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Upper Limits of Densification: A Global Analysis of Vertical Urban Evolution from 1975-2025

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Abstract This paper investigates the influence of tall buildings on urban densification across 524 global cities with present-day populations over one million, from 1975 to 2025. Using a dataset that spans this period in five-year intervals and integrates satellite-derived metrics of built-up area and volume, I analyze how urban form changes in tandem with population growth. I assess this growth not only in surface area and total built volume, but also a proxy for average building height, and integrate a new variable: completions of individual buildings over 200 meters (200 m+). The findings show that while population growth often outpaces surface expansion—signalling densification—this is more closely aligned with increases in overall volume than with citywide average building height. In most cases, height growth is negatively correlated with densification. Globally, completions of 200 m+ buildings show a small but statistically significant negative relationship with density gains, suggesting that symbolic verticality does not equate to functional densification. These trends vary sharply by region and city growth intensity, with Asian megacities achieving density through midrise expansion and low-growth cities in Europe or the Americas relying more on iconic vertical retrofitting. The research challenges potentially flawed assumptions about tall buildings as universal density solutions and advocates for a more nuanced understanding of spatial efficiency.

Keywords: densification, vertical growth, tall buildings, urban morphology, global cities

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1. Introduction

1.1. Urban Density in the Age of Megacities

The 21st century has been marked by an unprecedented concentration of population growth in large urban agglomerations. In 1975, approximately 37% of the global population lived in urban areas; by 2020, that figure had risen to 56%, and projections by the United Nations suggest that this will further rise to 68% by 2050 (UN DESA, 2019). Much of this growth is concentrated in so-called "megacities"—urbanized areas with populations exceeding 10 million—most of which are in the Global South and are characterized by rapid and co-occurrent demographic expansion and spatial reconfiguration.

This urban transformation has renewed urbanists' interest in the physical structure of cities, particularly the relationship between spatial form and functional density. Cities are expanding not only in horizontal extent but increasingly through vertical intensification, with ever-taller buildings reshaping skylines from Shenzhen to São Paulo. Urban policy and real estate narratives frequently equate building height with land-use efficiency, arguing that taller buildings naturally reduce urban sprawl, increase housing supply, and promote transit-oriented development (Graham & Hewitt, 2013; Galeser, 2011).

However, the assumption that verticality automatically yields higher population or built density remains empirically underexamined. While tall buildings may offer symbolic capital or architectural visibility, their actual contribution to accommodating urban populations depends on numerous factors: floor area ratio (FAR), occupancy rates, contextual land-use mix, and regulatory frameworks. Previous research has shown that many cities achieve high densities through mid-rise, high-coverage development, particularly in Asia and parts of Europe (Angel et al., 2021). Thus, strictly vertical expansion in pursuit of height alone is only one of several possible pathways to densification—raising the need for a more nuanced and data-driven understanding of how cities absorb growth dimensionally.

1.2. The Myth and Promise of Vertical Growth

The proliferation of tall buildings has been positioned as a hallmark of urban modernity, reflecting technological advancement, economic ambition, and spatial efficiency. Since the late 19th century, cities such as New York, Chicago,

and later Hong Kong and Shanghai, have embraced vertical construction as both a response to rising land values and a visual representation of global competitiveness (Abel et al., 2010; Olds, 2001). Consequently, verticality is colloquially equated with economic progress and promoted as a spatial solution to the scarcities that high densities induce: land, infrastructure, and housing.

The empirical link between tall building construction and actual urban density performance remains ambiguous. While tall buildings can increase floor area per land unit, they do not guarantee high occupancy, affordability, or social inclusion. In some cases, vertical expansion has led to what scholars term "vertical sprawl"—a phenomenon where towers are sparsely occupied, spaced widely apart, or disconnected from the surrounding urban fabric, undermining their intended spatial efficiency (Graham & Hewitt, 2013; Harris, 2015). Moreover, luxury buildings in cities such as London, Vancouver, and Dubai have been associated with speculative investment, vacancy, and exclusionary development, often contributing little to resolving housing demand or equitable access to infrastructure (Shen & Wu, 2020; Atkinson, 2020).

Critics of tall buildings argue that their typologies, while visually dominant, may not represent the most effective or context-sensitive strategy for accommodating urban growth. In contrast, urban environments characterized by mid-rise, high-coverage buildings—as found in Barcelona or Tokyo—often achieve high population densities with superior walkability, livability, and integration with transit networks. This paper engages with these debates by examining whether tall buildings, as the most visible form of vertical intensification, are statistically associated with urban densification over time, or whether alternative spatial configurations play a more critical role.

1.3. Research Questions and Contribution

This research explores the extent to which vertical growth contributes to urban densification by analyzing built environment metrics across all 524 known urban areas with populations over one million as of 2025 (hereafter "cities" or "urban areas"). The primary research questions are:

1. Is vertical growth a statistically significant driver of densification?
2. How does the relationship between height and density vary by region and growth intensity?

2. Data And Methods

2.1. Dataset Description

The analyses in this study draw on a harmonized panel dataset spanning ten time points at five-year intervals from 1975 to 2025, allowing for strong temporal analysis of urban change. The core variables include population size, built-up surface area, total built volume, and a derived measure of average building height. Additionally, the dataset integrates site-specific records of tall building completions (200 m+), enabling a fine-grained assessment of vertical construction activity over time.

The dataset used in this study draws from the Global Human Settlement Layer (GHSL) Data Package 2023, produced by the European Commission's Joint Research Centre. This data package integrates global satellite imagery—primarily from Landsat (MSS, TM, ETM+) and Sentinel-2 MSI—with ancillary data to produce a consistent, multi-temporal grid of urban built-up area (GHS-BUILT-S) (Pesaresi & Politis, 2023a) and built volume (GHS-BUILT-V) (Pesaresi & Politis, 2023b). The GHSL dataset offers global coverage at a 100-meter spatial resolution, with data provided for ten benchmark years between 1975 and 2025. Urban extent (built-up surface) is calculated by analyzing built-up probability thresholds over time, while volume is estimated using a combination of satellite-derived building heights, where available, and modeled elevation information from TanDEM-X and other digital surface models. Population estimates are then joined from Schiavina et al. (2023), who use grid-based interpolations to produce consistent, 100 m^2-resolution demographic data across the timescale.

