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Tales of a few cities!

Examining trends in growth of cities in India using novel high frequency data

EAC-PM Working Paper Series
EAC-PM/WP/36/2024

Bibek Debroy & Devi Prasad Misra

December, 2024

The artwork featured here is from the *Lodhi Art District*, India's first open-air public art district, located in Lodi Colony, New Delhi. The painting, titled *The Origin of The World* celebrates life and movement and has been created by *Borondo*.

Tales of a few cities

Examining trends in growth of cities in India using novel high frequency data

Bibek Debroy[1] & Devi Prasad Misra[2]

December, 2024

Abstract

This is a companion paper to "400 Million Dreams! - Examining volume and directions of domestic migration in India using novel high frequency data", (Debroy, Misra, 2024) where we proposed a model for analysing movement of passengers; building origin-destination dyads and identifying popular sources of origin and destinations using high frequency, granular passenger movement data from the Indian Railways Unreserved Ticketing System (IR-UTS).

Here we extend the model to look at urban growth in four metropolitan cities – Mumbai, Chennai, Delhi and Kolkata using data on suburban travel on the IR network. While not an indicator of migration per se, suburban travel is a useful indicator for observing and analysing spatial growth in urban areas.

We go on to analyse publicly available geospatial earth observation data along with data on housing property prices to explore linkages between population dispersion and property prices.

We combine this with processed satellite imagery and Land Use Land Classification (LULC) data to understand the directions of Urban Growth.

Our findings indicate that overall, post Covid-19 related lockdowns, suburban travel quickly rebounded back but still hasn't quite reached pre-pandemic levels. This might be on account of shift of transport preferences or due to the rise of counter magnets.

We go on to study the trends in passenger arrivals from the top districts of origins for each of the above cities in order to analyse patterns on urban growth and understand LULC changes in the suburban districts.

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Introduction

Cities are engines of economic growth as they play a crucial role in concentrating human capital, innovation, infrastructure and institutions which eventually leads to a growth in productivity[3]. By concentrating skilled workers together, cities facilitate innovation and entrepreneurship leading to greater wage growth which in turn attracts more human capital[4].

Higher concentration of markets and consumers also brings about economies of scale and eventually leads to improvement in infrastructure[5]. This virtuous cycle, helps cities emerge as hubs of growth by minimizing transportation and logistics costs; maximizing returns on investment; and by serving as focal points for trade and commerce[6].

It is in this context that understanding the growth of cities is important not only for understanding the contours of economic growth today but also to understanding the likely urban requirements of tomorrow.

We take forward our exploration of movement of passengers as a marker of migration and view the dataset from a different perspective to understand patterns in suburban travel and thereby trends in growth of cities.

As per Census, 2011, out of India's total population of 121.02 Crore, 37.7 Crore were in urban areas i.e. 31.6% of the total. Moreover, in the period 2001-2011, population in urban areas increased by over 9.1 Crore - a growth rate of 31.8%[7].

We use data from the Indian Railways Unreserved Ticket System (IR-UTS) for II Class passengers, typically the cheapest class of tickets on the IR network and is often favoured by blue collar workers. We geocode the origin/destination pairs to filter out non-suburban travel. Indian Railways

[3] Glaeser, E.L., & Gottlieb, J.D. (2009). The Wealth of Cities: Agglomeration Economies and Spatial Equilibrium in the United States. Journal of Economic Literature

[4] Moretti, E. (2012). The New Geography of Jobs. Houghton Mifflin Harcourt

[5] Ciccone, A., & Hall, R.E. (1996). Productivity and the Density of Economic Activity. American Economic Review, 86(1), 54-70

[6] Krugman, P. (1991). Increasing Returns and Economic Geography. Journal of Political Economy, 99(3), 483-499

[7] Ministry of Housing & Urban Affairs; https://mohua.gov.in/cms/urban-growth.php

defines suburban services as normally being **upto 150 Kms**. from the origin[8].

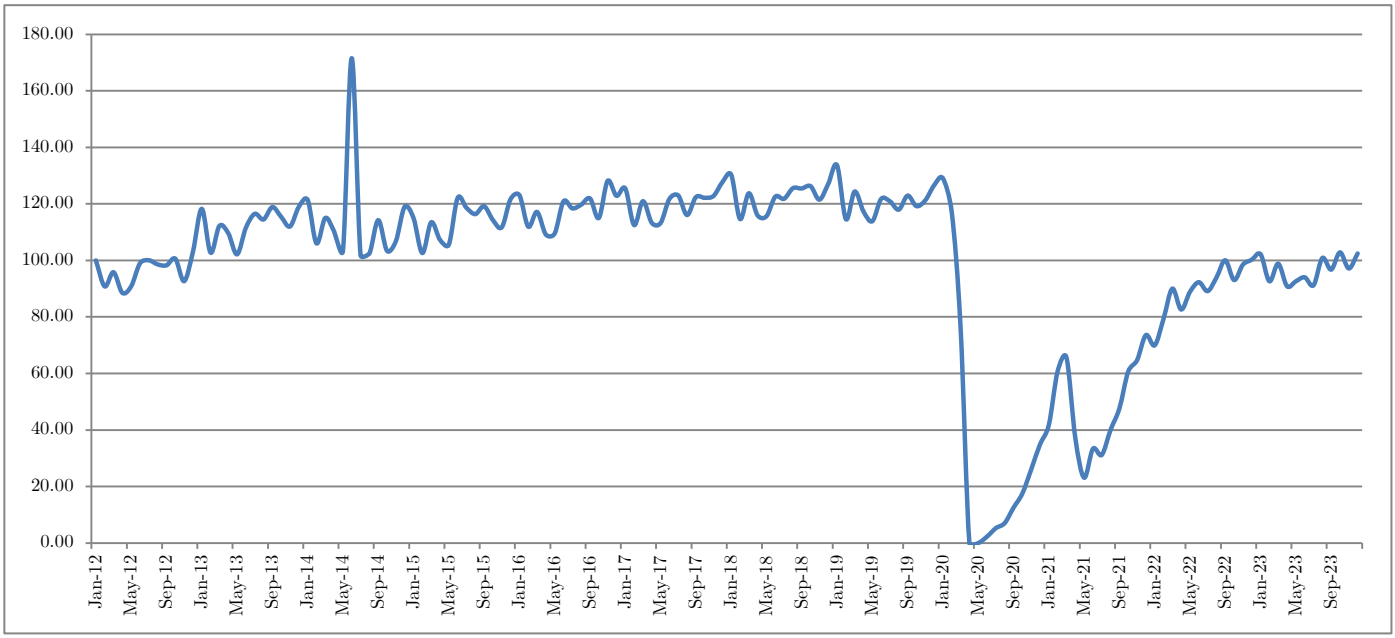
In this paper we limit our examination to the movement of people within 150 kms from the respective city centres. We take a look at the sources, the volume and the seasonality of movement for four cities – *Mumbai*, *Chennai*, *Kolkata* and *Delhi*. Further, using geospatial earth observation data we make an attempt to understand the spatial growth in the respective urban agglomerations.

Mumbai: Maximum City

We open our examination by taking a look at Mumbai. For the purposes of this section, Mumbai refers to the Mumbai City district[9] and the suburban districts including the Mumbai Suburban district are excluded.

The trends in the suburban travel in Mumbai [as per Indian Railways UTS II Class tickets data] are as under. The figures are indexed with Jan 2012 set at 100 (Figure 1).

Fig. 1: Trends in all Suburban Travel in Mumbai [Index 100 = Jan 2012, IR UTS II Class]



[8] Lok Sabha PAC 69th Report (2016-17); Suburban Train Services In Indian Railways; https://eparlib.nic.in/bitstream/123456789/65704/1/16_Public_Accounts_69.pdf

[9] https://mumbaicity.gov.in/

From the above we can see that suburban travel [defined as travel upto 150 kms from Mumbai City district[10]] showed a steady upward trend just prior to the pandemic related lockdowns. While sub-urban travel quickly rebounded post the lockdowns, however, we estimate that the levels have only reached the January 2012 level as by end-2023.

There is one caveat though, in this period Mumbai has also added a Metro railway network. It is possible that some passenger traffic might have shifted to the Mumbai Metro. Further, a spike in the number of travellers is noted for the month of June 2014. We are unable to explain the likely reasons for this and it appears to be a statistical anomaly.

Spatial Patterns in suburban travel

Suburban travellers into Mumbai originate from the following districts – Thane, Palghar, Raigad and Mumbai Suburban. Intra-Mumbai UTS II Class Traffic i.e. traffic originating within Mumbai was estimated to be about 65% of all UTS II Class suburban travel destined to Mumbai, in 2012. This percentage has since **reduced to about 58% in 2023**.

In terms of suburban travel from outside Mumbai City district, Thane continues to be the single largest originating district. In 2012, ~21% the total suburban travel destined for Mumbai originated in Thane. This number has since **increased to more than 25% in 2023**. This is an indicator of the suburban area spreading towards Thane district[11].

Palghar, Raigad and Mumbai Suburban districts make up the rest. As a percentage of total suburban travel, UTS II Class passengers originating in Palghar and destined to Mumbai, increased from ~10% in 2012 to about 13% in 2023.

It may be noted that these figures are organized as per originating and destination districts. Therefore, the figures for places like Navi Mumbai

[10] Lok Sabha PAC 69th Report (2016-17); Suburban Train Services In Indian Railways; https://eparlib.nic.in/bitstream/123456789/65704/1/16_Public_Accounts_69.pdf

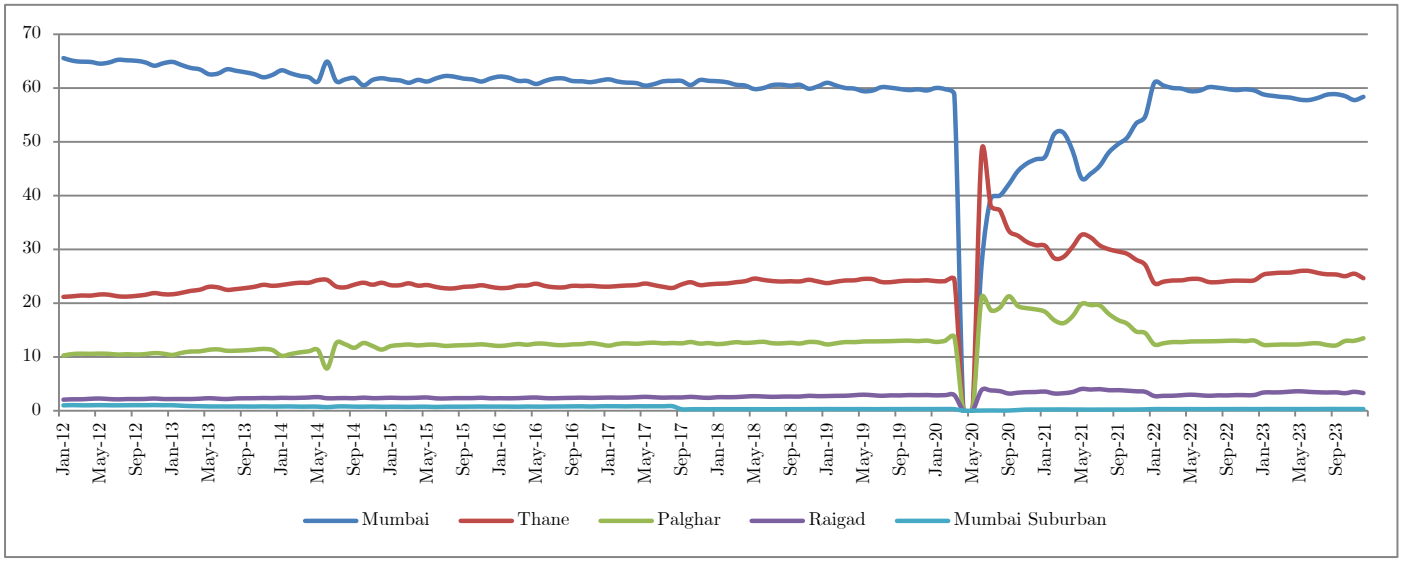
[11] This number is likely to be an underestimation given that the erstwhile Thane district was bifurcated in 2014 into Palghar and present day Thane district *[https://palgharpolice.gov.in/History]*.

