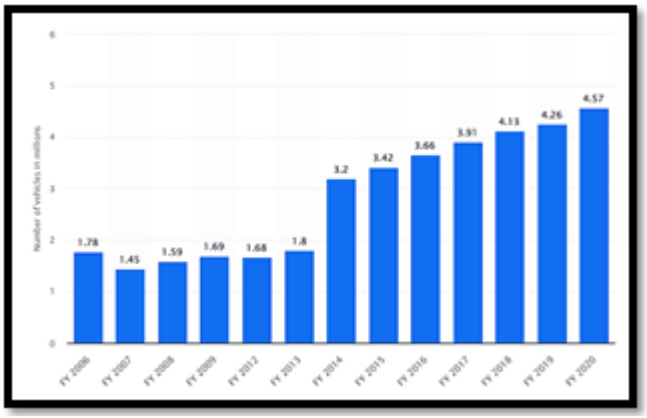


Figure 6: Rate of Vehicular Ownership w.r.t. Year

The road space per vehicular can be calculated as the ratio of total area of the city to the number of vehicles owned. The result comes out to be 0.54 m per person, which is very little space for driving safely. This increases the rate of driving safety. This increases the rate of accident deaths to 35.26% for the year 2021-22 and 29.7% for the year 2020-21. The factor affecting accidents is increased number of vehicles i.e. overcrowding and poor planning of the roads and transit systems by government. Multiple options for single route can create overlapping which cause traffic. Also, the new Bullet train project is ongoing construction at Sabarmati. The proper road and transport planning for the city under smart city development project would be necessary for the ease of mobility and to avoid accidents.

