shaping the way cities move

Spatial Impact Assessment of Namma Metro - Case of Rajajinagar

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Executive Summary

The introduction of a mass transit system in a city has a significant impact on the spatial characteristics of the area around the transit stations. It is critical to understand these impacts to investigate ways to optimize limited urban space and create more livable neighborhoods. This research document is an effort on the part of the Directorate of Urban Land Transport, Government of Karnataka to document the methodology and approach used for assessing the spatial impact of metro on a neighbourhood in its influence area and deriving insights for developing appropriate regulations to encourage Transit-oriented development. The current study assessed the impact of metro on the spatial character of the core TOD zone (500m walking catchment) in the neighborhood of Rajajinagar in the city of Bengaluru. The following research questions were attempted to be answered through this study:1) the extent and nature of transformation of the spatial character of the area and various factors that are influencing it; 2) the utilization of FAR in in-situ developments and amalgamated plots, if any 3) the potential for land value capture etc.

Plot level data on land use, building heights, plot areas, and floor-wise uses were captured through detailed site and household surveys. The current dataset thus captured was analyzed and compared to the developments of the year 2014. Further, statistical analysis was carried out to validate inferences from the above analysis.

The study helped in understanding the dynamics of spatial transformation due to mass transit. Based on the learnings, the methodology and approach have been finetuned for application in similarly placed transit zones.

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List of Abbreviations

BBMP	Bruhat Bengaluru Mahanagara Palike
BDA	Bengaluru Development Authority
BESCOM	Bangalore Electricity Supply Company
BIAAPA	Bangalore International Airport Area Planning Authority
BMA	Bangalore Metropolitan Area
TOD	Transit Oriented Development
MRT	Mass Rapid Transit System

1. BACKGROUND AND NEED

The cities in India are urbanizing rapidly and are competing with the fastest-growing countries in the world. This generates the need for mass transit systems that can cater to the present and future travel demands. The development and augmentation of any transit infrastructure in a city beget changes in the form of spatial, economic, and travel behavior of people and the real estate market in its immediate neighborhoods.

The Comprehensive Mobility Plans (CMPs) are prepared for cities having a population of two million or more to address the need and the demand for the transit infrastructure and services. Most of the tier one cities have adopted metro rail to cater to the existing and future demand. Bengaluru recognized the need for the mass rapid transit system (MRTS) in the late 20th Century. Subsequently, the Namma Metro (Bangalore Metro) got commenced in 2011 with its first line.

In a few cities, however, MRTS fails to achieve desired ridership even years after the inception of the projects. This is due to the lack of integration between land use and transit system. The concept of Transit-oriented development (TOD) has been introduced around the world to bridge this gap.

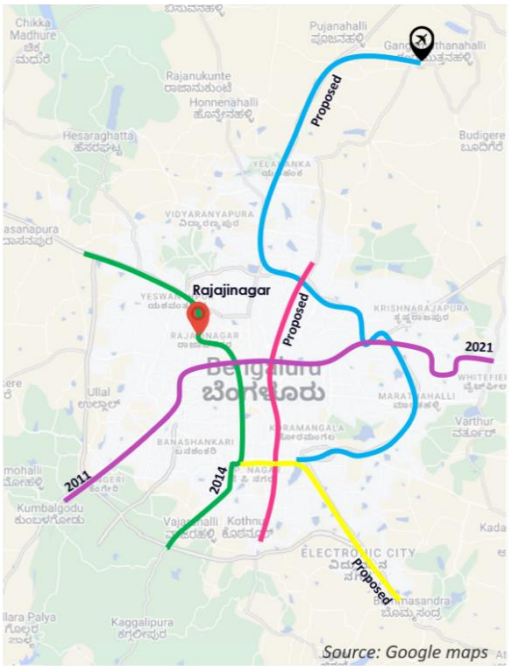


Figure 1 Existing and proposed metro lines

TOD aims to develop planned sustainable urban growth centers, having walkable and livable communes with high density mixed land use. This development targets the area of 500m-800m around transit stations along the transit lines which are called TOD influence zones as per the National TOD (NTOD) policy (Ministry of Urban Development, 2017). The NTOD policy of India formulated in 2017 serves as a guideline in preparing city-level TOD policies and frameworks.

The Directorate of Urban Land Transport (DULT) has prepared a TOD policy for Bengaluru City to ensure high mode share for public transport through a coordinated public transport service which is one of its key objectives. As per this policy, TOD zone delineation is proposed to be done for 12-minute walking or 6-minute cycling distance which roughly translates to 1000m from the MRT stations using isochrone approach.

Both the National and City level policies have principles which directs majorly towards compact development around transit nodes and routes. This form of development can be achieved by densification in the influence zones by increasing the FAR and promoting mixed-use development thereby facilitating the increase in ridership. In addition, mixed-use development plays a pivotal role in reducing the overall number of trips, trip lengths, and need for travel. Thus, in a city, the integration of land use and transportation plays a vital role in enabling TOD.

1.1. NEED FOR THE STUDY:

Spatial Impact Assessment (SIA) may be defined as a systematic and coherent method of established analytical techniques to assess the expected or foreseeable impacts of various policy measures, programs, and projects. SIA aims at providing an integrated picture of the consequences of a public policy plan etc. for a specific region. In recent years, SIAs have drawn a lot of attention; scholars and practitioners have been exploring various analytic tools to study the impact of a MRT system on its surrounding areas and inform the continued application of TOD principles in urban development across cities.

The positive capitalization of metro systems is reflected in property values in areas surrounding metro systems, although the impacts may vary spatially, temporally and geographically. In addition, metro systems impact on the natural and built environments by reducing air pollution and greenhouse gas emissions, encouraging new development, urban renewal, facilitating commercial growth and residential development, and increasing mixed land use and urban density. However, there are mixed effects, both positive and negative, of metro systems on equality of transit opportunity, accessibility and connectivity, travel behavior, travel experience and safety. This study sheds light on the impacts of metro systems on land use and land value and provides essential information for scaling up and future planning of the immediate vicinity of the Metro System for the city.

2. INTRODUCTION

Bangalore has a population of around 13 million that requires a transportation system that can ease its congestion and reduce travel time. Bangalore Metropolitan Transport Corporation (BMTC) buses are the primary mode of public transport with an effective fleet of 6218 buses, which is 0.1% of the vehicle population and has a daily ridership of 3.8 lakh (Bangalore Metro Rail Corporation Limited, 2022) making it one of the largest city bus operators in the country.

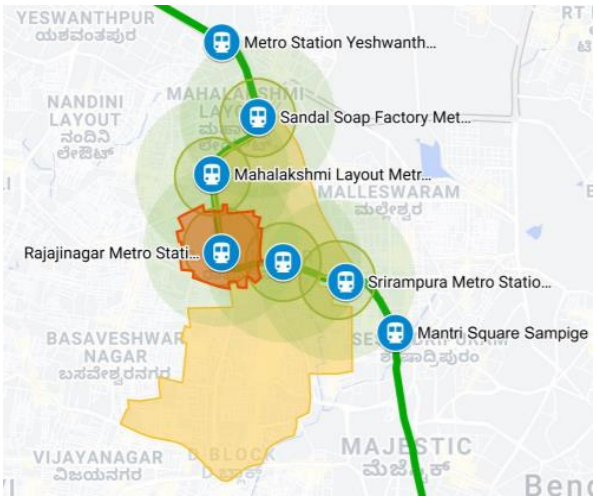


Figure 2 Rajajinagar Metro Station

In addition to the city bus services, Bengaluru Metro christened as “Namma Metro” is an urban Mass Rapid Transit System (MRTS) for the city which got operationalized in 2011. Namma Metro provides a safe, quick, reliable, and comfortable public transport system. Besides this, it is a major environment-friendly addition that significantly contributes to the reduction of carbon emissions. Currently, there are two lines in operation in phase-I: The purple line and the green line. The Purple line is a 25.60km long route running from Baiyyappanahalli – to Kengeri covering 22 stations in the East-West direction of the city. The second line is the green line having 30km of stretch with 29 stations from Nagasandra – Silk Institute in the North-South direction of the city. Phase-II of metro lines: Pink, Blue, yellow, and extension of purple and green line are under the construction.

Rajaji Nagar Metro station is selected as the Study Area which lies on the Green Line Metro. Rajajinagar is one of the oldest residential neighborhoods and is now an upcoming business hub located in the west of Bangalore bordered by Basaveshwaranagar, Malleshwaram, and Mahalakshmipuram. The study area lies in the core zone of the delineated TOD zone along the metro corridor which translates to roughly 500m around the transit station.

3. AIM OF THE STUDY

3.1. AIM

To evaluate the impact of mass transit like metro on spatial characteristics such as Land Use, Density, and Residential Land values in the TOD Zone of Rajajinagar.

3.2. OBJECTIVES

1. To document and analyze the transformation of spatial characteristics such as land use, plot sizes, and densities over 7 years within the TOD zone.
2. To assess the land appreciation trend among residential plots since the commencement of the metro.

3.3. RESEARCH QUESTIONS

1. What is the extent and nature of the change in spatial characteristics of the study area due to introduction of metro?
2. Does the proximity to the metro affect the FAR utilization in-situ developments and amalgamated plots?
3. Has the commencement of metro affected the land values in the study areas?

4. METHODOLOGY

The adopted methodology entails an initial understanding of spatial analysis, defining the aim and objective of the study, and getting familiarized with the site context and extent of the study area. Data collection and analysis were planned and initiated through primary and secondary sources. Primary sources included surveys in which all plot level details like land use, building heights, setbacks, parking provisions, etc. were captured for all 3108 plots in the study area and household surveys of 130 households which captured household size, income, mode choice, property value, rental value, etc. The secondary sources included a review of documents like Station Accessibility Plan Reports, Master Plans, Guidance Value documents, and other supporting literature. The data collected was further collated and analyzed to generate spatial maps, run statistical analysis and draw relevant inferences for the study.