The GHSL built volume layer (GHS-BUILT-V) serves as a novel proxy for verticality by quantifying the above-ground built volume per grid cell. To calculate an average building height proxy per city, this study divides total volume by total built-up surface within each urban center, yielding a unit of meters that allows comparative analysis across cities and time. Importantly, GHSL urban centers are not administrative boundaries, but rather functional urban extents based on population density and built-up continuity, derived using the GHS Urban Centre Database (UCDB) methodology.

GHSL's harmonized classification and standardized time series enable direct comparison across cities and decades, filling a critical gap in global urban form analysis. While modeled height data introduces uncertainties—particularly in mixed-use districts or informal settlements—GHSL remains one of the only globally consistent sources of 3D built environment data, enabling this study's longitudinal, cross-city analysis of densification patterns and vertical urban form.

Completions of buildings over 200 meters in height (200 m+)—including year of delivery, height, and function—are drawn from the Council on Tall Buildings and Urban Habitat (CTBUH) Tall Building Database (CTBUH, 2025a), an industry-standard reference for high-rise construction globally. As of 1 April 2025, there are 2,437 such completed buildings globally, over half of which have been constructed in the past decade. Buildings at and above this height threshold have become an important indicator for vertical growth more generally in their respective cities, as measured by CTBUH's annual Trends and Forecasts report (CTBUH, 2025b).

Initial descriptive analysis of the data revealed that

global cities have, on average, doubled their built-up volume between 1975 and 2025, while surface area has expanded at a slower pace, and height has increased modestly. Tall buildings have been disproportionately clustered in specific regions—most notably in East Asia, the Middle East, and select North American cities—but do not uniformly track with population growth. These preliminary observations underscored the need for a deeper analytical investigation into whether vertical expansion has facilitated, or merely symbolized, urban densification.

2.1.1. Geographic and Temporal Coverage

The 524 subject cities span all inhabited continents and represent a broad spectrum of demographic scales, income levels, political regimes, and planning paradigms. Spatial consistency across time is ensured through the application of stable urban boundary definitions provided by the Global Human Settlement Layer Urban Centre Database (Marí Rivero et al., 2024). These boundaries are harmonized with administrative units from GADM 4.1 to maintain consistency in geospatial alignment and temporal comparability. This approach mitigates the common analytical problem of shifting administrative boundaries, allowing for accurate comparison of built form and population metrics within fixed boundaries.

The geographic coverage includes both rapidly urbanizing metropolises—such as Lagos, Dhaka, and Kinshasa—and mature urban systems like Vienna, Tokyo, and Toronto, supporting a comparative perspective on how these different city typologies evolve. Using world regions as defined by CTBUH, the data includes 248 cities in Asia (47.3%), followed by 90 in Africa (17.2%), 55 in Europe (10.5%), 41 in South America (7.8%), 35 in the Middle East (6.7%), 30 in North America (5.7%), 20 in Central America (3.8%), and 5 in Oceania (1.0%). This broad geographic inclusion facilitates the stratified analyses that follow in Sections 4 and 5.

Temporally, the 50-year span from 1975 to 2025 captures a range of macro-urban transitions, including the decline of industrial manufacturing cores in the Global North, the explosive urbanization of the Global South, and more recently, the mainstreaming of climate-responsive and density-oriented urban planning schemes. This period also aligns with the proliferation of satellite-based urban measurement tools, enabling such consistent spatial metrics across decades. The dataset's temporal granularity allows for the detection of both gradual and punctuated shifts in urban expansion, including the emergence of tall building clusters, infrastructure megaprojects, and post-pandemic spatial reconfigurations in the early 2020s.

Preliminary tabulations showed that over 300 cities in the sample added more than 50% to their built-up surface area between 1975 and 2025, while over 100 cities experienced a fourfold increase in built-up volume—highlighting the magnitude of physical transformation in the contemporary urban form.

2.1.2. Key Variables: Population, Surface, Volume, Height Proxy

Five core metrics underpin the analysis:

- **Population**: total urban population at each time point, analyzed as a spatial raster dataset with 100 m^2 resolution.
- **Urban Area**: the built-up surface area in square meters, defined as the cumulative building footprint area within each cell of a spatial raster dataset with 100 m^2 resolution.
- **Building Volume**: the estimated total volume of built structures in cubic meters, defined as the product of a given area's average building height and built-up surface area.
- **Building Height Proxy**: average building height, calculated as Building Volume divided by Urban Area in each 100 m^2 cell.
- **Tall Buildings (200 m+)**: the location of all 2,437 completed buildings of at least 200 meters in height, including attribute data on building function, derived from the CTBUH Tall Building Database as of 1 April 2025.

2.2. Defining Urban Densification

Urban densification, in this study, is defined as the increase in population relative to the expansion of built-up urban surface area. It reflects a more intensive use of land and infrastructure within a fixed urban boundary and is framed by UN-Habitat (2020) and Neuman (2005) as a desirable objective for enhancing sustainability, reducing emissions, and curbing undesirable urban. Densification is not simply a matter of increasing population; rather, it occurs when urban form becomes more compact, and population growth outpaces the spatial footprint of the city.

Formally, I define densification (D) as follows:

$$D = P_g - U_g$$

Where:

- P_g = the percentage growth in population over a five-year interval
- U_g = the percentage growth in built-up urban surface area over the same interval

Densification is considered positive when $D > 0$, i.e., when population growth exceeds areal expansion. This formulation allows for the identification of cities that are accommodating more people per unit of land, a fundamental indicator of urban land-use efficiency.

To capture the vertical dimension of urban expansion—often invoked in densification discourse but seldom measured systematically—I introduce a proxy for average building height (H), calculated as:

$$H = \frac{B_v}{U_a}$$

Where:

- B_v = total built volume (in cubic meters)
- U_a = built-up surface area (in square meters)

This derived variable provides a normalized measure of verticality, allowing for consistent cross-sectional and longitudinal comparison where precise or more granular data on tall building locations and volumes may be unavailable or incomplete. While this proxy does not capture architectural height directly (e.g., the number of occupied stories, structural heights, or pinnacle heights), it reflects the average massing of the built environment and provides an empirically grounded indicator of intensification at the natural limits of contemporary and publicly available remote sensing technologies.

