Exploring changes in an emerging city of the Global South: a spatio-temporal analysis of built-up density in Hanoi

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Abstract

Rapid urbanization in the Global South presents substantial challenges for sustainable development. This study conducts a spatio-temporal analysis of urban form morphology in Hanoi, Vietnam as a prime example of an emerging metropolis. A key methodological contribution of our work is the Relative Built-up Density index, a replicable and comparable proxy for urban density. This index integrates high-resolution land cover data with national population and housing census data. Our analysis uncovers a dual morphological trajectory. We observed intense vertical densification in saturated urban districts, often driven by the 'residentialization' of former industrial estates, alongside rapid horizontal expansion into suburban areas spurred by policies for New Urban Areas. This dual development has revealed a significant paradox. Although the average floor area per capita has impressively increased, this trend masks a severe housing affordability crisis. The Relative Built-up Density index is a valuable, low-cost tool for monitoring these nuanced changes in data-limited regions in the Global South. Our findings underscore the need for differentiated policy imperatives. The central urban districts require infrastructural retrofitting, whereas the sprawling periphery demands proactive planning to prevent future inequality.

Keywords

urban density measure, urban morphology, emerging cities, Hanoi, the Global South

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Introduction

Southeast Asia stands as one of the most dynamic regions in the Global South, characterized by rapid economic growth, increasing geopolitical influence, and a high rate of urbanization (Federal Foreign Office, 2022). This makes the region an ideal context for exploring the complexities of urbanization (Beall *et al.*, 2012). Vietnam serves as a prime example of such transformative growth, having transitioned from one of the world's poorest nations to the third-fastest-growing economy in Asia and the fourth in the world in under three decades (Geertman, 2010; Vanham, 2018). This economic shift has spurred significant societal and land-use changes across the country (Tuan, 2022). Notably, Vietnam is experiencing a rapid rural-to-urban transition, with urban populations steadily increasing since the 1990s, while the rural population share is projected to decline in the coming decades (Labbé, 2021; Open Development Vietnam, 2024).

The rapid urbanization in Southeast Asian cities presents various challenges for planning

authorities trying to keep pace with the swift development (Kolomiiets, 2013). The surge in population and urban sprawl often occurs unevenly, putting immense pressure on the technical and social infrastructure required to deliver essential public services. Factors such as laissez-faire policies, bureaucratic inefficiencies, an unregulated private sector and disorganized governmental structures further hinder efforts to manage urban growth. This results in inadequately-designed traffic systems, insufficient public amenities such as schools, water supplies, and waste management services, contributing to a range of environmental and social issues (Matsumoto and Daudey, 2015; UN.ESCAP and UN-HABITAT, 2015). Furthermore, urban green spaces, critical for improving urban livability, are often compromised by the densification process (Haaland and van Den Bosch, 2015).

Addressing these challenges requires the implementation of adaptive urban planning strategies that are regularly monitored, evaluated, and refined over time. For rapidly-developing countries such as Vietnam, cost-effective monitoring tools based on limited data availability are essential to track ongoing urban changes. Remote sensing technologies have become integral for observing shifts in urban landscapes with high spatial resolution, offering valuable insights for effective spatial planning in such fast-changing regions (Miller and Small, 2003; Weng, 2012; Brook *et al.*, 2013; Kaur and Pandey, 2022). Several studies have successfully applied remote sensing data to analyze urbanization in Hanoi, demonstrating the utility of these tools for urban monitoring (N. D. Duong *et al.*, 2001; Duan and Shibayama, 2009; H. M. Pham *et al.*, 2011; Nong *et al.*, 2015; V. C. Pham, *et al.*, 2015; Tran *et al.*, 2019; Mauro, 2020).

A recent study revealed that most applications of urban expansion models do not adequately account for the social processes that drive urban growth patterns in the Global South (Agyemang and Sahana, 2025). Urbanization often entails a shift from a 'traditional' rural society to a 'modern' urban one, with distinct demands for public services and goods (Webster and Muller, 2009; Dudwick, 2011; Hutchings *et al.*, 2022). These transitions are crucial for urban planners tasked with ensuring that infrastructure and services keep pace with growth. The challenges presented by densely-populated city centers differ significantly from those in suburban areas, where long-distance mobility becomes more of a priority. Thus, a comprehensive understanding of a city's historical development, urban sprawl hotspots and socio-economic transformations is necessary (Yunda and Sletto, 2020). To achieve a holistic perspective, mixed-method approaches that combine remote sensing data with socio-economic indicators tailored to data-scarce regions are required (Fox *et al.*, 2003; Schneider *et al.*, 2015). Monitoring population and housing densities offers an initial step toward understanding socio-economic transitions (Ahmadian *et al.*, 2019).

Despite the growing body of research, Hanoi remains an area where integrated studies of urbanization patterns using remote sensing data and socio-economic analysis are limited. Notable early efforts, such as the work by Nong *et al.* (2021), combined population data with spatial metrics, showing that peri-urban areas can be distinguished from rural and urban categories and that they exhibit a greater level of landscape fragmentation and a higher pace of population growth. However, a detailed, administrative-level assessment is necessary to get a deeper understanding of spatial patterns and areas of concern. This study seeks to address this gap by examining Hanoi's urban evolution over recent decades, focusing on building densities at the commune and district level. We begin by analyzing the spatial expansion of Hanoi's built-up areas from 1990 to 2019, using land cover data from the Japanese Aerospace Exploration Agency (JAXA) (Phan *et al.*, 2021). In the subsequent step, population data at the commune level for the same period will be collected and analyzed. By combining both datasets, we will derive the built-up density index for Hanoi's core districts. This research proposes a new measure that can help monitor urban development, guide targeted interventions to address infrastructural and environmental

concerns, and ultimately inform strategies that enhance the quality of life in rapidly evolving metropolises in the Global South.

Background of the study area

Hanoi, the capital city of Vietnam, is strategically located in the heart of the Red River Delta in northern Vietnam (Figure 1). Since the introduction of the Doi Moi policy in 1986, Hanoi has undergone profound transformations in its socio-economic landscape and physical infrastructure (Tsuboi, 2007). The city expanded its administrative boundaries in August 2008, becoming one of the world's 17 largest capitals by area. By 2019, Hanoi's population exceeded 8 million residents, of which 49.2% are urban and 50.8% are rural. The study area encompasses 12 urban districts (*quận*) and 4 suburban districts (*huyện*), all of which have undergone notable changes during the study period. Tu Liem was a district before 2013; however, on 27 December 2013, the government adjusted the administrative boundary of Tu Liem district to establish Bac Tu Liem and Nam Tu Liem districts under Resolution 132/NQ-CP. Therefore, for spatial statistic calculations, the boundaries after the resolution took effect have been used. Table 1 summarizes the characteristics of districts in the study area in 2019, where the population figure was obtained from the population and housing census and the district area was calculated using geometric calculations of the shapefile boundaries.

In 2023, the population density in Hanoi reached 2,556 people per km^2, making Hanoi the second most densely populated city in Vietnam after Ho Chi Minh City (Statista, 2023). This growth has been fueled by rural-to-urban migration, predominantly by young adults seeking improved prospects in the city. However, this surge has not kept pace with infrastructure development, leading to traffic congestion and housing accessibility issues, particularly for migrant workers. The rapid urbanization, unfolding at an unprecedented pace over recent decades, makes Hanoi suitable for examining urban transformations in the Global South.

Methodological approach and data sources

The concept of density presents challenges not only from a normative urban planning perspective but also due to the inherent complexities in objectively measuring urban density. Density fundamentally serves as a metric that describes the relationship between

Table 1. Characteristics of districts in the study area.