(which is spread across Thane and Raigad districts[12]) would have originating passengers reflected in those districts respectively.

We visualize the month wise contribution of the districts neighbouring Mumbai city to the total suburban travel destined to Mumbai in Figure 2.

Fig. 2: Percentage composition of total suburban travellers destined to Mumbai

[2012-2023; IR UTS II Class]



Note: Apportioned as per present day district boundaries

Analysis of the data above is perhaps an indicator of the growth of the suburbs of Mumbai, especially Thane and Palghar. In order to get a better sense of this growth we make use of the Land Use Classification (LUC) Data maintained by the Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare[13].

In particular, we take a look at Land use Change under the heading, '*Area under Non-agricultural Uses*' which is defined as all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land put to uses other than agriculture[14]. This has been used as measure of urbanization in a number of academic papers[15].

[12] Navi Mumbai Municipal Corporation; https://www.nmmc.gov.in/navimumbai/history1540201195

[13] *https://data.desagri.gov.in/weblus/classification-of-area-report-web*

[14] Land Use Statistics Concepts & Definitions- Nine-Fold Classification; *https://desagri.gov.in/wp-content/uploads/2021/04/4-Concepts-Definitions.pdf*

[15] Urbanization and agricultural land loss in India: Comparing satellite estimates with census data (Pandey, Seto; 2015);

Between the years 2018-19 [first year when figures for bifurcated Thane district are available] and 2022-23, area under non-agricultural uses has grown from 59700 hectares in 2018-19 to 798300 hectares in 2022-23 a growth of over 31%! For context, in the same period the growth in area under non-agricultural uses for the entire state of Maharashtra has been about 4.48%.

For the above, it is apparent that there is growth in urbanization in Thane district. However, at a granular level, which are the areas of most urbanization growth and whether these areas contiguous to Mumbai urban agglomeration?

From infinity and beyond

We use Earth Observation data from *Bhuvan*, the Geo-sensing platform of the National Remote Sensing Centre (NRSC), Indian Space Research Organization (ISRO)[16] to seek answer these questions. Night Light illumination has been found to a reliable indicator not just of urbanization but also of population density and economic activity[17].

While remote sensing and use of satellite earth observation data has been in use for some time now, however accessing high quality satellite data, processing and analysing the images, correcting for radiometric and atmospheric effects and extracting usable data from the images typically requires specialized skill.

However, this process has been considerably smoothened by handy tools placed in public domain by the National Remote Sensing Centre (NRSC)[18] of the Indian Space Research Organization (ISRO). For the following analysis, we use ISRO NRSC's *Bhuvan* suite of tools[19].

The Night Lights data put out by NSRC is from the Visible Infrared Imaging Radiometer Suite (VIIRS) night-time sensor (Day/Night Band) -

[16] https://bhuvan-app1.nrsc.gov.in/bhuvan_ntl/

[17] Remote Sensing of Night Lights—Beyond DMSP (Levin, Kyba, Zhang; 2019)

[18] https://www.nrsc.gov.in/

[19] https://bhuvan.nrsc.gov.in/home/index.php

VIIRS/DNB. The VIIRS/DNB sensor is on the Suomi National Polar-orbiting Partnership (NPP) and NOAA-20 satellites[20].

It collects images in a 3,000 km swath at a resolution of 742 m and hosts a unique panchromatic Day/Night band (DNB), which is ultra-sensitive in low-light conditions that allows it to observe night-time lights (NTL) with enhanced spatial and temporal resolutions[21].

ISRO's *BHUVAN* uses the *Black Marble* NTL product, derived from VIIRS/DNB at 15 arc-second spatial resolution and is available in Daily, Monthly and Annual Composite periodicities from January 2012 onwards.

The imagery is processed through a chain of algorithms including Lunar *Bidirectional Reflectance Distribution Function* (BRDF), terrain and atmospheric corrections like *Atmospheric airglow contamination*, correction for stray lights, *Aurora removal*, correcting for *Aerosol Optical Depth* (AOD) effects, Cloud contamination etc. Subsequently, the datasets are processed for Geo-Tagging and extraction of administrative boundaries and calculation of statistics[22].

The night light radiance expressed in *nanowatts per square centimeter per steradian* ($nW/cm^2/sr$) – broadly indicating the amount of light energy detected over a specific area and angle for the district of Thane for the years 2012 and 2023 were taken from the ISRO *Bhuvan Night Time Light over India from Space* service[23] (Figure 3A/3B).

[20] Decadal Change of Night Time Light (NTL) over India from Space (2012 – 2021); *https://bhuvan-app1.nrsc.gov.in/2dresources/NTL_Atlas.pdf*

[21] https://ladsweb.modaps.eosdis.nasa.gov/missions-and-measurements/viirs/

[22] Decadal Change of Night Time Light (NTL) over India from Space (2012 – 2021); https://bhuvan-app1.nrsc.gov.in/2dresources/NTL_Atlas.pdf

[23] https://bhuvan-app1.nrsc.gov.in/bhuvan_ntl

Fig. 3A: Night Light Radiance; Thane District, 2012

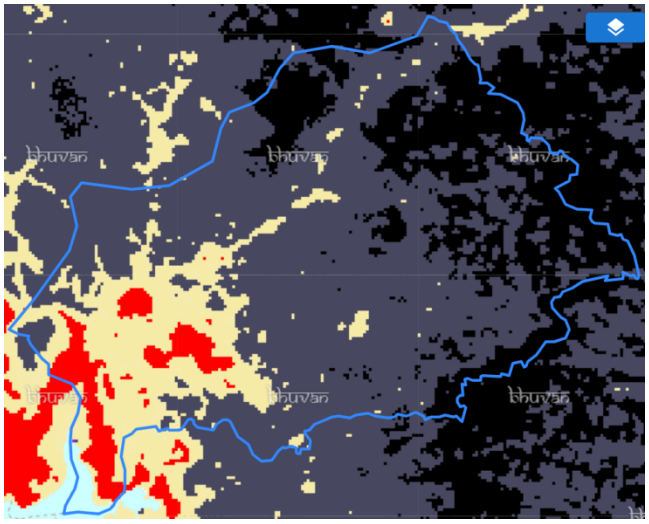
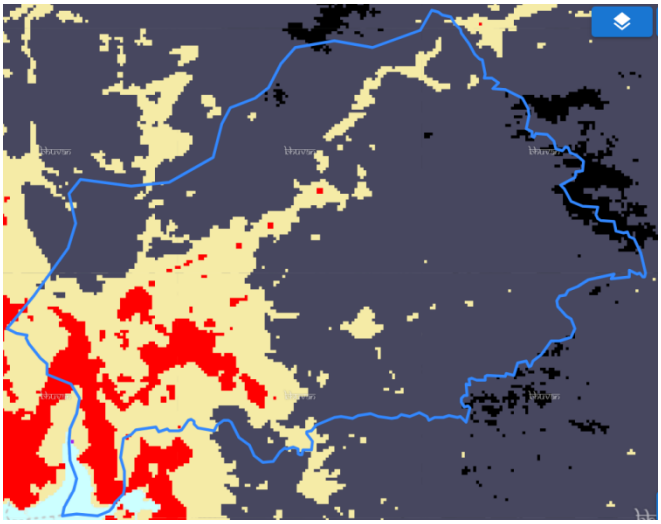


Fig. 3B: Night Light Radiance; Thane District, 2023



The colours in the above images correspond to the following Radiance scales (Table 1):

Table 1: Night Time Lights (NTL) Radiance *nanowatts per square centimeter per steradian* (nW/cm²/sr)

Sl. No.	Colour	Range *nanowatts per square centimeter per steradian* (nW/cm²/sr)	Interpretation
1		< 5	**Very Low Radiance Band**: Indicates areas with minimal artificial lighting, often corresponding to rural/undeveloped areas, natural landscapes, forested/sparsely populated regions.
2		5 - 25	**Low Radiance Band**: Typically indicates small villages, rural settlements, sparsely populated suburban zones, or industrial areas with minimal night-time lighting.
3		26 - 200	**Moderate Radiance Band**: Typically represents semi-urban or peri-urban areas. This band might capture small towns, medium-sized cities, and industrial zones.
4		> 200	**High Radiance Band**: Usually corresponds to major urban areas, commercial districts, and densely populated areas with substantial artificial lighting - such as the central business districts etc.
5		No Data	-

Comparing Figure 3A/3B the following points emerge:

i. the *Red* Band [High Radiance Band > 200] has steadily grown between 2012 [Fig. 3A] and 2023 [Fig. 3B] this is an indicator of **growth of the urban area** as well as increasing human presence;

ii. this growth is towards the **proximity of the Mumbai Suburban area**;

iii. the *Brown* Band [Moderate Radian Band 26 - 200] has also grown which reflects the **growth in peri-urban areas**;

iv. the urban growth appears to be **along a transport corridor** going towards the North East of Thane District

While the above gives us a general idea of the trends, a more granular picture emerges when we quantify the radiance bands. We note that as of 2023, the **moderate radiance band** [*Brown*] has **increased to cover 9.87% of the area** of the district [a *45% increase* from 6.8% in 2012] and the **high radiance band** [*Red*] has **increased to cover 2.94% of the area** of the district [a *33% increase* from 2.2% in 2012].

This increase in urbanization and in population density has implications for urban governance, infrastructure planning and provision of public services etc. since enhanced population pressure on urban area has typically been linked to an increase in demand for housing[24].

To explore this effect, we use the National Housing Bank (NHB) Residex Housing Price Indices (HPI). The HPI covers 50 cities in India and represents price changes in residential housing properties[25].

