Research Paper

Balancing Urban Densities: Exploring Retail and Population Distribution for Sustainable Indian Cities

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Abstract

Urban districts exhibit substantial complexity, characterized by diverse urban densities across various neighborhoods in different city regions. There is a substantial disparity between the prevailing trends of urbanization and the prerequisites for sustainable urban development. India's commercial industry keeps evolving every day with newer concepts, leading to significant changes in the retail density to cater to the demand. The rise in population density proportionately affects the concentration of retail establishments. This study explores the relationship between retail and population density to provide insights into sustainable urban development in Indian neighborhoods. It focuses on two main areas: the city core and the outskirts. This discrepancy affects urban sustainability pertaining to transportation, as well as economic vitality. The results illustrate major variations in the density of retail businesses across urban cores and peripheries, influencing characteristics such as the number of establishments, social interactions, and economic activity. The research also explores important urban strategies to balance retail and population densities effectively. These have immense implications for augmenting sustainable urban development practices. This research improves our understanding of the dynamics of urban density and, therefore, provides practical insights for city planners and policymakers seeking to create livable and environmentally sustainable cities.

Keywords

Urban Density, Retail Density, Sustainable development approach

1. Introduction

An urban structure is a collection of complex spatial arrangements and their respective activities, impacting a city's morphology and functional life (Shen, 2017). The urban structure of the city is an amalgamation of its various degrees of connectivity and accessibility marked by land use diversity (Zhong *et al.*, 2017; Kotni, 2019). Accessibility is significantly determined by spatial arrangement, which determines the function of the city's functionality (Hillier, 1996). The urban spatial structure is a collection of spatial relationships associated with the interactions among diverse urban entities and the urban form (Anas, Arnott, and Small, 1998). Urban spaces are intrinsically dynamic, continuously influenced by consumer demand and the adaptive supply systems that address these requirements, resulting in the gradual evolution of commerce. This ongoing transition is integral to a larger movement toward cities that tackle the issues presented by static sites and the dynamic nature of urban functional movements to uncover more intricate spatial configurations (Sui, 2015). Rapid urbanization, in tandem with industrialization, has significantly altered the global land use pattern (Pritipadmaja and Garg, 2022). As a result, increasing population demands,

instigate a vicious cycle of infrastructure development and city centre development in urban and peri-urban areas. This leads to migration to urban areas for better living standards and economic opportunities, which further increases resource demand. An urban spatial structure can thus be understood as the generalized interpretation of a spatial layout of the city, together with the organizational structure underpinning those interconnections that characterize its form of urban design (Foley, 2016).

Economic transactions tend to cluster in different places within a city. This agglomeration of economies led to the creation of business districts, also known as urban centers. The formation of centers is caused by factors like Spatial Inhomogeneities, Internal, and External Scale Economies, and Imperfect Competition (Murphy, Shleifer and Vishny, 1989; Anas, Arnott and Small, 1998). The urban structure can thus be classified into Monocentric and Polycentric in terms of economic agglomerations, according to the degree of clustering and dispersion.

Commercial centres are urban centres or business districts that nurture economic and employment opportunities. The Indianapolis 2012 document states that commercial areas emphasize commercial transactions and business, encompassing establishments such as offices and shopping centres. The theory of commercial location posits that the interaction among different rent structures, market supply-demand dynamics, and the strategies of aggregation and diffusion predominantly shape the evolution of urban business districts (Chen *et al.*, 2016). Commercial spaces are fundamental to urban interactions, connecting space and functionality. The necessity for trade among or across groups emerged as social populations began to coalesce into cohorts (Benton, 2019). It was conceived when housewives traded food products during times of necessity, evolving from Barter Systems to QCommerce thereafter (Casson and Lee, 2011). The maximal degree of commercial transactions transpires when there exists a substantial disparity, intense demand, and minimal distance (Guy, 1998).

Commercial spaces have emerged as an integral part of land-use planning to address the growing demand in urban areas (Jhamb and Kiran, 2012). The rapid proliferation and unsustainable development of commercial sectors have resulted in significant obstacles, including encroachment, the emergence of informal sectors, pressure on existing infrastructure, waste production, and environmental issues, such as deteriorating air quality and the urban heat island phenomenon. However, a contrast between planned strategies and reality has hindered infrastructure development and effective urban governance in Indian cities.

This gulf is often caused by inadequate holistic analysis of the market area, which leads to dead commercial places with low footfall and low economic cycles (Ganesh, Aithal and Kirubadevi, 2020). Considering that retail is a continuously changing sector, comprehending the dynamic characteristics of commercial settings and their adaptive methods within competitive contexts has become imperative (Turhan, Akalın and Zehir, 2013). Analyzing the distribution patterns of commercial operations and examining the associated trends are essential for forecasting future adaptations and facilitating sustainable urban planning (Porta *et al.*, 2009; Xing and Meng, 2020).

Sustainable urban development is increasingly focused on compact cities (Soltani *et al.*, 2022). Density is an integral part of a compact city since it promotes the functionality of cities (Frank *et al.*, 2010), livable neighborhoods, and thriving local economies (Page *et al.*, 2024). There are also negative sustainability effects associated with density, particularly within the contexts of ecology and social sustainability (Bramley *et al.*, 2009; Page *et al.*, 2024). This aims to ensure that consumers have easy reachability to a range of vital services within walkable distances from their houses, hence leading to the creation of multiple retail clusters across the city (Yoon, 2018; Gower and Grodach, 2022; Thornton *et al.*, 2022). Retail clusters require a significant customer base for profitable sales revenue; hence, fluctuations in this base

strongly correlate with the overall performance of commercial areas. Factors such as a rise in residential and transient populations, along with asset developments and enhancements in public transit, may lead to an expanded consumer base (Teller and Reutterer, 2008; Schuetz, 2015; Yoon, 2018).

Commercial precincts are predominantly situated in regions with high population density, facilitating convenient access for consumers (Huff, 1964). The volume of local sales is crucial to the retail clusters, especially when consumers are hesitant to drive considerable distances for a product. The increase in consumer demand stimulates commercial operations, hence promoting economic growth and improving urban quality of life, thus indicating that demography significantly influences the economic transactions inside an urban precinct (Wang *et al.*, 2018; Xing and Meng, 2020; Lima *et al.*, 2024). The socio-economic and ecological impacts of urban expansion also help us achieve a holistic understanding of commercialization (Leichenko, 2001; Wentz *et al.*, 2006).

Thus, this research will explore the relationship between retail and population density in order to provide insight into sustainable development within urban neighborhoods in India. The objectives of the study are to assess the interaction of retail and population densities in selected city cores and outskirts and the socio-economic distribution in the residential neighborhoods of Indian cities. This study also strives to identify sustainable urban strategies to balance retail and population densities. This study explores the residential and commercial land coverage and does not include the number of floors or multiple households in a single unit. Public and Semi-Public land use is not considered.