District code	District name	Population in 2019 (people)	Area (km^2)
1	Ba Dinh	221,893	9.4
2	Hoan Kiem	135,618	5.2
3	Tay Ho	160,495	25.0
4	Long Bien	322,549	59.9
5	Cau Giay	292,536	12.4
6	Dong Da	371,606	9.9
7	Hai Ba Trung	303,586	9.7
8	Hoang Mai	506,347	40.1
9	Thanh Xuan	293,524	9.2
17	Dong Anh*	405,749	186.3
18	Gia Lam*	286,102	116.7
19	Nam Tu Liem	264,246	32.1
20	Thanh Tri*	275,745	62.9
21	Bac Tu Liem	335,110	44.2
268	Ha Dong	397,854	49.8
274	Hoai Duc*	262,978	85.0

*Suburban district

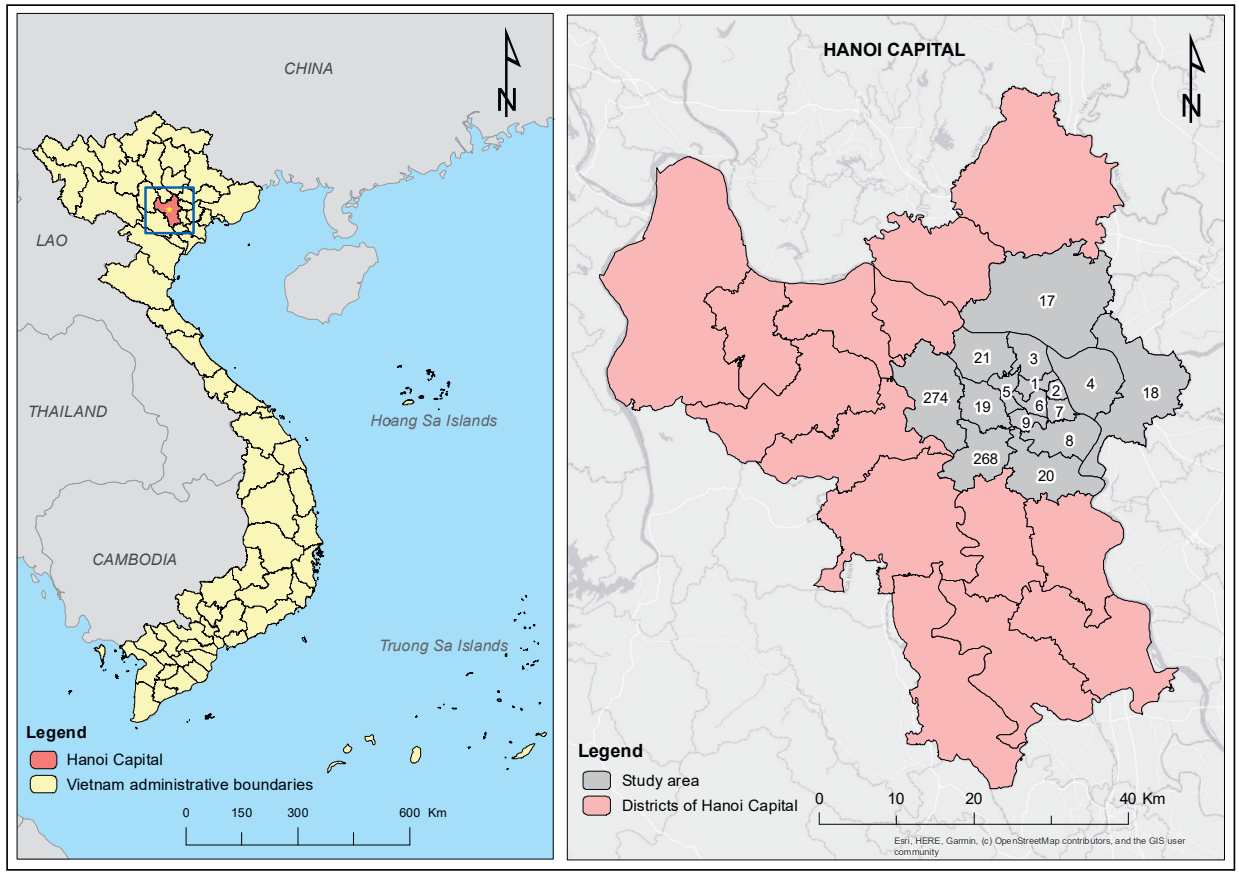


Figure 1. Study area.

entities, such as residents, buildings, dwellings or jobs, and a designated reference area. This measure is expressed as a fraction, with the number of entities as the numerator and the size of the reference area as the denominator (Krehl *et al.*, 2016). Two primary categories of density can be distinguished: building densities and activity densities. Building density, measured by dwelling units per acre or by the floor area ratio (building square footage divided by land area), affects not only how crowded or developed a neighbourhood appears but also the value of the land and buildings (Peiser, 2015). Conversely, activity density combines measurements of the resident population and the number of jobs to indicate the level of human activity in an area over time (Landcom, 2011). Building densities tend to exhibit relative stability as changes in built structures occur gradually, especially within a larger spatial context. In contrast, activity densities are subject to constant fluctuation, being reliant on dynamic demographic and socioeconomic processes that are often discontinuous.

Measuring building densities is often challenging due to empirical problems, particularly at the property, block, or neighborhood levels. This difficulty arises because official statistical surveys, such as censuses, typically do not cover data at these granular levels. Consequently, studies relying on self-collected data (for example through site visits) or private geodatabases have limited utility, either due to their complexity or a lack of data transparency. Historically, density studies have largely been conducted as individual municipal analyses or collections of case studies (Landcom, 2011; Krehl *et al.*, 2016). Comparing results across different municipalities or territorial units often faces constraints, and these challenges are intensified when defining valid measurement indicators universally (Abarca-Alvarez *et al.*, 2019).

To provide an understanding of urban density changes in Hanoi, this study proposes a Relative Built-up Density (RBuD) index. The methodological workflow for deriving the index, as illustrated in Figure 2, integrates two

