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IPPR

Tales of a few cities

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

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Abstract

This paper extends a previously developed model for analysing passenger movement using Indian Railways Unreserved Ticketing System (IR-UTS) data to examine urban growth in Mumbai, Chennai, Delhi, and Kolkata. The study analyses suburban travel patterns on the Indian Railways network as an indicator of spatial urban expansion. While suburban travel differs from migration, it effectively reveals urban growth patterns. The research integrates geospatial earth observation data with housing property prices to explore relationships between population dispersion and real estate values. Combining processed satellite imagery with Land Use Land Classification (LULC) data enables mapping of urban growth directions. Key findings show suburban travel rebounded post-COVID lockdowns but remains below pre-pandemic levels, potentially due to changed transport preferences or emerging counter-magnets. The analysis examines passenger arrival trends from top origin districts for each metropolitan city to understand urban growth patterns and LULC changes in suburban areas. The methodology demonstrates how high-frequency railway passenger data can effectively track urban spatial expansion when combined with geospatial and property market data. This integrated approach provides valuable insights into post-pandemic urban development patterns across India's major metropolitan centres, offering a novel framework for urban planning and policy analysis.

Keywords: Transportation Economics, Migration, Urban Economics

JEL Codes: J61; O15; R23; R30

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1. 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 (Glaeser and Gottlieb 2009). By concentrating skilled workers together, cities facilitate innovation and entrepreneurship, leading to greater wage growth, which in turn attracts more human capital (Moretti 2012).

Higher concentration of markets and consumers also brings about economies of scale, and eventually leads to improvement in infrastructure (Ciccone and Hall 1996). This virtuous cycle helps cities emerge as hubs of growth by minimising transportation and logistics costs, maximising returns on investment, and by serving as focal points for trade and commerce (Krugman 1991). 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 for 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[1] 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% (Ministry of Housing and Urban Affairs 2024).

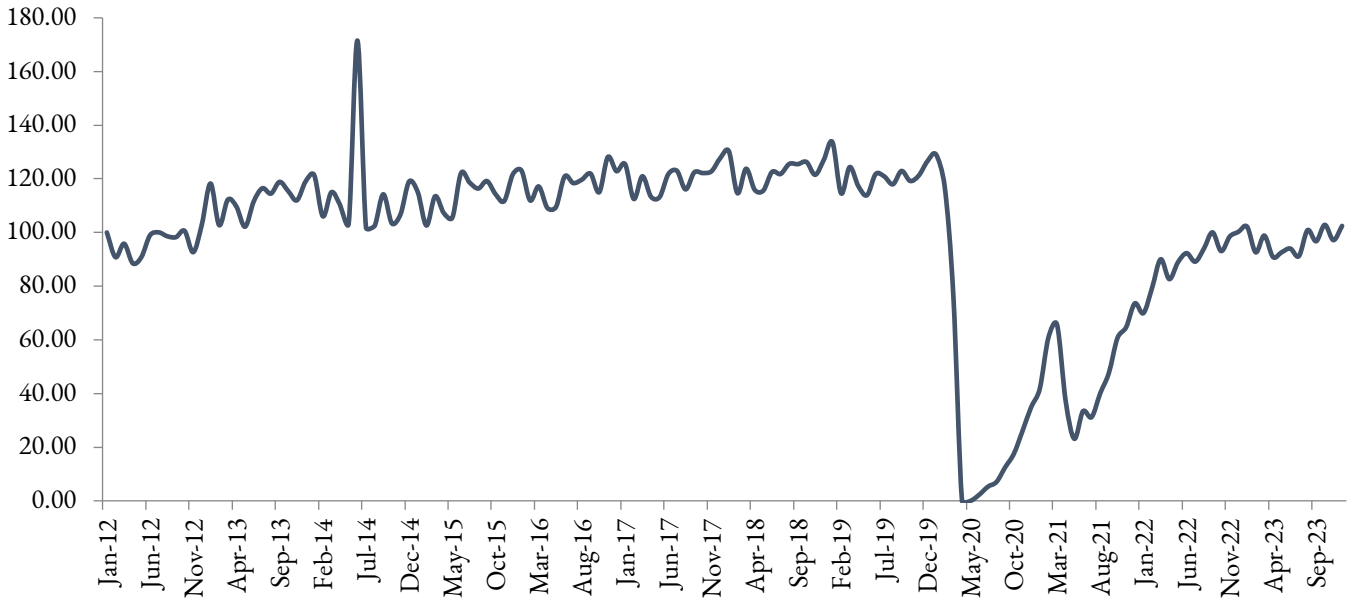
We use data from the Indian Railways Unreserved Ticket System (IR-UTS) for II Class passengers, typically the cheapest class of tickets on the IR network and is often favoured by blue collar workers. We geocode the origin/destination pairs to filter out non-suburban travel. Indian Railways defines suburban services as normally being **upto 150 Kms**. from the origin (Public Accounts Committee; Ministry of Railways 2016-17). 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.

2. 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[2]; the suburban districts (Mumbai Suburban, Thane, Palghar, Raigad) are excluded. The trends in 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]



From the above we can see that suburban travel[3] 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.

The caveat is that, 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 – it appears to be a statistical anomaly.

2.1 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 to Mumbai, in 2012. This percentage has since **reduced to about 58% in 2023**.

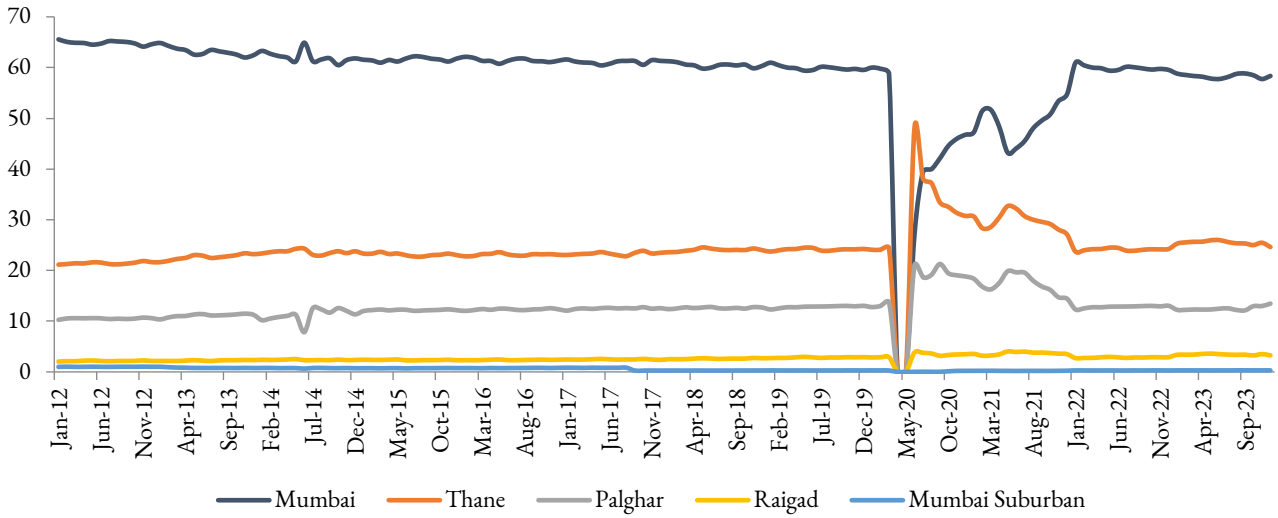
In terms of suburban travel from outside Mumbai City district, Thane continues to be the single largest originating district. In 2012, ~21% the total suburban travel destined for Mumbai originated in Thane. This number has since **increased to more than 25% in 2023**. This is an indicator of the suburban area spreading towards Thane district[4].