2. Study Area, Data and Methods

2.1. Study Area

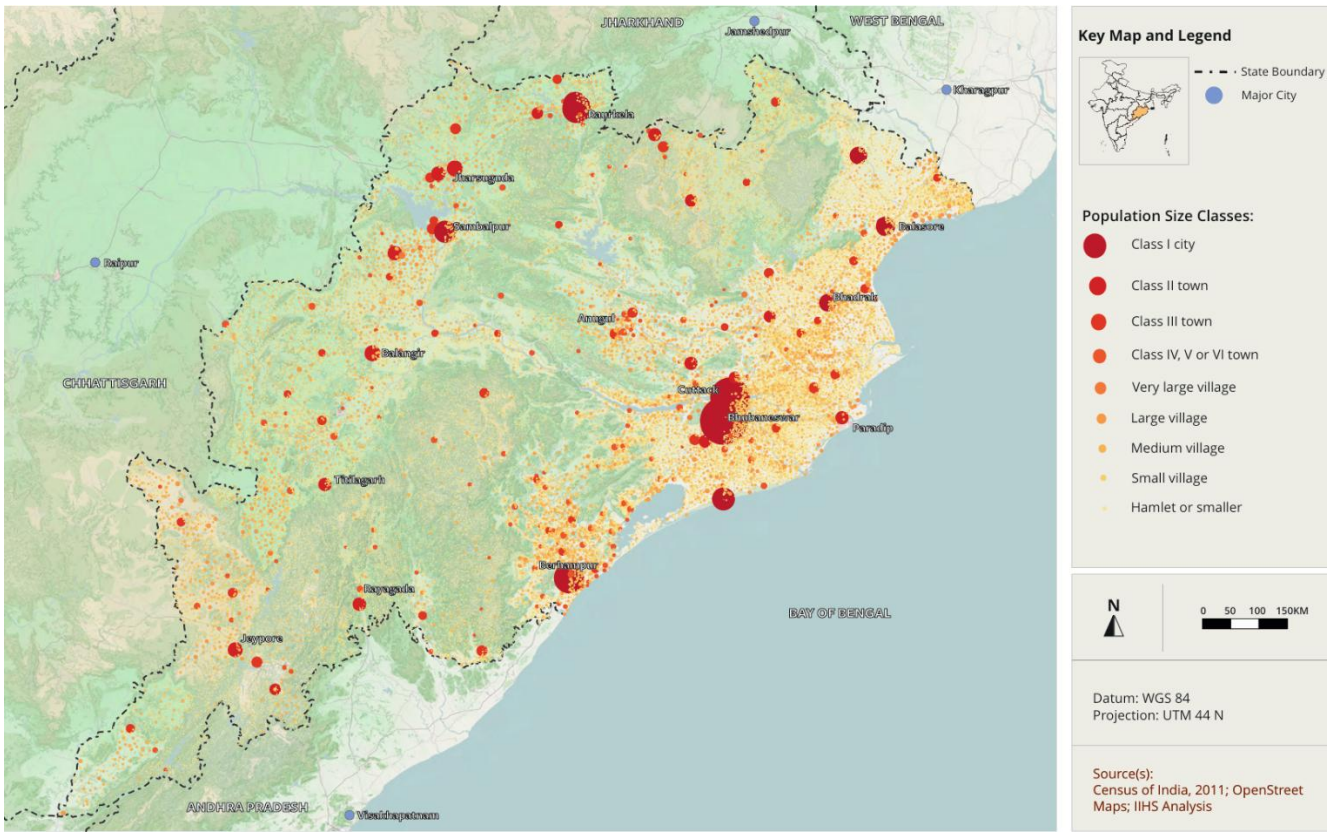

Figure 1 . Map showing Bhubaneswar. Source(s): Census of India, 2011; OpenStreet Maps; IIHS Analysis

Bhubaneswar, the capital of Odisha, is a significant urban centre in eastern India, distinguished by its distinctive combination of old city charms and planned neighbourhood concept. Also known as Ekamra Kshetra or the Temple City, it accounts for approximately 2% of the state's urban population. It was designed in 1946 by the German architect Otto H. Königsberger for administration and residential use for a target population of 50,000 (Mohanty, 2015). The city depicts a unique integration of linear planning and organic growth. It follows a neighborhood-centric approach in terms of layout, which makes it ideal for analyzing commercial space within residential blocks. The city has grown predominantly towards the southwest as there reserve forests are found in the northwest and flood plains in the east region (Pathy and Panda, 2012).

According to the 2011 census, the population of Bhubaneswar Municipal Corporation stands at 844,000, which has been rapidly escalating, approaching the milestone of 1 billion. The percentage of commercial land use in Bhubaneswar stood at 2.17%, a figure that has seen a notable increase over the last twenty years. The city's decadal growth rate stands at an impressive 30.2%, signifying that Bhubaneswar is experiencing substantial growth (Anand and Deb, 2017). The city has experienced notable expansion both horizontally and vertically in recent years. Within the jurisdiction of the BMC, approximately 32% is allocated for residential use, while 15% is designated for commercial and industrial activities. (Datey *et al.*, 2012; Roy and Basu, 2020).

Over the past few decades, due to urban expansion and diversification, the housing and commercial sectors are adjusting to demographic and economic changes. Rapid urbanization has increased demand for a variety of housing types, from single-family homes to high-rise apartments, and commercial spaces, especially near major residential zones, have developed to meet local demands and improve convenience. The Smart City status of Bhubaneswar has brought in investments in modem infrastructures, encouraging integrated residential and commercial schemes and sustainable urban development (Kar *et al.*, 2016). Bhubaneswar, which was once a residential metropolis, has now turned into a multifunctional urban space, thus making it is an excellent location to analyze residential and commercial developments. It is essential to comprehend the indicators that contribute to the significant expansions of the city's commercial landscape in order to formulate strategic plans for improved commercial establishments.