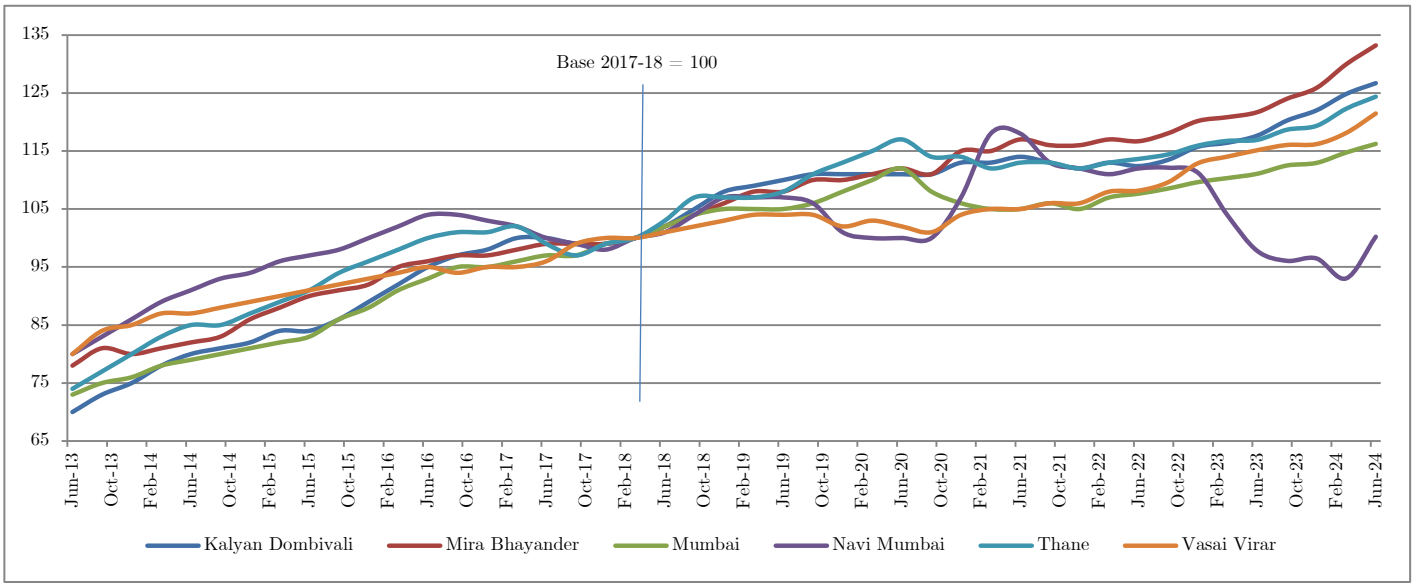
Under HPI, the three indices viz., *HPI@Registered Prices*, *HPI@Assessment Prices* and *HPI@Market Prices* for Under Construction Properties together provide a sense of the movement in prevailing prices at the sub-city level at quarterly intervals, starting from June, 2013 with year 2017-18 taken as 100 in the index.

The HPI uses data from diverse sources such as registration data collected from Sub Registrar Offices (SROs) of States/UTs; valuation data collected from Primary Lending Institutions and primary and secondary data collected through market surveys, especially for prices for Under Construction Properties.

The *Composite Housing Price Indices* are computed using population weights on city wise indices to give a true representation of housing prices in the country. We use the NHB Residex City-wise Housing Price index[26] to track movement in housing prices of Mumbai and some of its suburbs (Fig. 4).

[24] The relationship between population and housing (CH Mulder, University of Amsterdam; 2006)
[25] https://residex.nhbonline.org.in/

Fig. 4: NHB Residex City-wise Housing Price index [Mumbai Suburbs; Jun-13 to June-24]



From the above, we can note that the prices in Mira Bhayander, Kalyan Dombivali, Thane and Vasai Virar have shown a higher rate of growth as compared to the property prices in the city of Mumbai and that property prices in Navi Mumbai have dipped.

Mira Bhayander, Kalyan Dombivali are both parts of *Thane* district; whereas Vasai Virar is part of the *Palghar* district. Therefore, the growth in demand for residential property in the district of Thane is appears to reflect the growth of suburbanization towards Thane.

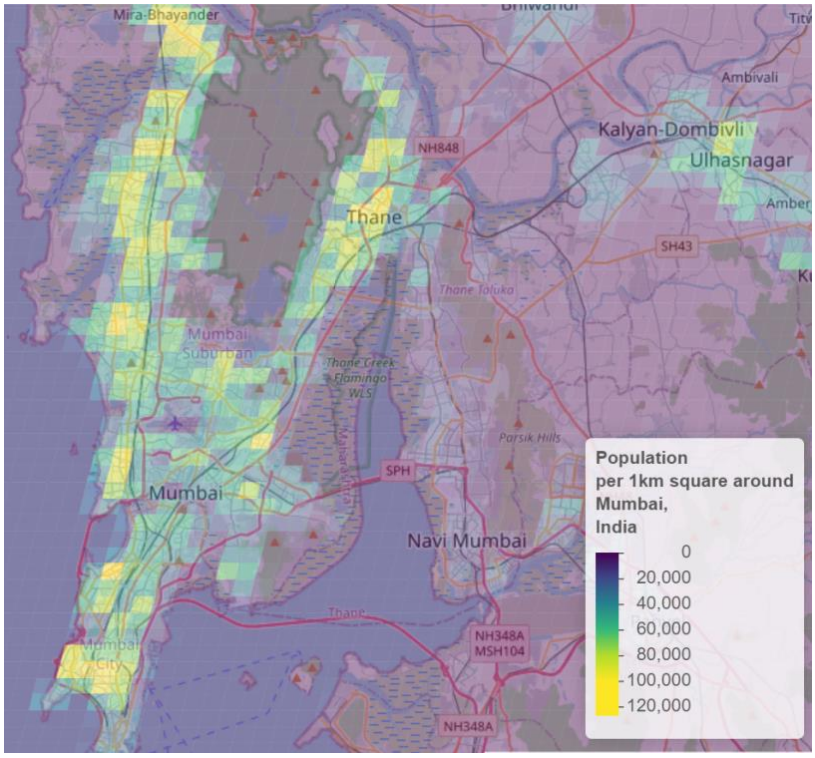
Another way to visualize this is to use gridded population maps. There are multiple ways to look at the number of people living/working in a city - absolute population, population density and population living in the commuter zone of a city.

However, sans the geographical context, the absolute numbers have limited meaning. For example, including the Sanjay Gandhi National Park in the area of Mumbai would drastically change the population density statistics.

Gridded population maps break up the map into a grid at 1 km^2 grids and overlay population density data over a basemap[27] (Nolan; 2024). The data is taken from the Global Human Settlement Layer (GHSL) and is based on the last Census[28].

We look at the spatial extent of population in two ways – population at 1 km^2 grid level (Figure 5A) and relative population weighted densities of people living at a defined distances from the city centre (Figure 5B).

Fig. 5A: Population per 1 km^2 in Mumbai; Census 2011 Data

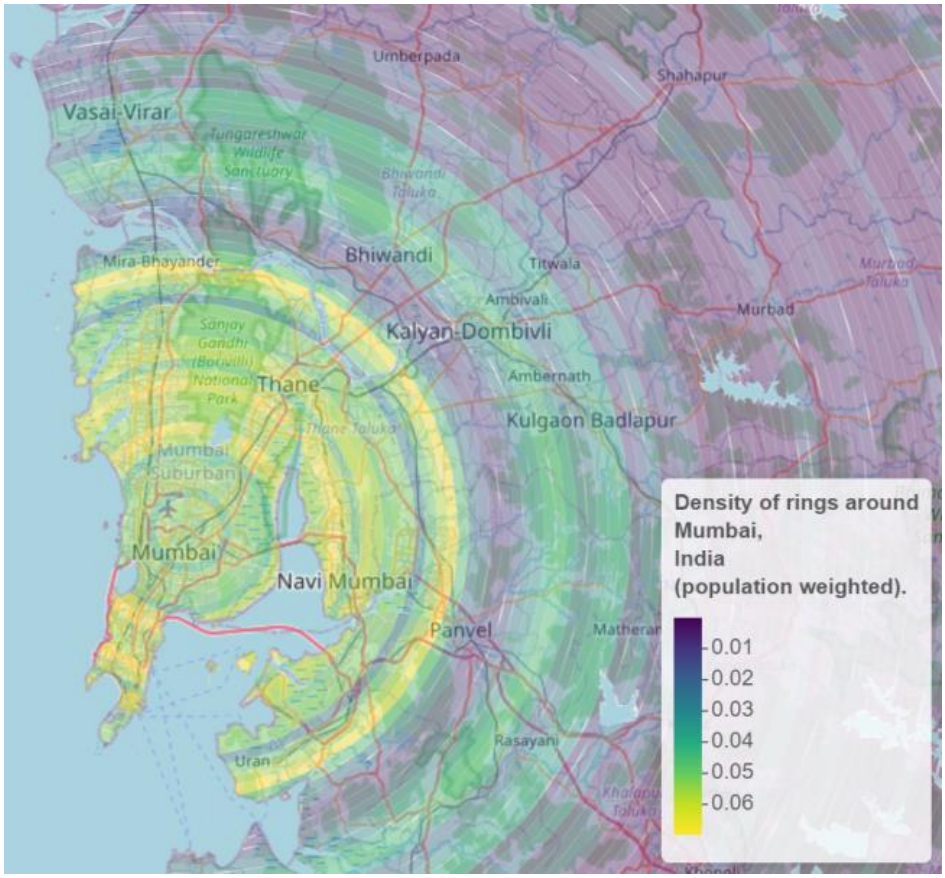


[27] Jonathan Nolan, 2024; https://www.blog.jonathannolan.net/p/how-dense-is-your-city

[28] GHS-POP R2015A; GHS population grid, GPW4, multitemporal (1975, 1990, 2000, 2015); https://human-settlement.emergency.copernicus.eu/ghs_pop.php

Fig. 5B: Population weighted densities at defined distances from the city centre

[Relative Measures; Population based on Census 2011 Data]