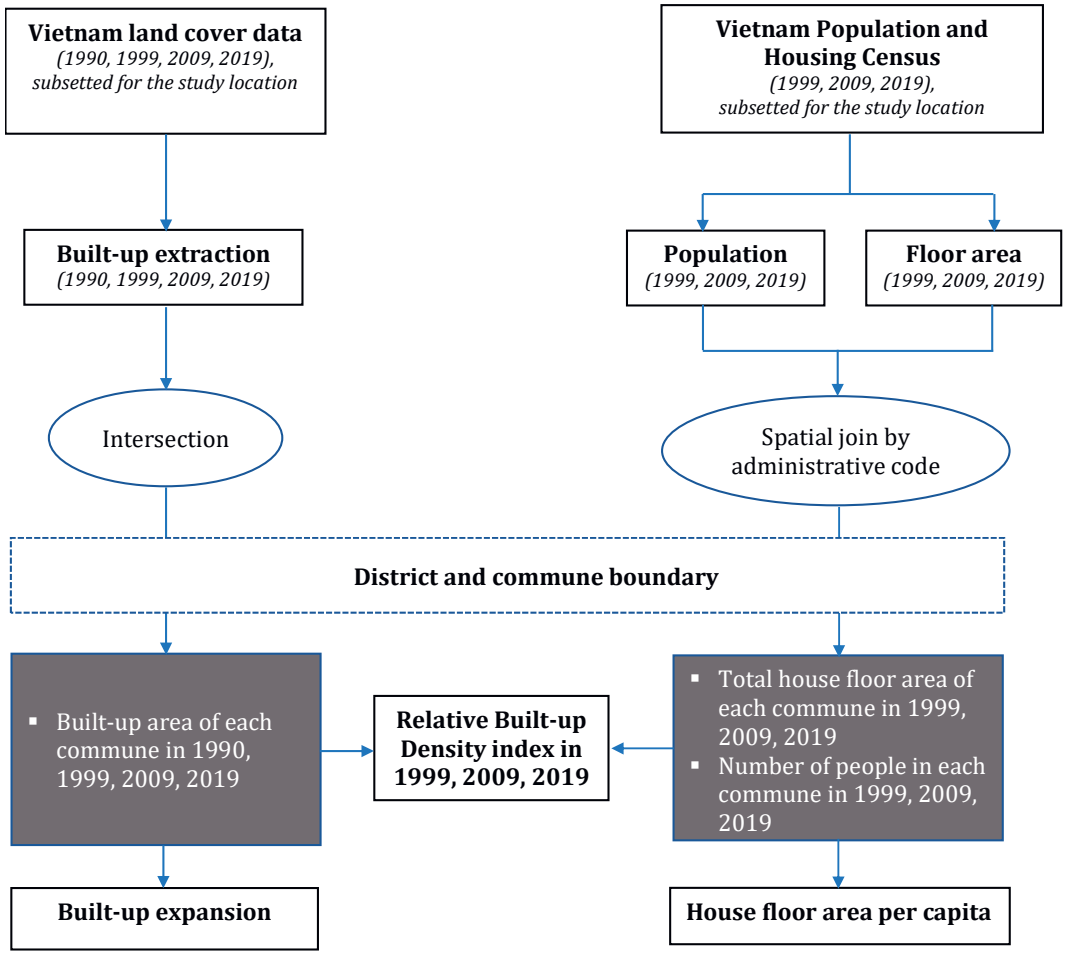


Figure 2. Workflow for deriving the relative built-up density index.

primary data streams: geospatial land cover data and socio-economic census data. The process is designed to produce a relative indicator of how intensively built-up land is utilized for residential purposes at the commune level.

The workflow begins with the acquisition and processing of two distinct datasets as follows.

1. Land cover data processing: the first stream utilizes land cover data for Vietnam sourced from the Japan Aerospace Exploration Agency (JAXA) for the years 1990, 1999, 2009, and 2019 (Phan *et al.*, 2021). The land cover data has the resolution of 30m × 30m and classified the land cover into 10 categories including built-up land, rice paddies, cropland, grassland, barren land, scrub land, forest, wetland, open water, and aquaculture. Built-up land defined in this study includes low- and high-developed areas; the former is defined as land covered by buildings and other man-made structures < 50% of constructed cover and < 20% vegetation, while the latter is defined as land covered by buildings and other man-made structures > 50 % of constructed cover and < 20 % vegetation (Phan *et al.*, 2021). In the initial step, built-up extraction involves isolating all pixels classified as 'built-up' areas from the broader land cover maps for each year. Following extraction, a geospatial intersection is performed. This process overlays the extracted built-up layers with a map of Hanoi's administrative boundaries (districts and communes). The result is the precise calculation of the total built-up area (m^2) within each commune for each time period. This value serves as the denominator in the RBuD formula and is also used to analyze patterns of built-up expansion over time.
2. Census data processing: the second stream is based on the Population and Housing Census for the years 1999, 2009,

and 2019 (General Statistics Office of Vietnam, 1999, 2009, 2019). The General Statistics Office of Vietnam administers this nationwide survey on a 10-year cycle, with the initial survey launched in 1989. The most recent Population and Housing Census was conducted in 2019, collecting diverse information on population and housing throughout the entire nation. From the census, two key variables are extracted: the number of people in each household and the household's floor area in square metres. This household-level data is then aggregated to the commune level. A spatial join is then executed, linking the aggregated tabular data (total population and total floor area) to the corresponding commune polygon using a unique administrative code. This critical step geographically anchors the census data, yielding the total household floor area (m^2) and total population for each commune in each census year. The total house floor area becomes the numerator in the RBuD formula.

Calculation of the RBuD Index: once pre-processing is complete, the two data streams are integrated to calculate the Relative Built-up Density (RBuD) index. The RBuD is a proxy measure of urban density, defined by the formula below.

$$RBuD = \frac{Total\ house\ floor\ area\ of\ the\ commune}{Total\ built\text{-}up\ land\ area\ of\ the\ commune}$$

This index does not measure the exact building density, commonly quantified by dwelling units per acre or floor area ratio (FAR), which requires precise building footprints. Instead, it provides a powerful relative indicator of how intensively the built-up land is being used for residential space. This calculation was performed for each commune for 1999, 2009, and 2019, allowing for a spatio-temporal analysis of density changes.

Results and Discussion

Expansion of built-up area over time

Table 2 and Figure 3 present the changes in built-up areas of each district in three time periods: 1990–99, 1999–2009, and 2009–19. It is evident that the built-up areas in Hanoi have expanded rapidly across all districts, except for the four central urban districts (Ba Dinh, Dong Da, Hoan Kiem, and Hai

Table 2: Cumulative built-up area and its expansion from 1990 to 2019.

District code	District name	1990 (ha)	1999 (ha)	Change 1990–1999 (%)	2009 (ha)	Change 1999–2009 (%)	2019 (ha)	Change 2009–2019 (%)
1	Ba Dinh	460	705.6	53.4	711.8	0.9	713.5	0.2
2	Hoan Kiem	330.1	385.8	16.9	386.8	0.3	388.7	0.5
3	Tay Ho	221.1	555.6	151.3	672.8	21.1	855.5	27.1
4	Long Bien	453.7	1,265.5	178.9	1,599.8	26.4	2,321.1	45.1
5	Cau Giay	242	643.2	165.8	916.4	42.5	1,028.7	12.3
6	Dong Da	653.6	892.5	36.6	901.1	1	905.6	0.5
7	Hai Ba Trung	582.4	764.1	31.2	771.3	0.9	778.3	0.9
8	Hoang Mai	532.1	1,194.9	124.6	1,558.6	30.4	1,955.7	25.5
9	Thanh Xuan	369	671.6	82	748.3	11.4	790.5	5.6
17	Dong Anh	614.5	1,986.1	223.2	2,853.2	43.7	3,603.1	26.3
18	Gia Lam	505.2	1,468.1	190.6	1,536.4	4.7	2,284	48.7
19	Nam Tu Liem	172.2	556.2	223	969.1	74.2	1,464.3	51.1
20	Thanh Tri	308	924.2	200	991.8	7.3	1,723.7	73.8
21	Bac Tu Liem	293.3	939	220.1	1,234.4	31.5	1,642.4	33
268	Ha Dong	421	911.2	116.4	1,459.4	60.2	2,122.7	45.4
274	Hoai Duc	365.1	913.2	150.1	1,561.9	71	2,166.7	38.7
	Total area	6,523.4	14,777.0		18,873.1		24,744.4	