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 organised as per originating and destination districts. Therefore, the figures for places like Navi Mumbai (which is spread across Thane and Raigad districts[5]) would have originating passengers reflected in those districts respectively.

We visualise 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 (Directorate of Economics and Statistics n.d.).

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[6]. This has been used as measure of urbanisation in a number of academic papers (Pandey and 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 urbanisation in Thane district. However, at a granular level, which are the areas of most urbanisation growth and whether these areas contiguous to Mumbai urban agglomeration?

2.2 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 Organisation (ISRO)[7] to seek answer these questions. Night Light illumination has been found to a reliable indicator not just of urbanisation but also of population density and economic activity (Levin, Kyba and Zhang 2019).

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 specialised skill. However, this process has been considerably smoothened by handy tools placed in public domain by the National Remote Sensing Centre (NRSC)[8] of the Indian Space Research Organisation (ISRO). For the following analysis, we use ISRO NRSC's *Bhuvan* suite of tools[9].

The Night Lights data put out by NSRC is from the Visible Infrared Imaging Radiometer Suite (VIIRS) night-time sensor (Day/Night Band) - VIIRS/DNB. The VIIRS/DNB sensor is on the Suomi National Polar-orbiting Partnership (NPP) and NOAA-20 satellites (ISRO; Dept. of Space 2022). 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[10].

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 (ISRO; Dept. of Space 2022).

The night light radiance expressed in *nanowatts per square centimetre 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[11] (Figure 3A/3B).

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

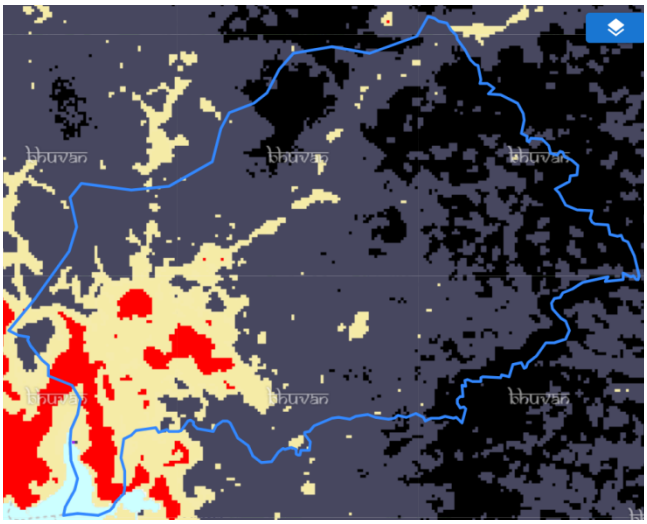
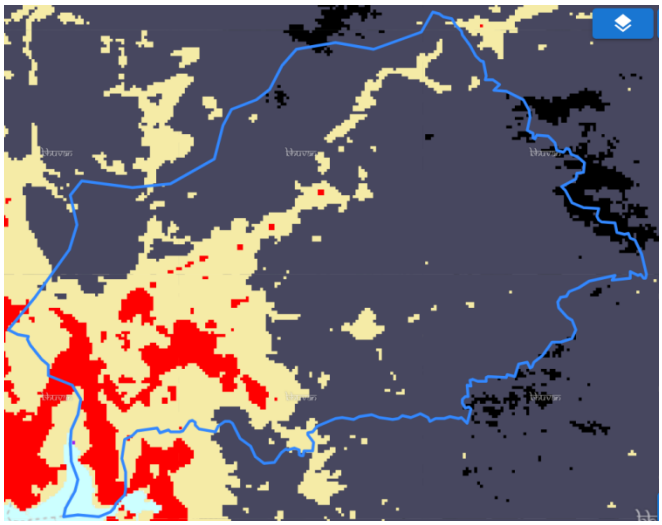


Fig. 3B: Night Light Radiance; Thane District, 2023



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

Table 1: Night Time Lights (NTL) Radiance *nanowatts per square centimetre per steradian* ($nW/cm^2/sr$)

Sl. No.	Colour	Range ($nW/cm^2/sr$)	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].

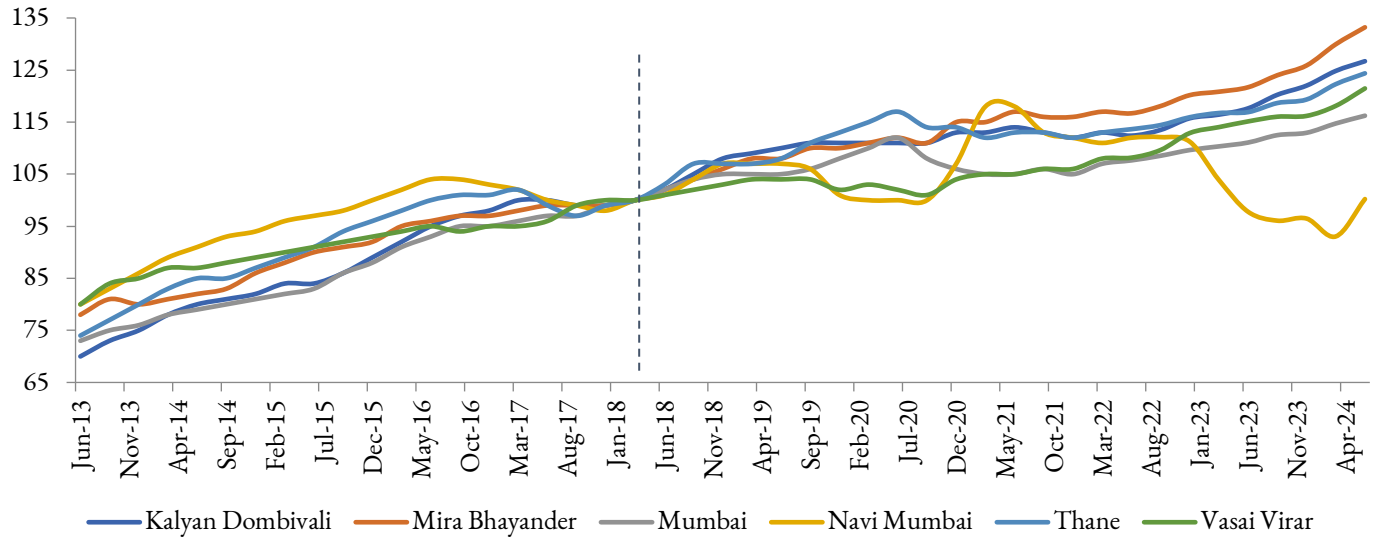
This increase in urbanisation and in population density has implications for urban governance, infrastructure planning and provision of public services etc., since enhanced population pressure on urban area has typically been linked to an increase in demand for housing (Mulder 2006).

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[12]. 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 to track movement in housing prices of Mumbai and some of its suburbs (Fig. 4).

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 and 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 appears to reflect the growth of suburbanisation towards Thane.

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. To visualise this more effectively, one can use gridded population maps.

Gridded population maps break up the map into a grid at 1 km^2 grids and overlay population density data over a basemap (Nolan 2024). The data is taken from the Global Human Settlement Layer (GHSL) and is based on the last Census (Copernicus 2015).