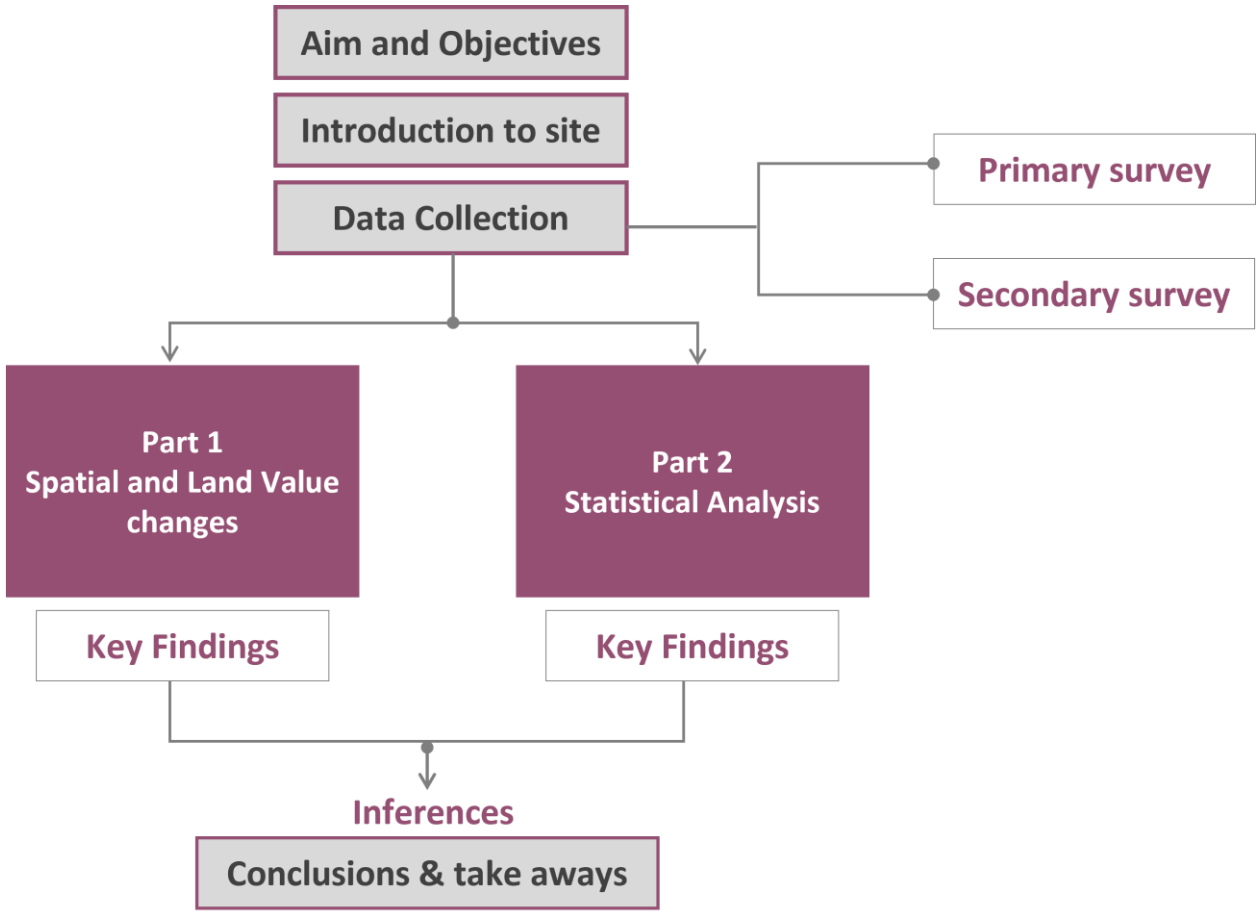


Figure 3 Study Methodology

5. LITERATURE REVIEW

Impact assessment is an integral part of planning for a city-scale infrastructure project. These assessments mainly focus on environmental, economic, social, and transportation and not predominantly on spatial transformation. Specific and comparable studies keeping spatial transformation in the forefront that assess the proposed development strategies are seldom created. Studies from across the world have shown that neighborhood areas respond positively to any new addition or improvement in the transportation infrastructure. As accessibility and mobility are key concerns in Indian cities, the demand increases for urban real estate along transit lines, especially in the core areas around transit stations which are also known as core TOD zones. These zones also transform spatially in response to the transit facility. These responses could be in terms of land use, building heights, FAR, etc. Research on the Thessaloniki metro station in Greece recorded the land use characteristics within a buffer zone of 500m. The study showed an increase in commercial land uses with the residential getting converted into mixed-use. It has also shown a rise in building heights. It conducted several interviews out of which 70% of the interviewees claimed that they would use the station for their trips (Basbas, 2012). Apart from mobility, the study has also shown varied results in terms of accessibility, particularly in the working population, and growth in industrial and commercial opportunities. Thereby, showcasing the impact of the metro on land use. The study of Singapore MRT mainly assessed MRT's impact on accessibility. The study found that the construction of a new line in the Northeast direction has greatly improved the accessibility of northeastern areas, however, it does not have a significant impact on accessibility in the rest of the areas of the country (Xuan Zhu, 2004).

It is also perceived that transport infrastructure also impacts the real-estate scenarios in the areas in its vicinity. Conventional wisdom holds that the value of land is essentially influenced by the trade-off between accessibility and transport costs. Infrastructure improvement thus plays an important role in the rise of land values. In particular, accessibility improvement in the form of public transportation or road improvement is found to cause the value of land to rise. In a study of the Delhi Metro on Residential properties, it was recorded that the impact of the metro on property rates was high in low-income group areas and negative or negligible in high-income group areas. Much of this study simultaneously focused on Hedonic regression for estimating the property value and the dependency on affecting attributes. The statistical results inferred that the distance from the metro is the most significant attribute for LIG and MIG properties whereas, property area was found most significant attribute for HIG properties. Furthermore, it states that with an increase in each meter of distance from the metro; the residential property prices decrease.

The benefits of a new transport infrastructure get capitalized in real estate prices in a shorter period as compared to the land use conversion. Studies of Seoul BRT revealed that the land parcels within 500 meters from the BRT bus stops were more likely to convert into more intensive land uses as opposed to parcels that are beyond 500 meters. However, out of all the attributes considered, the study showed that the distance from arterial roads had the greatest impact on the land use conversions, i.e., the likelihood of switching to multifamily and mixed uses. Furthermore, it has also been recorded that the land parcels of a neighborhood with higher rates significantly increased the possibility of converting single-family residences to higher end uses like condominiums and mixed uses. Along with this, the land-use conversions into mixed-use were seen as a contribution to the higher permissible floor area in the neighborhood (Robert Cervero, 2010).

Empirical research on Transit investments and land-price impact has produced mixed results. Few cities like Miami with Mass Rapid Transit Systems have shown slight or discernable impacts on land prices owing to low ridership and demand. In contrast, the impact study of urban transit systems conducted for the city of Naples has shown that the real estate values rose from 8% to 22% of the total amount due to the impact of high-frequency metro lines. The study states that increasing the number of high-frequency metro lines may produce an appreciable increase in real estate values (Gallo, 2018).

Previous studies have provided insights on impact by the MRTs, however not much is available on its spatial impacts. There is lack of relevant studies showcasing spatial impact of namma metro in Bengaluru, which has been in operation since 2014. As there is a general presumption that metro has brought in change and transformation in its influence area; with more lines being introduced in the system, it becomes imperative to study the impact in detail and derive the findings.

Therefore, our research aims to extend insights gained from previous studies by analyzing the transformations over a decade in land use and land value along the metro line. The study investigates the impacts on residential properties in the core TOD zone around a metro station in Rajajinagar, Bangalore.

6. DATA COLLECTION

The study required extensive data collection from both primary and secondary sources. The secondary data sources included the Revised Master Plan (RMP) 2015, Station Accessibility Plan (SAP) 2014, and Guidance values obtained from the stamp and registration department. The process of primary data collection included plot level data collection for the delineated study area through the Arc collector app and Household (HH) survey for statistical analysis.

Table 1 Primary Data

Primary data collection
Existing land use
Building height
Age of the structure
Building Typology
Bedrooms
Income levels
Education level
Mode choice
Travel pattern

Table 2 Secondary Data

Secondary data collection
Guidance values
Land use map 2003, RMP 2015
Land use data 2014, SAP report

6.1 PRIMARY SURVEY

6.1.1. RECONNAISSANCE SURVEY

The reconnaissance survey was carried out to get a basic understanding of the study area. The survey involved visual observations and mapping of the existing spatial character of the area. Spatial characters like land use, building heights, street character, walkability, etc.

Figure 4 Parameters observed during reconnaissance survey

6.1.2. LANDUSE SURVEY

The spatial information for each plot was collected using the tool, Arc GIS collector app. The shapefiles of the plot boundaries were uploaded onto the app and data was entered based on plot-level observations on site. In total, the data was collected for 3108 plots. ArcGIS software was used to generate spatial maps for further analysis.