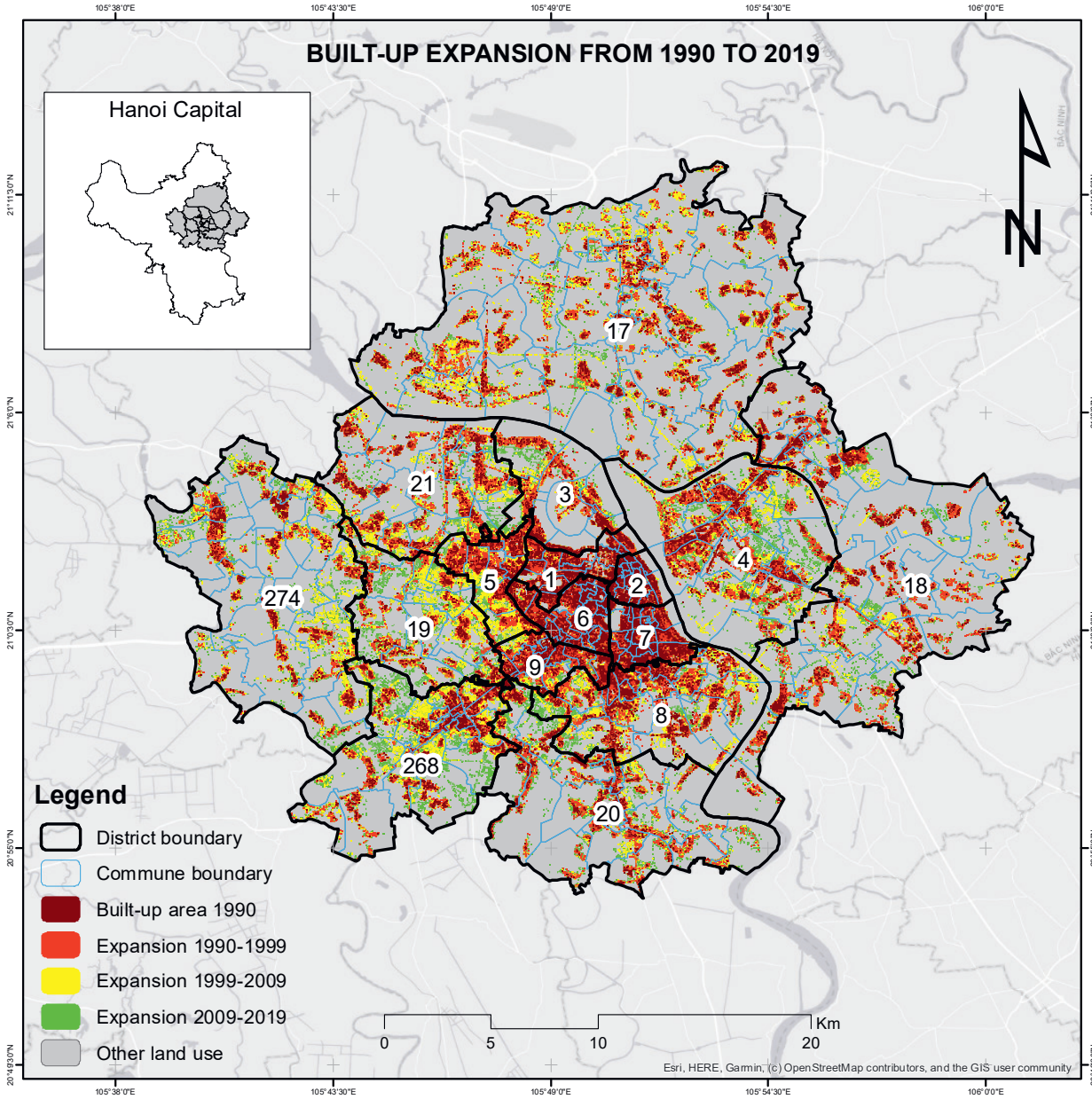


Figure 3. Expansion of built-up area of the districts between 1990 and 2019 (numbers are district codes).

Ba Trung) which remained compact due to limited space for expansion and the strong commitment of the municipal government to preserving the historical nucleus encompassing the Old Quarter and the French Quarter for their crucial roles in safeguarding the city's cultural heritage. The most substantial changes occurred in the period 1990–99, followed by the period 2009–19, with an expansion exceeding 200% in certain districts between 1990 and 1999, such as Thanh Tri, Bac Tu Liem, Nam Tu Liem and Dong Anh. This expansion of built-up areas since 1990 has primarily taken the form of peri-urbanization, leading to significant transformations in agricultural land use (Castrence *et al.*, 2014; Nong *et al.*, 2018; Mauro, 2020). Regarding spatial expansion, Figure 3 illustrates that, before 2009, most of the expansion occurred on the western side of the Red River. This well reflects the urban development plan set forth in Decision No. 108/1998/QD-TTg in 1998 which primarily prioritized Hanoi's expansion to the west, creating a cluster of towns including Xuan Mai, Hoa Lac, and Son Tay, and to the north with the development of towns such as Soc Son, Xuan Hoa, Dai Lai, and Phuc Yen.

The Hanoi master plan for 2021–2030 period, with a vision to 2050 (Socialist

Republic of Viet Nam, 2024), offers a compelling example of how cities in the Global South are attempting to manage rapid urbanization. With the establishment of multiple satellite towns, Hanoi's strategy reflects a broader shift from monocentric megacities to polycentric urban clusters. This trajectory aligns with the experiences of Bangalore, Delhi, and São Paulo, which highlight both the opportunities and risks of accelerated urban growth.

A key feature of the Hanoi master plan is its emphasis on polycentric expansion, particularly through 'cities within the Capital' such as Hoa Lac, Soc Son and Xuan Mai. This is reminiscent of Bengaluru's suburban sprawl, where rapid growth at the periphery has created new hubs of economic activity but also widened spatial inequalities in service provision. Studies of Bengaluru reveal that central wards consistently outperform peripheral areas in terms of access to water, sanitation and health services (Sridhar *et al.*, 2021). Hanoi's forward-looking plan, with its focus on synchronous infrastructure and transit-oriented development (TOD), attempts to preempt similar inequalities by embedding service delivery into new growth nodes (Toan, 2022).

The Hanoi master plan also stresses sustainability and heritage conservation, balancing modern development with the preservation of cultural assets such as the Old Quarter and Son Tay citadel. Delhi offers a useful comparison: while it has invested in large-scale infrastructure such as the metro and wastewater reuse systems, its rapid urbanization has often come at the cost of deteriorating air quality, loss of green space, and unmanaged peri-urban growth (Pant *et al.*, 2015; Dutta *et al.*, 2020; Paul *et al.*, 2021). Hanoi's commitment to eco-urban models, underground space utilization and the integration of green and blue infrastructure reflects lessons drawn from such challenges across the Global South. At the same time, Hanoi seeks to position itself as an engine of economic growth, with specialized hubs for high-tech industries, innovation, and services. São Paulo, Latin America's largest city, illustrates both the potential and pitfalls of such an approach. Its economic dynamism has attracted investment and talent, but it has also exacerbated inequality, with wealthy enclaves existing alongside vast informal settlements (de Castro Mazarro *et al.*, 2022). Hanoi's vision of "green – smart – modern – connected globally" urbanization aims to avoid this imbalance, but the risk of socio-spatial polarization remains a pressing concern.

The Hanoi master plan acknowledges the importance of governance and institutional innovation, proposing special mechanisms for its new sub-cities. Governance deficits have been a recurring challenge in many Global South cities. In Bengaluru, fragmented local governance has hindered service delivery and resource management (Beleyur, 2025), while in São Paulo, weak institutional frameworks have often delayed slum upgrading and inclusive planning (Rocha Formicki, 2018). By explicitly addressing governance structures, Hanoi signals an awareness of this shared vulnerability.