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).

In Figure 5A, the grid squares are colour coded to indicate population density in the respective grid - squares with deeper shades of yellow show higher population density. Similarly, in Figure 5B, the coloured rings show the density of population as we go away from the city centre - here too the yellow rings reflect higher population density.

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

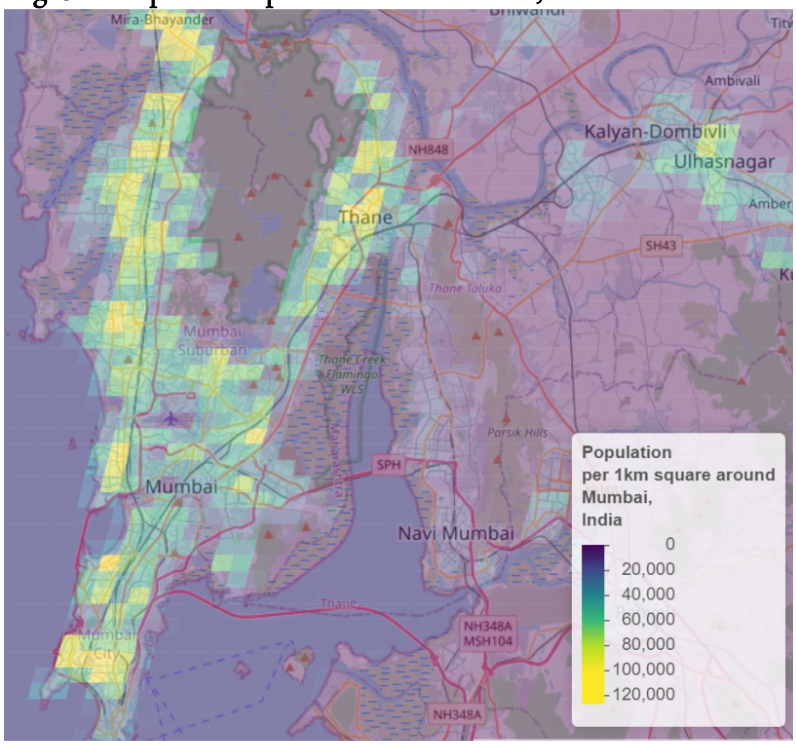
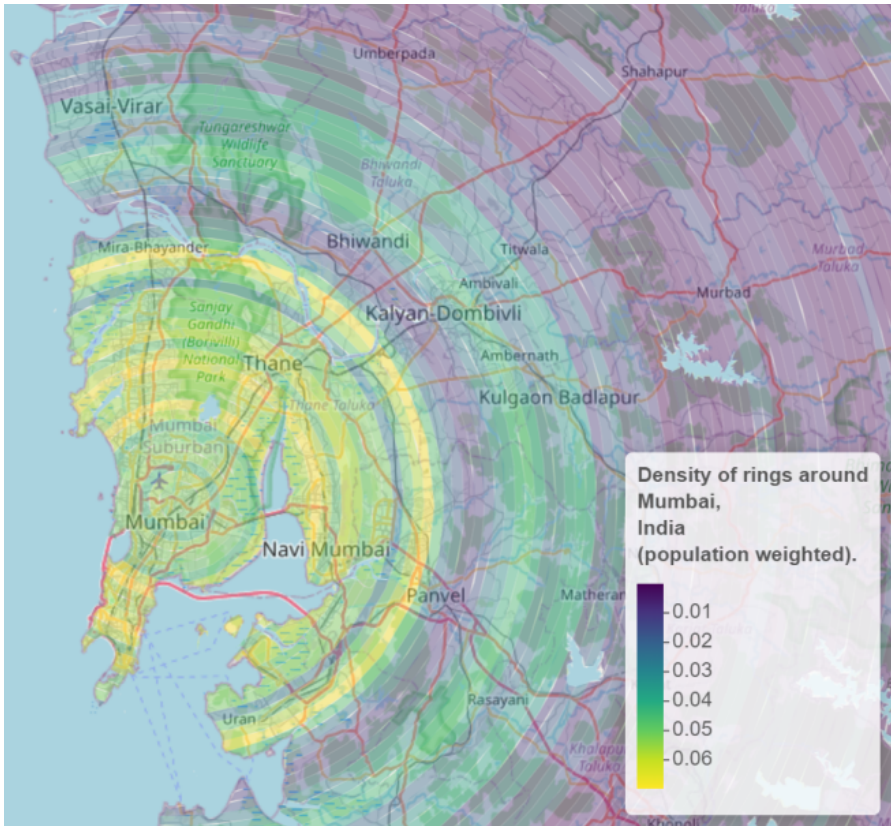


Fig. 5B: Population weighted densities at defined distances from the city centre

[Relative Measures; Population based on Census 2011 Data]

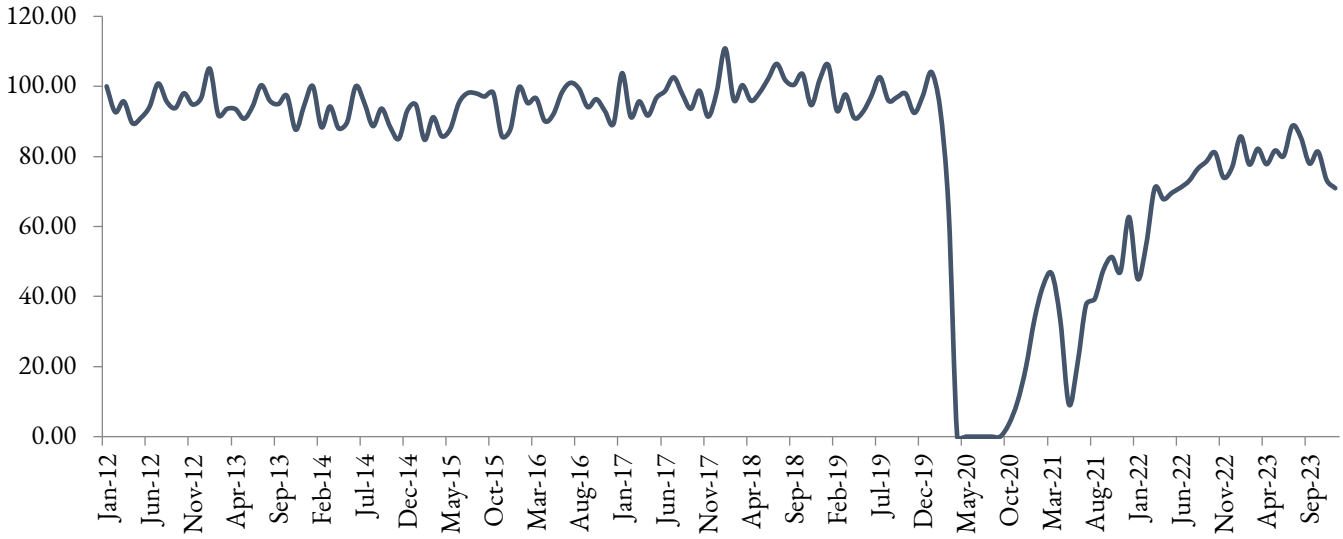


3. Chennai Express: Suburban Growth of the city of culture and tradition

From Mumbai to shift our focus southwards to the city of Chennai – a bustling metropolis with a population of 46,46,732 (Directorate of Census Operations 2011). For the purposes of this section, Chennai is taken as meaning Chennai district [as defined in the District Census Handbook]. 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).