2.3. Analytical Methods

2.3.1.Software Tools

All analyses were conducted using a combination of Python (v3.11) and R (v4.3) for statistical computation, PostgreSQL with the PostGIS extension for geospatial data processing, and ArcGIS Pro (v3.3) for raster transformation, spatial alignment, and urban extent validation. Python's *pandas*, *statsmodels*, and *seaborn* libraries were used for time series manipulation, regression modelling, and preliminary visualization. The integration of relational database management with geospatial scripting allowed for scalable processing of over 5 million individual observations.

2.3.2. Growth Rate Calculations

Growth rates were computed for each variable at the five-year intervals described in Section 2.1. Percent change formulas were then applied uniformly to capture short-term dynamics and long-term trends across the 50-year period.

For each city and five-year interval (e.g., 1975-1980, …, 2020-2025), percentage growth rates were calculated for the following variables: population, built-up surface area, total built volume, and average height proxy (volume/surface). The general form of the growth rate calculation is:

$$G_t = \frac{X_{t+1} - X_t}{X_t}$$

Where G_s is the growth rate of variable X between year t and $t+1$. Only intervals with valid non-zero denominators were included to avoid distortion from edge-case zero values in early time periods. These growth rates formed the basis for the densification metric and all subsequent correlational and inferential modelling.

2.3.3. Correlation Analyses

Pearson correlation coefficients were calculated to explore the basic linear relationships among key variables: population growth, urban area growth, building volume growth, and building height proxy growth. These correlations were calculated across all city-interval observations, and then subset by region and by densification pattern (positive versus non-positive densification in the observation period). Initial results revealed a moderate positive correlation between population and volume growth ($r \approx 0.52$), weaker correlation with surface growth ($r \approx 0.43$), and a negative correlation with height growth ($r \approx -0.19$) in the full sample. These findings informed the structure of the regression models described below.

2.3.4. Regression Modelling

To test the hypothesis that vertical construction contributes to densification, I fit a series of ordinary least squares (OLS) regression models with densification (population growth rate minus surface growth rate) as the dependent variable. A univariate model was first estimated using only the building height growth proxy as the sole predictor. This was followed by a multivariate specification including the building height growth proxy, built-up surface growth, and built volume growth as independent variables. An additional model incorporated nominal completions of 200 m+ buildings as a fourth predictor, accommodating the analysis of symbolic verticality as a distinct influence on densification.

The model specification was:

$$D = \beta_0 + \beta_1 H + \beta_2 S + \beta_3 V + \beta_4 T + \varepsilon$$

Where:

- D = Densification (population growth / surface growth)
- H = Height growth
- S = Surface growth
- V = Volume growth
- T = Number of 200 m+ building completions

Model performance was assessed using adjusted R^2, and predictor significance was evaluated at $p < 0.05$.

2.3.5. Stratification by Region and Growth Intensity

To account for spatial heterogeneity, I stratified the dataset by both geographic region and urban growth intensity. Growth categories were defined using the median value of average population growth across all cities from 1975–2025. Cities above the median were classified as high-growth, while those below were designated low-growth. Separate regressions were run for each region-growth typology combination, enabling further comparisons of effect size and explanatory power. These stratified models revealed divergent drivers of densification: volume growth remained consistently significant, while the role of tall building completions varied by regional condition.

2.4. Limitations and Uncertainties

While the dataset used in this study provides a uniquely comprehensive, multi-decade perspective, several limitations

must be acknowledged. The proxy measure for building height (volume divided by surface) does not capture detailed variations in actual built height profiles, mixed-use programs, or the true number of occupied stories, potentially leading to underestimation or overestimation in certain contexts. Second, the absence of granular data on land use, zoning codes, building occupancy rates, or functional mix (e.g., residential vs. commercial) limits the ability to directly attribute volume growth to population accommodation. Third, variations in data quality and measurement methodologies, especially for earlier decades, may introduce regional biases or uncertainties. These highlight the importance of caution in interpreting the findings as strictly deterministic relationships and underscore the need for complementary local studies to validate the broader global patterns.

Notably, the primary datasets used in this study include generalized distinctions between residential and non-residential land uses. However, due to the context-sensitive and loosely defined nature of these classifications, such distinctions are not incorporated into the analysis. Instead, the study considers the overall height profile of each city. Iconic or supertall non-residential towers are treated as statistical outliers and have minimal influence on the aggregated results.

3. Global Patterns of Densification

3.1. Growth Trends Across All Cities

Across the full dataset of 524 cities, I observed substantial variation in how urban areas have expanded over the past five decades. As expected, average population growth has outpaced average built-up surface growth by 37.6%, indicating positive global densification trends. Such densification was largely unaffected by the growth of tall buildings over 200 meters. Cities with at least one complete 200 m+ building saw population growth outpace urban area growth by 39.0%, indicating the presence of such buildings had a marginal but positive effect on densification.

This reflects the reality that many tall buildings are not constructed in response to population pressures, but instead reflect speculative or symbolic motivations. The Council on Tall Buildings and Urban Habitat (2025b) has described this phenomenon as “vanity height”—referring to unoccupiable upper floors added for architectural or branding prestige rather than usable space. In such cases, height becomes decoupled from functional density, weakening the link between vertical growth and density. While this study focuses on quantifiable spatial patterns, it is essential to acknowledge the influential role of global and local actors in shaping verticality. Developers, architects, and engineers have played a pivotal role in advancing tall, supertall, and megatall construction, driven by spatial constraints, demographic pressures, commercial imperatives, branding objectives, and speculative investment. These projects often reflect a convergence of economic globalization, design ambition, and city image-making, particularly in high-profile urban centers.

This relationship between 200 m+ buildings and population varies greatly by region—an indication of how cultural context and urban planning regimes can have an outsized effect on sprawl. Africa, having just one city with a completed 200 m+ building, is excluded as an outlier in this analysis. In Central and South America, urban areas without a 200 m+ building densified moderately faster than those with such buildings (41.8% versus 40.5% and 77.0% versus 57.2%, respectively). In all other regions, the presence of at least one 200 m+ building indicated that city was densifying.