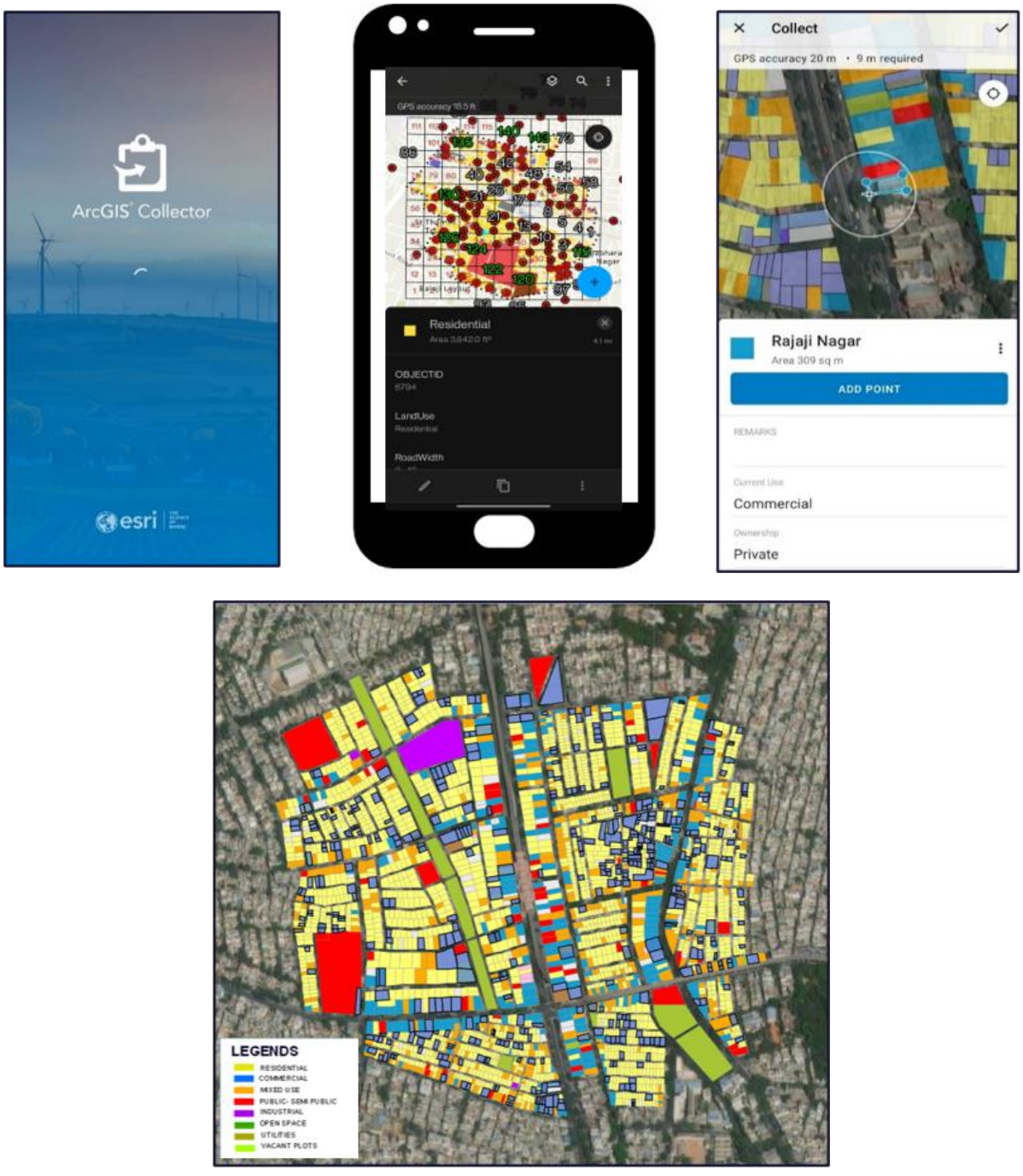


Figure 5 Data Collection through the Arc GIS Collector App

7. SPATIAL ANALYSIS

7.1 LAND USE 2003

According to the 2003 land use map, plots along arterial roads are primarily commercial. While plots along secondary and sub-arterial roads are mainly residential and mixed-use developments and tertiary roads are lined with residential buildings.

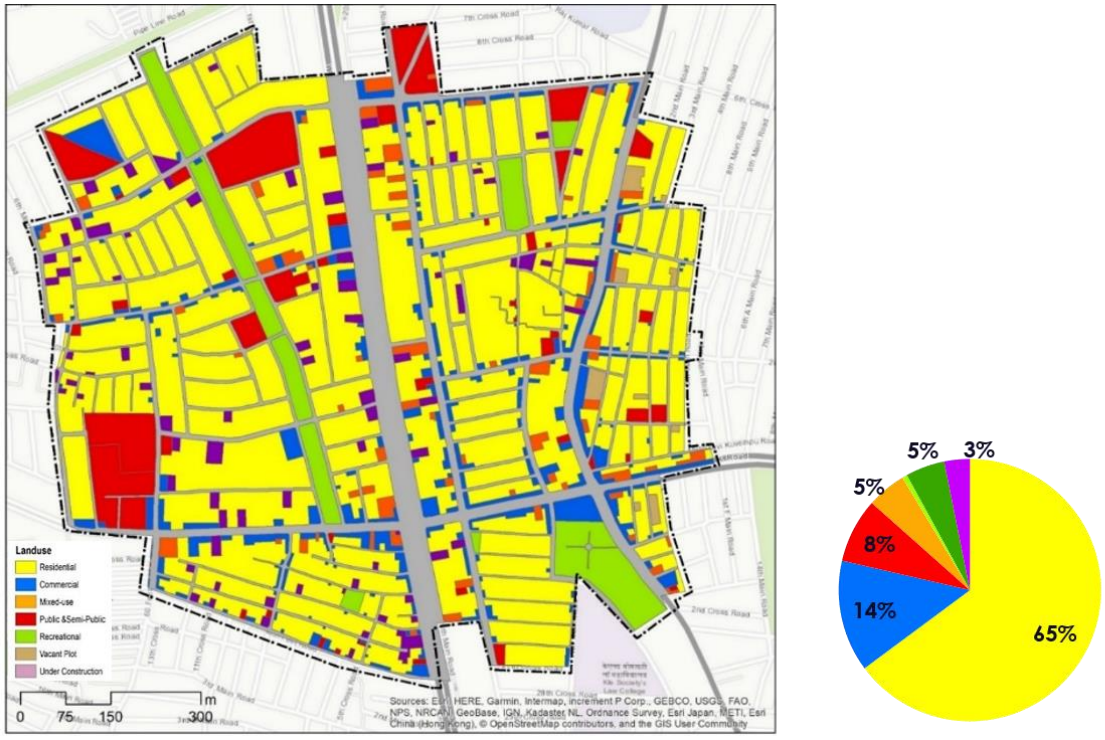


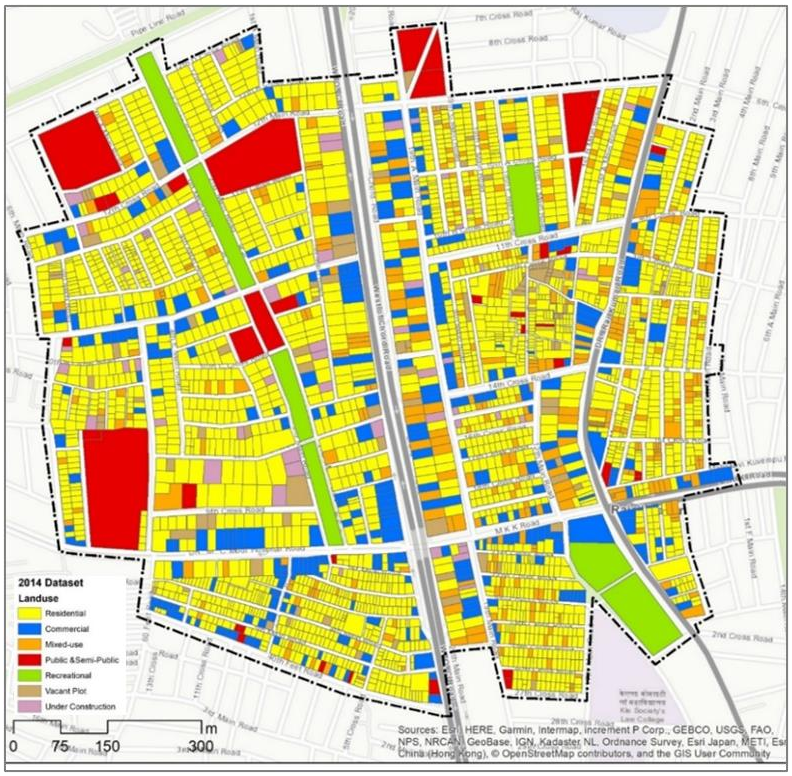
Figure 6 Landuse 2003

Source: (BDA, 2007)

A pie chart (figure 6) shows that in 2003 the residential land use accounts for 65%, commercial use for 14%, public semi-public lands for 8%, mixed-use for 5%, open space for 5%, and industrial use for 3%.

7.2 LANDUSE 2014

Land use map 2014 (figure 7) shows that the trend of commercialization along arterial road continues. There has been a significant increase in mixed-use development by 5% since 2003.



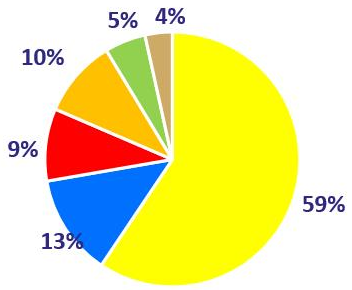


Figure 7 Existing Landuse 2014

Source: **(DULT, 2020)**

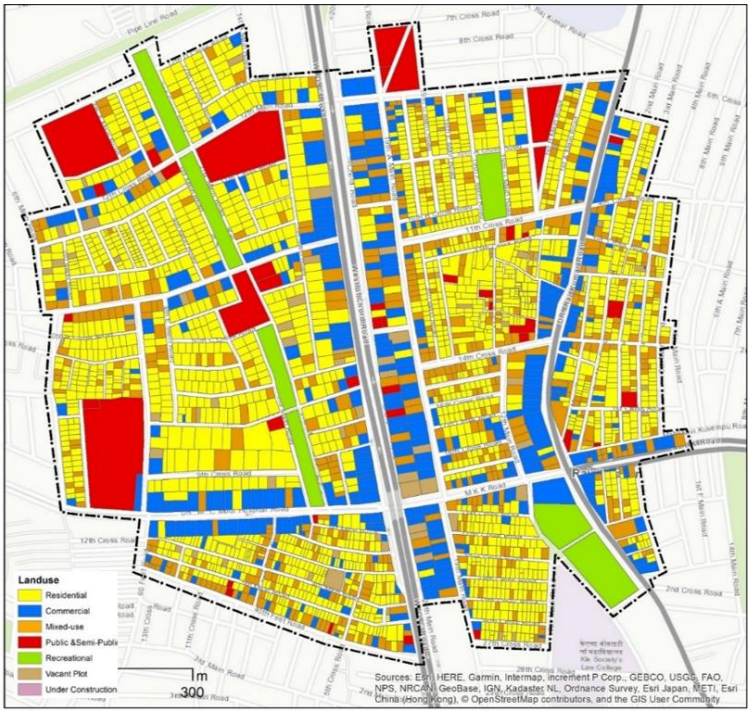
As shown in the pie chart, 59% of the area is residential, 13% is commercial, 10% is mixed-use, and 9% is public semipublic. The table 3 depicts the land use breakup in terms of plots, land use area, and land use area percentage.