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 (Public Accounts Committee; Ministry of Railways 2016-17)] first dipped from Jan 2012 levels till about mid-2016, after which an upward movement is seen. Post the pandemic, while sub-urban travel did bounce back, it is estimated that the pre-pandemic levels have not yet been reached as of end-2023.

3.1 Patterns in suburban travel

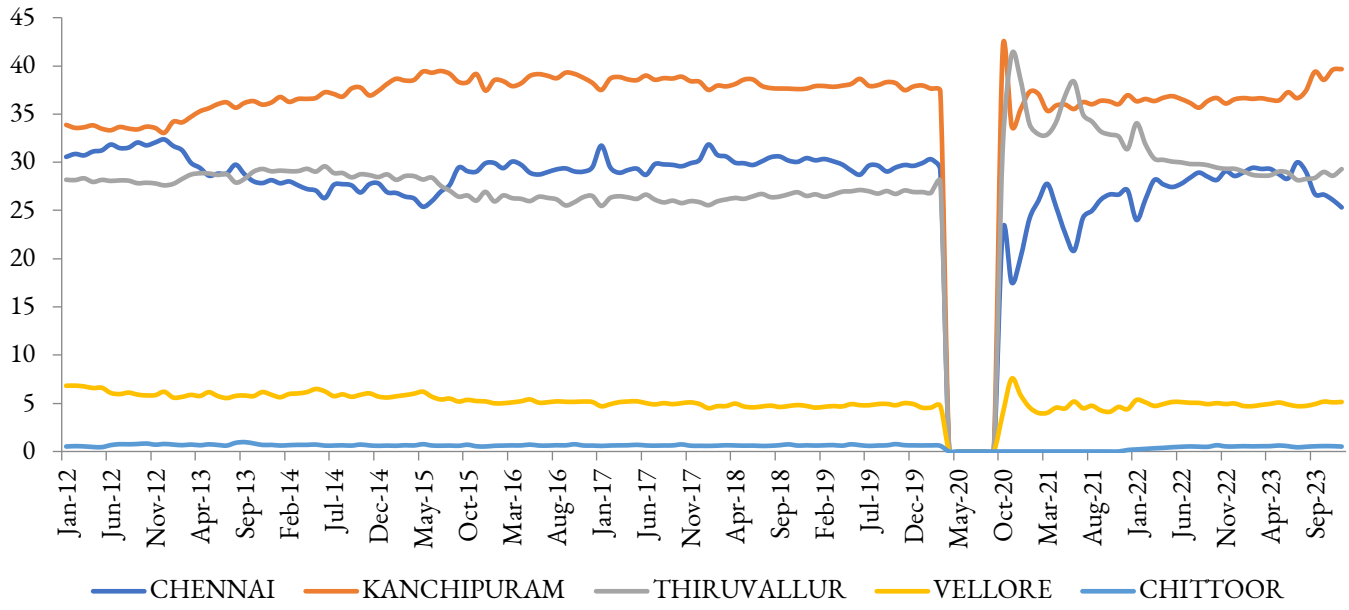
Suburban travellers into Chennai originate from Kanchipuram, Thiruvallur, Vellore, and Chittoor districts. Intra-Chennai UTS II Class Traffic i.e. traffic originating within Chennai was estimated to be about 30.56% of all UTS II Class suburban travel destined to Chennai, in 2012. This percentage has 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 number **increased to more than 39% in 2023**. This is an indicator of the suburban area spreading towards Kanchipuram district.

We visualise 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 (Nolan 2024) (Figure 8B).