The Hanoi master plan both mirrors and seeks to improve upon the broader urbanization trajectory of the Global South. Like Bengaluru, Delhi, and São Paulo, it faces the dual challenge of harnessing urbanization for economic dynamism while mitigating environmental pressures, inequality, and governance shortfalls. Its polycentric, sustainability-oriented approach places Hanoi within the mainstream of Global South urban planning, while also offering a case of deliberate, anticipatory governance aimed at balancing growth, heritage, and equity.

Changes in living space

The evolution of housing in Hanoi over the past two decades presents a significant paradox, a theme clearly reflected in the statistical trends and the lived realities of its citizens. The data presented in Table 3 and Figure 4 illustrates a consistent and impressive upward trajectory in the average house floor area per capita across all selected districts from 1999 to 2019. This quantitative expansion, which saw the average grow from 10.9 m^2 to 31.1 m^2 per

Table 3: Changes in house floor area per capita (m^2/capita) from 1999 to 2009.

District code	District name	Floor area per capita in 1999	Floor area per capita in 2009	Floor area per capita in 2019
1	Ba Dinh	12.6	20.0	30.9
2	Hoan Kiem	9.4	12.2	19.4
3	Tay Ho	12.5	26.0	36.7
4	Long Bien	11.5	21.8	36.0
5	Cau Giay	13.5	24.4	30.6
6	Dong Da	12.7	19.6	29.0
7	Hai Ba Trung	10.6	17.1	27.7
8	Hoang Mai	11.0	20.7	30.5
9	Thanh Xuan	13.2	21.4	32.0
17	Dong Anh	9.4	17.6	33.0
18	Gia Lam	9.3	17.3	35.1
19	Nam Tu Liem	9.7	20.4	29.9
20	Thanh Tri	9.6	16.6	31.9
21	Bac Tu Liem	9.2	17.1	28.9
268	Ha Dong	10.4	18.3	33.1
274	Hoai Duc	9.4	14.8	32.2
Average		10.9	19.1	31.1

capita, suggesting a substantial improvement in living conditions and a successful outcome of housing development policies.

A closer examination of the spatial distribution of this growth, however, reveals the complex dynamics of Hanoi's urbanization. The data delineates a clear spatial pattern that aligns with the city's development strategy. Hoan Kiem district, the historic and commercial heart of the city, consistently recorded the lowest average floor area (12.2 m^2 in 2009 and 19.4 m^2 in 2019). This is indicative of a hyper-dense urban core where land is exceptionally scarce and expensive, and development is constrained, limiting the potential for spatial expansion for the average resident.

In contrast, districts on the urban fringe and in newly developed areas exhibit the most dramatic growth and the highest per capita figures in 2019, including, Tay Ho (36.7 m^2), Long Bien (36.0 m^2), Dong Anh (33.0 m^2) and Gia Lam (35.1 m^2). This trend is a direct result of policies that have encouraged the development of large-scale New Urban Areas (NUAs) and commercial housing projects in these peri-urban locations where land was more readily available (Minh *et al.*, 2017). These areas became the primary sites for expanding the city's housing stock, offering more spacious living conditions that attracted residents seeking an escape from the congestion of the inner city. Between these two extremes lie the established inner districts such as Ba Dinh, Dong Da and Hai Ba Trung which, while showing significant improvement, faced greater constraints to growth than the suburban areas.

The increase in living space in the urban centre has profound implications for infrastructure, creating new demands for schools, healthcare facilities, and recreational space, while also exacerbating traffic congestion. In addition, while the growth of spacious NUAs in the periphery has, in theory, eased crowding in the centre, it has also created new and possibly greater infrastructural challenges. This peri-urban expansion demands the costly new infrastructural systems (transportation, water, and energy) across vast areas, a task that often lags behind rapid residential construction. This lag creates a service provision gap similar to that seen in other sprawling Global South cities. Consequently, rather than solving congestion, this pattern can exacerbate it by creating longer-distance car-dependent commutes from these new suburban developments to the

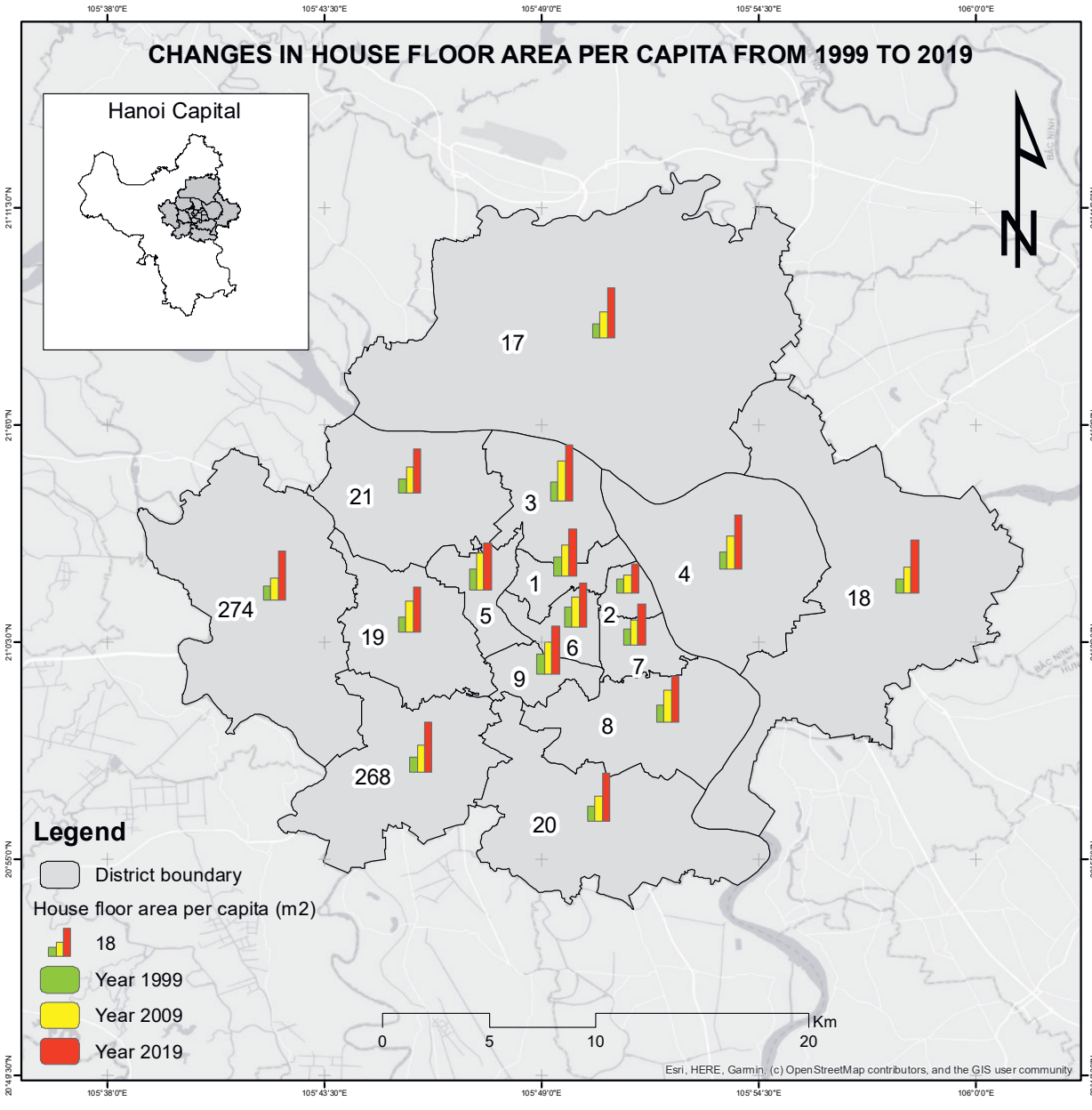


Figure 4. Changes in house floor area per capita in different districts over time (numbers are district codes).

central business districts, putting more pressure on the city's main transportation systems.