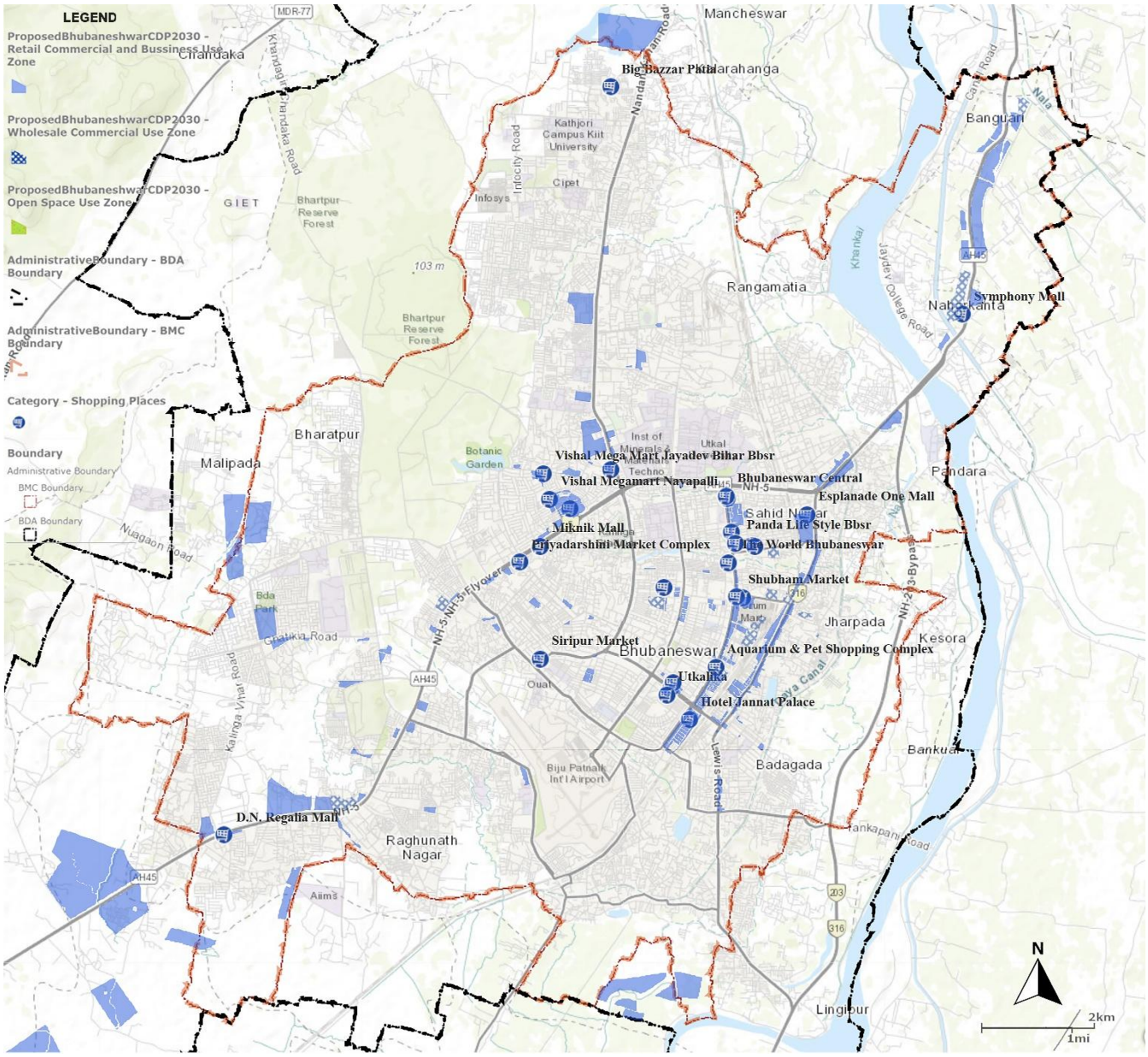

Figure 2. shows the map of the commercial areas of Bhubaneswar, Odisha . Source: Bhubaneswarone.in

2.2. Data Collection

A Reconnaissance Survey was conducted to understand the neighborhoods' spatial layout and socio-economic distribution. Discussion with the shopkeepers and the head of the market committee was also conducted to understand the market's current situation. The data collected for this study was spatially oriented. Google Earth Pro and OpenStreetMap were utilized to acquire the spatial location data of residential and commercial buildings.

Wards are regarded as the most fundamental political and administrative division in India. There have been evidence of studies that have relied on ward-level data due to the unavailability of finer spatial scales (Bharathi *et al.*, 2021). Two wards, i.e., ward no. 40 and 24, in Bhubaneswar, were chosen for the survey, one in the city core characterized by high population density and concentrated retail establishments, and

the other in the city outskirts towards the growth direction of the city, often marked by lower population density and dispersed retail environments. They are situated along major road network axes of Bhubaneswar and have a Königsberger neighborhood layout and informal growth for residential areas. They have government-allocated markets that serve the local neighborhoods and have a broader catchment area, supplying goods to the entire ward.

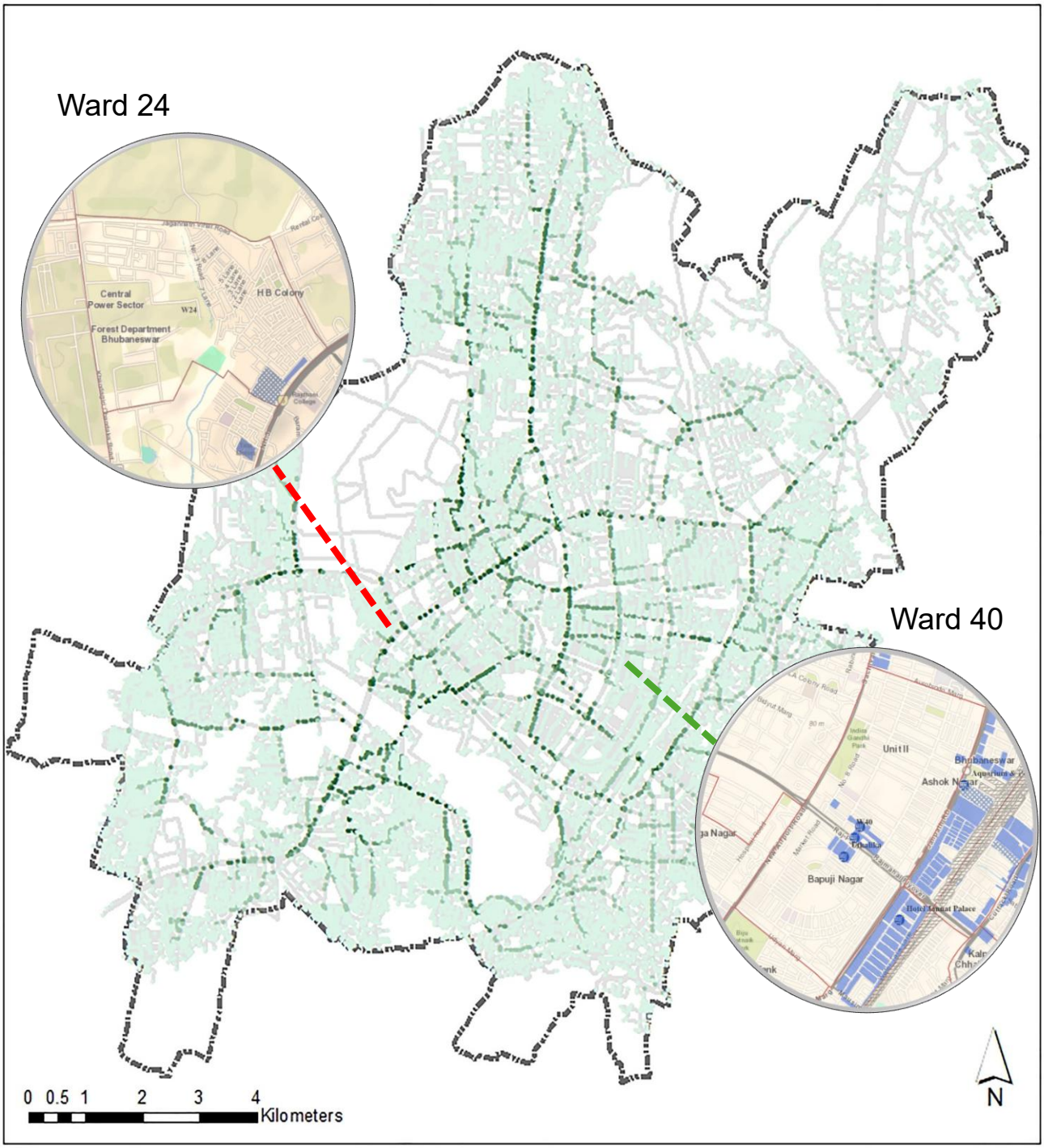

Figure 3. shows the road network of Bhubaneswar and the selected wards for the studt. Source: Bhubaneswarone.in and author