Fig. 8A: Population per 1 km^2 in Chennai; Census 2011 Data

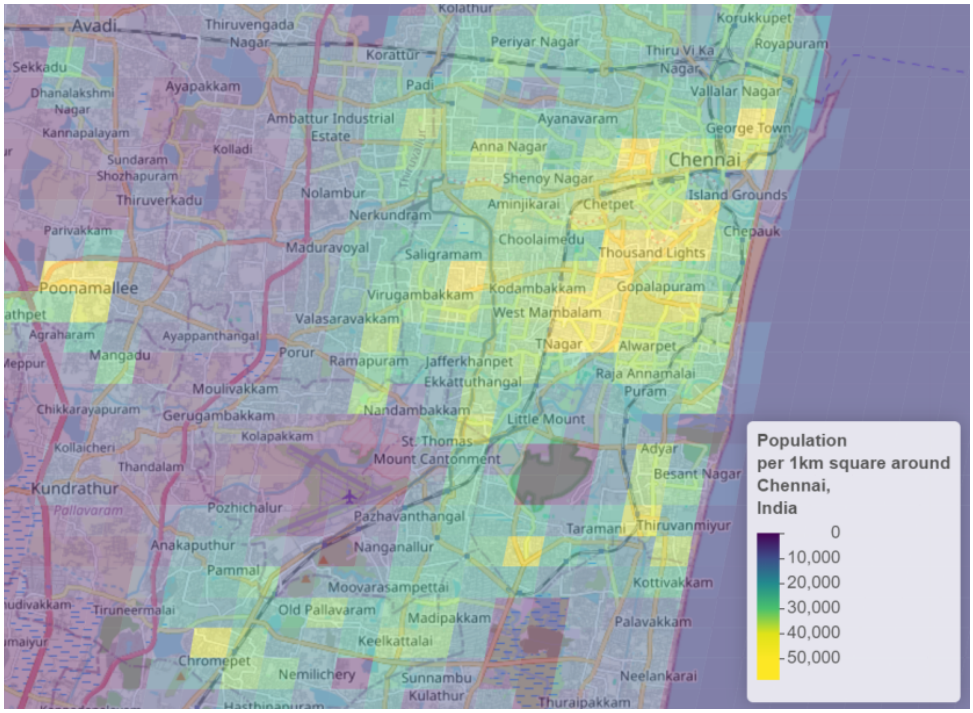


Fig. 8B: Population weighted densities at defined distances from the city centre

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

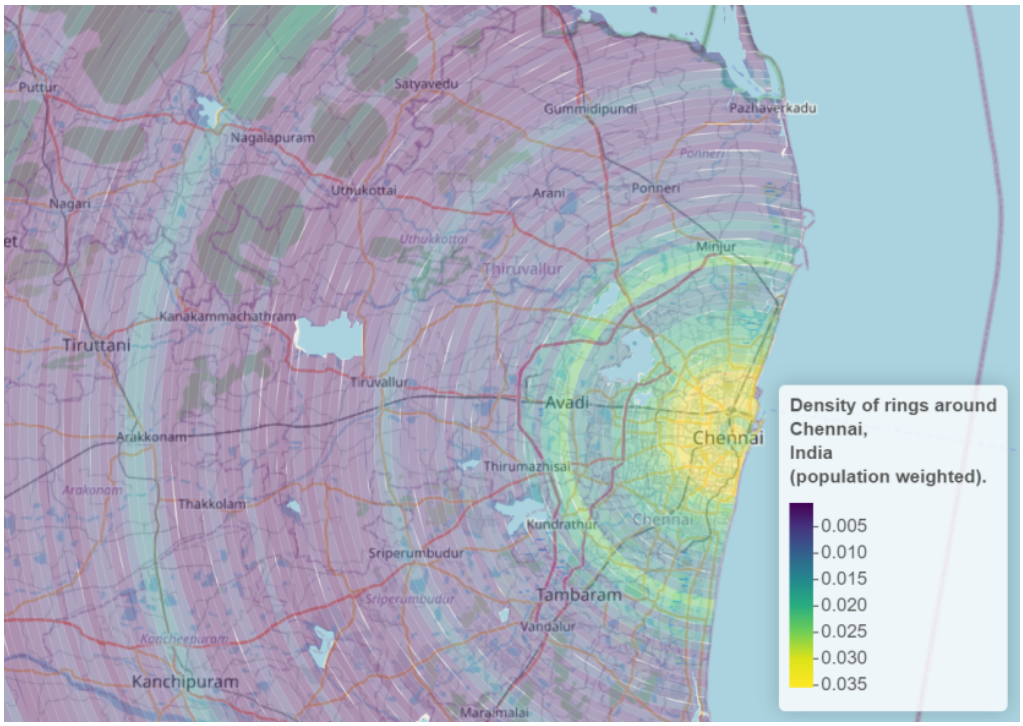


Figure 9 presents the data for night light radiance for the district of Kanchipuram for the years 2012 and 2023 [taken from the ISRO *Bhuvan Night Time Light over India from Space* service] (Figure 9A/9B). The area on the top right of the images, beyond the blue border, corresponds to Chennai District.

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

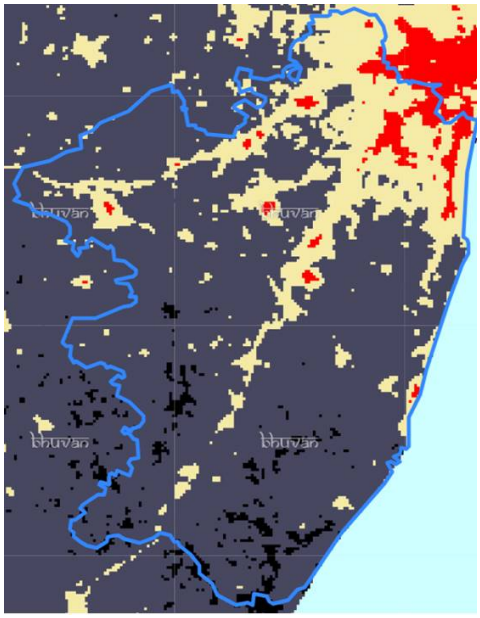
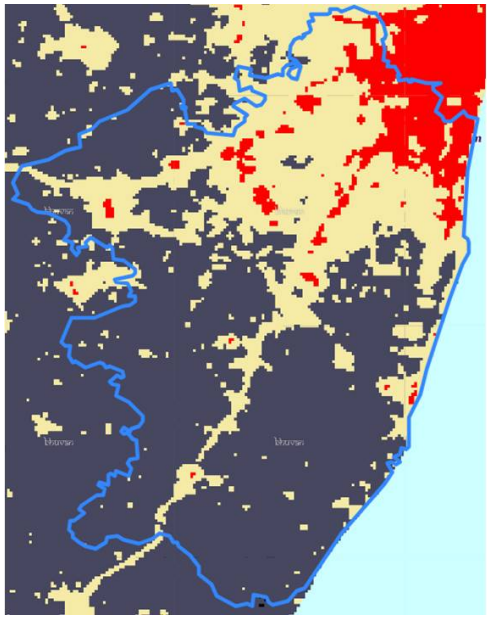


Fig. 9A: Night Light Radiance; Kanchipuram District, 2023



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 greater in **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.

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

[% change from 2012 to 2023]

Sl. No.	Colour	Range ($nW/cm^2/sr$)	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.	-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

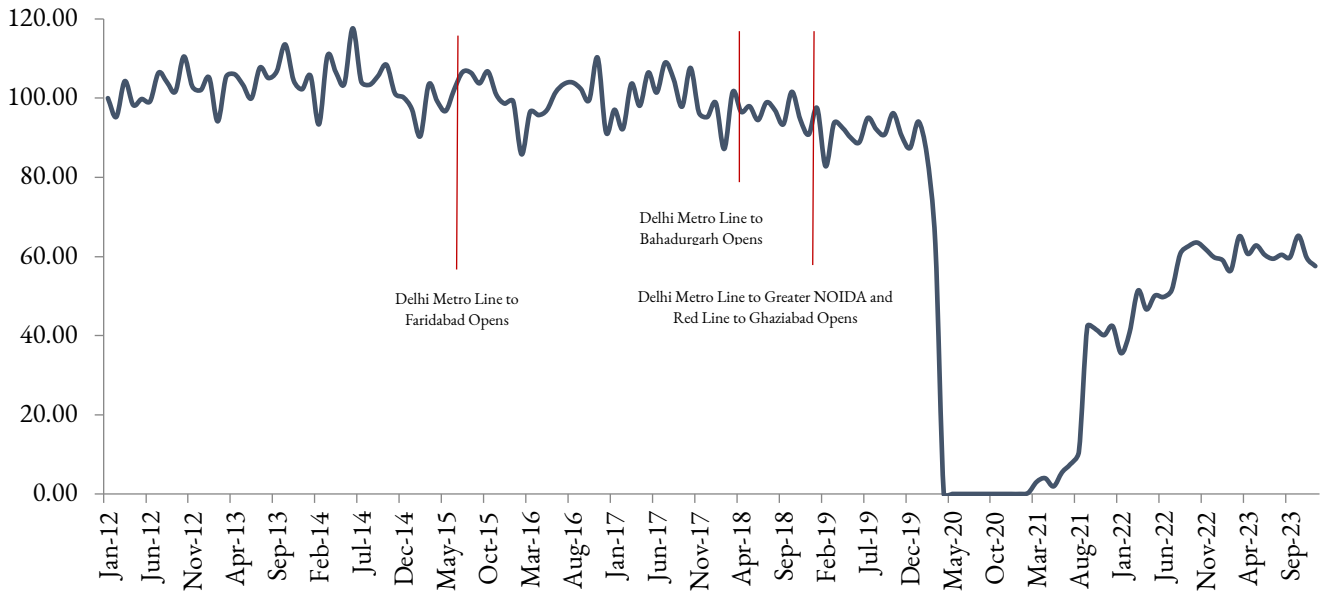
4. Delhi: The City of Djinns

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 (Directorate of Census Operations 2011). For the purposes of this section, Delhi is taken as meaning the eleven districts of Delhi [as defined in the *District Census Handbook*]. 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).