On the social aspect, this narrative of quantitative success masks a significant challenge of accessibility and affordability. The policies that spurred the construction of spacious housing in suburban districts also contributed to an imbalanced market structure. Development has overwhelmingly catered to the mid- to high-end segments and speculative investors, driving property prices to levels far beyond the reach of the average working-class family. According to the cost-of-living database Numbeo, Vietnam's House Price to Income Ratio (HPR) is one of the highest in Southeast Asia at 22.8, double that of Malaysia and exceeding those of developed countries including Japan, Singapore and South Korea. This ratio has risen by 27% since 2014, making homeownership increasingly challenging for many (Dang and Viet, 2024). Therefore, the high per capita floor area in a district such as Tay Ho or Long Bien does not necessarily reflect equitable access to housing; rather, it is an average skewed by luxury villas and high-end condominiums. Within these same districts, a significant population of labourers and low-income families may still reside in small, informal rental accommodations. Housing prices have

continued their relentless climb, far outpacing income growth. Consequently, the dream of *an cu lạc nghiệp*, a Vietnamese proverb suggesting that a stable home leads to prosperity, has become increasingly unattainable for millions. This situation fosters social inequality and potentially hampers the city's long-term economic competitiveness by reducing its appeal to the young workforce.

Therefore, housing policy must pivot from a purely quantitative focus on increasing the average floor area to a qualitative one centered on equity and affordability. Key policy recommendations include: (i) rebalancing housing supply: implementing decisive measures, such as mandatory land fund allocations and streamlined administrative procedures, to aggressively promote the development of social housing and affordable commercial apartments; (ii) controlling speculation: introducing fiscal tools, such as progressive property taxes and taxes on unoccupied homes, to curb speculative investment and stabilize market prices; and (iii) developing a formal rental market: establishing a regulatory framework for a formal, quality-controlled rental market to provide secure and decent housing options for those not yet able to purchase a home.

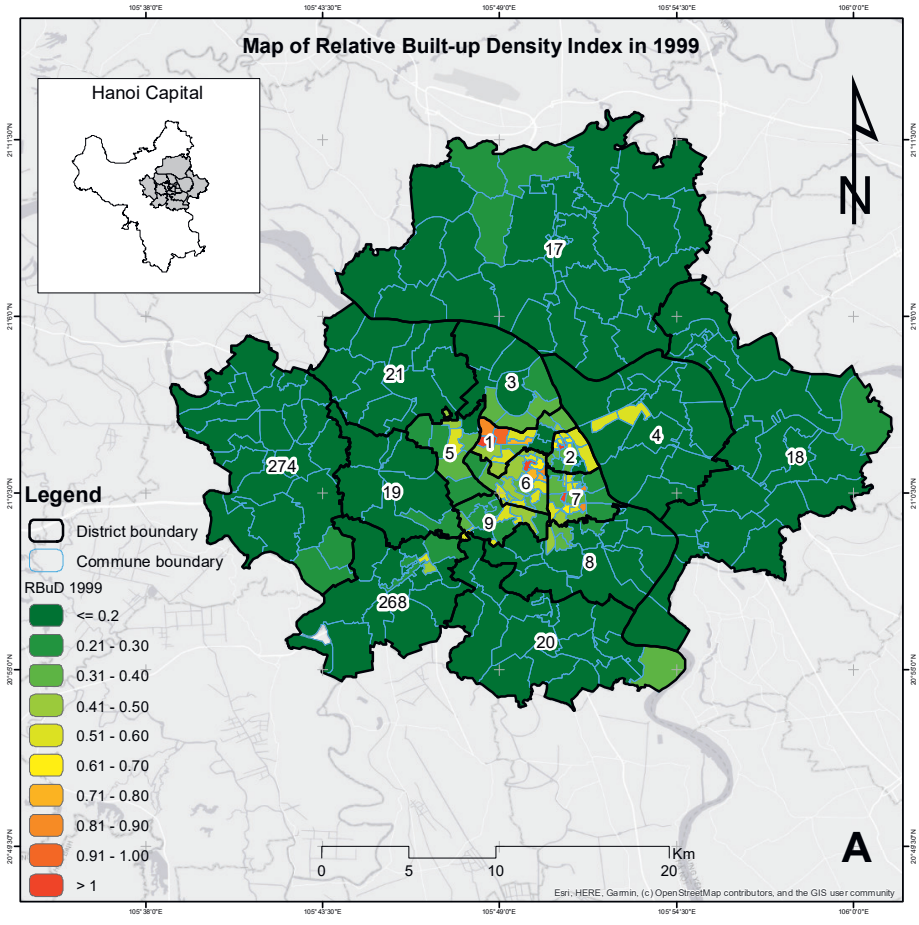
While the statistical increase in living space per capita is a tangible achievement, it is a hollow victory if much of the population cannot afford to access it. Addressing the paradox of Hanoi's housing market requires a comprehensive approach that ensures the city's growth is not only expansive but also inclusive and sustainable for all its residents.