Figure 4 . The present condition of commercial spaces of Ward 40 i.e. at the city Centre. Source: author

Figure 5 . Present condition of commercial spaces of Ward 24 i.e., at the growth direction. Source: author

2.3. Methodology

The commercial landscape is experiencing substantial transformations attributed to evolving lifestyles and accelerated urbanization (Dahiya, 2017). This research study used a systematic approach to examine the interaction between residential and commercial density. This methodology represents an extensive approach for analyzing spatial and socio-economic aspects that affect urban density distribution. The methods adopted in the study are as follows:

1. A Reconnaissance Survey was conducted to identify major commercial places and socio-economic characteristics of residential areas. The demographic and economic data to understand market scenarios and population distribution, was also collected.
2. Spatial mapping was done using OpenStreetMap and Google Earth to outline the road network and map the spatial locations of commercial and residential buildings.
3. Kernel Density Estimation (KDE), a GIS tool, was used on the mapped residential and commercial spatial points to create density maps, envisaging the spatial distribution.

4. The spatial density map was assessed to the clusters and variations in commercial and residential density against the socio-economic distribution.
5. The KDE density values were converted into spatial data points for both residential and commercial density values using Arc GIS.
6. Pearson's Correlation coefficient was calculated for the derived data points with density values to assess the strength and direction of the relationship between residential and commercial density distributions of different wards.
7. Reconnaissance insights, KDE patterns, and correlation results were integrated to interpret the influence of residential density on commercial density within the socio-economic context of the study area.

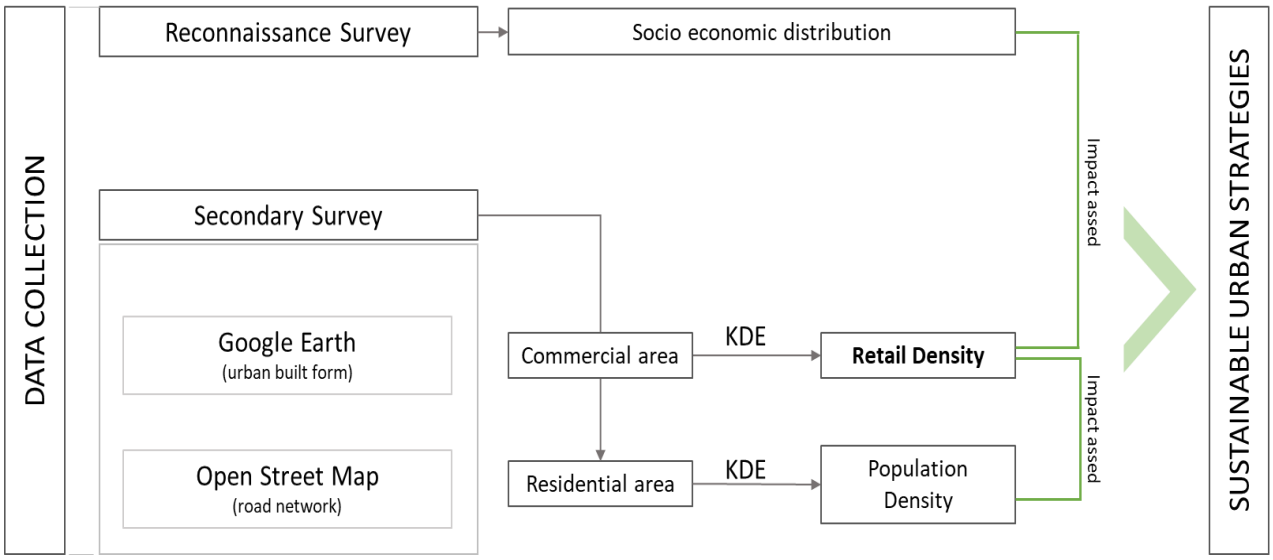

Figure 6 shows the methodology used in this study. Source: Author

3. Findings and Discussions

The spatial data procured from Google Earth mapping, in tandem with the road network from Open Street Map, was evaluated using ArcGIS tools to examine the relationship between residential density and retail density, to achieve a balance that enhances economic performance and improves residents' quality of life while upholding the cultural attributes and the spirit of the urban area.

Figure 7 and 8 illustrates the residential and commercial locations that have been mapped in wards 40 and 24. Whereas the colour green denotes the residential areas, the commercial areas are distinguished by the colour grey. The commercial places are found to be clustered around a main road network, around public and semi-public structures, and in close proximity to dwellings belonging to high-income groups. Additionally, it was seen that smaller pockets of slums and squatters emerged surrounding the denser retail cluster to meet the demand for employment in the neighbourhoods it was located in.

Figure 7 shows the map of residential and commercial locations in Ward 40. Source: Author