Fig. 10: Trends in all Suburban Travel in Delhi

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

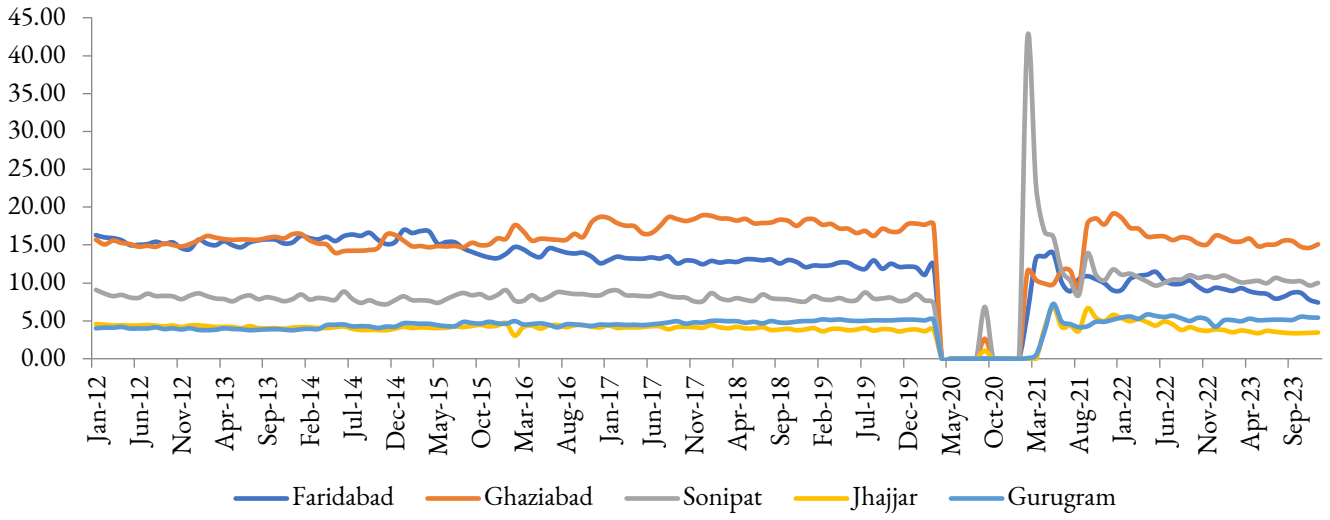


From the above it is evident that suburban travel into Delhi was on a slightly declining trend prior to the pandemic. Post the pandemic, while there has been an uptick, it is still far from the pre-pandemic levels. The opening of selected Delhi Metro connections to suburban areas is indicated in Fig. 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 visualise 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

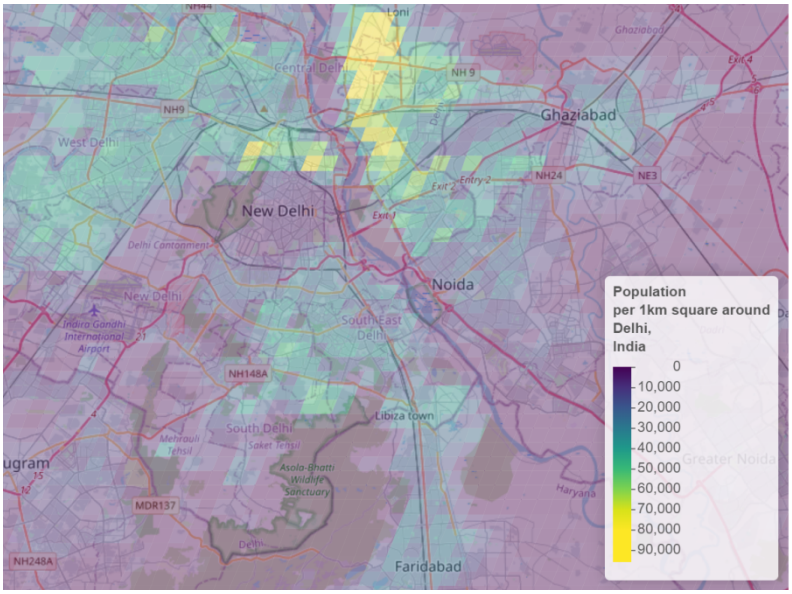
[2012-2023; IR UTS II Class]



From the above, it 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 (Nolan 2024) (Figure 12B).

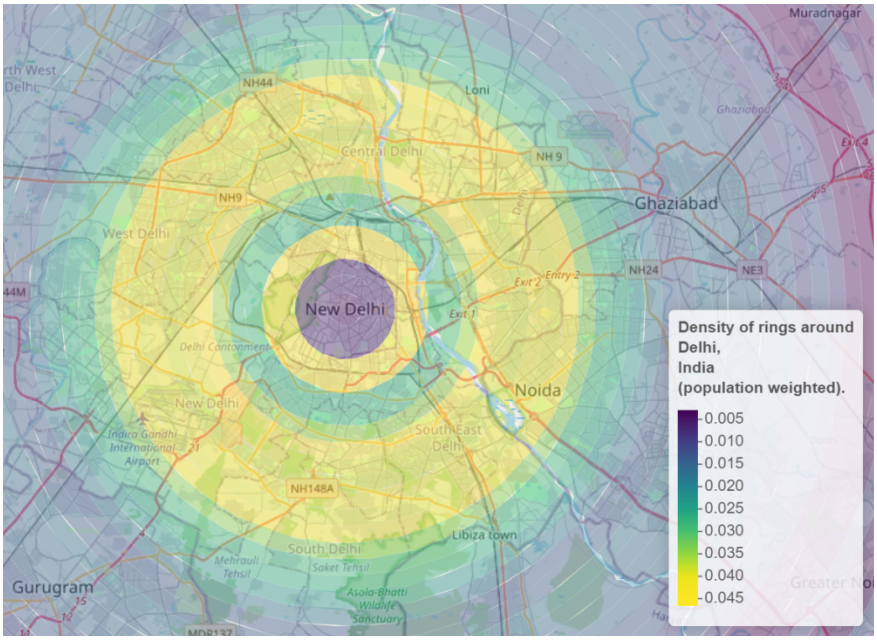
Fig. 12A: Population per 1 km^2 in Delhi; Census 2011 Data



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] (Figure 13A/13B).

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

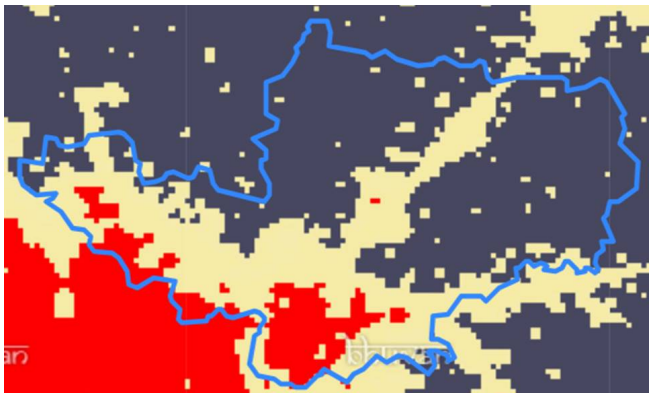
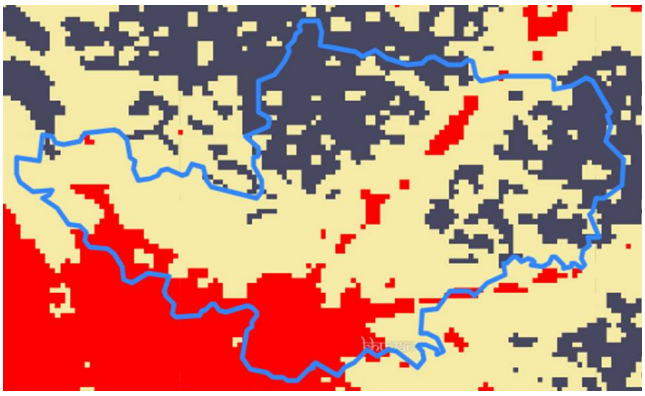


Fig. 13B: Night Light Radiance; Ghaziabad District, 2023



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 ($nW/cm^2/sr$)	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 (Directorate of Economics and Statistics n.d.) for the district of Ghaziabad. In particular, the change in land use under the heading, '*Area under Non-agricultural Uses*'[13] has been used as measure of urbanisation in a number of academic papers (Pandey and Seto 2015).