Chennai Express: Suburban Growth of the city of culture and tradition

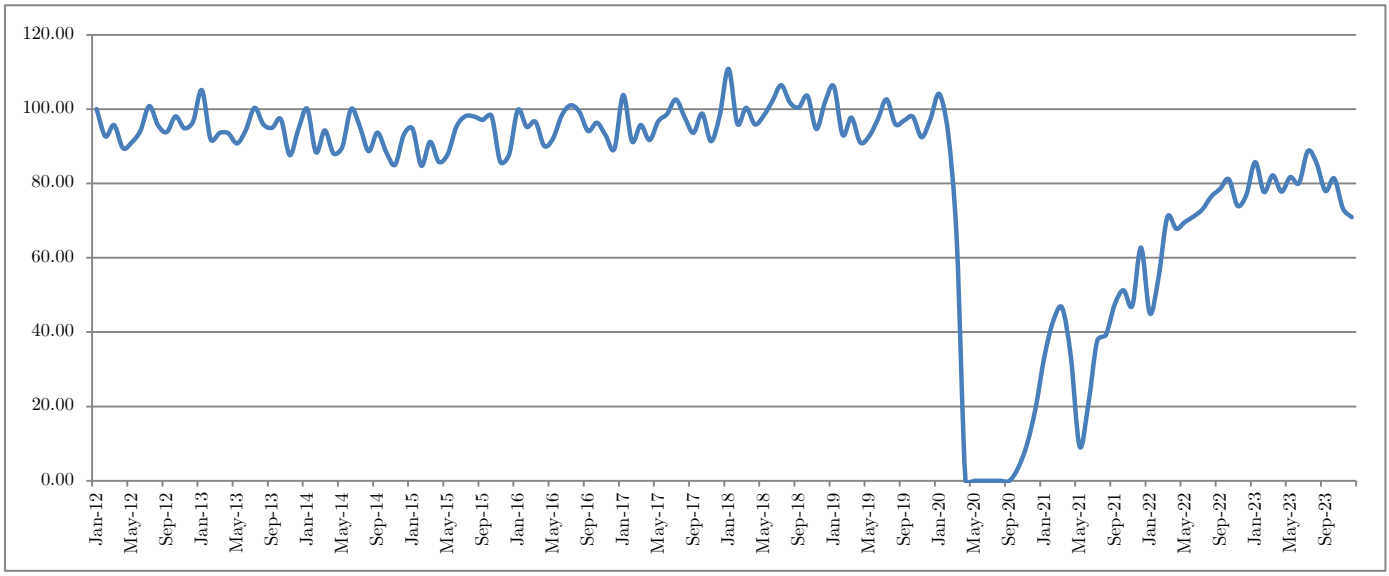
From Mumbai to shift our focus southwards to the city of Chennai – a bustling metropolis with a population of 46,46,732[29]. For the purposes of this section, Chennai is taken as meaning Chennai district [as defined in the District Census Handbook[30]]. Further, given the discussion in the previous section, in the subsequent sections the discussion on the theory will be kept to a minimum.

The trends in the suburban travel in Chennai [as per Indian Railways UTS II Class ticketing data] are as under. The figures are indexed with Jan 2012 set at 100 (Figure 6).

[29] District Census Handbook, Chennai; Pg. ix

[30] https://cdn.s3waas.gov.in/s313f3cf8c531952d72e5847c4183e6910/uploads/2018/06/2018062912.pdf

Fig. 6: Trends in all Suburban Travel in Chennai [Index 100 = Jan 2012, IR UTS II Class]



From the above we can see that suburban travel [defined as travel upto 150 kms from Chennai[31]] first dipped from Jan 2012 levels till about mid-2016 after which an upward movement is seen.

However, post the pandemic related lockdowns, while sub-urban travel did bounce back however, it is estimated that the pre-pandemic levels have not yet been reached as of end-2023.

Patterns in suburban travel

Suburban travellers into Chennai originate from the following districts – Kanchipuram, Thiruvallur, Vellore and Chittoor. Intra-Chennai UTS II Class Traffic i.e. traffic originating within Chennai was estimated to be about 30.56% of all UTS II Class suburban travel destined to Chennai, in 2012. This percentage has since **reduced to about 25.31% in 2023**.

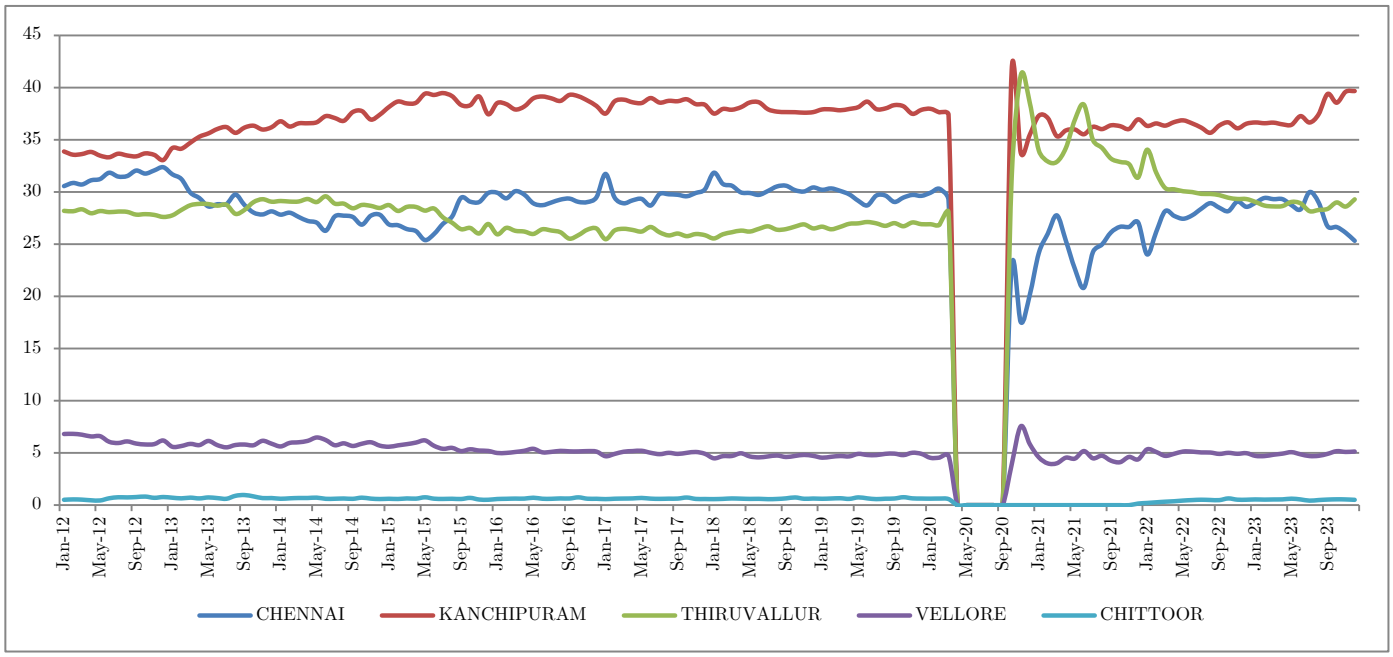
For suburban travel from outside Chennai district, **Kanchipuram** continues to be the single largest originating district. In 2012, ~34% the total suburban travel destined for Chennai originated in Kanchipuram. This

[31] Lok Sabha PAC 69th Report (2016-17); Suburban Train Services In Indian Railways; https://eparlib.nic.in/bitstream/123456789/65704/1/16_Public_Accounts_69.pdf

number **increased to more than 39% in 2023**. This is an indicator of the suburban area spreading towards Kanchipuram district.

We visualize the month wise contribution of the districts neighbouring Chennai to the total suburban travel destined to Chennai in Figure 7.

Fig. 7: Percentage composition of total suburban travellers destined to Chennai
[2012-2023; IR UTS II Class]



We look at the spatial extent of population at 1 km^2 grid level (Figure 8A) and relative population weighted densities of people living at a defined distances from the city centre[32] (Figure 8B).

[32] Jonathan Nolan, 2024; https://www.blog.jonathannolan.net/p/how-dense-is-your-city

Fig. 8A: Population per 1 km² in Chennai; Census 2011 Data

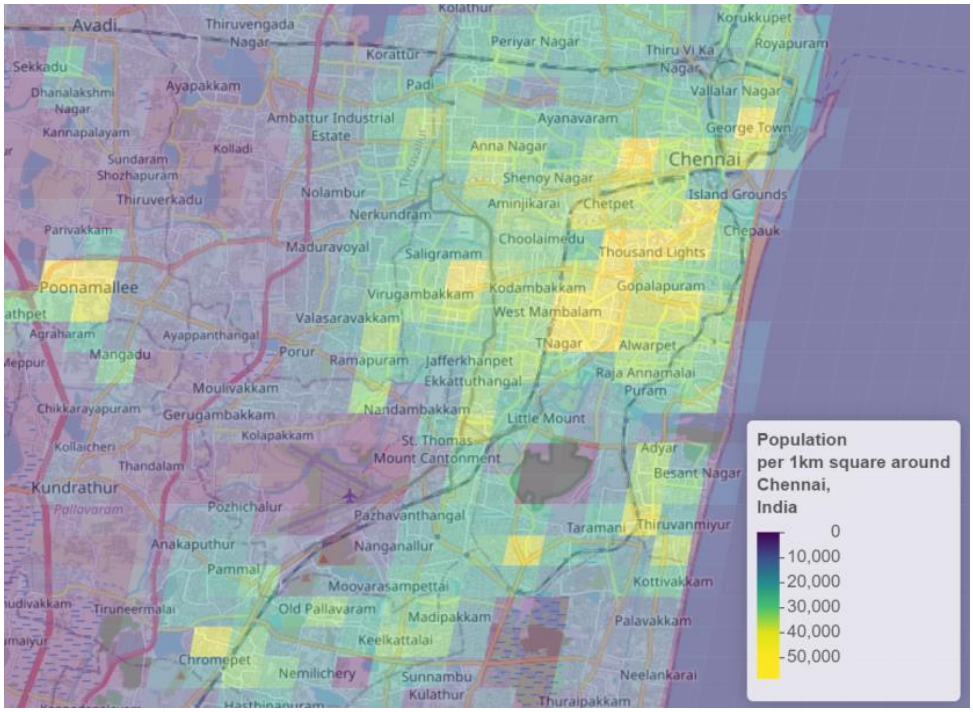
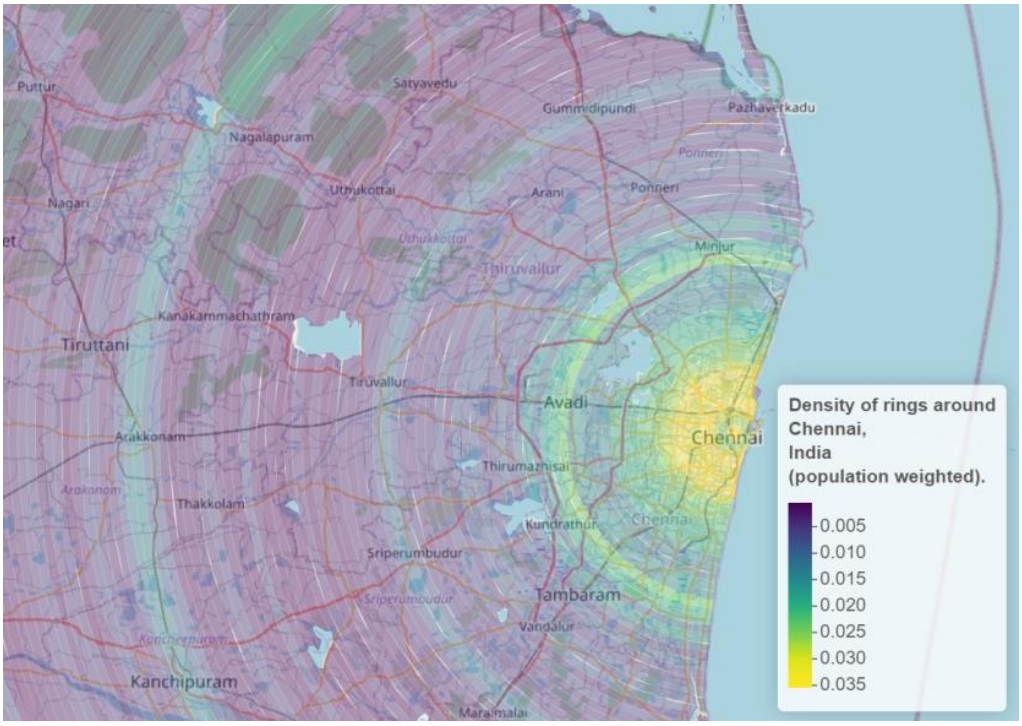


Fig. 8B: Population weighted densities at defined distances from the city centre

[Chennai, Relative Measures; Population based on Census 2011 Data]



We now take a peek at the data for night light radiance for the district of Kanchipuram for the years 2012 and 2023 [taken from the ISRO *Bhuvan*

Night Time Light over India from Space service[33]] (Figure 9A/9B). The area on the top right of the images, beyond the blue border, corresponds to Chennai District.