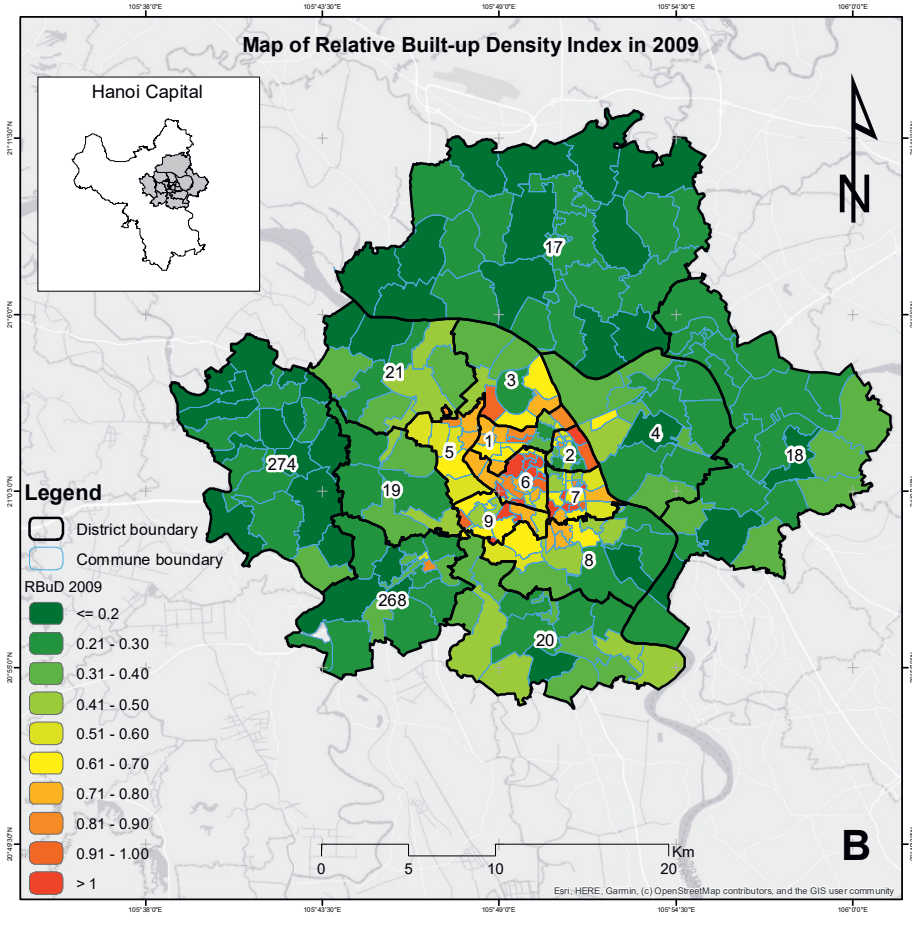
Changes in built-up density in Hanoi

The relative built-up density index (RBuD) can serve as a key indicator to evaluate the urbanization of an area over time. Examining these changes offers information about Hanoi's historical urban growth and future development trends. Table 4 and Figure 5 present the RBuD for selected districts in Hanoi for the years 1999, 2009, and 2019. The data indicates a consistent increase in the built-up density in Hanoi over the two decades (1999–2019). While all districts have shown an increase in RBuD, the growth rates vary considerably among districts and between two periods. Between 1999 and 2009, some districts grew more than 100%, such as Tay Ho, Cau Giay, Hoang Mai, Gia Lam, Tu Liem and Thanh Tri. In the later period, between 2009 and 2019, districts such as Hoang Mai, Thanh Xuan, Dong Anh, Gia Lam, Bac Tu

Table 4: The Relative Built-up Density index of selected districts between 1999 and 2019.

District code	District name	RBuD 1999	RBuD 2009	Change 1999–2009 (%)	RBuD 2019	Change 2009–2019 (%)
1	Ba Dinh	0.52	0.65	25.0	1.01	53.8
2	Hoan Kiem	0.50	0.55	10.0	0.82	49.1
3	Tay Ho	0.23	0.55	139.1	0.81	47.3
4	Long Bien	0.18	0.32	77.8	0.51	59.4
5	Cau Giay	0.31	0.63	103.2	0.91	44.4
6	Dong Da	0.57	0.87	52.6	1.28	47.1
7	Hai Ba Trung	0.49	0.77	57.1	1.21	57.1
8	Hoang Mai	0.17	0.49	188.2	0.86	75.5
9	Thanh Xuan	0.36	0.71	97.2	1.35	90.1
17	Dong Anh	0.13	0.21	61.5	0.38	81.0
18	Gia Lam	0.13	0.27	107.7	0.44	63.0
19	Nam Tu Liem	0.13	0.34	161.5	0.55	61.8
20	Thanh Tri	0.16	0.34	112.5	0.49	44.1
21	Bac Tu Liem	0.11	0.31	181.8	0.56	80.6
268	Ha Dong	0.22	0.30	36.4	0.72	140.0
274	Hoai Duc	0.17	0.20	17.6	0.40	100.0


Map of Relative Built-up Density Index in 1999
Hanoi Capital
Legend
District boundary
Commune boundary
RBuD 1999
<= 0.2
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
> 1
0 5 10 20 Km
A
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community


Map of Relative Built-up Density Index in 2009
Hanoi Capital
Legend
District boundary
Commune boundary
RBuD 2009
<= 0.2
0.21 - 0.30
0.31 - 0.40
0.41 - 0.50
0.51 - 0.60
0.61 - 0.70
0.71 - 0.80
0.81 - 0.90
0.91 - 1.00
> 1
0 5 10 20 Km
B
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community

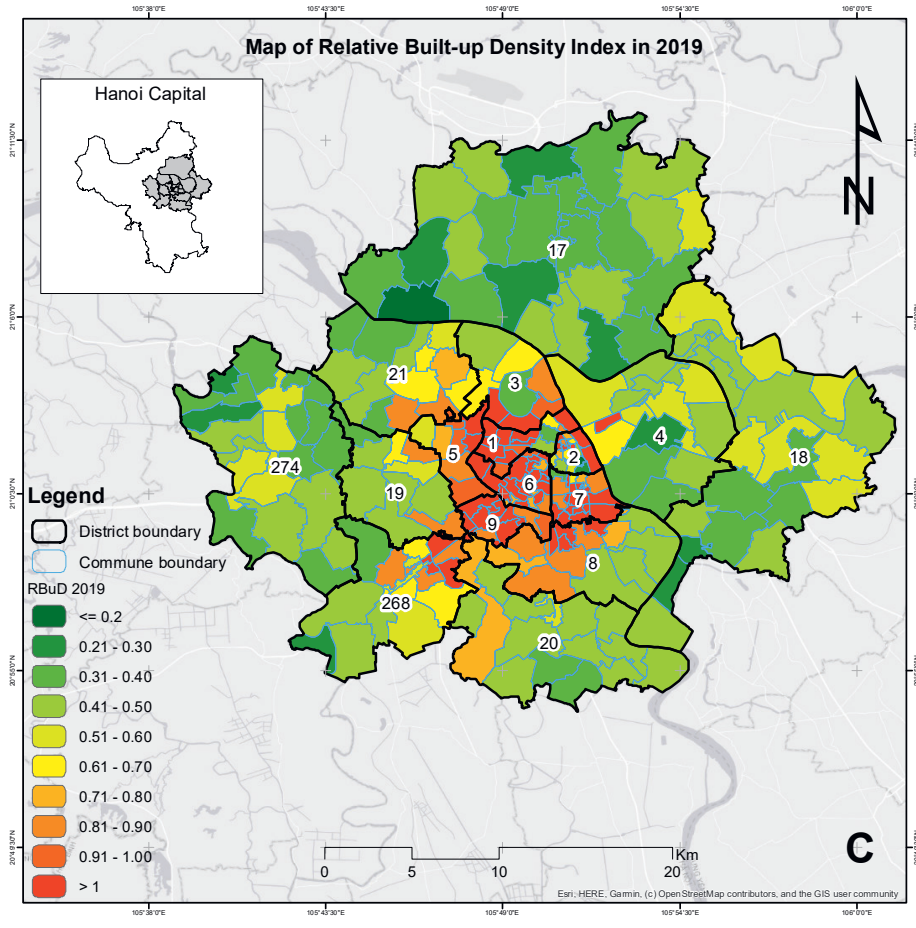


Figure 5. Maps of relative built-up density index in 1999, 2009, and 2019.

Liem, Nam Tu Liem, Ha Dong and Hoai Duc experienced faster growth, with rates ranging from 61.8% to 140%.

By 2019, districts such as Ba Dinh, Dong Da, Hai Ba Trung and Thanh Xuan recorded the highest RBuD values (greater than 1), demonstrating substantially high population density, increased construction, and infrastructure development. Other districts, such as Long Bien, Dong Anh, Gia Lam, Bac Tu Liem, Nam Tu Liem, Thanh Tri and Hoai Duc recorded lower values of RBuD. As these districts are in transition from rural to urban areas, they have more room for urban development and are positioned to be sites of rapid urban growth now and in the future.

Beyond the development of new apartment buildings on open land as the process of peri-urbanization, the process of residentialization, as part of urban renewal, is a significant driver of increased urban built-up density in Hanoi. Four major trends identified by Tung (2018) illustrate how existing urban land is being repurposed and intensified.

1. Renovation of old residential neighbourhoods: this trend directly increases density by replacing low-rise, often degraded housing with new, high-density projects. A prominent example is the conversion of 4- to 5-storey old Soviet-style apartment estates into modern high-rise new urban areas (T. T. Duong, 2022). This replacement dramatically increases the floor area ratio and the number of dwelling units on the original land plot.
2. Transformation of former industrial estates: this process involves a functional and physical conversion that boosts density. Outdated, polluted factories and industrial parks, which typically have a low built-up volume relative to their large land area, are redeveloped into residential neighborhoods, mainly in the form of NUAs.
3. Conversion of existing public facilities: similar to industrial estates, this trend

Figure 6. Examples illustrating urban renewal trends in Hanoi's urban districts (source: sample pictures retrieved from Google Earth historical image archive in 2000 and 2021).

reclaims land from often sprawling, low-rise public facilities that are now useless. By redeveloping these sites into residential neighbourhoods, the land use is intensified, replacing low-density administrative or service functions with high-density housing.