Between the years 2012-13 and 2022-23, area under non-agricultural uses has grown from 27,478 hectares in 2012-13 to 32,627 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%.

5. Kolkata: The city of joy

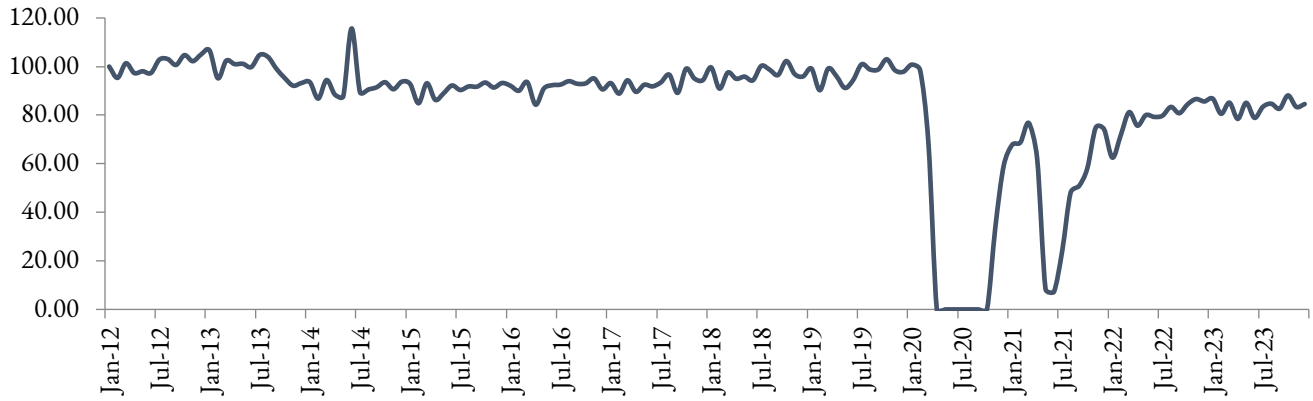
We now move northwards for a quick look at the city of Kolkata, the largest city in India's east, with a population of 44,96,694 as per Census 2011 (Directorate of Census Operations 2011). For the purposes of this section we treat the districts of Howrah and Kolkata as a conurbation (Dey 2021), and the analysis in the following section considers arrivals in Kolkata and Howrah together. The

population of Howrah district as per Census 2011 stood at 48,50,029 (Directorate of Census Operations 2011).

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]

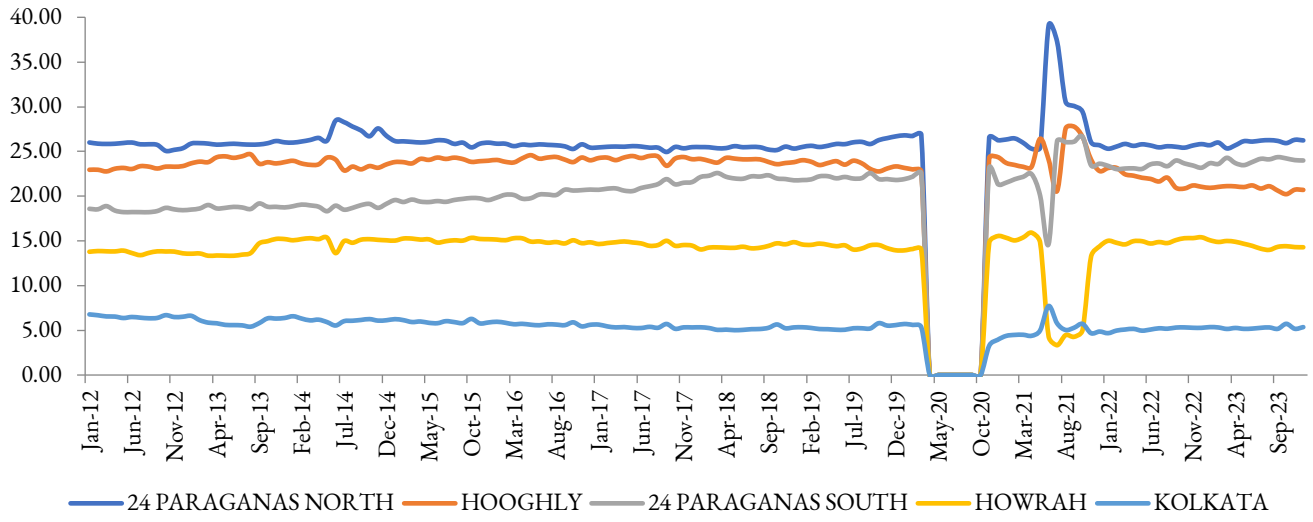


From the above, we can see that from 2015-16 to 2019-20 there is a slight increase in suburban travel to Kolkata. However, after the sharp decrease during the pandemic, the level of suburban travel continues to be about 17-20% lesser than just prior to the pandemic.

We now visualise 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

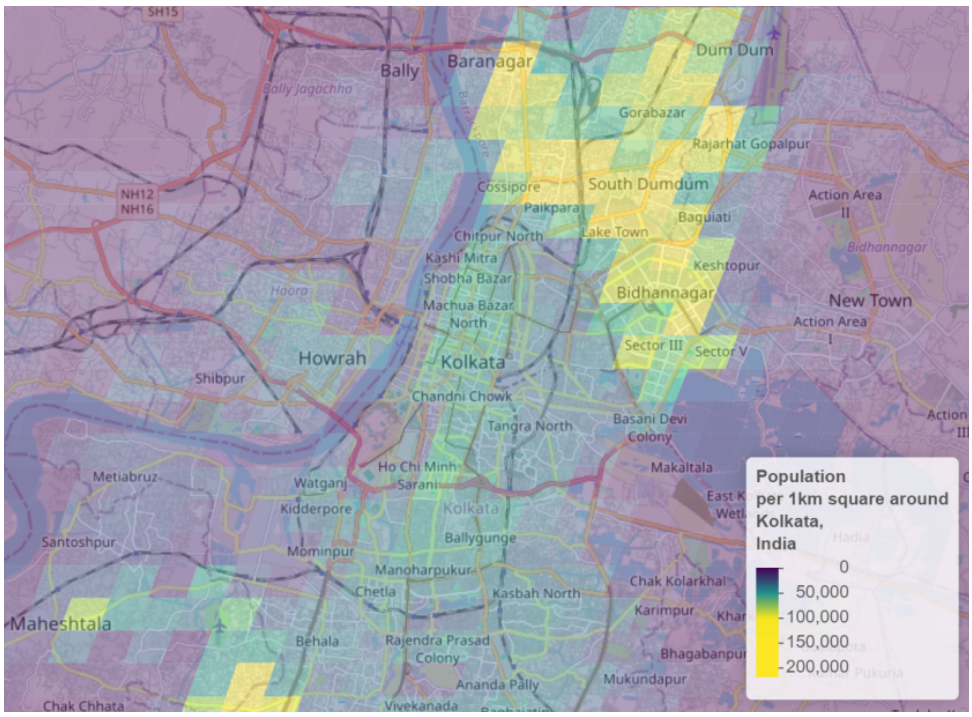
[2012-2023; IR UTS II Class]



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 (Nolan 2024) (Figure 16B).