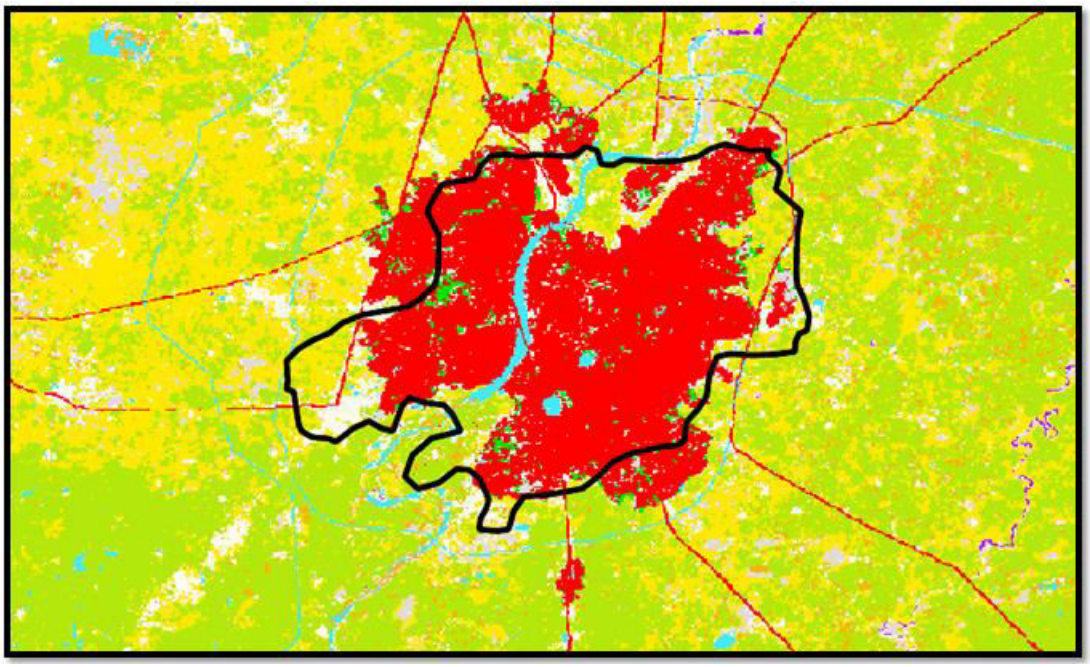


Figure 4: Year 2005 Landcover/Land-use of Ahmedabad City

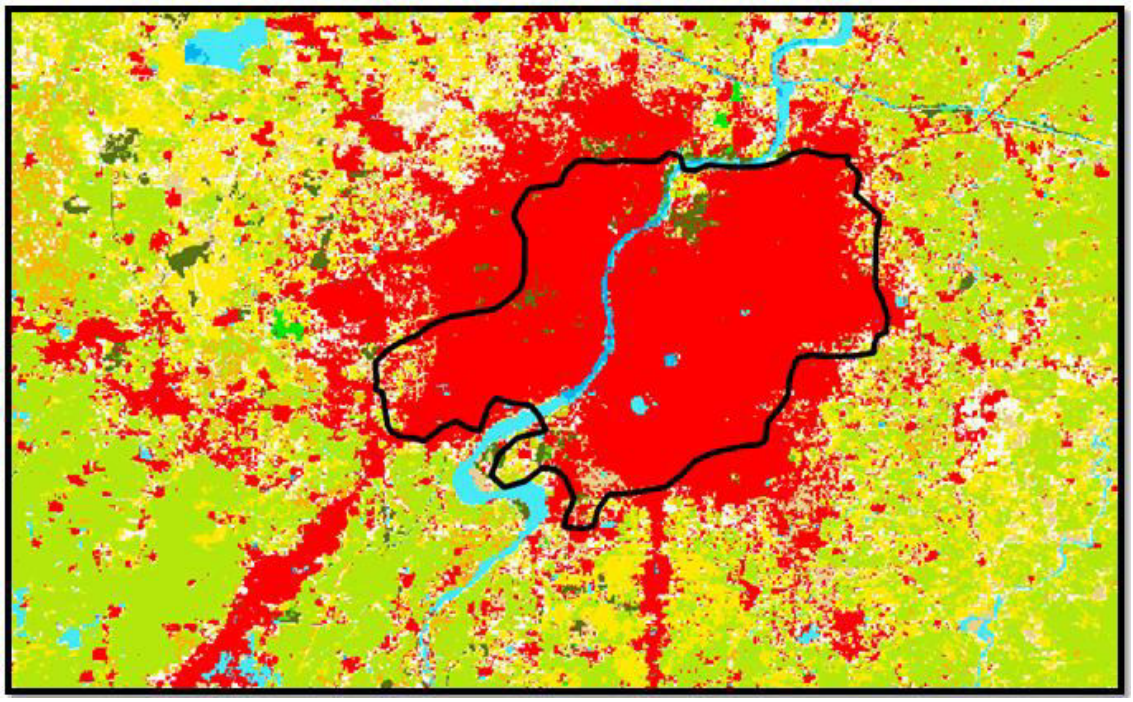


Figure 5: Year 2023 Landcover/Land-use of Ahmedabad City

5.5 Heatmap of Ahmedabad

An accidental heatmap is a visual representation of the spatial distribution and density of accidents within a geographic area. It uses color gradients to depict areas with varying levels of accident frequency. Darker colors typically represent higher densities of accidents, while lighter colors represent lower densities. They are generated by aggregating the locations of individual accidents and applying a density calculation algorithm to produce a heatmap layer in QGIS. These heatmaps are valuable tools for analyzing accident patterns, identifying accident hotspots, and understanding the spatial impact of accidents on a city or region. They can help transportation authorities, urban planners, and policymakers make informed decisions about traffic safety measures, infrastructure improvements, and accident prevention strategies. The heatmap of Ahmedabad shows the areas of major accidental risks shown in figure 9. The vector data point is downloaded from Keggal datasets and interpreted on QGIS for clear visualization. The city consists of major risk zones of danger.

5.6 Pollution Analysis

The above study proved the increase of people and increase of vehicles over the period of time which concludes the increase of pollution is evident. The use of fossil fuels in the vehicles and emission of harmful toxic gases in environment by industries affect the air heavily. Also, the discharge of pollutant and dirt in the Sabarmati River can be adversely effective on human body. An initiated GIS web named Tropomi Explorer is used to bring out the percentage by which the emission of toxic gases affects the city. The figure 7 and figure 8 gives a graphical representation of the NO_2 (Nitrogen oxide) and CO (Carbon monoxide) emission is shown in seasonal interface from 2019 to 2023. There two gases are significantly very dangerous with its detrimental effect on human health and environment. The effects on human of NO_2 gas seems to be respiratory irritation, lung damage or inflammation and cardiovascular effect including heart attack and hypertension and also it contributes to the formation of ground level ozone (o_3) and particulate matter (PM) which both are harmful air pollutants and contribute to smog formation, visibility reduction and environmental degradation. Carbon Monoxide (CO) is a colourless and odourless poisonous gas when inhaled, it can bind with haemoglobin in bloodstream reducing its oxygen carrying capacity causing slow death. It also has neurological effects on human like memory impairment and cognitive deficits and also contributes to the environmental degradation.