Table 3 ELU 2014 Classification

Land use 2014	Number of Plots	Area in Sq.m	Area in %
Residential	2382	404637.34	59%
Commercial	380	87576.859	13%
Public-Semi-Public	38	62547.67	9%
Mixed-use	374	67309.336	10%
Open Space	7	35415.305	5%
Vacant Plot	101	23541.777	4%
Total	3337	697377.43	100%

7.3 LANDUSE 2021

Land use related information for 2021 (map 3-3) was collected through a primary survey. The trend of commercialization along arterial roads has been the same since 2003, with an increase of 4% from 13% to 17%. In addition, mixed-use development has experienced a 12% increase since 2003, as well as a 7% increase since 2014. No significant change was observed in vacant plots.



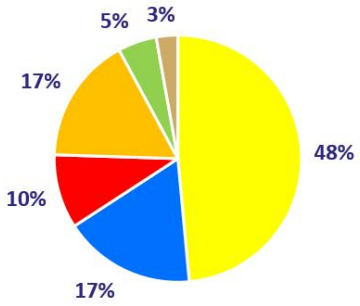


Figure 8 Landuse 2021(Current Study)

The above pie chart (figure 8) shows the percentages of residential, commercial, mixed-use, public semi-public, and vacant plots, with 48% being residential, 17% being commercial, and 17% being mixed-use.

The table 4 depicts the land use breakup in terms of plots, land use area, and land use area percentage.

Table 4 Land Use 2021 Classification

Land use 2021	Number of Plots	Area in Sq.m	Area in %
Residential	1940	338418.938	48%
Commercial	419	120512.104	17%
Public-Semi-Public	41	67603.8715	10%
Mixed-use	629	115801.654	17%
Open Space	7	35415.3197	5%
Vacant Plot	72	19625.5443	3%
Total	3108	697377.432	100%

7.4 TIME SERIES ANALYSIS

The land use comparison from 2003, 2014, and 2021 shows the increase in mixed-use and commercial development and subsequent reduction in residential growth. A prominent increase in commercial development along major arterial roads has been observed in recent years. There has been a significant increase in mixed-use development throughout the area.

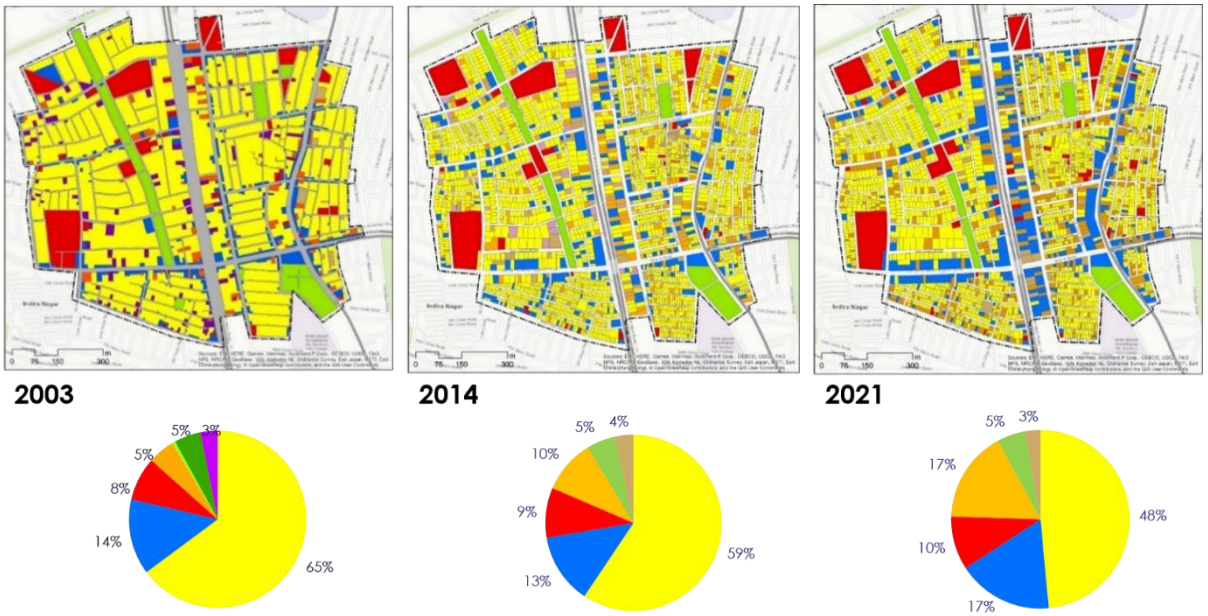


Figure 9 Landuse Change (2003, 2014, 2021)

As shown in the pie chart (Figure 9) above, Residential has declined from 65% in 2003 to 48% in 2021, while mixed-use has increased from 5 percent to 17 percent.

Due to the limitations of the 2003 data, table 5 provides a detailed classification of changes in the area from 2014 to 2021. The degree of change in plot area under the mixed-use category is 72%. This indicates a clear transformation potential of an area into mixed-use neighbourhood which is an evidence of TOD initiation.

Table 5 Percentage Area of Landuse 2014 & 2021

Land use	**2014**		**2021**		**% Change**
	Plot area (sqm)	% Of plot area	Plot area (sqm)	% Of plot area	
Residential	405092.27	58.09	338418.94	48.53	-16
Commercial	87577.09	12.56	119922.47	17.20	38
Mixed-use	67309.34	9.65	115801.65	16.61	72
Public and Semi-Public	62573.30	8.97	67603.87	9.69	8
Recreational	35415.30	5.08	35415.3	5.08	0
Vacant Plot	23541.77	3.38	20215.2	2.90	-16
Total	697377.43	100.00	697377.43	100.00	

Figure 10 shows the graphical representation of the change in land areas by land uses in 2014 and 2021 in the form of a bar graph.

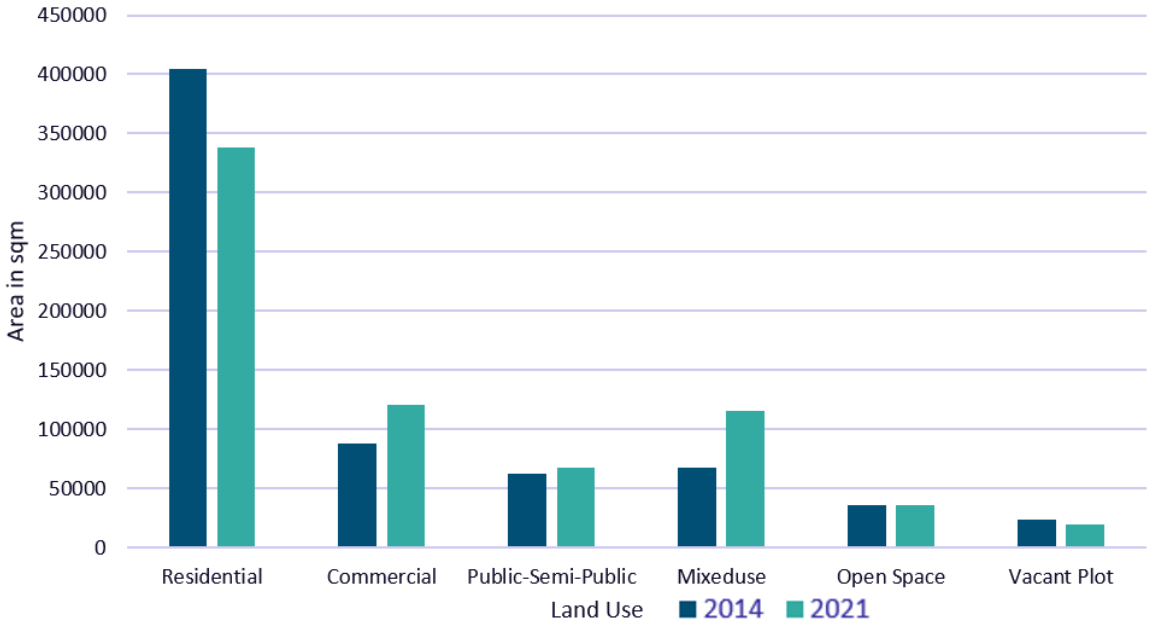


Figure 10 Graphical representation of the change in land areas by land uses in 2014 and 2021

7.5 RESIDENTIAL CONVERSION

As seen previously, in the last decade the residential has decreased whereas commercial and mixed-use have increased. However, the portion of residential area in 2003 that has now been converted to commercial and mixed-use in 2021 is 35% and 65%, respectively. The map (Figure 11) highlights the converted commercial and mixed-use areas in 2021. The pattern describes the commercial growth along the arterial roads and mixed-use development scattered throughout the area.

Figure 11 Landuse Conversion 2014 to 2021 - Residential to Commercial and Mixed Use

7.6 AMALGAMATED PLOTS MAP

Amalgamation is a process, where two or more small land parcels are merged and converted into a larger land parcel to provide an opportunity for a bigger and good quality development. This process is predominantly market driven and dependent on the land owner's willingness to merge or sell and re/develop the land. Through amalgamation, one would benefit from opportunities like utilization of higher FAR, increase in building heights and provision of open spaces within the amalgamated plot.

Figure 12 Amalgamated Plots 2021

A high-density development in a station area could be triggered by various factors one being increasing the permissible FAR. This additional FAR to plot owners is one of the main instruments for incentivizing them to amalgamate plots for mutual benefit. In the Rajaji Nagar study area, about 12% of the total plots in 2014 underwent amalgamation. The total number of plots in 2014 was 3337, out of which 389 plots went under changes i.e, 229 plots merged into 160 parent plots. Thereby, reducing the total number of plots to 3108 in 2021.

The visual representation of amalgamation in the area shows that the process is prevalent across the entire study area, however, it is prominent along the cluster of residential plots between Chord Road and Rajkumar Road. This area in particular has smaller plot areas with relatively lower land values. A similar trend is observed to the south of the study area i.e., Manjunath Nagar and Rajajinagar 2nd block. (Fig-12).These properties have been redeveloped into buildings with a higher number of floors with residential and mixed-use land uses in these above mentioned areas. The spatial map does not showcase a particular pattern of amalgamation (adjacent to arterial roads or metro lines) but is rather distributed across the area.

7.6.1. LAND USE CHANGE UNDER AMALGAMATION

The spatial analysis showed that the majority of the plots that underwent amalgamation have also undergone land use transformation. The area of the plots before and after amalgamation have been presented in (Figure 13)

Post amalgamation the areas under vacant plots and residential land use were observed to have decreased whereas areas under mixed-use and public semi-public use have increased. Most of the mixed-use transformation observed is along the arterial roads.