Fig. 9A: Night Light Radiance; Kanchipuram District, 2012

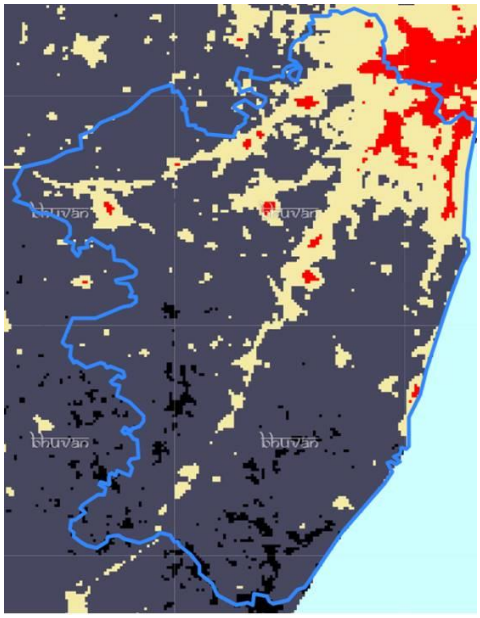
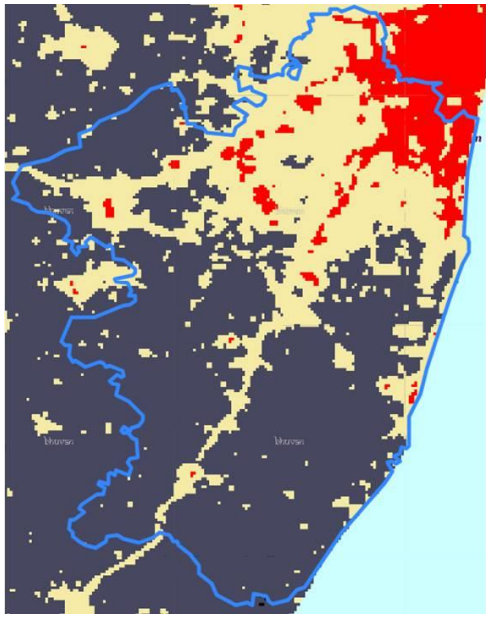


Fig. 9A: Night Light Radiance; Kanchipuram District, 2023



From the above the following points emerge:

i. the *Red* Band [High Radiance Band > 200] has steadily grown between 2012 [Fig. 8A] and 2023 [Fig. 8B] this is an indicator of **growth of the urban area** as well as increasing human presence;

ii. this growth is towards the **proximity of the Chennai Suburban area**;

iii. the *Brown* Band [Moderate Radian Band 26 - 200] has also grown which reflects the **growth in peri-urban areas**;

iv. the urban growth appears to be **along a transport corridor** going towards the south west of Chennai District;

v. The high radiance band [*Red*] corresponding to **densely populated urban/commercial areas** for **Chennai district** seems to have **increased significantly**.

The change for Kanchipuram District is tabulated here under (Table 2). It may be seen that, although on a small base, the greatest growth has come in the High Radiance Band indicating growth in densely populated urban areas.

[33] https://bhuvan-app1.nrsc.gov.in/bhuvan_ntl

Table 2: Quantifying Night Time Lights (NTL) Radiance for Kanchipuram District

[% change from 2012 to 2023]

Sl. No.	Colour	**Range** nanowatts per square centimeter per steradian (nW/cm²/sr)	Interpretation	**% Change** [2023 from 2012]
1		< 5	**Very Low Radiance Band**: Indicates areas with minimal artificial lighting, often corresponding to rural/undeveloped areas, natural landscapes, forested/sparsely populated regions.	-3.82
2		5 - 25	**Low Radiance Band**: Typically indicates small villages, rural settlements, sparsely populated suburban zones, or industrial areas with minimal night-time lighting.	-17.82
3		26 - 200	**Moderate Radiance Band**: Typically represents semi-urban or peri-urban areas. This band might capture small towns, medium-sized cities, and industrial zones.	54.89
4		> 200	**High Radiance Band**: Usually corresponds to major urban areas, commercial districts, and densely populated areas with substantial artificial lighting - such as the central business districts etc.	159.28

Delhi: The City of Djinns

We now move northwards for a quick look at the capital city of Delhi. After Mumbai, Delhi is India's second most populous city with a population of 1,10,34,555 as per Census 2011[34].

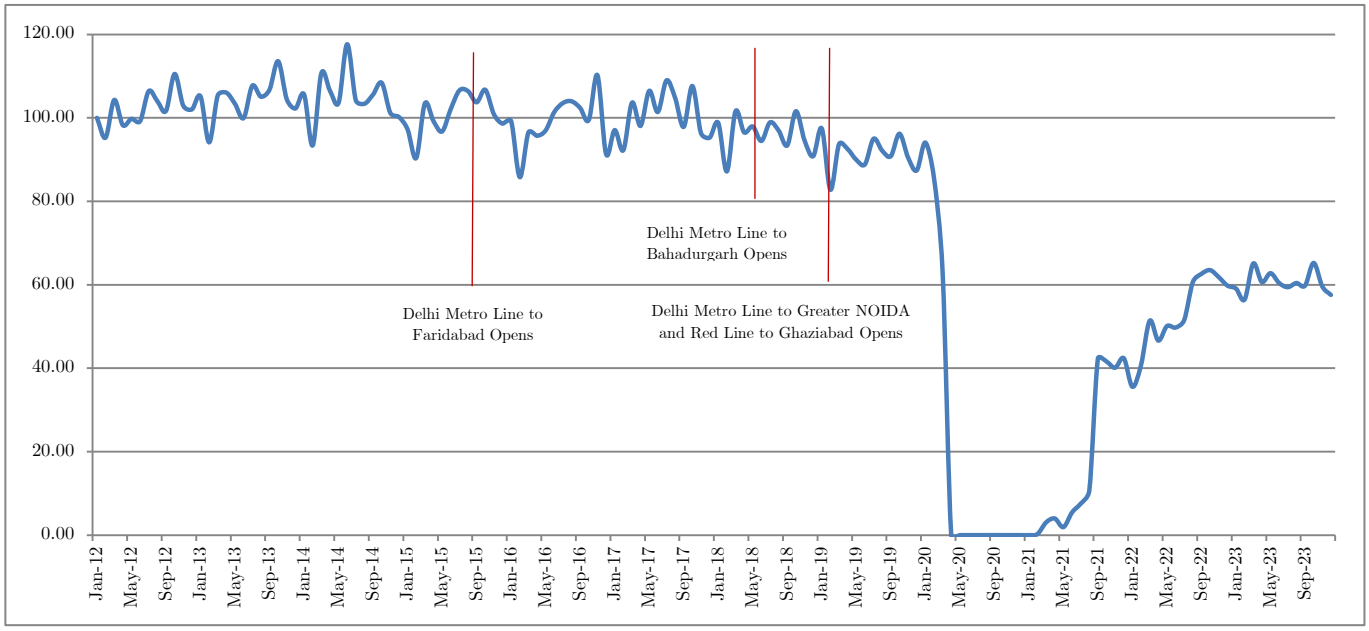
For the purposes of this section, Delhi is taken as meaning the eleven districts of Delhi [as defined in the *District Census Handbook*[35]]. Further, as in the previous section, the discussion on the theory is kept to a minimum in this section.

It bears noting that with Delhi's extensive Metro network, there is a likelihood of shift of passenger traffic to the Metro lines especially those connecting to suburban areas such as Gurgaon, Faridabad and NOIDA. With that caveat, the trends in the suburban travel to Delhi [as per Indian Railways UTS II Class ticketing data] are as under. The figures are indexed with Jan 2012 set at 100 (Figure 10).

[34] District Census Handbook, NCT of Delhi; DH_2011_0700_PART_A_DCHB_NCT_OF_DELHI; Pg. 581; *https://censusindia.gov.in/nada/index.php/catalog/912*

[35] https://cdn.s3waas.gov.in/s313f3cf8c531952d72e5847c4183e6910/uploads/2018/06/2018062912.pdf

Fig. 10: Trends in all Suburban Travel in Delhi [2012-23; Index 100 = Jan 2012, IR UTS II Class]



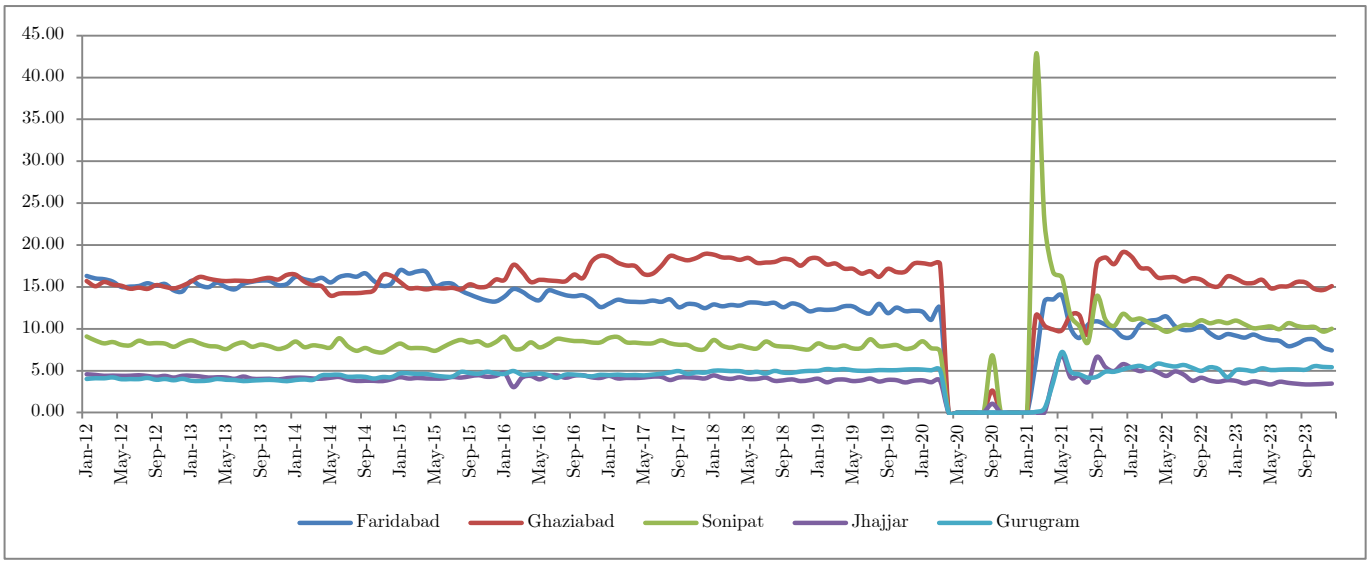
From the above it is evident that suburban travel into Delhi was on a slightly declining trend prior to the pandemic. Post the pandemic related lockdowns while there has been an uptick it is hardly near the pre-pandemic levels.