The increase of these gases is the cause of increased pollution in the city. Especially the rate of toxic gas emission seems maximum during the September to January i.e. winter season. The noticeable reason behind this is temperature inversion, increased combustion of fossil fuel for heating purpose, traffic congestion (fossil fuel by vehicles), stagnant air and biomass burning in winters. Overall combination of meteorological conditions and increased combustion activities exacerbates the emission of NO_2 and CO during winters. Besides the seasonal change, the average emission of NO_2 in Ahmedabad is 16.6 $\mu g/m^3$ and CO emission is 752 $\mu g/m^3$ resulting the PM2.5 to 66 $\mu g/m^3$ and PM10 to 129 $\mu g/m^3$. The Air Quality index of Ahmedabad city is stated poor by WHO.

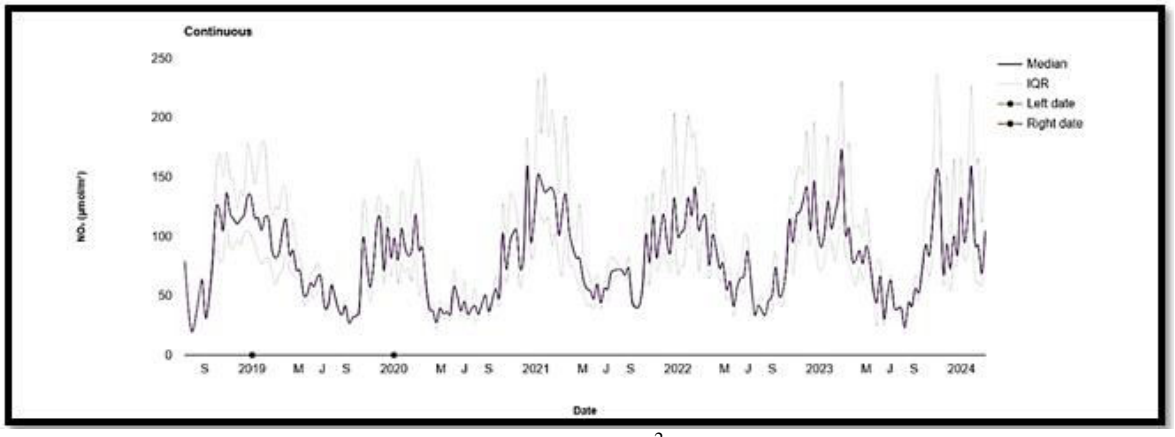


Figure 7: NO_2 Emission(μmol/m^2) throughout the year

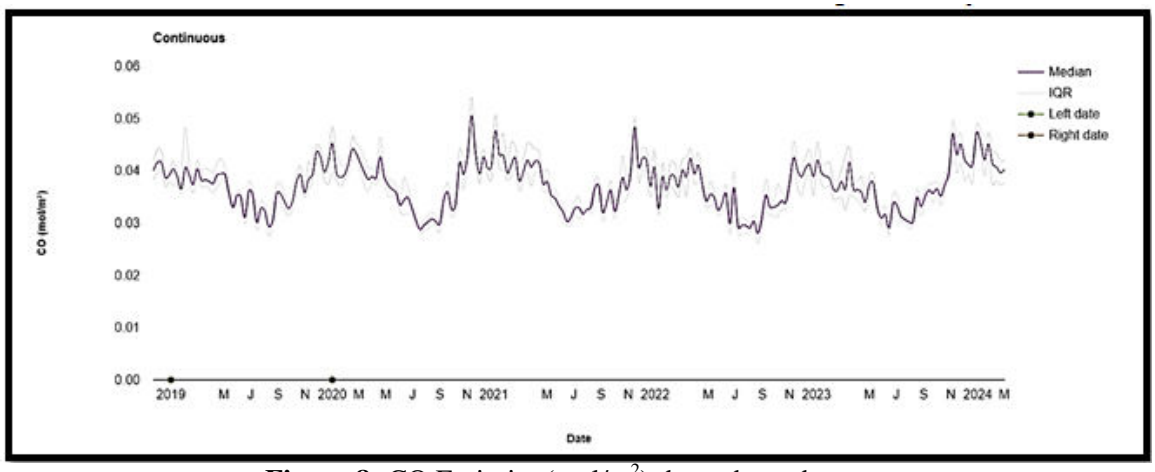


Figure 8: CO Emission(mol/m^2) throughout the year

6. CONCLUSION

This paper shows the evidential and analytical study of Ahmedabad city. This research conceptualized urban sprawl from a geographic perspective in order to assess the spatial distribution of sprawl patterns. In this work, with the use of GIS and remote sensing technology an attempt has been made to study the criteria and patterns of expansion with respect to direction in the recent 18 decades. It also helped to understand the need of built-up area for the growing city and the way in which the demand is being fulfilled by construction.