The observation shows an increase of 5.86% in area under mixed-use, 4.36% in public semi-public by 4.36%, and only 0.15% in commercial use. Hence, it is evident that a maximum number of plots during the amalgamation process have converted from their previous land use in 2014 into mixed Use in 2021.

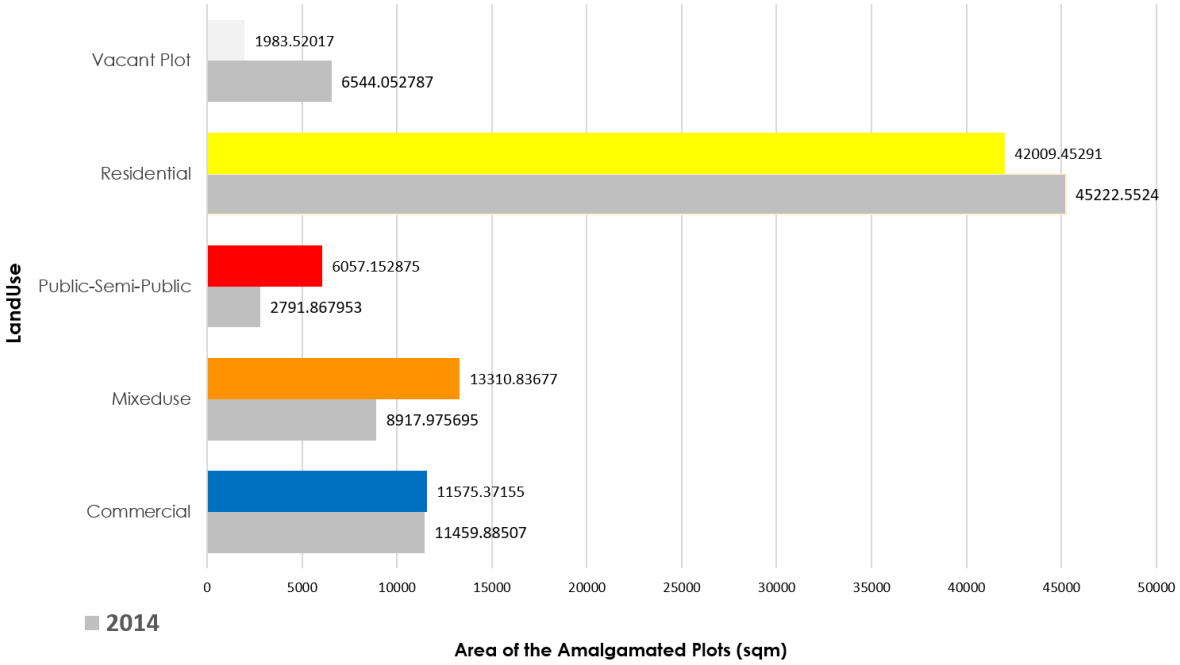
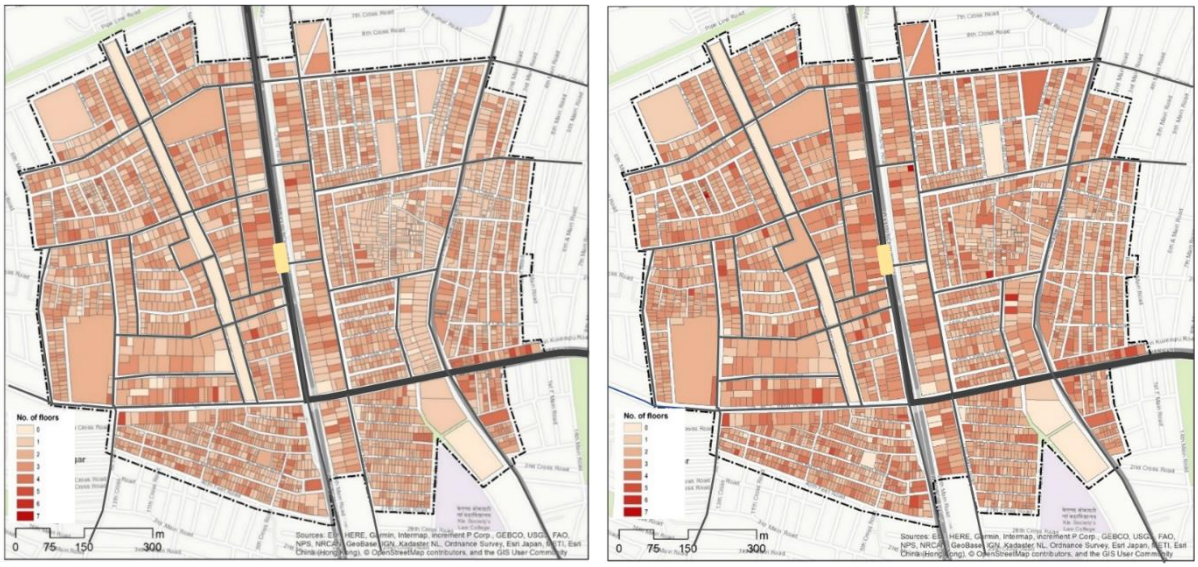


Figure 13 Change in land use with plot amalgamation from 2014 to 2021

7.7 TRANSFORMATION IN BUILDING HEIGHTS

It is noted that densification of an area is either through horizontal or vertical development. The former is more prominent in green-field areas and areas where space is available whereas, the latter is prominent in brown-field areas where land is in scarcity.

As densification is one of the objectives of TOD, a study on vertical development in terms of building heights and FSI consumption is essential. Therefore, an analysis of transformation in building heights was carried out for the study area.



2014 **2021**

Figure 14 Building heights in 2014 and 2021

Spatial analysis of 2014 showed that G, G+1, and G+2 structures were predominant and that the G+2 and above structures were mainly observed along arterial roads. In 2021, the high-rise development of G+5 and G+6 was observed. These buildings were mainly residential and mixed-use developments.

Table 6 Percentage change in building heights in residential, mixed, and commercial use

No. of Floors	2014		2021		% Change in building heights
	Total no. of plots	No. of plots in each LU	Total no. of plots	No. of plots in each LU	
1 (GF)	970	695 107 80	445	313 69 48	-54%
2 (G+1)	1361	1054 158 139	1332	917 266 132	-0.02%
3 (G+2)	773	549 93 128	1002	577 235 179	22%
4 (G+3)	123	75 15 32	224	117 49 54	45%
5 (G+4)	11	9 1 1	27	13 8 6	59%
6 (G+5)	0	0 0 0	3	2 1 0	100%
7 (G+6)	0	0 0 0	2	1 1 0	100%

About 54% decrease in G+1 structures and a 45% increase (from 2014 to 2021) was observed in G+3 structures and a 59% increase (from 2014 to 2021) was observed in G+4 structures (Table 1). Due to increased demand for commercial & retails spaces, land scarcity for horizontal expansion, and favorable development opportunities, buildings have grown vertically.

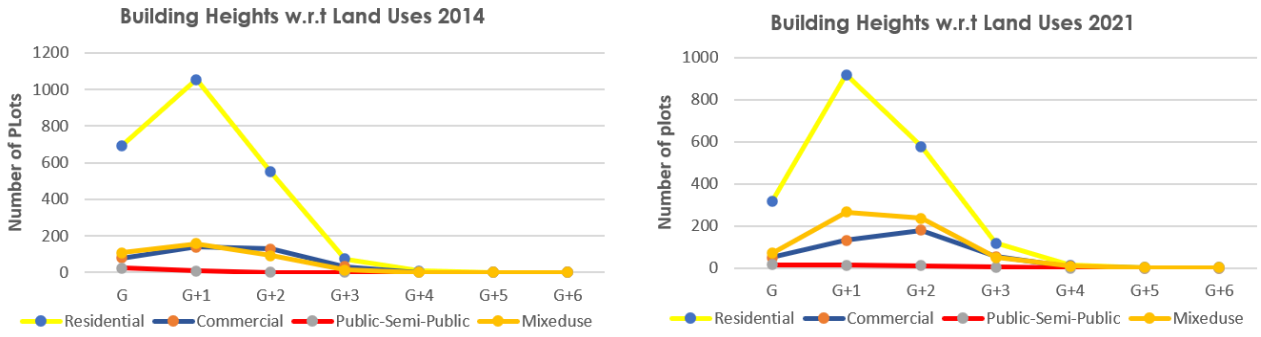


Figure 15 Building heights w.r.t land use

The shift in residential plots is seen in towards G+2 and G+3. Mixed-use has shown a maximum rise in G+1 and G+2. Whereas, in commercial, the peak is seen in the G+2 structure followed by G+1. It can therefore be observed that most of the building height transformations in 2021 were towards G+2 i.e, two floors above the ground floor. The land use of G+5 and G+6 buildings is mainly residential and mixed-use.

7.8 FAR TRANSFORMATIONS

As the building footprints were unavailable for the study area that could be accurately overlaid onto plot boundaries hence, plot level FAR calculations were replaced by Bulk net FAR calculations based on fishnet analysis.

Fishnet analysis is a method of creating a series of grids of appropriate size enclosing the study area. This process facilitates a representation of various datasets on a spatial level by assigning a value to each grid. Therefore, the study area was divided into grids of sizes 50m by 50m for FAR computation.