However, volumetric growth—representing the total quantity of constructed space of all functions—more closely mirrored population increases than surface area did, suggesting that built volume, rather than surface or height individually, may be the most direct spatial correlate of population change. Population growth outpaced building volume growth by 58.0% from 1975 to 2025, and in urban areas with at least one complete 200 m+ building, that figure increased to 71.5%. South America was the only region where building volume growth outpaced population growth, indicating either an overbuild in housing units or the growth of average housing unit square footage overall.

3.1.1. Univariate and Multivariate Regression Models

Over the 50-year study period, cities in the global sample demonstrated distinct and uneven growth trajectories across key indicators of urban form. Average five-year population growth rates hovered between 2.1% and 4.2%, tapering modestly in recent decades but remaining positive in nearly all intervals. In contrast, built-up surface area expanded more slowly, with a long-run average growth of 1.6% per interval, reflecting widespread land-use intensification even as urban footprints expanded.

Built volume grew more consistently than surface alone, averaging 2.7% growth per interval. This indicates that many cities added population capacity by building vertically, but without entering the realm of 200 m+ building construction. Indeed, when I normalized volume by surface to generate the proxy measure for average building height, the results show only modest gains: average height increased by less than 1% per interval over the full period. This suggests that most densification has occurred not through dramatic verticalization, but through modest mid-rise intensification.

These divergent rates of change underscore the importance of distinguishing between symbolic verticality (i.e., iconic tall buildings) and functional verticality (i.e., overall volume added through mid-rise infill). The gradual and moderate height increase across the global sample further supports the claim that urban density has been achieved more through horizontal compactness and volumetric

Table 1. Average percent change in population, urban area, built volume, and height by decade, all cities

Decade	Population +/-	Urban Area +/-	Built Volume +/-	Height +/-
1970s	17.5%	9.5%	8.1%	–1.2%
1980s	15.4%	10.5%	8.9%	–1.3%
1990s	15.2%	14.5%	13.7%	–0.7%
2000s	10.2%	8.7%	7.5%	–1.1%
2010s	9.9%	6.4%	5.1%	–1.1%
2020s (to 2025)	6.6%	1.6%	1.0%	–0.6%

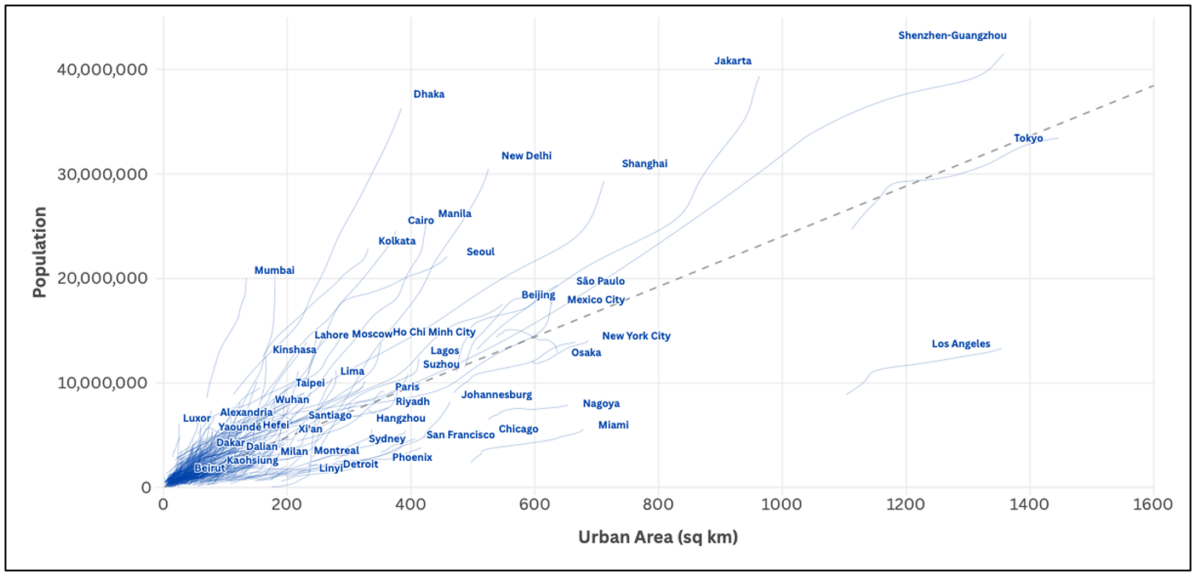


Figure 1. Average growth trajectories for population vs. surface area, 1975-2025. Larger cities are labelled with their UCDB-designated agglomeration name. Lines deviating from the mean horizontally indicate sprawl, whilst lines growing vertically beyond the mean indicate vertical growth.

infill than through widespread adoption of tall towers.

The multi-decade time series also captured changes in urban expansion regimes over time. Growth in all indicators accelerated into the early 2000s, corresponding with the rise of megacity regions in Asia and Africa and global capital flows into urban real estate. By the 2010–2015 interval, however, growth rates began to decelerate, reflecting demographic transitions, market saturation in some regions, and the onset of more climate- and equity-conscious urban planning agendas.

3.2. Correlation Analysis

3.2.1. Relationships Between Population Growth and Physical Metrics

To explore the relationships between demographic and spatial change, I calculated Pearson correlation coefficients across four key variables: population growth, surface growth, volume growth, and average building height growth. The results provide important insight into the structural patterns of urban expansion over the 1975–2025 period.

Across all city-interval observations, population growth correlates moderately with built-up surface growth ($r \approx 0.53$) and with volume growth ($r \approx 0.52$). This indicates that cities accommodating more people tend to expand outward and upward in volume simultaneously—but not necessarily in height. The relatively stronger association with volume supports the proposition that total constructed space, rather than land area or height alone, is the more precise spatial correlate of urban population dynamics.