Apart from population and built-ups, the major two challenges of city are mentions in this paper i.e. traffic congestion and pollution. The heat map of accidental study for red spots shows the real-life threatening situation for citizen. Ahmedabad is a very good example for a developing smart city if some safety measures are taken to control pollution and population. The study of this paper might help to plan the city accordingly more effectively to establish the sustainable environment.

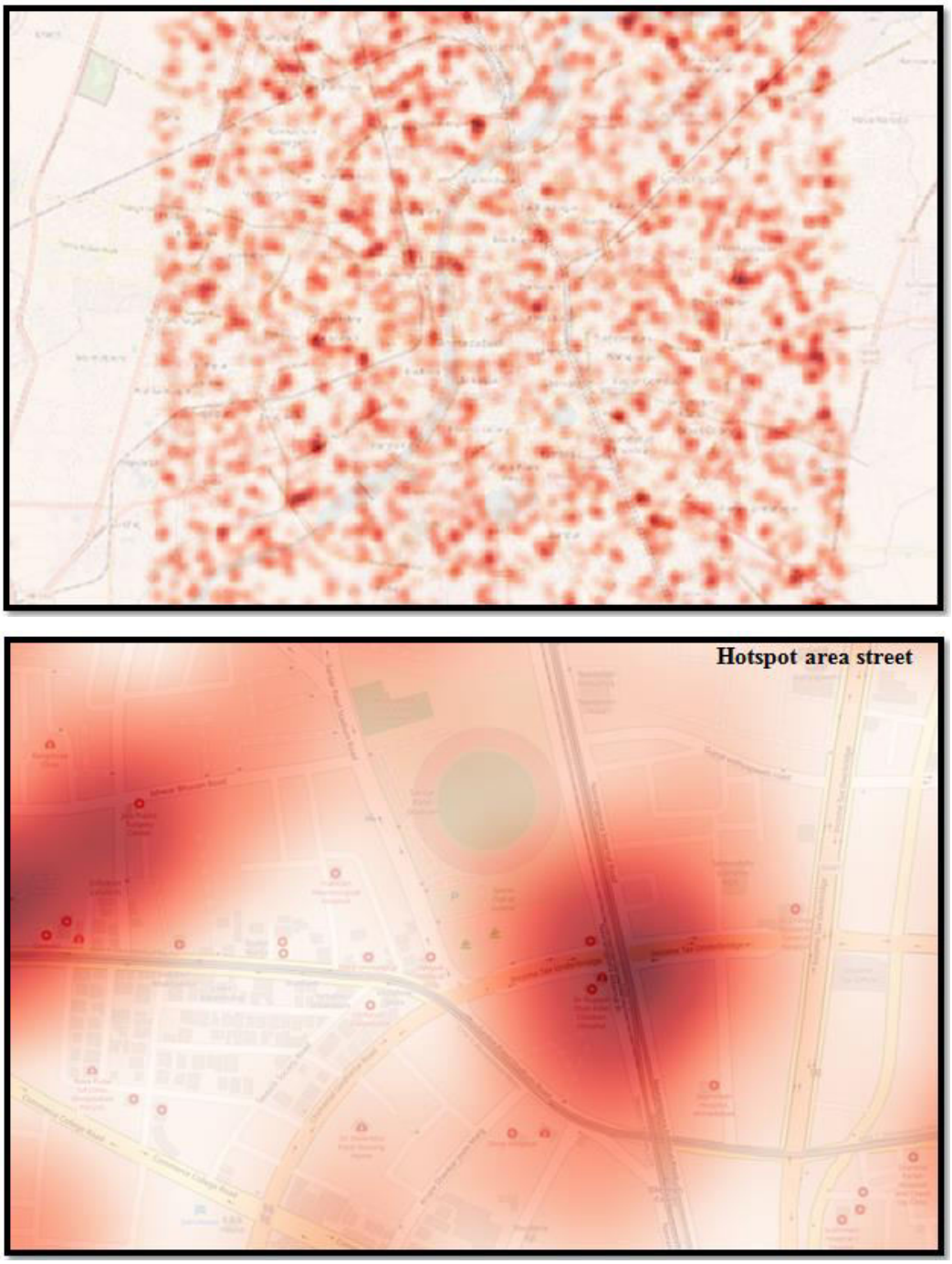


Figure 9: Heatmap for accident rate in Ahmedabad

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