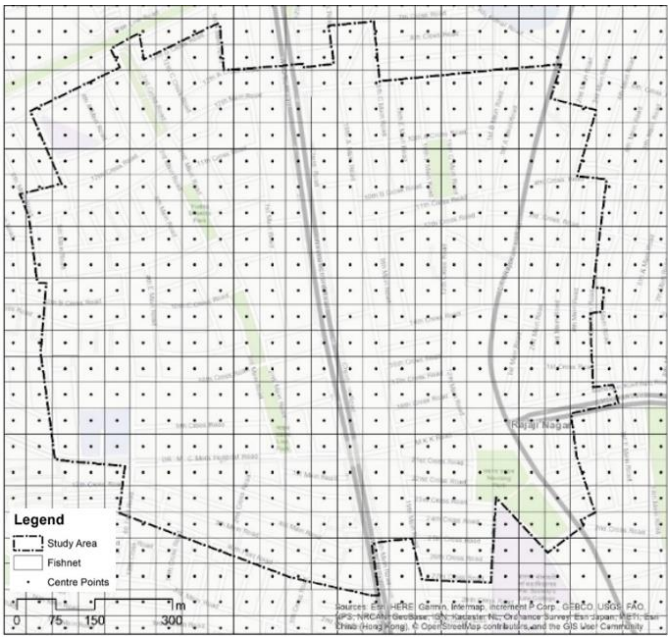


Figure 16 Fishnet for a study area

The calculation is as stated below-

$$\text{Bulk Net FSI} = \frac{\Sigma\,(\text{BUA1} + \text{BUA2} + \text{BUA3}.....)}{\text{Grid Area}}$$

Where,
BUA = Plot area x No. of floors
Grid Area – 50m x 50m

The bulk net FAR mapping showed that along the metro line the average and maximum FAR for the years 2014 and 2021 were as tabulated,

Years	Average FAR	Maximum FAR
2014	**1.3**	**3.2**
2021	**1.6**	**4.3**

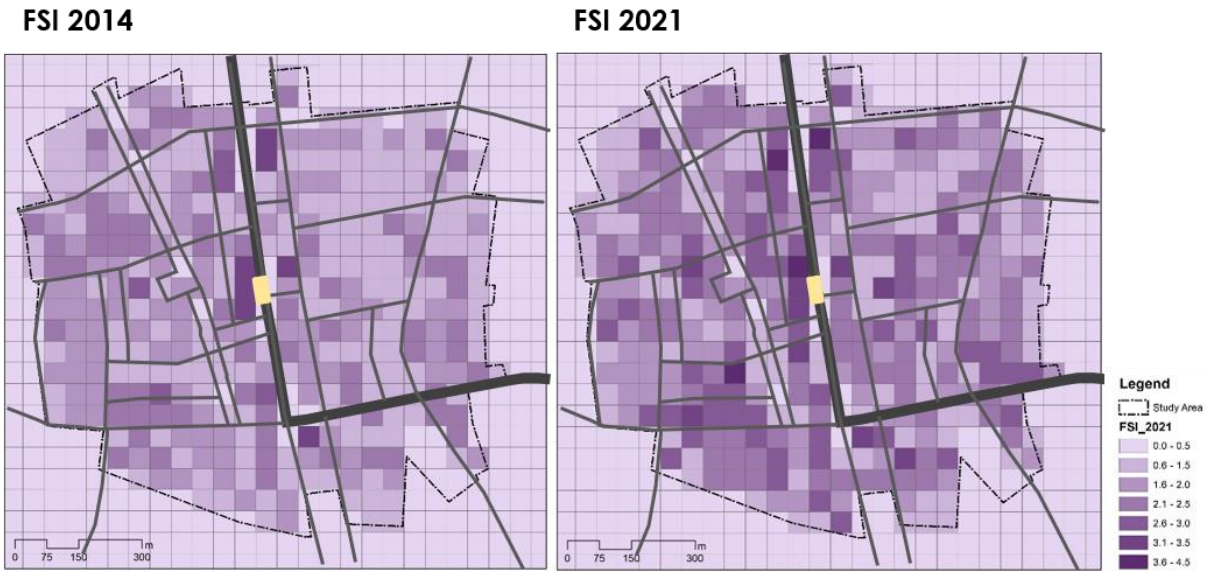


Figure 17 Fishnet analysis of FSI (2014 and 2021)

The average FAR along the metro line is about 1.4 in 2014 and 1.7 in 2021. The mapping showed that there has been an emerging trend of densification but it is not highly significant. The densification is also observed along the arterial roads and not only along the metro line. Since a significant change in FAR and building heights has not been observed it is essential to plan for interventions to trigger and incentivize development aligning to the TOD policy.

8. LAND VALUE ANALYSIS

The position and location of the land can have a direct influence on its value. For example, a remote parcel of land may have a lower value because it does not have access to amenities, utilities, transportation, or other resources that could make the property useful. The value of the land might increase if the property is located near a popular destination such as transit hubs, business centers, entertainment, or services that are in demand.

Due to the unavailability of relevant data on the market values of the properties, the study was

undertaken using only Guidance values. To study the implication of the metro on the land value, the guidance values (for the years 2014 and 2021) were analysis, and inferences were based on such analysis. The guidance values were obtained from the Department of stamp and registration – Rajajinagar, Bangalore. The guidance value sheet has a list of land values that are apportioned with respect to the block areas and adjacent roads. The values mentioned are only for residential plots. The value of a plot increases if it has some locational benefit in its neighborhood. For example, if the plot is park facing it will have an additional value of 10% on it. Figure 18 shows the Guidance value allotment rules.

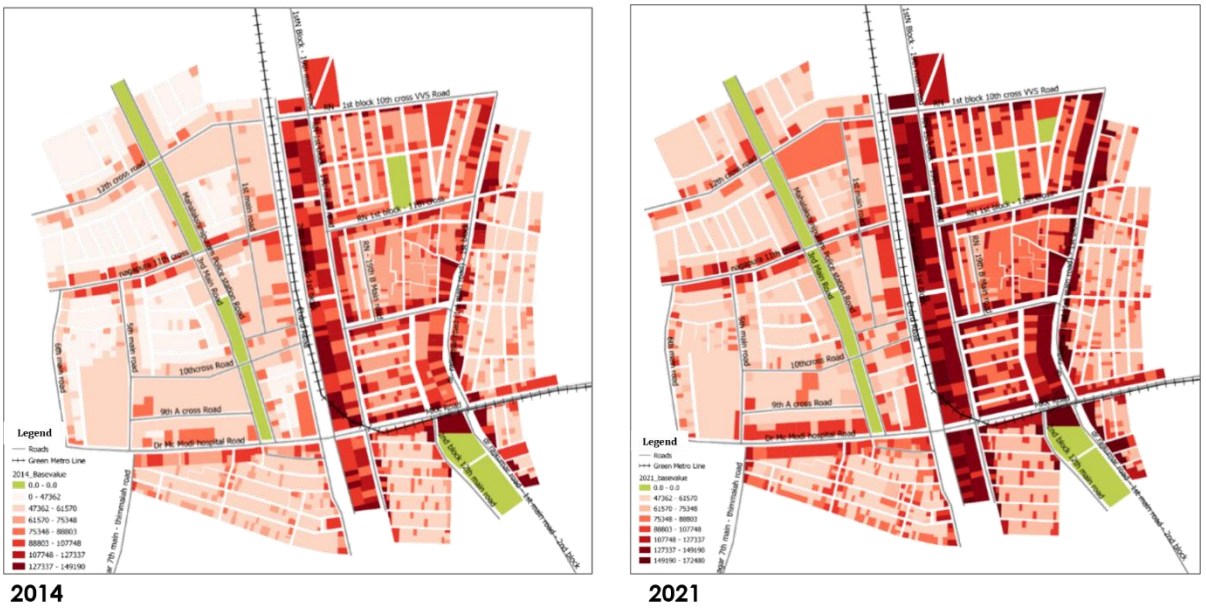
Figure 18 Guidance Value Allotment

From the Guidance Value Rules for the City:

- Residential land values are allotted block-wise
- Residential land values are allotted road-wise – adjacent plots to particular roads only if mentioned
- Commercial/mixed Land Values are 40% of the residential values in that particular block area
- Corner plots have a 10% additional value
- Plots abutting the park have a 10% additional value
- Plots abutting major roads have 30% additional value unless otherwise mentioned
- Plots abutting secondary roads have 20% additional value unless otherwise mentioned
- Public semi-public and vacant land plots are allocated residential values

8.1. LAND VALUE ASSESSMENT

The Land Value maps are generated using the Guidance Values assigned for the city using ArcGIS. The color of the plots from light to dark indicates the land values in ascending order.



2014 **2021**

Figure 19 Land value distribution in 2014 and 2021

For 2014, the values range from 47,362/sqm to 149,190/sqm. The Arterial roads and the metro line show darker color plots due to the commercial development which has predominantly increased along Rajkumar road, Nagapura 11th cross, Maha Kavi Kuvempu Road, and Chord Road. Rajajinagar 1st block has a higher land value as compared to other blocks in the study area.

The map of land value 2021 has shown an overall increase in land values as compared to 2014. The range varies from 47,362/sqm to 172,480/sqm. The neighborhood lying on the east of the chord road – Rajajinagar 1st block, continued to have higher land values. The increase in values in 2021 has shown a similar trajectory as of 2014 for commercial establishments along arterial roads.

8.2. LAND VALUE COMPARATIVE

The variation in the land values from 2014 to 2021 is shown in the bar graph below (Figure 20). The plots with values between 50,000-80,000/sqm range have decreased in 2021 and increased significantly between 80,000-1,20,000/sqm. The price range of 1,50,000-1,80,000/sqm has shown a significant increase in 2021.

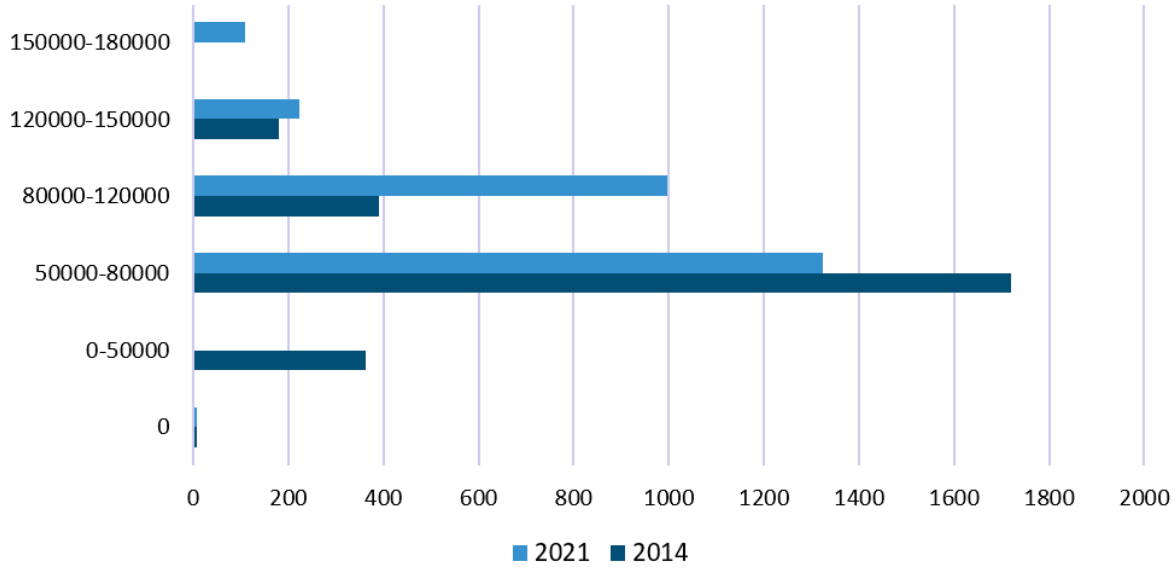


Figure 20 Land Value Comparison (2014 & 2021)

The map (Figure 21) shows growth in land values in 2021 in comparison to 2014. It also depicts a higher land value along the east of the chord road- Rajajinagar 1st block as compared to west of cord road - Nagapura and Manjunath Nagar.