Perhaps surprisingly, the correlation between population growth and height growth is negative ($r \approx -0.19$) (see Figure 2 and Table 2). This suggests that citywide increases in average building height are not directly associated with greater population absorption, and in many cases may indicate material- and capital-intensive, low-occupancy development. The finding calls into question the assumption that taller buildings inherently lead to denser cities. Instead, it suggests that symbolic verticality often diverges from functional density—a theme further developed in Sections and .

Further subgroup analyses revealed that this negative correlation was most pronounced in high-income cities in regions such as North America and the Middle East, where tall buildings frequently serve speculative purposes

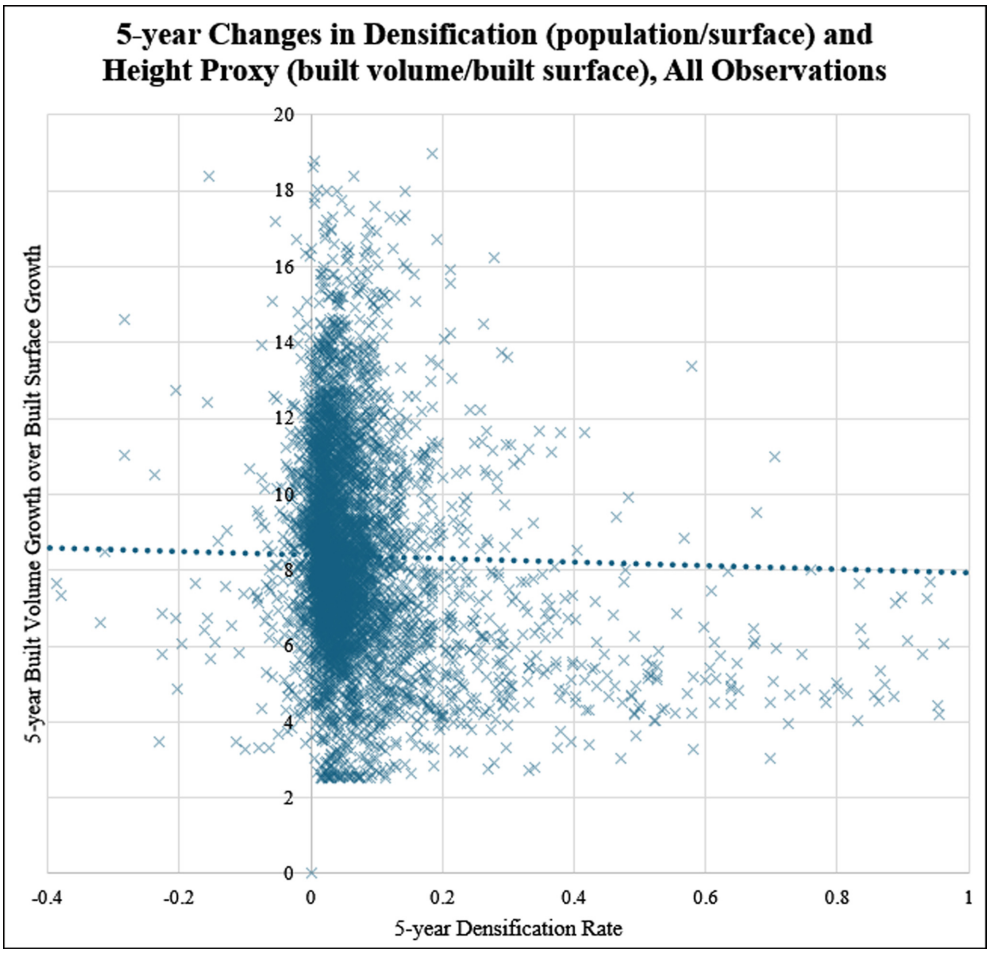


Figure 2. All observations of the 5-year rate of densification (population/surface) and growth of the height proxy (volume/surface) across all cities, indicating a modest negative correlation between densification and height growth.

Table 2. Correlation matrix of all cities

ALL CITIES	Population	Urban Area (Surface)	Building Volume	Building Height
Population		0.52893	0.52236	-0.19467
Urban Area (Surface)	0.52893		0.98576	-0.39399
Building Volume	0.52236	0.98576		-0.23445
Building Height	-0.19467	-0.39399	-0.23445	

or symbolize prestige (see Table 3). In contrast, regions characterized by mid-rise, high-coverage urbanism, particularly in East and Southeast Asia, exhibit stronger correlations between population and volumetric growth, with minimal change in height growth. While both paths may achieve densification to some degree, these patterns suggest that cities may densify more efficiently through the horizontal accumulation of built form than through pure vertical intensification.

3.3. Regression Findings: Densification Drivers

3.3.1. Univariate and Multivariate Regression Models

To assess the relative contribution of different spatial growth forms to urban densification, a series of ordinary least squares (OLS) regression models were estimated using densification as the dependent variable. In the univariate model, where average building height growth was the sole predictor, the coefficient was negative and statistically significant ($\beta = -2.66$, $p < 0.001$). This result reinforced the earlier correlation findings and suggested that cities experiencing vertical growth do not, on average, densify more effectively than their midrise counterparts. In fact, height growth appears to be inversely related to efficient land-use intensification. A reverse OLS model, in which densification was the sole predictor of building height, I found a positive and statistically significant correlation ($\beta = 2.86$, $p < 0.001$).

This finding contradicts a common narrative that equates building height with functional density. Instead, it points to a decoupling between verticality and livability, echoing critiques in urban theory that warn against conflating

Table 3. Correlations stratified by region, with brief insights into each result

Region	Population and Building Height	Urban Area and Building Height	Building Volume and Height	Insights
Africa	0.04	-0.18	-0.01	Weak influence of height; most densification not from vertical growth.
Europe	-0.01	-0.07	0.03	Building height barely changes despite densification.
Middle East	-0.19	-0.1	0.04	Mixed results; some vertical contribution to densification.
Asia	-0.36	-0.44	-0.28	Densification negatively correlated with vertical growth, possibly due to rapid growth of urban area and infill development.
South America	-0.07	-0.41	-0.32	Some negative relationship; suggests sprawl containment strategies or geographic constraints.
North America	-0.17	-0.34	-0.28	Modest negative relationship, less reliance on verticality to intensify urban areas.
Central America	-0.01	0.09	0.23	Slightly positive vertical correlation.
Oceania	-0.09	-0.81	-0.77	Strong inverse correlation: taller buildings may be used to offset reductions in sprawl.