Fig. 16A: Population per 1 km^2 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.

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] (Figure 17A/17B), we see that there has been some increase in the High Radiance [*Red*] and Moderate Radiance [*Brown*] bands [Table 4].

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

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

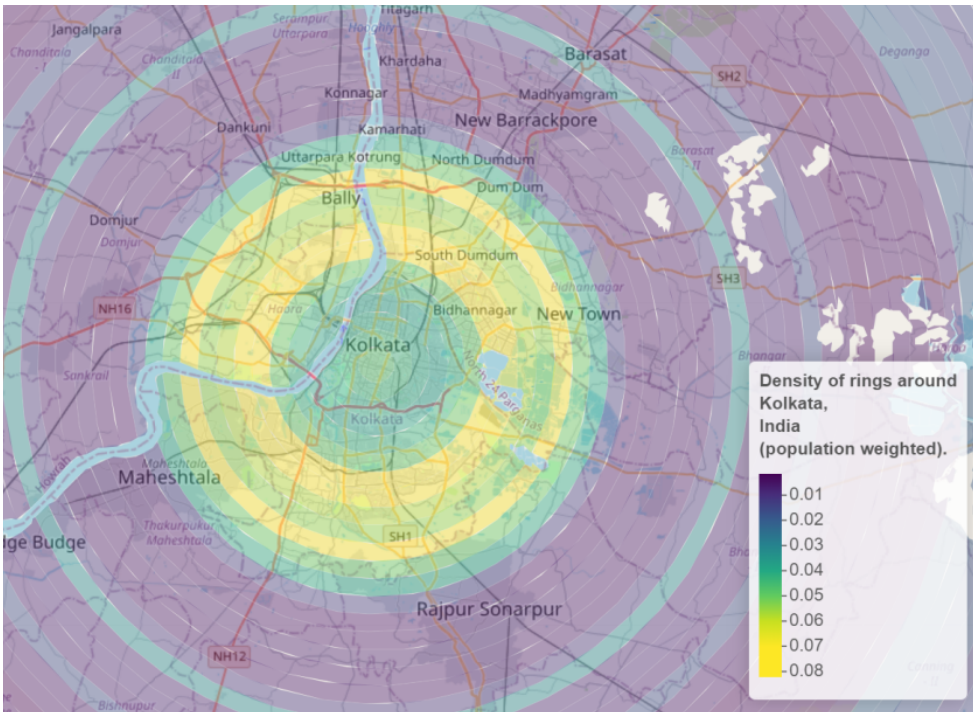


Fig. 13A: Night Light Radiance; North 24 Paraganas District, 2012

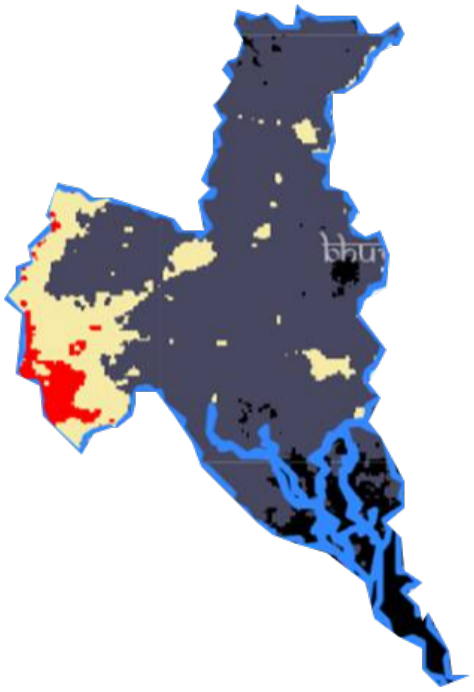


Fig. 13B: Night Light Radiance; North 24 Paraganas District, 2023

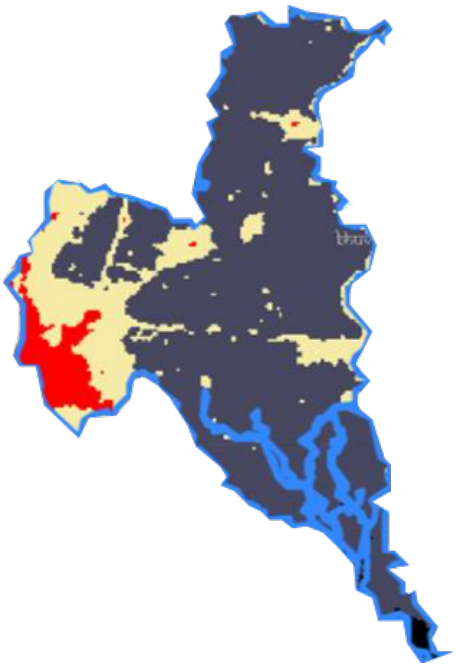


Table 4: Quantifying Night Time Lights (NTL) Radiance for North 24 Paraganas District

[% change from 2012 to 2023]

Sl. No.	Colour	Range (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 (Directorate of Economics and Statistics n.d.) 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*'. 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%.

6. Conclusion

The above examination used passenger data from Indian Railways, coupled with earth observation and Land Use Land Classification (LULC) data to understand the relationship between four metropolitan cities and their suburbs.

Overall, we see that post the COVID-related lockdowns, while suburban travel has quickly rebounded, it still remains somewhat lower than 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.

Subject to that caveat, we analyse this data to understand the directions of growth of the selected cities. Urban growth has been seen contiguous to the existing high density urban cores, and is typically accompanied by a reduction in agricultural area.

Our findings are summarised as under:

For Mumbai, suburban travel showed a steady upward trend just prior to the pandemic; while suburban travel quickly rebounded post the lockdowns, however, we estimate that the levels have only reached the January 2012 level as of 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. Post the pandemic, while sub-urban travel did bounce back, 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, while there has been an uptick, it is not yet 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, 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 intra-district 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*' in the period 2012 to 2024.

Urban India is growing. At present, 35% of our population is estimated to live in urban areas (Ministry of Housing and Urban Affairs 2023); this number is likely to go up to 40% [~600 million] by 2036 and in excess of 820 million [50%] by 2047 (Jain 2011). Already urban areas contribute about 60% of India's Gross Domestic Product (GDP) (Niti Ayog, Asian Development Bank 2022). This figure is projected to rise to about 75% by 2047 (Jain 2011).

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 suburbanisation 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.

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Notes

[1] The primary data used for this analysis is of Unreserved Ticket bookings maintained by the Indian Railways Centre for Railway Information Systems (CRIS). Amongst the many systems that CRIS runs is the Unreserved Ticketing System (UTS). On an average, the system serves over 21 million passengers, issuing over 8 million tickets across 100 variations [concessional, seasonal, etc.] and involving revenue in excess of Rs. 500 Million – every day. The UTS is the backbone that serves passengers using the Unreserved or General Tickets – typically the most affordable tickets on the Indian Railways network. We analyse this large and high frequency dataset to give us interesting insights into the movement of people within the country

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

[3] See Lok Sabha PAC 69th Report (2016-17); Suburban Train Services In Indian Railways

[4] 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]*.

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

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

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

[8] See https://www.nrsc.gov.in/

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

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

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

[12] See https://residex.nhbonline.org.in/

[13] For additional information, see Land and Use Statistics Concepts & Definitions- Nine-Fold Classification; *https://desagri.gov.in/wp-content/uploads/2021/04/4-Concepts-Definitions.pdf*