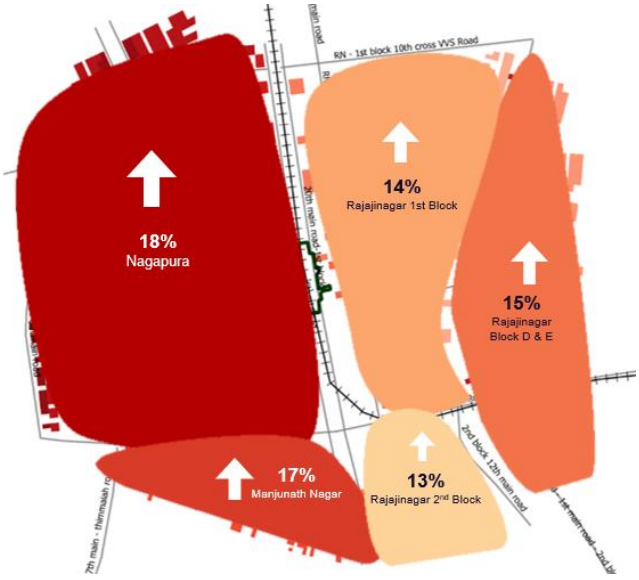


Figure 21 Percentage growth in land values from 2014 to 2021

However, the percentage change in land value from 2014 to 2021 is higher in the west than in the east. The Nagapura and Manjunath nagar have shown an increase in land value by 18% and 17% respectively. Therefore, showcasing that the plots with lower land values have a higher growth rate.

9. KEY FINDINGS

Based on the spatial transformation analysis the following observations were made –

Land Use Transformation:

- The Land Use time series analysis of 2003, 2014, and 2021 reveals that the growth pattern of the area has been consistent over time, with an increase in commercial development along arterial routes.
- Between 2014 and 2021, there was a drop in residential land use, with 35% of residential properties becoming commercial and 65% becoming mixed-use.
- Total mixed-use development indicates a 12% growth from 2003 to 2021 and a 7% increase from 2014 to 2021, demonstrating a trend in line with ToD principles of mixed-use development.
- Although there is an increase in commercial development along the metro line, there has not been an increase in mixed-use development, therefore creating inactive and dead street life post working hours.
- About 12% of the total plots in 2014 underwent the process of amalgamation. About 5.86% of residential properties have been converted into mixed-use.

Height and FSI Transformation:

- Between 2014 and 2021, there was no discernible change in building heights. From 2014 to 2021, it was found that G+1 structures decreased by about 54%, G+3 structures increased by 45%, and G+4 structures increased by 59%. There was no significant change in building heights in 2014 and 2021. The land use of G+5 and G+6 buildings (2021) was mainly residential and mixed-use.
- The average FSI along the metro line is about 1.4 in 2014 and 1.7 in 2021. The mapping revealed a new tendency toward densification; however, it is not very substantial. Grids with a higher density were seen along the metro lines and arterial roadways. Since there is no significant change in FSI and building heights, it is essential to plan for interventions to trigger and incentivize development aligning to the TOD principles.

Land Value Transformation:

- Land value increase in 2021 has shown a similar trajectory as of 2014. The land value growth rate of lower-valued properties has shown an increase of 17-18% in Manjunath Nagar and Nagapura as compared to higher valued properties in the Rajajinagar 1st, 2nd, D, and E blocks in the study area.

Need for TOD zone planning:

- There is a need for developmental triggers to promote transit-oriented development in the study area. Currently, there is a greater focus on commercial use along the metro line, whereas as per the TOD principles the trend should be towards mixed-use to promote live, work, and play concept and have an active and accessible public realm.

PART II

10 STATISTICAL ANALYSIS

Statistical analysis was carried out to prove and strengthen the outcomes of the spatial analysis. The process of collecting and analyzing data to identify patterns/ trends and undertake informed decision-making is known as statistical analysis. It is classified into two types: Descriptive statistics which explains and visualizes data, whereas inferential statistics extrapolates data collected in the study area. Inferential statistics begin with a hypothesis (a statement or conjecture about the relationship between two or more variables that you intend to investigate) and investigate whether the data support that hypothesis.

Hence, this study included statical analysis to further investigate and validate the findings from spatial analysis, and thus draw relevant conclusions and suggestions.

10.1 DATA SETS

The study used two data sets for statistical analysis. The details of the plot-level datasets are as follows-

1. GIS Data-
    a. The data set includes plot-level data on land use, building heights, guidance value (property values as per government rates), and distance of the property to the metro station.

    b. Total dataset of **1941** samples (only residential plots).

2. Household Survey Data –
    a. This is based on the household survey which includes the Land value of 2021, age of the structure, property size (built-up area), typology (apartment or independent house), FAR (total built-up area/ total plot area), Number of Bedrooms, Educational level of the household (proportion of graduated/ total number of people above 18years old), Income levels of the household, Metro Ridership (Proportion of the people who use the metro to commute/ total number of people who commute), Job accessibility within 30mins (Number of people who can access their workplace within 30 mins by any mode of transport/ total number of people who are working); Locational characteristics include distances from the metro station, from nearest bus stops, from nearest arterial roads – these are obtained from ArcGIS.

    b. Total dataset of **109** samples.

Table 7 Attributes and data sources

Attributes	Data source	Method	Data format
Property Size (sq m)	HH survey	Total Built-up area and plot area	numeric
Distance from metro station(m)	GIS	the shortest walkable route in meters	numeric
Ridership	HH survey	metro ridership proportion per household	numeric
Distance to nearest urban arterial (m)	GIS	shortest walkable route to the nearest arterial	numeric
Distance to the nearest bus stop (m)	GIS	Shortest distance to the nearest bus stop	numeric
Job accessibility within 30mins	HH Survey	cumulative proportion of the HH	numeric
Floor area ratio	HH survey	Total built-up area/total plot area	numeric
Residents with a college degree - Education level	HH survey	in proportion but over 18 years of age	numeric
Bedroom	HH survey	typology - BHK;	numeric
Price per sqft (Rs)	HH survey	per sq m	numeric
Age(years)	HH survey	Property age	numeric
Median income (Rs)	HH survey	taking the median of all the members	numeric

**Note- all HH surveys and GIS data were collected and generated by DULT as part of the study*

10.1.1 ATTRIBUTE SELECTION CRITERIA

The criteria to select these attributes as variables for testing the hypothesis is based on the following explanation:

- **Land Value:** Numeric data is required to run the regression as property value is the dependent variable
- **Property size**: The property rates are based on per sq feet of the land size, hence the property size directly influences the property values
- **Distance from the Metro Station/ Distance from Bus Stops/ Distance from Arterial Roads:** Distance is a parameter to assess the accessibility of transportation infrastructure which influences the demand and the property rates
- **Metro Ridership:** Ridership is also a parameter of accessibility that generally influences rental properties to rise in the station area
- **Job accessibility within 30mins**: Job accessibility is a locational parameter indicating employment opportunities
- **FAR:** It is a land attribute that says the higher the FAR the higher the land prices
- **Education level:** This is a neighborhood characteristic, that influences the property owner's inclination to convert residences to amalgamated development/mixed use/high rise residential etc. To the property owner, intensification normally translates into higher valued properties and in some cases increases in rental income. This also affects the behavior of the society in terms of more awareness, social progress, security, safety etc.

- **No. of Bedroom**: Number of bedrooms is generally associated positively with the property prices
- **Building Age:** House characteristic that tend to depreciate over time. This also signifies the condition of the house.
- **Median Income:** neighborhood attribute depicting the social and economic development of the neighborhood (median income, educational attainment, etc.);

10.1.2 SAMPLING FOR HOUSEHOLD SURVEY

The Household survey provides socio-demographic data about the residents in the study area. For the study, a household survey is required to determine the values of the attributes chosen to run the regression model. The sample size is taken as 100 (5% of the total residential plots). The attributes are selected based on the hedonic price model which is widely used to determine the land values of the neighborhood.

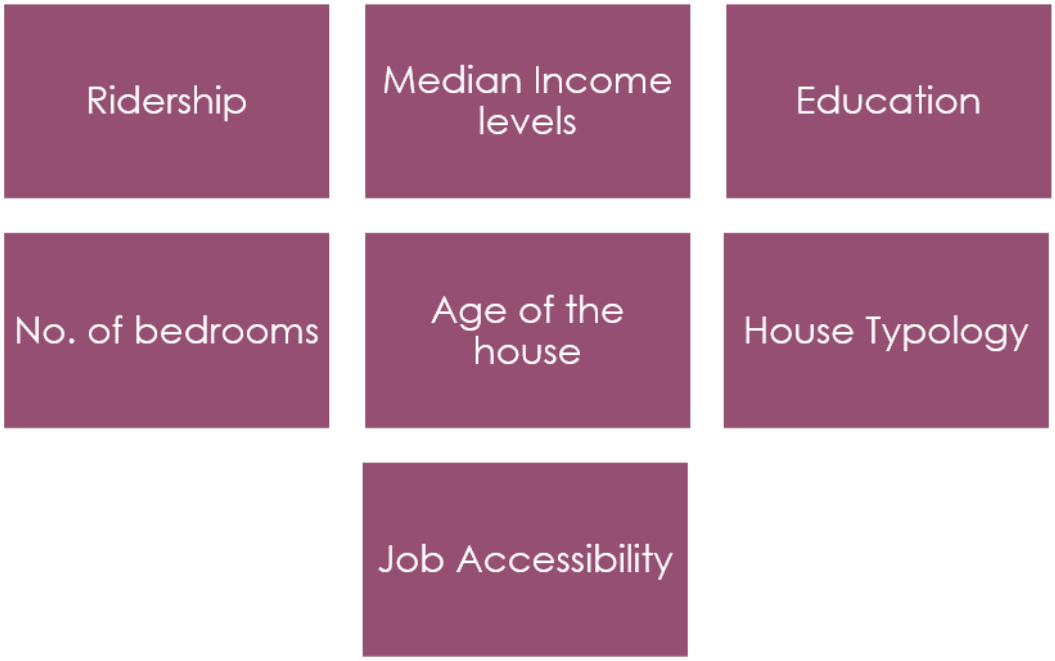


Figure 22 Attributes captured through a survey

The sample size was assumed to be 5% of the total residential properties in the study area. The number of samples was calculated as below,

5% of total residential plots → 5% X 1941 = 97 = ~100 samples

A random sampling method was used to identify the points in the study area. The random Sampling command was run on ArcGIS software with various global distances to get the required sample size. A 65m global distance was finally selected through which approximate of 133 sample points were obtained.