The opening of selected Delhi Metro connections to suburban areas indicated in Fig. 10. Prima facie it appears that Delhi Metro does have an impact on the use of suburban travel on the Indian Railway network. This could be on account of wider reach, better interoperability and commuter convenience.

We now visualize the month wise contribution of the districts neighbouring Delhi to the total suburban travel destined to Delhi in Figure 11.

Fig. 11: Percentage composition of total suburban travellers destined to Delhi

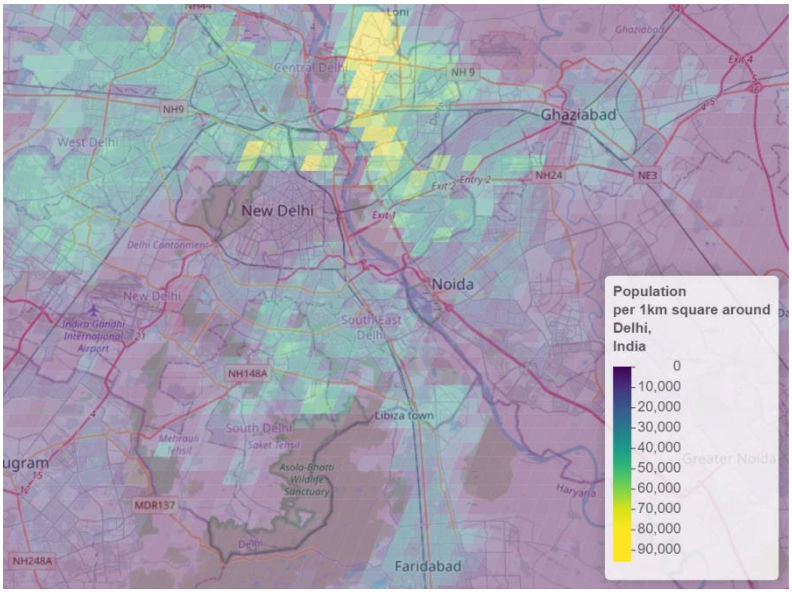
[2012-2023; IR UTS II Class]



From the above is appears that travel from Ghaziabad district has been steadily rising, despite enhanced availability of Delhi Metro rail connectivity in Ghaziabad. Exploring Delhi Metro ridership data is likely to provide interesting insights into this.

We now look at the spatial extent of population at 1 km^2 grid level (Figure 12A) and relative population weighted densities of people living at a defined distances from the city centre[36] (Figure 12B).

Fig. 12A: Population per 1 km^2 in Delhi; Census 2011 Data

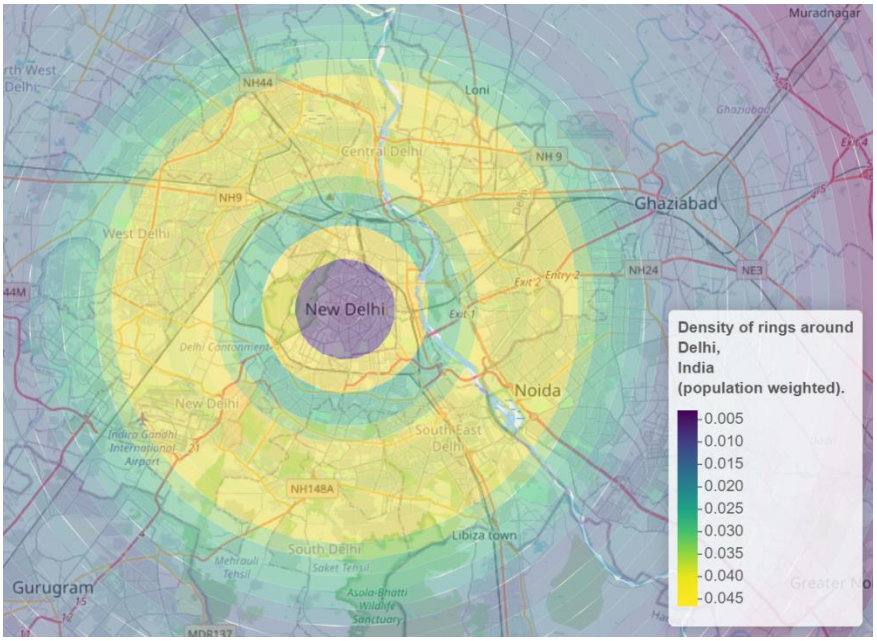


[36] Jonathan Nolan, 2024; https://www.blog.jonathannolan.net/p/how-dense-is-your-city

From the above we can see a high concentration of population to the east and North East of Delhi, especially the around the *Loni* area in Ghaziabad city. Amongst the suburbs, NOIDA and Gurugram appear to be less densely populated.

Fig. 12B: Population weighted densities at defined distances from the city centre

[Delhi, Relative Measures; Population based on Census 2011 Data]



We now view the night light radiance for the district of Ghaziabad for the years 2012 and 2023 [taken from the ISRO *Bhuvan Night Time Light over India from Space* service[37]] (Figure 13A/13B).

Fig. 13A: Night Light Radiance; Ghaziabad District, 2012

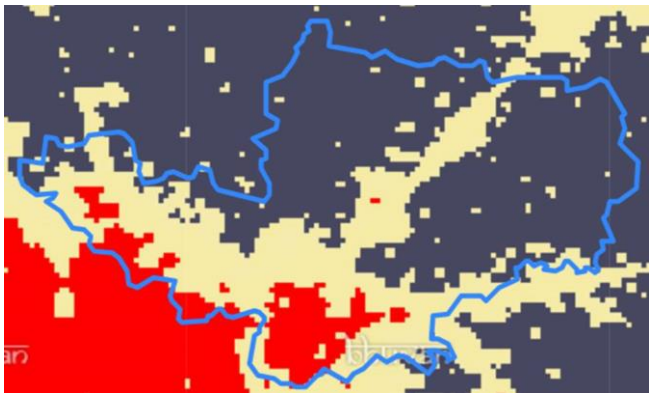
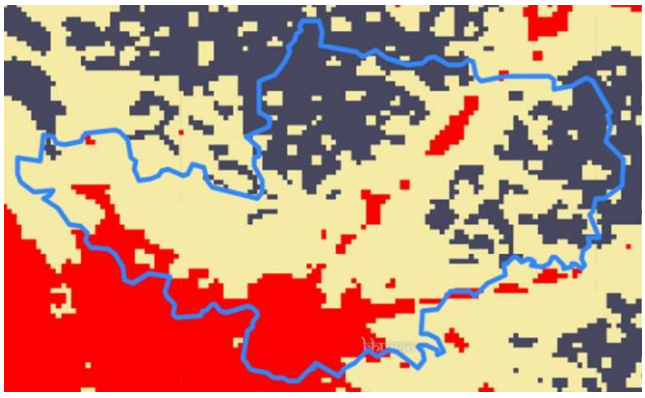


Fig. 13B: Night Light Radiance; Ghaziabad District, 2023



[37] https://bhuvan-app1.nrsc.gov.in/bhuvan_ntl

From the above images indicate the following:

i. the *Red* Band [High Radiance Band > 200] has grown significantly between 2012 [Fig. 8A] and 2023 [Fig. 12B] especially along transportation lines. This is an indicator of **growth of the urban area** as well as increasing population densities;
ii. this growth is practically contiguous to **Delhi**;
iii. the *Brown* Band [Moderate Radian Band 26 - 200] has also grown significantly which reflects the **growth in peri-urban areas**;
iv. the urban growth appears to be **along a transport corridor** going towards the north east of the district;

The change for Ghaziabad District is tabulated here under (Table 3). It may be seen that, although on a small base, the greatest growth has come in the High Radiance Band indicating growth in densely populated urban areas.

Table 3: Quantifying Night Time Lights (NTL) Radiance for Ghaziabad District

[% change from 2012 to 2023]

Sl. No.	**Colour**	**Range** nanowatts per square centimeter per steradian ($nW/cm^2/sr$)	**Interpretation**	**% Change** [2023 from 2012]
1		< 5	**Very Low Radiance Band**: Indicates areas with minimal artificial lighting, often corresponding to rural/undeveloped areas, natural landscapes, forested/sparsely populated regions.	~ 0
2		5 - 25	**Low Radiance Band**: Typically indicates small villages, rural settlements, sparsely populated suburban zones, or industrial areas with minimal night-time lighting.	- 52.28
3		26 - 200	**Moderate Radiance Band**: Typically represents semi-urban or peri-urban areas. This band might capture small towns, medium-sized cities, and industrial zones.	61.58
4		> 200	**High Radiance Band**: Usually corresponds to major urban areas, commercial districts, and densely populated areas with substantial artificial lighting - such as the central business districts etc.	74.95

We also take a quick look at the Land Use Classification (LUC) Data maintained by the Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare[38] for the district of Ghaziabad.

In particular, the change in land use under the heading, '*Area under Non-agricultural Uses*' which is defined as all land occupied by buildings, roads and railways or under water, e.g. rivers and canals, and other land

[38] https://data.desagri.gov.in/weblus/classification-of-area-report-web

put to uses other than agriculture[39]. This has been used as measure of urbanization in a number of academic papers[40].

Between the years 2012-13 and 2022-23, area under non-agricultural uses has grown from 27478 hectares in 2012-13 to 32627 hectares in 2022-23, a growth of over 18.73%. For context, in the same period the growth in area under non-agricultural uses for the entire state of Uttar Pradesh has been about 5.8%.

