From Pixels to Policy: Decoding urban morphology and policy influences

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Abstract

Urban planning effectiveness has traditionally been assessed using metrics such as population density, land use mix, and transportation efficiency. However, these measures often fail to capture the full complexity of urban form and its impact on sustainability, livability, and economic vitality. This paper proposes a novel approach to evaluating urban planning effectiveness by measuring the vertical height of cities. Drawing upon principles of urban morphology, spatial analysis, and building typology, we develop a framework for quantifying vertical urban density and assessing its implications for urban development. Through case studies and comparative analyses, we illustrate how vertical height can offer valuable insights into the effectiveness of urban planning strategies. Furthermore, we emphasize the pivotal role of planning policy in shaping urban morphology both vertically and horizontally. Our findings underscore the importance of integrating vertical dimensionality into planning evaluations to achieve a more comprehensive understanding of urban form and its dynamics.

Key words:
Urban development; Vertical expansion; Urbanization; Urban growth

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1. Introduction

Urbanization is reshaping the global landscape, with more people living in cities than ever before (UN-DESA, 2019). As urban populations continue to grow, the demand for efficient, sustainable, and livable urban environments becomes increasingly urgent (Sun et al., 2020; Pandey et al., 2022). Urban planning plays a crucial role in shaping the form and function of cities, influencing everything from transportation networks to housing affordability (Bibri et al., 2020; Lall et al., 2021). Traditionally, the effectiveness of urban planning has been evaluated using metrics such as population density, land use mix, and transportation efficiency (Heath et al., 2006; Long et al., 2015). While these measures offer valuable insights, they frequently neglect the vertical dimension of urban development, which serves as a crucial indicator of urban economic activity and productivity (Zhu et al., 2019; Lall et al., 2021).

Understanding the impact of planning policies and regulations on urban morphology and development patterns is crucial for fostering sustainable and inclusive urban development. The interactions among planning policies, regulations, and urban development constitute a complex and multifaceted dynamic involving diverse stakeholders and interrelationships (Lindholm & Behrends, 2012). Urban planning policy plays a crucial role in shaping urban development and fostering sustainable cities. It not only shapes the form of urban environments but also influences the activities within those spaces (Davies & Atkinson, 2012).

The relationship between planning policy, regulations, and their impact on urban morphology and development patterns has been explored in different dimensions. Tannier and Thomas (2013) discovered that the connection between urban boundary shape and built morphology within urban agglomerations is nuanced, indicating the distinct combination of morphological features in each city. Milojević et al. (2019) concentrated on street morphology in relation to open blocks, underscoring the role of urban planning in shaping the cityscape's urban form. Ronchi et al. (2018) underscored the significance of spatially assessing urban morphology for urban policy and landscape planning. Wu et al.

(2010) conducted scenario analyses, demonstrating that various policies influence urban growth patterns and sustainability. Additionally, Xiao et al. (2021) stressed that a deeper understanding of urban morphology serves as a valuable reference for urban planning, thereby enhancing sustainability.

While numerous attempts have been made to better comprehend the relationship between urban morphology and policies, it is crucial to acknowledge that without proper consideration of vertical heights and floor areas, such assessments remain incomplete. Urban morphology encompasses not only the horizontal layout and spatial arrangement of urban elements but also vertical dimensions and the distribution of building volumes within the urban fabric. Neglecting these vertical aspects can result in overlooking significant influences on urban form, density, and functionality. Therefore, a comprehensive understanding of urban morphology requires an integrated examination that includes horizontal and vertical dimensions to capture the full complexity of urban spaces and their interactions with policy interventions.

This study examines the complex dynamics of planning policies and regulations and their impact on urban morphology and development patterns. Given the rapid pace of urbanization and the evolving requirements of diverse communities, understanding the effectiveness and repercussions of planning policies has become essential for fostering sustainable and inclusive urban development. The central research question guiding this investigation is: "To what extent do planning policy and regulations shape urban morphology and development patterns?"

2. Methods

To deepen our understanding of urban spatial organization through a standardized metric, this paper utilizes the recently introduced Global 3D Built Environment Data, denoted as WSF 3D. Representing a pioneering and globally consistent compilation, this dataset meticulously characterizes the three-dimensional morphology and density of building stocks within human settlements across the

world (Esch et al., 2022). Integrating this dataset with city-level policy survey (Angel et al., 2012) and socio-economic profiles from the Urban Center Database (Florczyk et al., 2019), the study explores the influence of zoning regulations, land-use policies, density requirements, and other planning tools on the spatial organization of cities.

This study focuses on 168 cities with a population exceeding 200,000 in 2015, leveraging data availability from Angel et al. (2012), WSF-3D, and GHS-UCDB. The selected cities span various regions, including East Asia & Pacific (53 cities), Europe & Central Asia (26 cities), Latin America & Caribbean (20 cities), Middle East & North Africa (12 cities), North America (17 cities), South Asia (24 cities), and Sub-Saharan Africa (16 cities). Additionally, the cities encompass a range of income levels, with 46 classified as high income, 10 as low income, 48 as lower middle income, and 64 as upper middle income. This diverse selection ensures representation across different geographical regions and economic contexts, facilitating a comprehensive analysis of urban spatial organization and its relationship with planning policies and regulations.