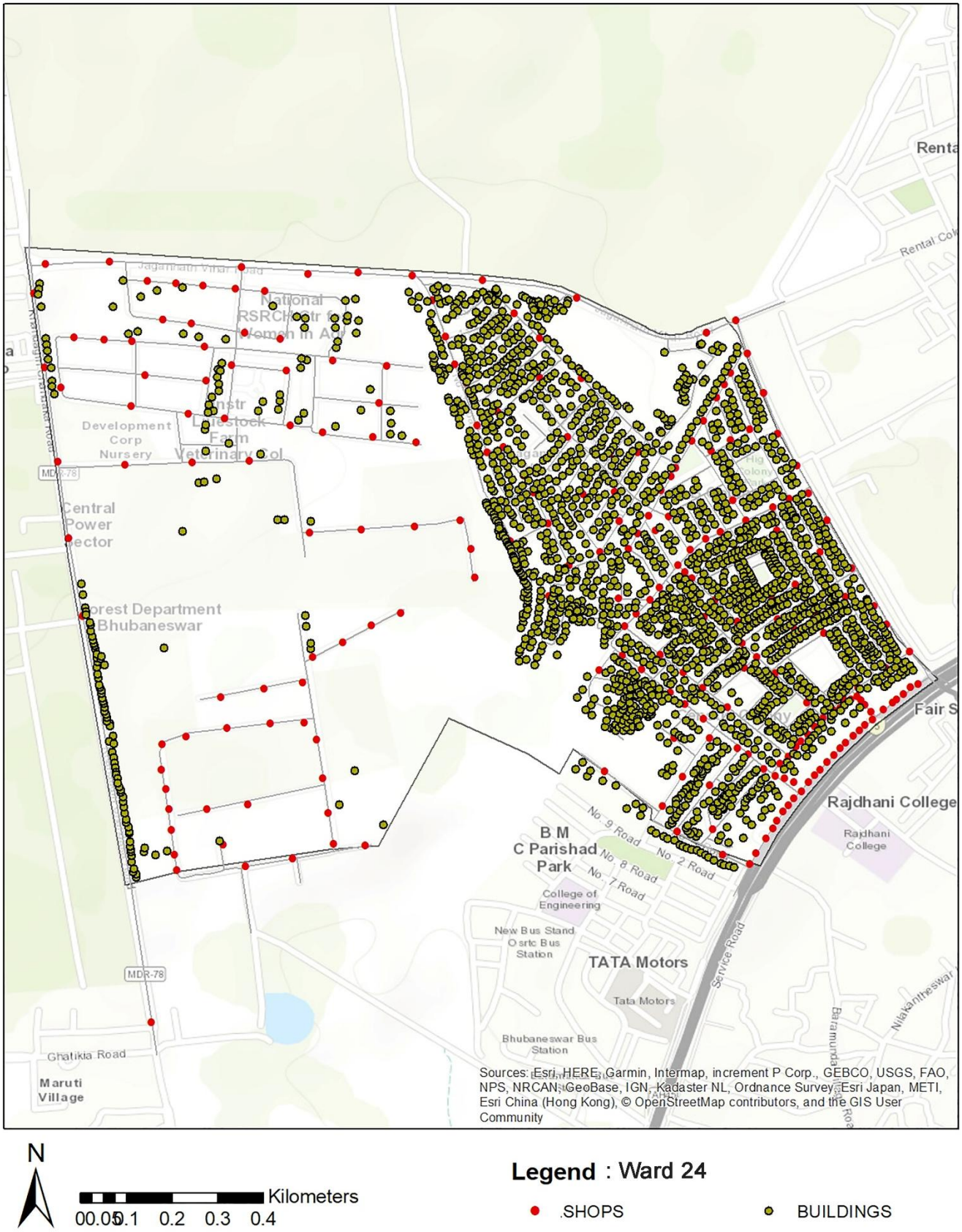

Figure 8 shows the map of the residential and commercial locations in Ward 24. Source: Author

Figure 9 and 10 shows the density distribution of residential and commercial locations of ward 40 using Kernel Density Estimation in Arc GIS. The lighter shades show lighter density distribution, while darker shades show denser clustering. It was seen that there was denser retail clustering around denser residential clusters and the major government-allocated commercial markets, i.e., Unit 1 and 2.

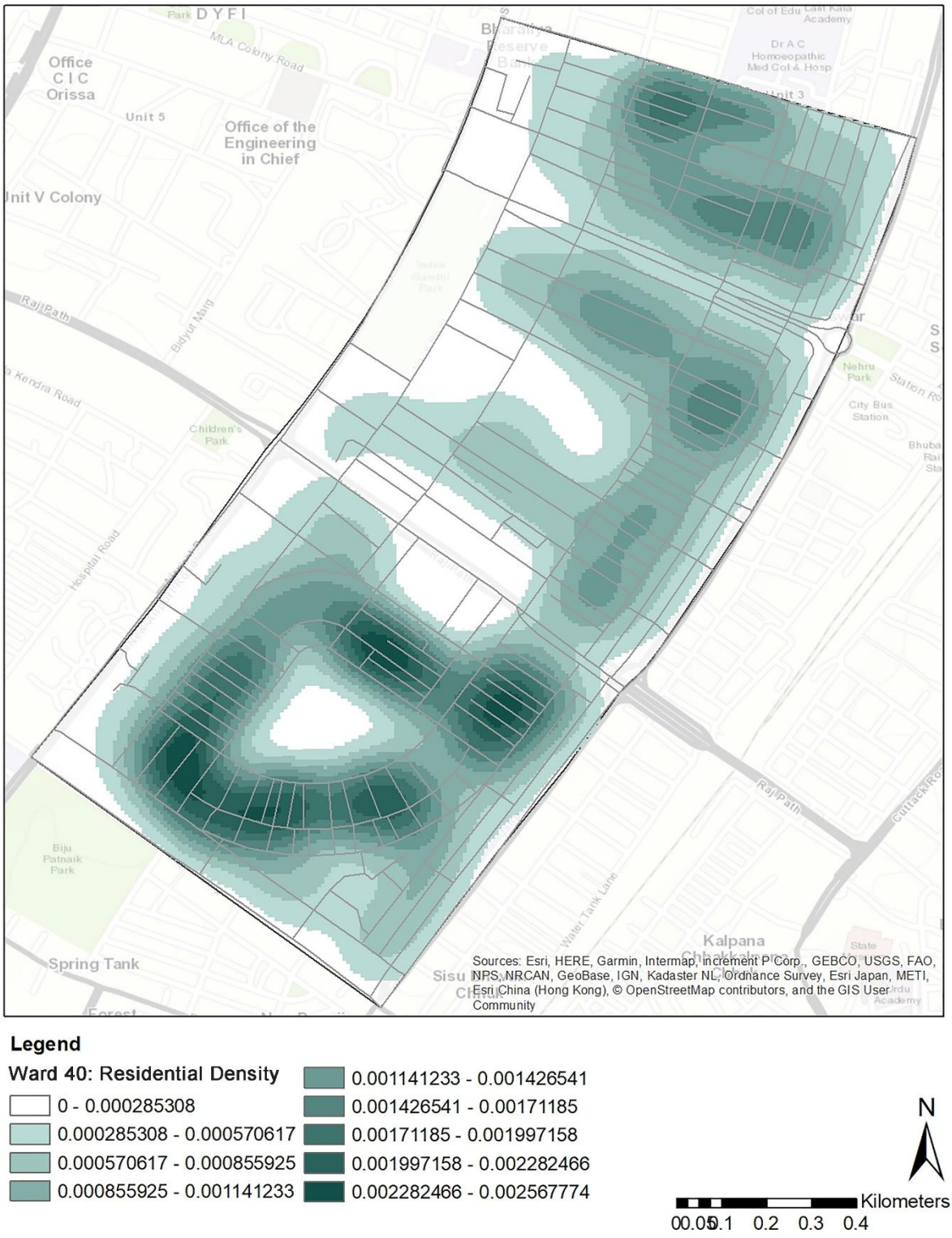

Figure 9 Map showing the density distribution of residential locations of Ward 40. Source: Author

Figure 10 Map showing the density distribution of commercial locations of Ward 40. Source: Author

Figure 11 and 12 shows the density distribution of residential and commercial locations of ward 24 using Kernel Density Estimation in Arc GIS. The lighter shades show lighter density distribution, while darker shades show denser clustering. It was seen that there was denser retail clustering around denser residential clusters.