Table 4. Population growth rate ratio to building volume growth rate, stratified between urban areas with and without 200 m+ buildings

	Rate that population growth outpaced building volume growth, 1975 - 2025	
	Urban areas without 200m+ buildings	Urban areas with 200m+ buildings
Global	0.57961	-0.01715
Africa	2.63373	Not enough data
Asia	1.16427	1.31913
Central America	1.55142	1.77094
Europe	1.08310	1.68701
Middle East	2.82095	4.26291
North America	1.96996	2.23620
Oceania	2.35776	2.78917
South America	1.92375	1.70768

"intensive form" with "dense outcomes" (Graham & Hewitt, 2013; Harris, 2015). Cities that build taller are not necessarily absorbing more population per square meter of land—at least not uniformly.

The explanatory power of the model improved substantially when volume growth and surface growth were added as covariates, with the multivariate model yielding an R^2 of 0.165. Within this specification, volume growth emerges as the strongest positive predictor of densification ($\beta = +3.09$, $p < 0.001$), while surface growth had a significant negative effect (the result of "urban sprawl"), and height growth remained negatively associated to a lesser degree.

These results demonstrate that total constructed floor space per unit land area—rather than how that space is vertically configured—is the key spatial mechanism through which cities densify. While tall buildings can certainly contribute to volume, they are not a necessary condition for volumetric expansion. In fact, vertical expansion may introduce diminishing spatial returns: taller buildings require deeper foundations, more structural supports, greater elevator core space, and often more stringent setback and tower spacing regulations. These architectural and regulatory realities, as Sorkin (2018) suggests, may limit net residential yield per parcel as height increases.

While the optimal built form is context-dependent, this model suggests that urban density at the city scale is best achieved through balanced increases in volume, not extreme height. This conclusion supports a shift in planning priorities away from the symbolic forms of existing tall buildings toward more pragmatic, midrise intensification strategies. The catalytic effect of symbolic tall buildings may yield greater contextual infill and therefore density, but as standalone interventions, they do not provide the substantial capacity for population absorption that might be expected.

3.3.2. Tall Building Completions

To further test the symbolic versus functional effects of verticality, the model was expanded to include the number



Figure 3. Correlation coefficients stratified by both region and high-low growth category. See Sections 4.1 through 4.4 for further details on select region and further explanation of methodology.

of 200 m+ building completions in each city during each five-year interval. This variable captures not just average height changes, but the presence of very tall structures, which are commonly associated with global visibility, economic success, and landmark urbanism.

The inclusion of this variable revealed a small but statistically significant negative effect on densification ($\beta = -0.0017$, $p < 0.05$). This result suggests that the completion of such iconic buildings does not systematically correspond to an increase in urban population efficiency. On the contrary, these buildings may cater disproportionately to luxury residential, corporate, or mixed-use markets that contribute minimally to per capita housing availability or spatial efficiency.

In certain cases, 200 m+ towers may reflect increased speculation or state-led iconicity, rather than responses to actual demographic pressure. Their construction may even displace potential infill development by consuming high-value parcels, enforcing greater setback regulations, or fragmenting pedestrian and transport networks. In this sense, and at this height threshold, tall building completions may signal capital density more than population density, as described by Atkinson (2020) in London and Shen & Wu (2020) in China.

4. Regional divergences in urban form

The relationship between verticality and densification proved to be quite uneven across global regions. Cultural norms, regulatory frameworks, housing markets, and infrastructural legacies all shape how cities grow how vertical growth translates (or fails to translate) into population efficiency. Stratifying regression models by both geographic region and population growth intensity

Table 5. Stratified regional coefficients by growth category, Asia

Region	Urban Growth Category	Building Height Coefficient	Urban Area Coefficient	Building Volume Coefficient	200m+ Building Coefficient	R^2
Asia	*High Growth*	3.26452	1.81651	-2.40249	-0.00238	0.23380
	Low Growth	-3.09638	-3.46322	2.83226	-0.00229	0.62230

revealed a set of distinctive patterns that challenge the applicability of a global theory of vertical urbanism.

4.1. Asia: Outside of China, Compactness Without Height

With cities in China as a near-universal exception, studied Asian cities present the clearest examples of high-density urbanism without reliance on building height. In the sample, cities such as Dhaka, Jakarta, and Manila showed strongly negative correlations between building height growth and densification, even while they achieved substantial increases in population per land unit. The regression models confirmed this trend: citywide average building height and 200 m+ completions had little explanatory power, while volume growth emerged as the dominant predictor of densification.

The pattern reflects a combination of mid-rise massing, informal intensification, and redevelopment of the low-rise urban fabric. Cities across South and Southeast Asia frequently add livable space through extensions, subdivided plots, and vertical additions within existing regulatory constraints rather than through planned tall building transformation. The compactness of these cities is not contingent on tall buildings, and they offer replicable models of efficient density through mixed-use mid-rise intensification (Turok & McGranahan, 2013).

4.2. Europe and South America: Strategic Vertical Intensification

In contrast to Asia's mid-rise efficiency, selected cities in Europe and South America exhibited positive associations between height growth and densification—but only within specific contexts. In these regions, verticality appeared to function less as a speculative mechanism and more as a targeted tool for intensification in already-developed areas. For example, Barcelona and São Paulo have actively pursued urban redevelopment strategies that incorporate taller buildings in nodes with existing infrastructure and high accessibility.

Regression models from these regions showed modest positive coefficients for both height growth and completions of 200 m+ buildings, though volumetric growth remained the more reliable predictor overall. These findings suggest that controlled vertical expansion can contribute meaningfully to density in cities with strong planning regimes and limited land availability.

4.3. Africa and the Middle East: Irregular Patterns of Growth

The picture is far less consistent in Africa and the Middle East, where urban expansion trajectories diverge sharply across national and subnational contexts. Many African cities—such as Lusaka, Kinshasa, and Addis Ababa—have undergone dramatic population growth with minimal changes to either surface or volume, indicating a prevalence of informal settlement patterns and low per capita floor area provision.