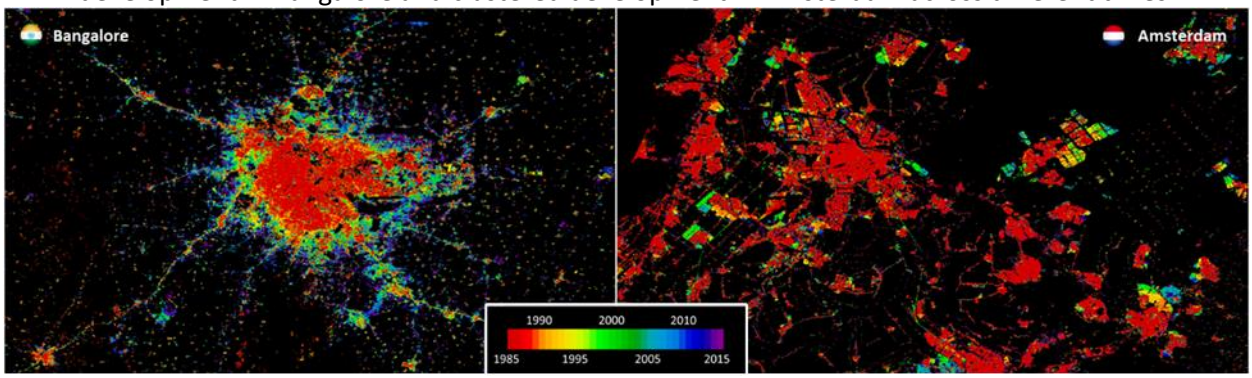
Adopting a comprehensive and interdisciplinary approach, this investigation integrates urban planning and spatial analytics, capitalizing on an innovative dataset derived from satellite imagery as the foundational basis for analysis. This dataset offers a unique opportunity to comprehensively understand and quantify urban morphology, providing a spatially explicit lens to scrutinize the impact of planning policies on the physical form of urban areas.

3. Results

The urban-built-up layer serves as a revealing lens, capturing the evolving landscape of the cities (Fig 1). For example, in Bangalore, a sprawling and fragmented urban form unfolds over time, characterized by dispersed development—unplanned expansion. In stark contrast, Amsterdam displays a more clustered and concentrated urban evolution, with a discernible pattern of development that

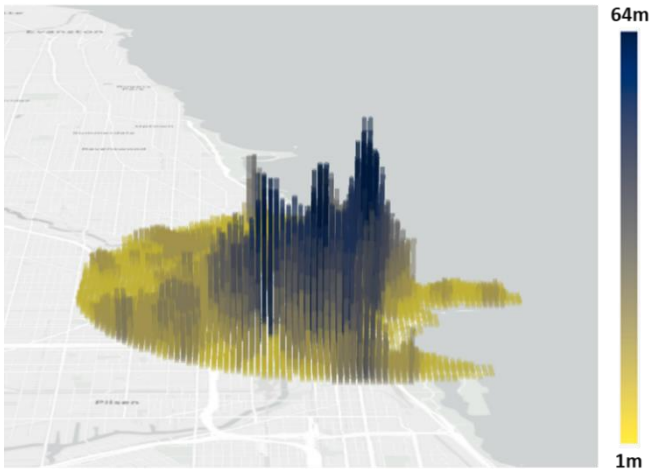
gravitates towards clustered cores. The urban-built-up layer unveils the distinctive signatures of urbanization, offering insights into how these cities have navigated and shaped their growth trajectories across diverse temporal contexts.

Figure 1. Comparing different patterns of urbanization, highlighting sprawled and fragment development in Bangalore and clustered development in Amsterdam across different times.