4. Adaptation of other specific spaces: this catch-all trend underscores the same mechanism: underutilized or specific-use spaces are transformed into residential neighbourhoods. In Hanoi's urban context, this invariably means developing high-rise, high-density structures.

These four trends show a consistent pattern of vertical densification and land-use intensification. By replacing low-density, non-residential or aging residential structures with modern, high-rise residential complexes, the residentialization process actively increases the overall built-up density within Hanoi's existing urban fabric. Figure 6 provides some examples of urban transformation that lead to this increased urban density.

Vertical vs horizontal expansion

Figure 7 shows the relationship between Relative Built-up Density (RBuD) (in bar columns) and urban footprint (in dot symbols) for 1999, 2009, and 2019. While the urban footprint represents horizontal expansion, RBuD measures compactness in both vertical and horizontal dimensions. The data documents a process of densification, with RBuD consistently increasing across all districts. However, the nature of this growth varies distinctly by location. The urban districts including Ba Dinh, Dong Da, Hoan Kiem, Hai Ba Trung and Thanh Xuan show a nearly saturated urban footprint (dot symbols from all three time periods are clustered together), demonstrating that their growth has been almost entirely vertical within an exceptionally compact layout. Other districts show both horizontal and vertical growth.

The intense verticalization within a constrained footprint is not merely a theoretical indicator of a compact city; it has produced tangible urban stresses in Hanoi's core. The concentration of development in tall structures has transformed these districts into the city's undisputed economic centres, but it has also led to chronic traffic congestion, a severe housing affordability crisis and overloaded public infrastructure. For instance, schools and hospitals in the central districts are notoriously overcrowded, and drainage systems are frequently overwhelmed leading to localized flooding. This reality reflects a critical failure to match infrastructure development with the pace of densification. In cities such as Manila and Bangkok, similar densification patterns without commensurate infrastructure investment have resulted in city-wide gridlock and hazardous levels of air pollution (Marks, 2020; Sidel, 2020). In Mumbai, unplanned hyper-density has led to the proliferation of vast informal settlements where residents lack access to clean water and sanitation, demonstrating the severe social costs of this development model (Subbaraman and Murthy, 2015). These examples show that without robust management, high density does not automatically yield the benefits of a compact city; instead, it creates significant challenges to livability, environmental quality and social equity, including a critical deficit of public green spaces.

This analysis moves beyond abstract models to highlight the urgent and differentiated policy imperatives facing Hanoi, which can be directly guided by the RBuD maps presented in Figure 5. For saturated urban districts such as Hoan Kiem, Ba Dinh, Dong Da, Hai Ba Trung and Thanh Xuan, the challenge is no longer about stimulating growth but about retrofitting and upgrading existing infrastructure to mitigate congestion, improve public service delivery and reclaim public space. Conversely, rapidly sprawling districts such as Dong Anh and Gia Lam require proactive planning: installing robust

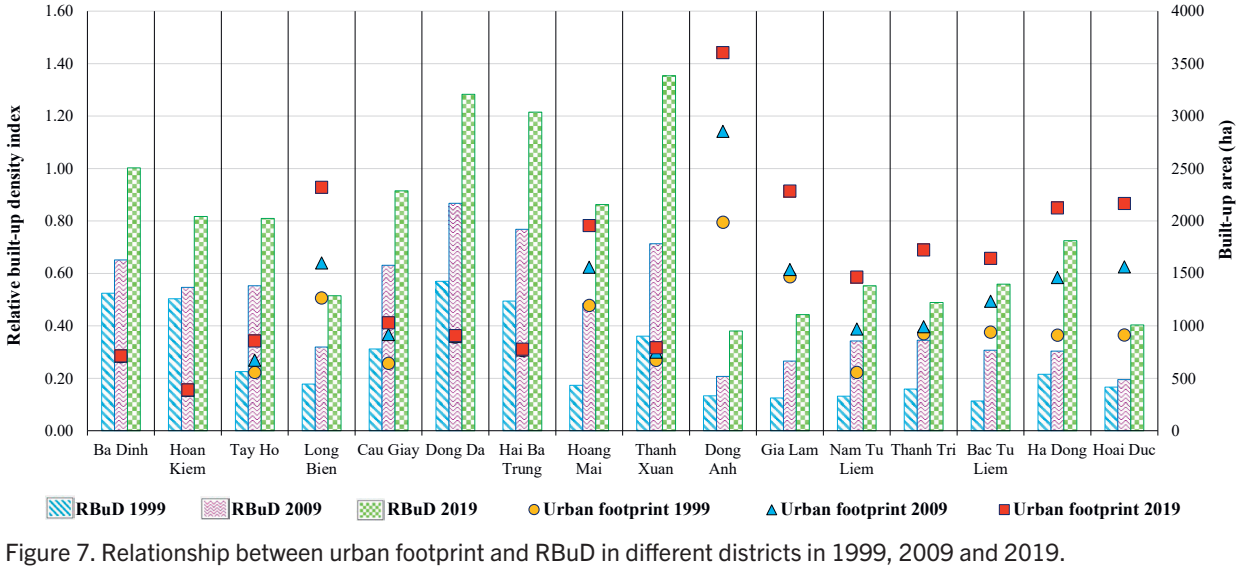


Figure 7. Relationship between urban footprint and RBuD in different districts in 1999, 2009 and 2019.

transportation networks, utilities and social infrastructure in advance of population growth. This foresight is essential to prevent the new urban fringe from replicating the intractable problems that plague the core, guiding Hanoi toward a more sustainable and equitable development trajectory.

Conclusion

The built-up density index presents a straightforward measure for monitoring local urban developments and assessing urban planning interventions. The analysis at the finest administrative level (commune/ward) enables the detection of variations in urbanization patterns and transformation rates across districts within metropolitan regions such as Hanoi. In this paper, the analysis of these morphological changes was contextualized with a discussion of their underlying social, economic, and political processes.

A key strength of this approach is its utilization of freely available remote sensing products and statistical figures, which are typically accessible at different administrative levels in the Global South countries. This low data demand makes it adaptable to other metropolitan regions of the Global South grappling with rapid urbanization and limited planning capacities. However, applying the built-up density index in other countries requires consideration of the following points. In areas with high shares of informal settlers or unregistered people, the actual population numbers might be largely underestimated, which would reproduce a distorted image via the built-up density index. Moreover, districts with high concentrations of second-home ownership may introduce additional uncertainties, potentially inflating built-up density estimates. Further challenges arise in delineating urban extents via the identification of urban and non-urban areas from satellite images. The process typically involves setting a fixed threshold that defines urban and non-urban pixels. For this reason, the complex transformations and intricate urban structures occurring in suburban regions transitioning from rural to urban landscapes may not be fully captured. To mitigate these limitations, it is essential to gain deeper insights into their developments and to validate the results of the built-up density index. This can be achieved, for instance, by collecting supplementary socio-economic data on ownership structures and wealth distributions and by conducting regular site visits.

Despite these challenges, the built-up density index remains a valuable and cost-effective tool for quantifying past and ongoing dynamics and informing sustainable planning strategies that tackle pressing issues such as housing accessibility, the loss of urban green space, infrastructural deficits, and deteriorated living conditions.

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