The Middle East, by contrast, includes cities like Dubai, Doha, and Riyadh, where vertical construction is

Table 6. Stratified regional coefficients by growth category, Europe and South America

Region	Urban Growth Category	Building Height Coefficient	Urban Area Coefficient	Building Volume Coefficient	200m+ Building Coefficient	R^2
Europe	*High Growth*	59.31358	48.51857	-49.23004	No data	0.54823
	Low Growth	7.28588	6.07013	-7.08470	0.00269	0.26660
South America	*High Growth*	34.91183	30.49631	-31.32950	-0.02044	0.13930
	Low Growth	51.17273	43.08230	-43.89707	-0.01228	0.24423

Table 7. Stratified regional coefficients by growth category, Africa and Middle East

Region	Urban Growth Category	Building Height Coefficient	Urban Area Coefficient	Building Volume Coefficient	200m+ Building Coefficient	R^2
Africa	*High Growth*	-12.08609	-12.24146	11.50165	-0.04571	0.13535
	Low Growth	24.50471	21.49904	-22.58267	-0.02148	0.31370
Middle East	*High Growth*	-21.58671	-18.40038	18.12148	0.00039	0.03692
	Low Growth	-77.13411	-72.74005	73.16237	No data	0.24423

prolific, but not strictly correlated with population absorption. While these cities boast some of the world's highest densities of tall buildings, the regression models show weak or negative associations between tall building completions and densification, pointing to an overrepresentation of non-residential structures, luxury residential buildings with large per-unit floor areas, or otherwise underoccupied structures.

In both regions, governance challenges, speculative development, and lack of comprehensive affordable housing frameworks appear to limit the efficacy of verticality as a population accommodation strategy.

4.4. Regional Comparison of Model Fit and Coefficients

When comparing the model fit (adjusted R^2) and regression coefficients across regions, a few patterns emerge. The models perform best in East Asia and North America, where development trajectories are relatively stable, and data quality is higher. In these contexts, volume growth maintains its explanatory strength, while building height and tall building completions are either weakly or negatively associated.

In Africa and Latin America, model performance is weaker, likely due to greater heterogeneity in informal urbanization and lower frequency of tall building developments. Notably, in low-growth cities in Europe and North America, tall building completions are sometimes positively associated with densification, suggesting that vertical retrofitting in post-industrial cities can incrementally increase efficiency at modest scale.

The regional variances underscore a central finding of the study: urban density cannot be decoupled from context. Verticality, where it works, is almost always embedded within broader spatial, political, and infrastructural strategies. The assumption that tall buildings inherently lead to greater urban efficiency is not supported by the data and must be reconsidered in favor of more nuanced, regionalized models of densification.

5. Growth Typologies: High vs. Low Growth Cities

Beyond regional variation, another critical axis lies in population growth intensity. Stratifying cities by long-run average population growth yields different patterns that reflect not only divergent demographic pressures but also institutional, economic, and morphological responses to urbanization. This section examines how high-growth and low-growth cities employ different strategies of densification.

5.1. Stratifying Cities by Population Growth Rate

To investigate this aspect, cities were classified into high-growth and low-growth groups based on the median average population growth rate (1975-2025) across the full sample. Cities above the median were designated high-growth, while those below were considered low-growth. This binary stratification captures differing urbanization dynamics: high-growth cities often face urgent needs for housing and infrastructure expansion, while low-growth cities typically engage in selective densification, often oriented around strategic infill and redevelopment.

This approach revealed a clear spatial distribution: high-growth cities are predominantly located in Asia, Sub-Saharan Africa, and parts of Latin America, while low-growth cities are concentrated in Europe, North America, and high-income parts of East Asia and Oceania.

5.2. Verticality in High-Growth Cities

High-growth cities exhibited a distinctive pattern of densification without vertical expansion. Despite adding substantial population over time, these cities tended to have low or negative average height growth and relatively few completions of buildings over 200 meters. Instead, the space to accommodate additional population was presumably added through horizontal intensification.

Regression results confirmed that in high-growth cities, volume growth remained the primary spatial correlate of densification, while height growth and tall building completions were statistically insignificant or negatively associated. This suggests that rapid urban growth in these contexts was managed more through mass delivery of space than symbolic verticality. Informal or unregulated construction practices facilitated speed and affordability at the expense of formal height-based planning.

This raises important questions for policy: in high-growth contexts, enabling midrise and flexible zoning may prove more effective at accommodating density than promoting isolated vertical megaprojects.

5.3. Verticality in Low-Growth Cities

By contrast, low-growth cities were more likely to engage in vertical retrofitting—the strategic introduction of tall buildings to stabilize or modestly expand urban populations in contexts of demographic plateau or decline. This is particularly visible in cities such as Toronto and Vancouver, where redevelopment projects introduce towers in transit-accessible or high-value districts presently covered with inefficient land uses.

In these cities, height growth and 200 m+ building completions were more positively associated with densification, though the effect was modest, particularly in the 200 m+ building class. Regression models for low-growth cities showed that tall building construction could complement infill strategies, particularly when coordinated with infrastructure investments. However, buildings of such height in these contexts can be concentrated in luxury residential communities central business districts and may contribute more positively to iconicity than to population efficiency. In such sprawling low-growth cities, the population increases attributable to a robust economic core—punctuated with tall buildings—are



Figure 4. Box plot of coefficients by high-low growth category across all cities.

diffused throughout the metropolitan area, but the two positively correlate nonetheless.

5.4. Interpretation: Density Without Tall Buildings?

Taken together, these findings challenge the notion that verticality is a universal requirement for urban density. High-growth cities achieve densification primarily through mid-rise volume additions, while low-growth cities adopt vertical forms more selectively and incrementally. The urban form most strongly associated with density is not the individual tall building, but the efficient massing of space per land unit, regardless of height.

Interestingly, there is support for the opposite conclusion: that densification naturally implies upward height growth to some degree, whether through tall buildings or incremental infill. The ordinary least-squares model supports the idea that inherently, densification requires population growth to exceed surface growth and thus, the urban footprint must expand vertically.