Total samples selected - 133

Figure 23 Sample distribution in the study area

The study area was further divided into grids of 250m to facilitate survey process on ground.

The samples collected were further analyzed and a few redundant samples were rejected. Hence, the total samples shortlisted for the analysis were 109.

10.1.3 ANALYSIS

Statistical analysis using SPSS software was undertaken to further strengthen the spatial observations and evaluate the impact of mass transit like the metro on spatial characteristics such as Land Use, Density, and Residential Land values in the TOD Zone of Rajajinagar.

The research questions and the corresponding findings are as below –

1. What is the extent and nature of the change in spatial characteristics of the study area due to the introduction of the metro?
2. Does the proximity to the metro affect the FAR utilization of in-situ developments and amalgamated plots?
3. Has the commencement of the metro affected the land values in the study areas?

Correlation coefficients measure the strength of the relationship between two variables. A correlation between variables indicates that as one variable changes in value, the other variable tends to change in a specific direction (positive or negative). Hence, the below-listed parameters were considered to assess the impact of the metro on land use, FAR, and land values.

To run the analysis on SPSS software the parameters and their categories were coded. The coding was done as below,

Type of Land Use	Details	Code
RE	Residential	1
MU	Mixed-Use	2
CO	Commercial	3

Range for distance(in m) from Arterial/Bus/Metro	Code
<100	1
100-200	2
200-300	3
300-400	4
400-500	5
>500	6

Range for plot area	Code
<100	1
100-200	2
200-500	3
500-1000	4
1000-5000	5
5000-10000	6
>10000	7

Range for land Value	Code
0	0
<10L	1
10L - 50L	2
50L-100L	3
1cr - 3cr	4
3cr - 5cr	5
5cr - 10cr	6

Figure 24 Coding for regression

1. Has the spatial character of the area been remodeled by the introduction of metro?

Dataset used – Plot data from the study area – 2500 samples

Variables used – Land Use 2014, Land Use 2021 and Distance to metro

Table 8 Correlation table - Distance to metro, land use 2014 and land use 2021

Correlations

		Distance to Metro	LandUse_14	LandUse_21
Distance to Metro	Pearson Correlation	1	**-.129****	**-.158****
	Sig. (2-tailed)		.000	.000
	N	2539	2539	2539
LandUse_14	Pearson Correlation	-.129**	1	.570**
	Sig. (2-tailed)	.000		.000
	N	2539	2539	2539
LandUse_21	Pearson Correlation	-.158**	.570**	1
	Sig. (2-tailed)	.000	.000	
	N	2539	2539	2539

**. Correlation is significant at the 0.01 level (2-tailed).

The negative sign indicates that the distance from the metro is inversely related to the Land use (as coded) i.e shorter the distance from the metro higher the code value of land use (Figure. 25)

Type of Land Use	Details	Code
RE	Residential	1
MU	Mixed-Use	2
CO	Commercial	3

Range for distance(in m) from Arterial/Bus/Metro	Code
<100	1
100-200	2
200-300	3
300-400	4
400-500	5
>500	6

Figure 25 Coding for land use and distance range

The dataset shows that commercial development is higher in proximity to the metro station. Therefore, in the study area land use is influenced by the distance of the metro station and the trend is consistent from 2014 to 2021.

2. Has metro rail significantly influenced the FAR consumption in the TOD Zone (number of floors)?

Dataset used – Plot data from the study area – 2500 samples

Variables used – Land Use 2014, Land Use 2021, and Distance to metro

Table 9 correlations table - Distance to metro, Building height of 2014, and Building heights 2021

Correlations

		Distance to Metro	Floor_14	Floor_21
Distance to Metro	Pearson Correlation	1	.001	-.012
	Sig. (2-tailed)		**.961**	**.547**
	N	2539	2539	2539
Floor_14	Pearson Correlation	.001	1	.620**
	Sig. (2-tailed)	.961		.000
	N	2539	2539	2539
Floor_21	Pearson Correlation	-.012	.620**	1
	Sig. (2-tailed)	.547	.000	
	N	2539	2539	2539

**. Correlation is significant at the 0.01 level (2-tailed).

The significance value for the number of floors in 2014 and 2021 is higher than 0.05 and hence is insignificant. Therefore, in the study area the distance from the metro does not have any significant influence on building heights.

3. Has the metro influenced the land values in the study area?

Dataset used – 109 samples from the Household survey

Analysis Method – Multiple Linear Regression

Dependent Variable – Property value 2021

Independent Variable – Plot area, annual HH income, education levels, employment within 30mins, distance to metro, distance to an arterial road, distance to the bus stop

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.606	.340		1.784	.077
	AREA_C	.791	.073	.722	10.783	.000
2	(Constant)	1.957	.547		3.581	.001
	AREA_C	.771	.071	.703	10.875	.000
	Metro_code	-.253	.082	-.200	-3.086	.003

Condition – Significance value (p-value) less than 0.05 is statistically significant for the model showing a significant relationship with the dependent variable.

The regression model has been generated by taking Land value 2021 as a dependent variable (DV) and, the area of the plot and distance to the metro as independent variables (IV). Analysis shows that both plot area and distance from metro variables are statistically significant for the model showing a significant relationship with DV (Land value).

The analysis for plot area and land value shows a positive sign indicating that the area of land is directly related to the land value i.e., the larger the area higher the land value.

The analysis for distance to the metro and land value shows a negative sign indicating that the distance from the metro is inversely related to the Land value i.e., the shorter the distance from the metro higher the code of land value (towards code 5). Other variables like HH income, education levels, employment with 30mins, and distance to arterial and bus stops are excluded from the model as they are insignificant.

Therefore, the analysis shows that in the study area distance to the metro is inversely related to land value i.e., the nearer the distance from the metro more likely the land value is higher.

11. CONCLUSION

Based on the spatial and statistical analysis, it is evident that the study area has transformed, and variations in land use, building heights, property values, and FSI have been observed. According to the time series analysis, there was a maximum increase in the mixed-use development of 12% from 2003 to 2021 and 7% from 2014 to 2021, demonstrating a trend aligning with ToD principles of mixed-use development. In addition, approximately 5.86% of amalgamated residential properties have been converted to mixed-use. However, commercial land use dominates the trend along the metro line. Since, the use along the metro line influences the activity along the street, purely commercial land use would create inactive and dead street life post-working hours. Therefore, there is a need to incentivize and promote mixed-use development in the core TOD zone of the metro station.

The analysis revealed no significant change in building heights in the study area. The structures G+3 and G+4 grew by 45% and 59%, respectively. However, this increase was not evenly distributed across the study area. The height of the properties along the metro line did not increase significantly. The average FSI along the metro line is about 1.4 in 2014 and 1.7 in 2021. The mapping revealed an emerging trend of densification, but it is not statistically significant. Along arterial roads and metro lines, higher density grids were observed. As there has been no significant change in FSI and building heights in the study area, it is critical to plan interventions to trigger and incentivize development aligning with the study area.

Statistical analysis shows that distance to the metro station influences land use in the study area, and the trend is consistent from 2014 to 2021. Near the metro station, commercial development is predominant. The analysis revealed that the distance from the metro has no significant effect on building heights. The analysis revealed that the distance to the metro is inversely proportional to land value, i.e., the closer the distance to the metro, the higher the land value.

As a result, there is a need for developmental triggers to promote transit-oriented development. Currently, there is a greater emphasis on commercial use along the metro line, whereas the TOD principles suggest that the trend should be toward mixed-use to promote live, work, and play, as well as an active public realm in the core zones.

However, the study area is only 500m radii from the metro, which is unlikely to show a significant difference in land value, land use, and building heights; thus, a richer and more data driven analysis could have been obtained if the study area was 1000-1500m radii. To determine the impact of the metro on the spatial character of the station, a similar exercise on different metro stations must be carried out to rule out biased results based on a single station, as this does not justify the city scenario because each station has different characteristics.

REFERENCES

Bangalore Metro Rail Corporation Limited. (2022). Retrieved from Namma Metro - Bangalore Metro Rail Corporation Limited: https://english.bmrc.co.in/#/

Basbas. (2012). *1. Impacts of a metro station to the land use and transport system: the thessaloniki metro case.*

BDA. (2007). *Revised Master Plan - 2015 Bengaluru.* Bengaluru: Bengaluru Development Authority.

Bo zhang, w. l. (2021). *Estimating the Impacts of Proximity to Public Transportation on residential property values: An empirical analysis for hartford and stamford areas, conencticut.* connecticut.

DULT. (2020). *Station Accessibility Plan.* Bengaluru: Directorate of Urban Land Transport,GoK.

Gallo, M. (2018). The Impact of Urban Transit Systems on Property Values: A model and some evidences from the city of Naples. *Journal of Advanced Transportation*.

Ministry of Urban Development. (2017). *National Transit Oriented Development (TOD) Policy.* New Delhi : Ministry of Urban Developement, Governement of India .

Robert Cervero, C. D. (2010). Bus rapid transit impacts on land uses and land values in Seoul, Korea.

Xuan Zhu, S. L. (2004). Analysis of the impact of the MRT system on accessibility in Singapore using an integrated GIS tool.

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