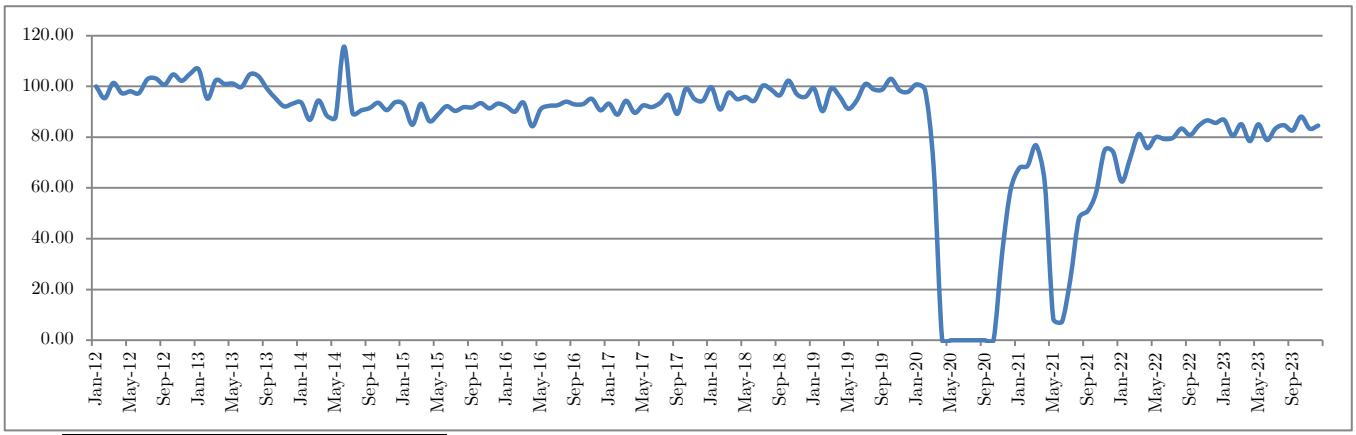
Kolkata: The city of joy

We now move northwards for a quick look at the city of Kolkata, the city of joy! Kolkata is the largest city in India's east with a population of 44,96,694 as per Census 2011[41]. For the purposes of this section we treat the districts of Howrah and Kolkata are a conurbation[42] and the analysis in the following section considers arrivals in Kolkata and Howrah together. The population of Howrah (sometimes spelt as *Haora*) district as per Census 2011 stood at 48,50,029[43].

The trends in suburban travel to Kolkata/Howrah [as per Indian Railways UTS II Class ticketing data] are as under. The figures are indexed with Jan 2012 set at 100 (Figure 12).

Fig. 14: Trends in all Suburban Travel in Kolkata/Howrah

[2012-23; Index 100 = Jan 2012, IR UTS II Class]



[39] Land Use Statistics Concepts & Definitions- Nine-Fold Classification; *https://desagri.gov.in/wp-content/uploads/2021/04/4-Concepts-Definitions.pdf*

[40] Urbanization and agricultural land loss in India: Comparing satellite estimates with census data (Pandey, Seto; 2015);

[41] District Census Handbook, Kolkata District; Pg. 61; *https://westbengal.census.gov.in/DCHB_2011_WB_Part_A/1916_PART_A_DCHB_KOLKATA.pdf*

[42] Dynamics of Urban Growth And Environmental Challenges: A Case of Kolkata, India; (Dey, 2021); https://doi.org/10.24057/2071-9388-2020-194

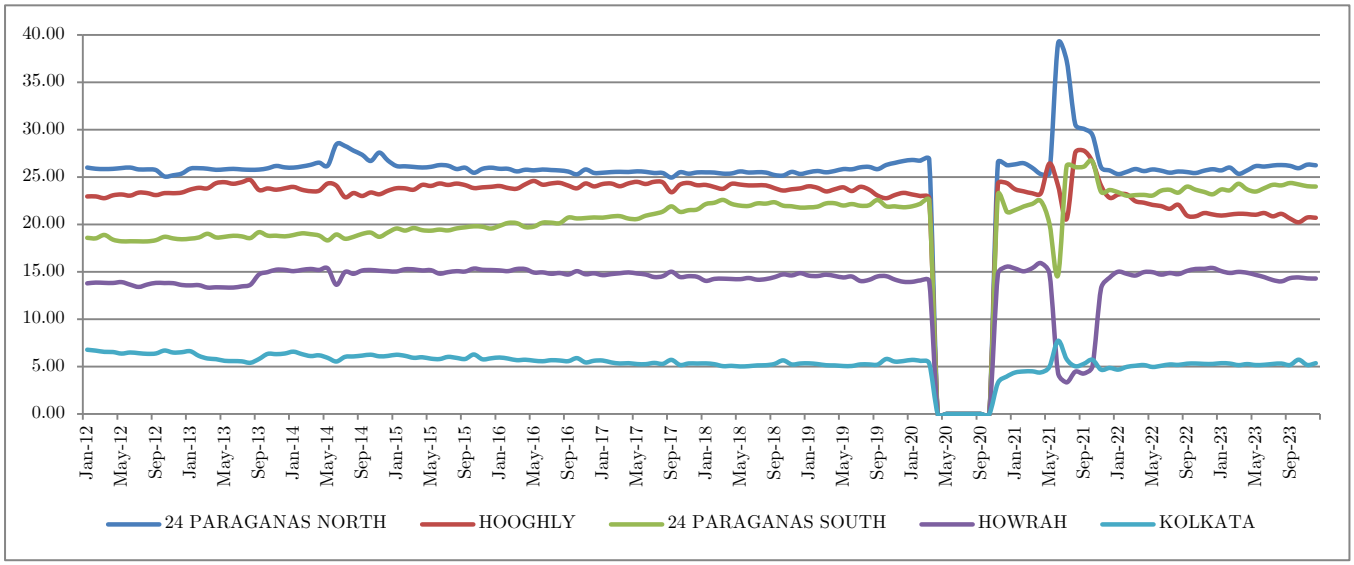
[43] District Census Handbook, Howrah District; Pg. 51; https://westbengal.census.gov.in/DCHB_2011_WB_Part_A/1915_PART_A_DCHB_HAORA.pdf

From the above, we can see that from 2015-16 to 2019-20 there is a slight increase in suburban travel to Kolkata. However, after the sharp decrease during the pandemic induced lockdowns, the level of suburban travel continues to be about 17-20% less than levels just prior to the pandemic and are yet to recover to pre-pandemic levels.

We now visualize the arrival of suburban passengers into Kolkata/Howrah from the neighbouring districts. For ease of reference, we take the top five origin districts which together represent about 90% of suburban arrivals in the Kolkata/Howrah conurbation (Figure 15).

Fig. 15: Percentage composition of total suburban travellers destined to Kolkata

[2012-2023; IR UTS II Class]

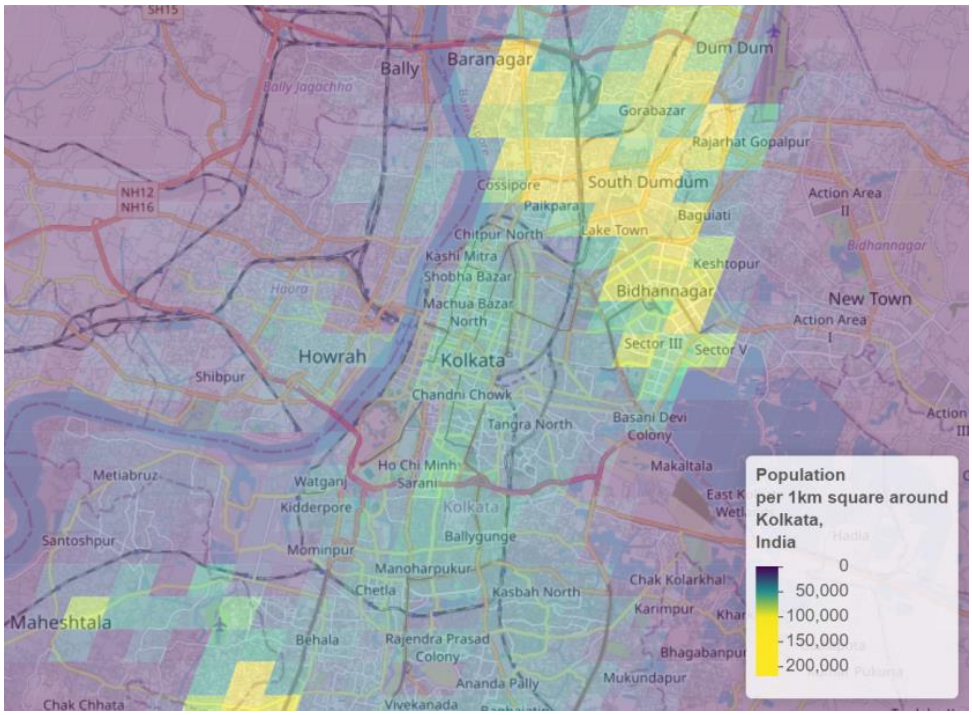


From the above we may see that passenger arrivals from *24 Paraganas North* and *24 Paraganas South* districts shows an increasing trend; whereas passenger arrivals from *Hooghly* district appears to be slightly decreasing over time and arrivals from Howrah and Kolkata appear flat.

We now look at the spatial extent of population at 1 km^2 grid level (Figure 16A) and relative population weighted densities of people living at a defined distances from the city centre[44] (Figure 16B).