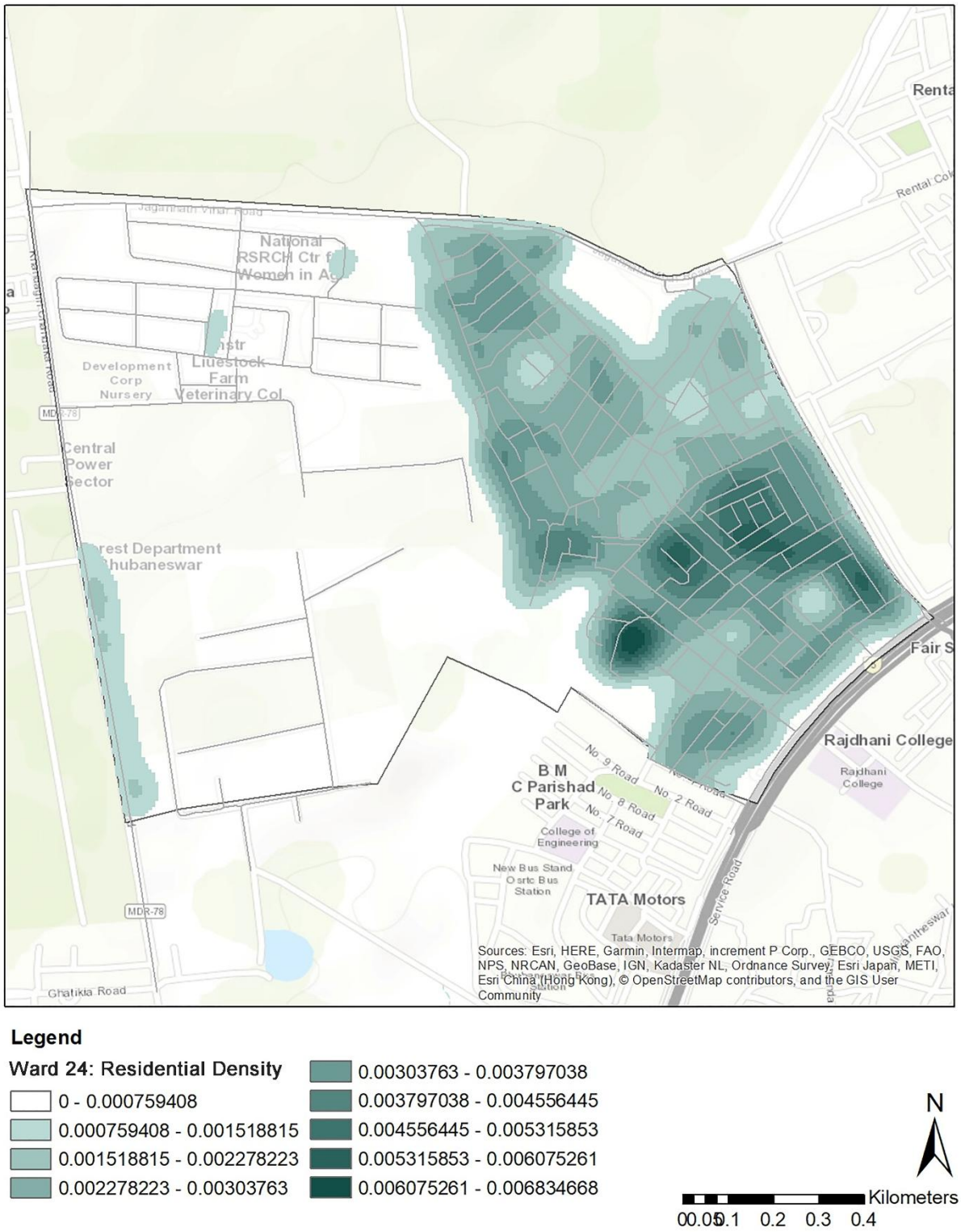

Figure 11 Map showing the density distribution of residential locations of Ward 24. Source: Author

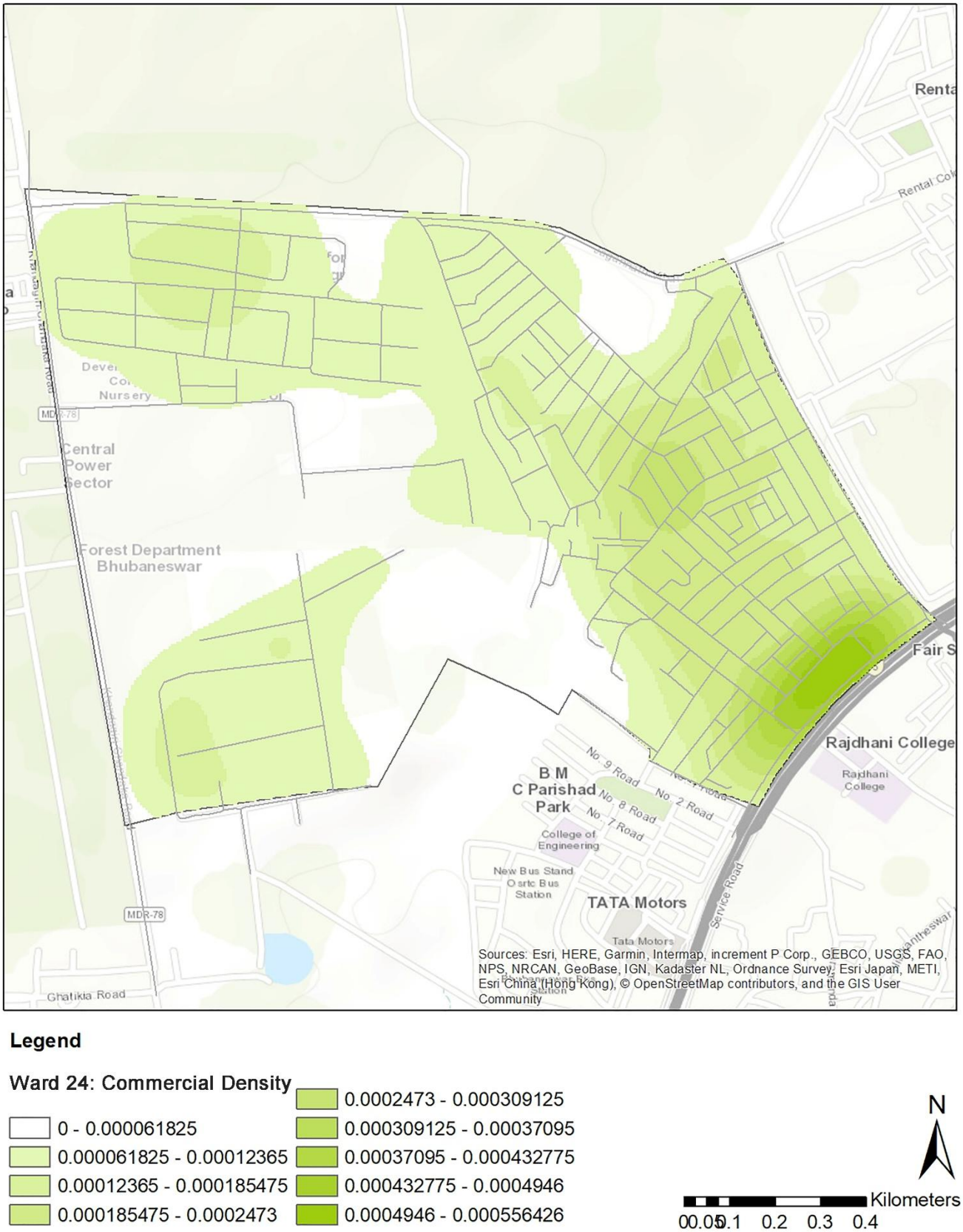

Figure 12 Map showing the density distribution of commercial locations of Ward 24. Source: Author

The Pearson's coefficient was determined by conducting a correlation analysis on the density values that were obtained using SPSS Software. A Pearson correlation is only acceptable when there is a linear relationship between the two variables (Chee and Queen, 2016). In order to ascertain whether a linear relationship existed between the density values, a scatter plot was generated. Figures 13 and 14 illustrate the scatter plot of the density values for Ward 40 and 24, respectively, which indicate a positive correlation between the strings. Table 1 and 2 shows the Bivariate Correlation analysis of wards 40 and 24, respectively, that demonstrate a strong correlation between residential and commercial densities, with a Pearson correlation coefficient of 0.610 and 0.634, respectively, and a significance level of < 0.001.