Rather than advancing a high-rise paradigm as a default solution, urban designers and policymakers should consider growth context, land markets, regulatory capacity, and cultural preferences when designing for density. The typological variance revealed here suggests a need for tailored approaches to spatial intensification—grounded in data, best practices of comparable cities, and local realities.

6. Implications for Urban Planning and Policy

The findings of this study challenge dominant assumptions about the spatial form of urban density and offer a novel empirical foundation for context-sensitive planning interventions. While tall buildings may be emblematic of urban modernity, they are not universally synonymous with densification. Instead, volume growth of any degree of verticality emerges as the clearest spatial correlate of efficient population absorption.

Urban density is often equated with verticality in policy and development discourse. This research provides strong evidence that, at a broad level, building height is not a reliable predictor of population density, and may, in fact, be negatively associated with densification at the city scale. Verticality must therefore be understood as one variable among many—subject to architectural, infrastructural, and market constraints that may limit its effectiveness in producing livable, efficient urban centres. Urban policymakers should resist the oversimplified logic that "taller is denser" and instead adopt a more pluralistic framework that recognizes the processes through which density is achieved. This includes attention to land-use diversity, parcel-level efficiency, walkability, and the integration of social and environmental infrastructure. As Lefebvre (1991) and Jacobs (1961) both argued in different registers, density is a social and political measure beyond its obvious spatial component.

Mid-rise development emerges from the analysis as a particularly reliable typology for delivering high-density outcomes without the costs, delays, and risks associated with high-rise construction. In many Asian and Latin American cities, densification has occurred through five- to ten-story buildings, often built incrementally, with high plot coverage and integration into existing neighborhoods. These forms are typically faster and cheaper to construct, and can still offer superior energy performance, lower carbon footprints compared to detached homes and other low-density forms (Alexander et al., 2012).

From a land-efficiency standpoint, mid-rise urbanism can achieve densities comparable to high-rise districts when built at scale and paired with supportive transit infrastructure, street-level retail, and social housing provisions. Cities such as Tokyo, Hanoi, and Mexico City exemplify how urban growth can be absorbed through medium-height development without sacrificing spatial efficiency.

6.1. Toward Context-Specific Urban Design Interventions

Perhaps the most salient implication of this research is the importance of contextual planning. Urban density is a negotiated outcome shaped by growth pressures, institutional capacity, land markets, and social norms. The same built form may yield vastly different outcomes depending on its regulatory and infrastructural context.

In high-growth cities, where population pressures are acute and regulatory capacity is often limited, planning interventions should focus on enabling densification of all forms, regardless of vertical considerations. This may include legalizing incremental development, supporting informal upgrading, and revising zoning codes to permit higher plot coverage and mid-rise intensification. In low-growth cities, vertical development may well be appropriate in targeted locations—particularly near transit nodes, brownfields, or ageing commercial corridors in need of revitalization. But even here, tall building construction should be given proper scrutiny regarding affordability, occupancy, and spatial integration.

For example, in Jakarta, mid-rise infill projects have demonstrated the ability to accommodate significant population growth without relying on iconic tall towers. In contrast, in Toronto, targeted tall building development along transit corridors have been coordinated with affordable housing incentives, demonstrating how verticality can play a complementary role in otherwise low-growth contexts. Targeted tall building development can be a powerful tool in enabling high density without compromising efficiency but requires intentional planning that low-growth cities may be better equipped to accommodate.

Rather than advocating a singular model, planners should work toward density regimes that are socially equitable, economically feasible, and environmentally resilient, with the tall building treated as a tool and not an umbrella solution. This requires questioning the vertical determinism that equates height with successful, efficient density, and embracing a broader spectrum of spatial strategies rooted in local contexts and data-informed outcomes.

7. Conclusion

7.1. Summary of Key Findings

This study analyzed the relationship between population growth, built-up surface expansion, volumetric construction, and vertical development across a global sample of 524 cities from 1975 to 2025. The results demonstrate that built volume, not building height, is the spatial metric most closely aligned with population growth. While citywide building height growth is statistically significant, it is negatively correlated with densification, suggesting that tall buildings on their own do not, on average, facilitate more efficient population absorption. Instead, volumetric growth emerges as the strongest positive predictor of densification, regardless of whether it occurs through mid-rise or high-rise construction. This finding holds across multiple regions and growth typologies and is robust to the inclusion of a tall building completions variable. Cities that densify effectively do so not by reaching ever taller, but by building more useable space per unit of land.

7.2. Contributions to the Density Debate

This provides a global, longitudinal, and empirical basis for rethinking urban form, which could support reframing the predominant narrative around verticality and underscores the importance of regional context in shaping density outcomes. This review also provides a new empirical foundation for reevaluating the role of tall buildings in the global planning discourse. The results broadly reposition the debate away from a narrow focus on tall buildings as isolated interventions and toward a broader understanding of how density is materially produced across geographies and time.

7.3. Future Research Directions

Several avenues for future inquiry emerge from this work. Incorporating household size and occupancy data could improve estimates of actual population accommodation, rather than built capacity alone. Integrating zoning regimes, land values, and regulatory typologies could help explain why similar cities adopt different densification strategies.

Additionally, expanding the analysis to include transit infrastructure, commute times, and job accessibility would allow for stronger inferences about the interaction between urban form population distribution. Advances in remote sensing, open-source building data, and 3D modelling may also allow for more accurate assessments of vertical form and its internal composition (e.g., subgrouping building height profiles by function at sub-200 meters). A more granular typology of building massing would also enhance explanatory depth and avoid the generalization of building height provided by the proxy measure in this work. This work evaluates the coarse urbanism organism, but a finer dataset could draw stronger connections between building height relative to immediate contexts (e.g., 200 m+ building projects' effects on a study neighborhood).

Comparative case studies of outlier cities may reveal institutional or morphological features that merit replication elsewhere. Importantly, cities that have effectively led their densification strategy based on taller buildings may provide a yet-undefined roadmap for high-growth cities to replicate. Densification is not a singular act of building taller; it is a continuous negotiation of space, infrastructure, and social need. Planners and policymakers can work to

build cities that are denser by developing a deeper understanding of these metrics and stratifying them at more hyperlocal and finite temporal scales.

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