[44] Jonathan Nolan, 2024; https://www.blog.jonathannolan.net/p/how-dense-is-your-city

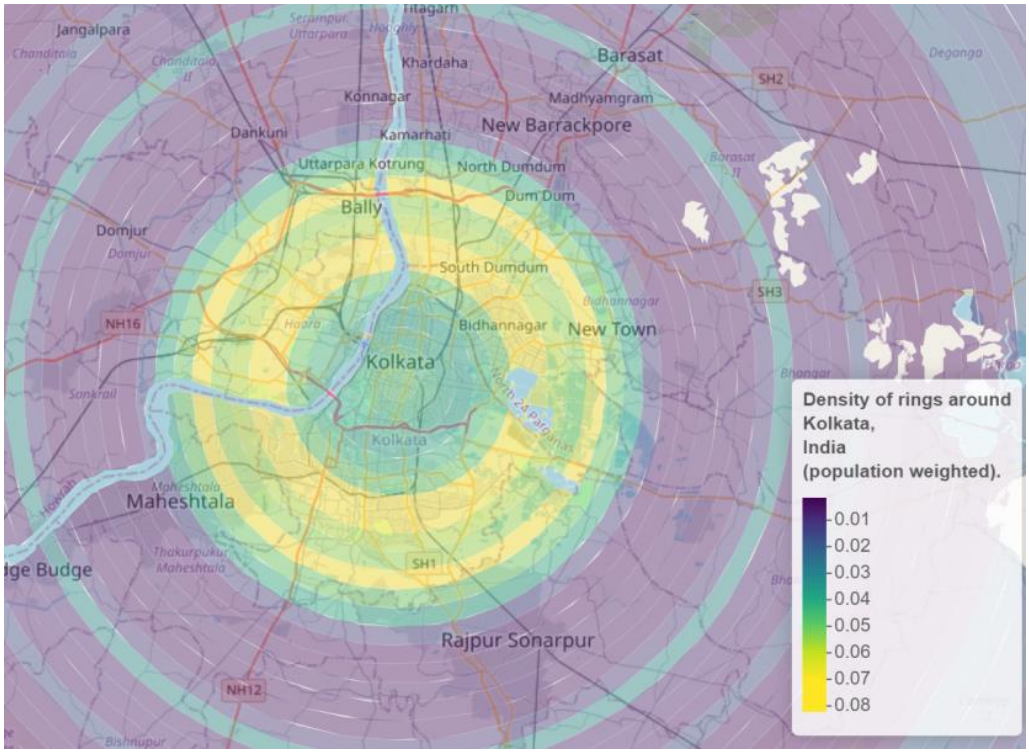
Fig. 16A: Population per 1 km² in Kolkata; Census 2011



From the above, we can see areas of high concentration of populations in the areas north east and east of the Kolkata/Howrah conurbation. These are the districts of 24 Paraganas North and 24 Paraganas South.

Fig. 16B: Population weighted densities at defined distances from the city centre

[Kolkata, Relative Measures; Population based on Census 2011 Data]



Looking that the night light radiance for the district of North 24 Paraganas for the years 2012 and 2023 [taken from the ISRO *Bhuvan Night Time Light over India from Space* service[45]] (Figure 17A/17B), we see that there has been some increase in the High Radiance [*Red*] and Moderate Radiance [*Brown*] bands [Table 4].

Fig. 13A: Night Light Radiance; North 24 Paraganas District, 2012

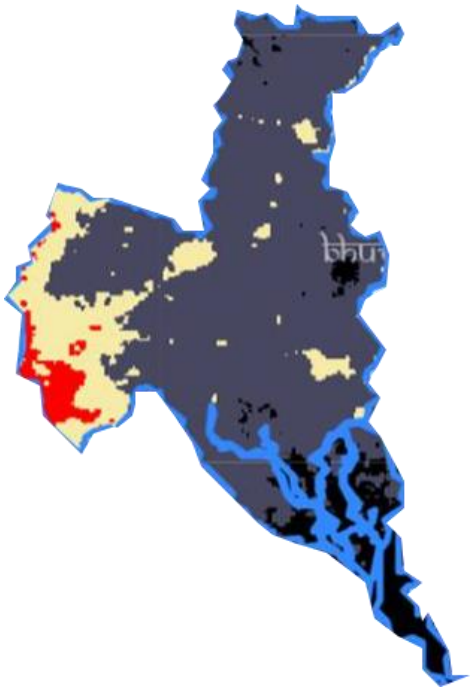
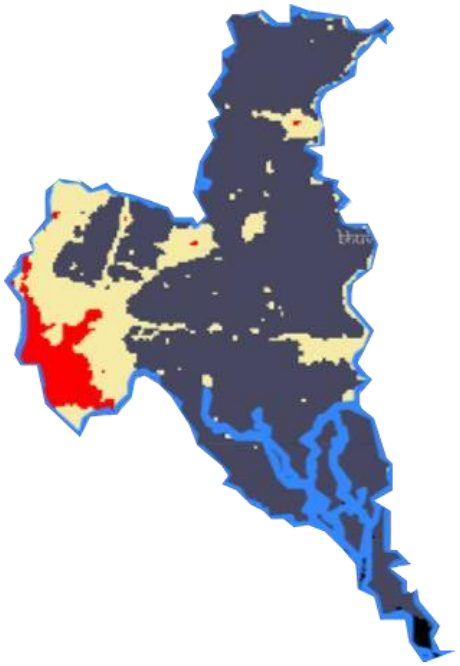


Fig. 13B: Night Light Radiance; North 24 Paraganas District, 2023



[45] https://bhuvan-app1.nrsc.gov.in/bhuvan_ntl

Table 4: Quantifying Night Time Lights (NTL) Radiance for North 24 Paraganas District

[% change from 2012 to 2023]

Sl. No.	Colour	Range nanowatts per square centimeter per steradian (nW/cm²/sr)	Interpretation	% Change [2023 from 2012]
1		< 5	**Very Low Radiance Band**: Indicates areas with minimal artificial lighting, often corresponding to rural/undeveloped areas, natural landscapes, forested/sparsely populated regions.	-3.69
2		May-25	**Low Radiance Band**: Typically indicates small villages, rural settlements, sparsely populated suburban zones, or industrial areas with minimal night-time lighting.	-1.56
3		26 - 200	**Moderate Radiance Band**: Typically represents semi-urban or peri-urban areas. This band might capture small towns, medium-sized cities, and industrial zones.	32.46
4		> 200	**High Radiance Band**: Usually corresponds to major urban areas, commercial districts, and densely populated areas with substantial artificial lighting - such as the central business districts etc.	64.15
5		No Data	-	

This change is also visible in the Land Use Classification (LUC) Data maintained by the Directorate of Economics & Statistics, Ministry of Agriculture & Farmers Welfare[46] for the district of North 24 Paraganas, where we see an increase of ~8.4% in land use under the heading, '*Area under Non-agricultural Uses*' i.e. all land occupied by buildings, roads and railways or under water, e.g. rivers and canals etc.

Between the years 2012-13 and 2022-23, area under non-agricultural uses has grown from 125302 hectares in 2012-13 to 135824 hectares in 2022-23, a growth of about 8.4%. For context, in the same period the growth in area under non-agricultural uses for the entire state of West Bengal has been about 4.8%.

Conclusion

The above examination used passenger data from Indian Railways, coupled with earth observation and Land Use Land Classification (LULC)

[46] https://data.desagri.gov.in/weblus/classification-of-area-report-web

data to understand the relationship between four metropolitan cities and their suburbs.

Overall, we see that post the Covid-19 related lockdowns, while suburban travel has quickly rebounded back but it hasn't quite reached the pre-pandemic levels. There is a likelihood that this might be on account of a shift away from Railways as means of suburban transport or on account of rise of counter magnets to cities we studied.

Further, with rising income levels, there could be a shift to other modes of transport. However, given that caveat we analyse this data to understand the directions of growth of the selected cities.

Furthermore, urban growth has been seen contiguous to the existing high density urban cores and typically is accompanied by a reduction in agricultural area.

Our findings are summarized as under:

- **For Mumbai**, suburban travel showed a steady upward trend just prior to the pandemic related lockdowns and while sub-urban travel quickly rebounded post the lockdowns, however, we estimate that the levels have only reached the January 2012 level as by end-2023
- Intra-Mumbai UTS II Class Traffic i.e. traffic originating within Mumbai was estimated to be about 65% of all UTS II Class suburban travel destined to Mumbai, in 2012. This percentage has since **reduced to about 58% in 2023**. This is perhaps indicative of a shift to other modes of travel.
- In terms of suburban travel from outside Mumbai City district, **Thane** continues to be the single largest originating district. In 2012, ~21% the total suburban travel destined for Mumbai originated in Thane. This number has since **increased to more than 25% in 2023**.
- Looking at LULC data, area under non-agricultural uses has grown by over 31%! For context, in the same period the growth in area under non-agricultural uses for the entire state of Maharashtra has been about 4.48%.
- Within Thane district, using geospatial earth observation data, we estimate that, between 2012 and 2023, the peri-urban area grew by 45%

and high density urban area grew 33% in the same period, albeit on a small base. This is hypothesis is confirmed by housing property prices.

- **For Chennai** - we see that suburban travel, first dipped from Jan 2012 till about mid-2016 after which an upward movement is seen. However, post the pandemic related lockdowns, while sub-urban travel did bounce back however, pre-pandemic levels had not been reached as of end-2023.
- For suburban travel from outside Chennai district, **Kanchipuram** continues to be the single largest originating district. In 2012, ~34% the total suburban travel destined for Chennai originated in Kanchipuram. This number **increased to more than 39% in 2023**. This is an indicator of the suburban area spreading towards Kanchipuram district.
- For Kanchipuram district we note that both the peri-urban and the high density urban areas contiguous to Chennai have shown significant growth in the period 2012 to 2023

- **For Delhi** – It is seen that suburban travel into Delhi was on a slightly declining trend prior to the pandemic. This could be on account of the spread of Delhi Metro Rail network to its suburbs. Post the pandemic related lockdowns while there has been an uptick it is hardly near the pre-pandemic levels.
- **Ghaziabad** emerges as the most popular suburb of Delhi. The urban and peri-urban areas in Ghaziabad have shown significant growth along with a concomitant reduction in agricultural land use. This growth is especially concentrated in regions contiguous to Delhi and along transportation lines

- **For Kolkata** - we can see that from 2015-16 to 2019-20 there is a slight increase in suburban travel to Kolkata. However, after the sharp decrease during the pandemic induced lockdowns, the level of suburban travel continues to be about 17-20% less than levels just prior to the pandemic.
- Amongst Kolkata suburbs, passenger arrivals from **24 Paraganas North** and **24 Paraganas South** districts shows an increasing trend; whereas passenger arrivals from *Hooghly* district appear to be slightly decreasing over time and arrivals from Howrah and Kolkata appear flat.
- LULC data shows an increase of ~8.4% in land use in *24 Paraganas North* under the heading, '*Area under Non-agricultural Uses*' i.e. all land occupied by buildings, roads and railways or under water, e.g. rivers and canals etc. in the period 2012 to 2024.

Urban India is growing. At present, 35% of our population is estimated to live in urban areas[47], this number is likely to go up to 40% [~600 million] by 2036 and in excess of 820 million [50%] by 2047[48]. Already urban areas contribute about 60% of India's Gross Domestic Product (GDP)[49]. This figure is projected to rise to about 75% by 2047[50].

While this would certainly have an impact on existing urban centres, however it would also inevitably lead to new centres of urban growth and growing suburbanization of present cities.

It is in this context, that understanding the spatial patterns in urban growth has many significant public policy applications – urban planning, transportation, provision of services etc.

The views expressed are the author's own.

Key Words: Transportation Economics, Migration, Urban Economics
JEL Classification Codes: J61; O15; R23; R30

[47] https://pib.gov.in/PressReleasePage.aspx?PRID=1906145

[48] https://www.iipa.org.in/publication/public/uploads/article/27911712048129.pdf

[49] Cities as Engines of Growth; NITI Aayog & ADB, 2022; https://www.niti.gov.in/sites/default/files/2022-05/Mod_CEOG_Executive_Summary_18052022.pdf

[50] *Urban Transformation for India @ 2047*; Jain; IIPA, 2023