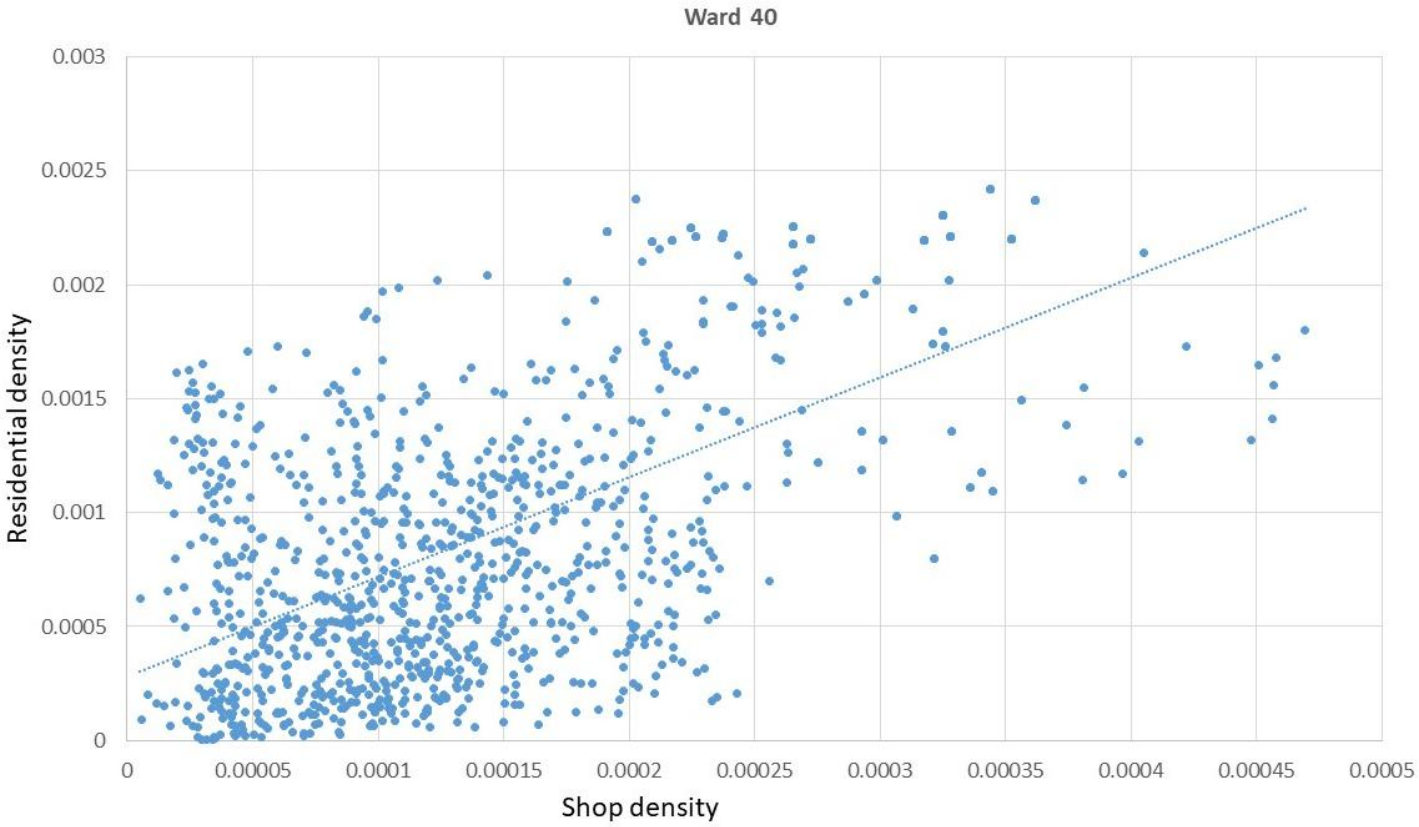

Figure 13. Scatter plot diagram of density values of Ward 40

Table 1. shows the Pearsons correlation coefficient of the residential & commercial density values of Ward 40

Correlations

		VAR00005	VAR00006
VAR00005	Pearson Correlation	1	.610**
	Sig. (2-tailed)		<.001
	N	1071	1071
VAR00006	Pearson Correlation	.610**	1
	Sig. (2-tailed)	<.001	
	N	1071	1071

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

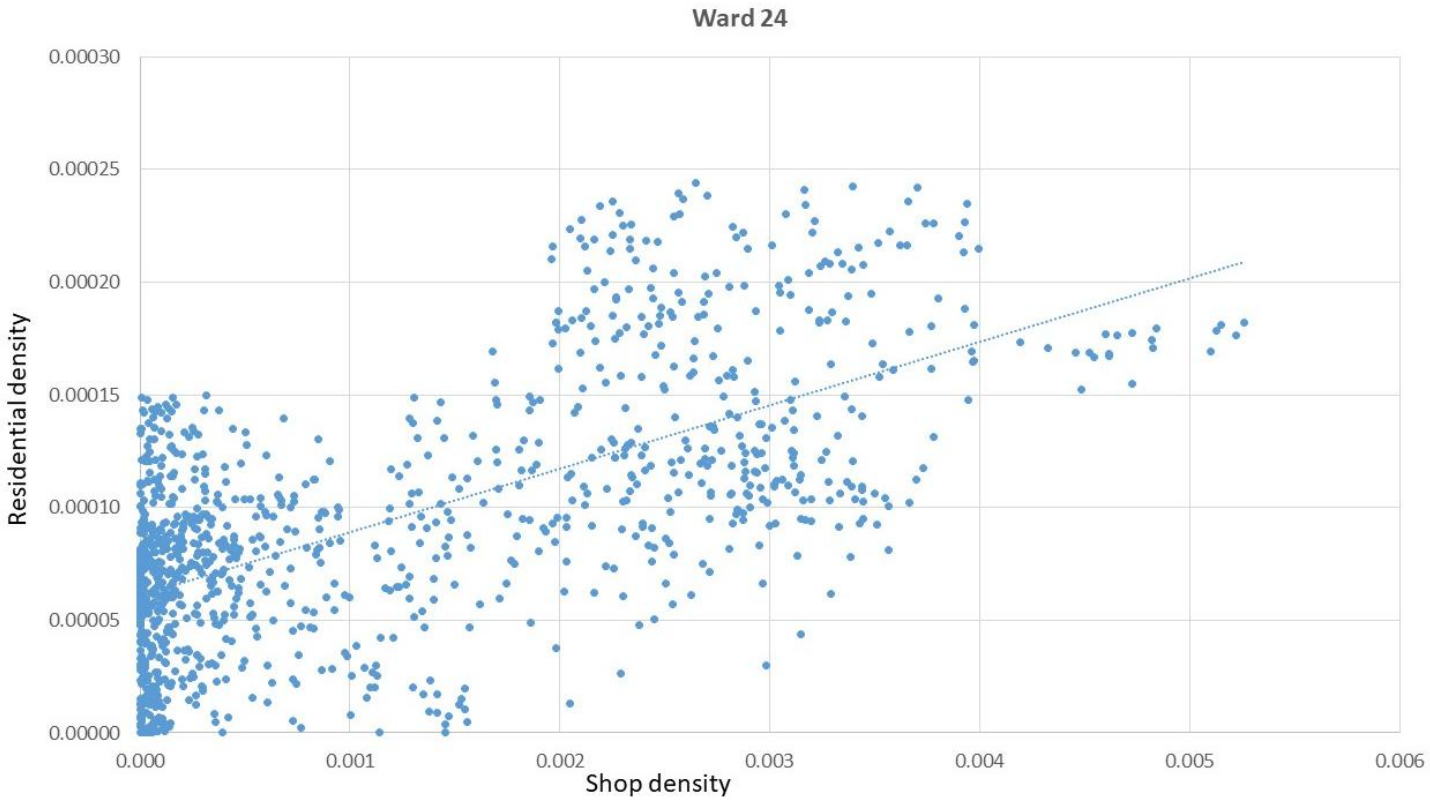

Figure 14. Scatter plot diagram of density values of Ward 24

Table 2. shows the Pearsons correlation coefficient of the residential & commercial density values of Ward 24

Correlations

		VAR00007	VAR00008
VAR00007	Pearson Correlation	1	.634**
	Sig. (2-tailed)		<.001
	N	1211	1211
VAR00008	Pearson Correlation	.634**	1
	Sig. (2-tailed)	<.001	
	N	1211	1211

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

This study analyses the impact of residential density, spatial locational attributes, and socio-economic factors on commercial density in Bhubaneswar. These interconnected elements significantly influence commercial density, as witnessed by the results of Pearson correlation analysis and kernel density estimation. Commercial establishments are attracted to regions with a higher residential density due to the constant demand for products and services. The proximity of consumers fosters an optimal setting for commercial interactions, thus promoting further commercial development. A positive correlation between residential and commercial density, as demonstrated by our findings, substantiates this relationship. High

residential density also leads to organic expansion in commercial establishments. This results in increased congestion, infrastructure strain, and environmental degradation in densely populated areas despite the fact that it fosters economic opportunity.

The analysis demonstrates that the commercial landscape is influenced by the socio-economic status of the establishments, which determines the quantity, quality, and type of these establishments. The purchasing power of residents in higher-income areas attracts more diverse and sophisticated commercial ventures. In contrast, wards with lower socio-economic indicators may experience restricted commercial development or commercial growth that is focused on essential products and services. The unequal distribution of commercial opportunities and amenities across the city is frequently exacerbated by this selective development, which is driven by socio-economic disparities.

The commercial density is also significantly influenced by the locational attribute, specifically the proximity of a ward to the city center. The city center is frequently distinguished by its superior connectivity and accessibility, which render it an ideal location for commercial activity. Ward 40, which is situated closer to the city center, exhibits a higher level of commercial density. Additionally, the strategic nature of Bhubaneswar's growth orientation is reflected in the accelerated commercial development of Ward 24, which is located along growth corridors. Commercial transactions anticipate and capitalize on population growth, which leads to commercial densification that corresponds with urban expansion patterns. Moreover, both wards have experienced a substantial increase in retail clusters due to their proximity to public and semi-public areas, as well as the primary road network.

Although residential density, socio-economic factors, and locational factors contributed to organic growth, which promoted commercial density, they also presented a variety of obstacles. Congestion, infrastructure strain, increased pollution, and reduced quality of life for residents can result from rapid, unanticipated commercial expansion. In high-density areas, the overuse of public utilities and the overcrowding that resulted from unchecked commercial development pose a threat to public health and safety. Further, the absence of strategic interventions in organic development patterns has exacerbated socio-economic inequality by restricting access to amenities in lower-income areas and concentrating resources in affluent zones or city-center wards.

Strategic interventions are essential to prevent the adverse effects of unplanned commercial expansion and assure the cohesive development of urban areas. The prioritization of balanced commercial distribution in sustainable urban planning is essential to ensure that growth is consistent with the city's strategic development objectives and infrastructure capacity. These concerns emphasize the pressing necessity of reevaluating sustainable development in urban settings, where managing the effects of urban growth is essential for the preservation of economic vitality, social equity, and Sustainable Development (Chen *et al.*, 2022; Kalfas *et al.*, 2023). As cities expand, harmful impacts at both local and global scales can be mitigated with sustainable development practices such as Mixed-Use Development, Green Building and Energy Efficiency, Compact Retail Formats, Walkability & Accessibility, and others must be integrated with infrastructure growth and improved transportation for environmental sustainability (Dambeebo and Jalloh, 2018; Wang *et al.*, 2022; Alizadeh, Doostvandi and Zandsalimi, 2024).

4. Conclusion

The research further examines sustainable urban strategies for effectively balancing population densities and retail, which has important ramifications for encouraging sustainable urban development methods. By improving our knowledge of urban density dynamics, this research offers useful advice to legislators and city planners who are working to build livable and ecologically sustainable cities. Higher residential

densities, which are also impacted by socio-economic factors and the distance from major transit hubs and city centers, are often supported by higher commercial densities. These results support the idea that strategic planning is essential for urban growth. Unplanned, organic growth can result in traffic, strain on the infrastructure and unequal access to amenities. It can also spur economic vibrancy due to the natural clustering of residential and commercial areas.

Since high residential density and socio-economic opportunities are inherently correlated with commercial density, strategic urban interventions are necessary to balance development and avoid resource overuse. This study's combination of statistical analysis and spatial mapping also shows how effective it is to combine qualitative and quantitative methods for a thorough evaluation of the relationships between urban densities. These techniques provide urban planners with a flexible framework for maximizing commercial development in harmony with residential expansion.

There are a number of directions for future research that could build upon and improve these findings to establish cohesion between residential and commercial densities. Analyzing the change in residential and commercial densities over time may provide information about urban sprawl dynamics and growth trends. Monitoring these changes in density clusters and their socio-economic effects through longitudinal research would be beneficial in guiding proactive planning as opposed to reactive planning. A more thorough understanding of how residential density affects commercial density may be possible through a multi-layered analysis that takes into account additional socio-economic variables, local cultural characteristics, and environmental factors. The study will also be enhanced by investigating appropriate sustainable strategies to achieve a balance between the densities.

In conclusion, this study lays the foundation for comprehending and controlling the relationships between urban densities. Urban planners can create cities that are harmonious, balanced, and economically vibrant by carefully addressing the factors that affect residential and commercial density. Thus, the research emphasizes that the commercial density of Bhubaneswar is considerably influenced by residential density, socio-economic factors, and locational attributes. The absence of strategic, sustainable interventions can also result in environmental stress, congestion, and uneven development. A balanced, cohesive urban environment that supports both economic performance and quality of life can be achieved by adopting a structured approach to urban planning that includes green infrastructure, targeted development corridors, improved transit, and mixed-use zoning.

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