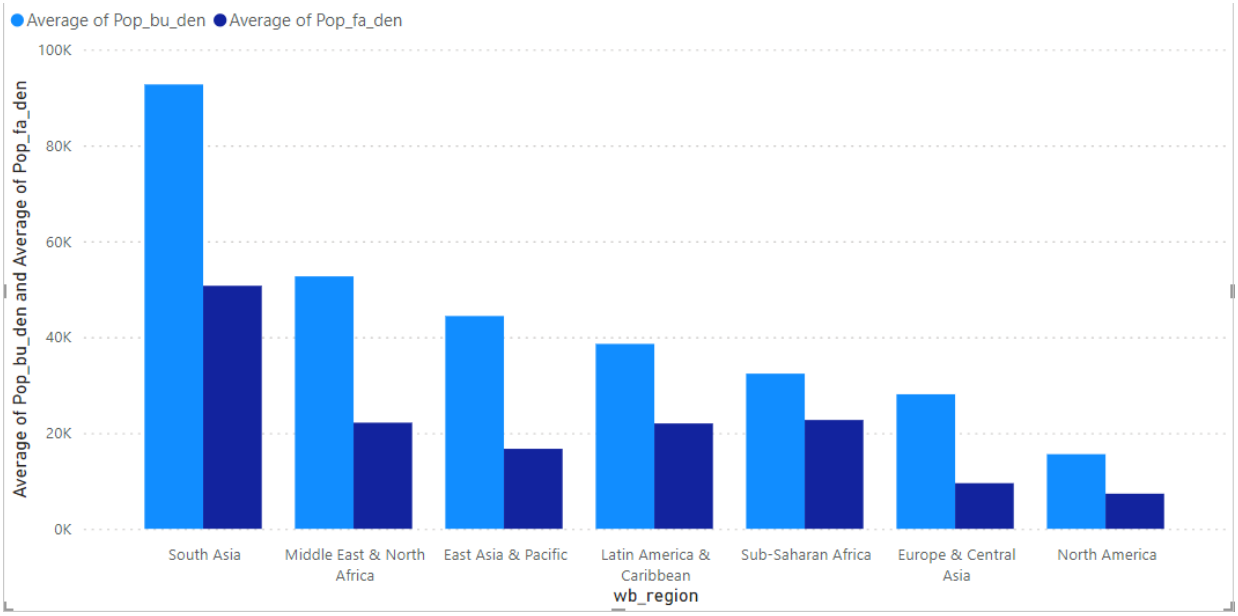
In addition to the traditional built-up later retrieved from remote sensing imagery, examining built-up volume and height data is crucial for gaining a nuanced understanding of population density and assessing the quality of "livable" space within urban environments. Built-up volume refers to the three-dimensional space occupied by structures, encompassing not only the ground area but also the vertical dimension (Fig 2). This metric is particularly insightful as it reflects the overall spatial efficiency and intensity of development in a given area.

Figure 2. Average building height in Chicago, USA using WSF 3D, retrieved from Lall et al. (2021)



Utilizing the vertical height profile of cities, it becomes imperative to integrate the concept of floor areas into the analysis. This approach enables the calculation of population density per unit of floor area, providing a more refined understanding of urban density patterns. By incorporating floor areas alongside vertical height, researchers can effectively evaluate how space is utilized within urban environments, not only based on the built-up areas. As depicted in Figure 3, the population density based on built-up areas and population density based on floor areas exhibits striking differences in both global ranking and sheer density.

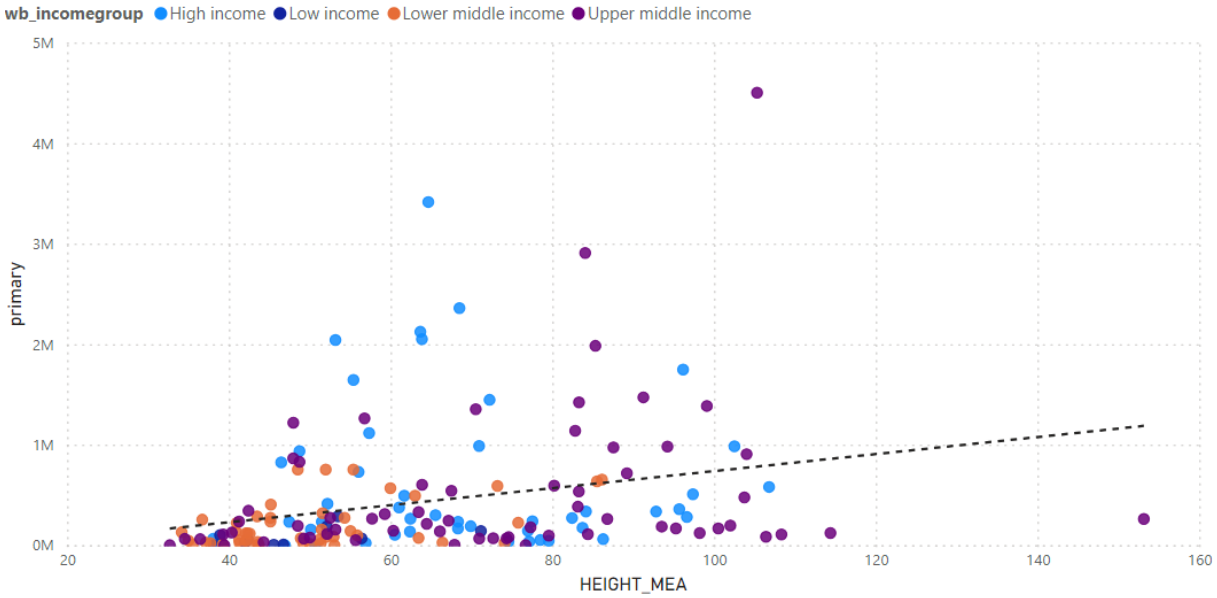
Figure 3. Population density based on built-up areas and floor areas.



Vertical height serves as a valuable indicator of the level of infrastructure development, as higher urban fabric is only sustainable with adequate infrastructure provision. Figure 4 illustrates a positive correlation between the average height of cities and the total length of primary roads, as calculated from OpenStreetMap data. This correlation underscores the notion that taller urban structures tend to coincide with more extensive primary road networks, suggesting a relationship between vertical growth and infrastructure expansion. Thus, by analyzing vertical height alongside

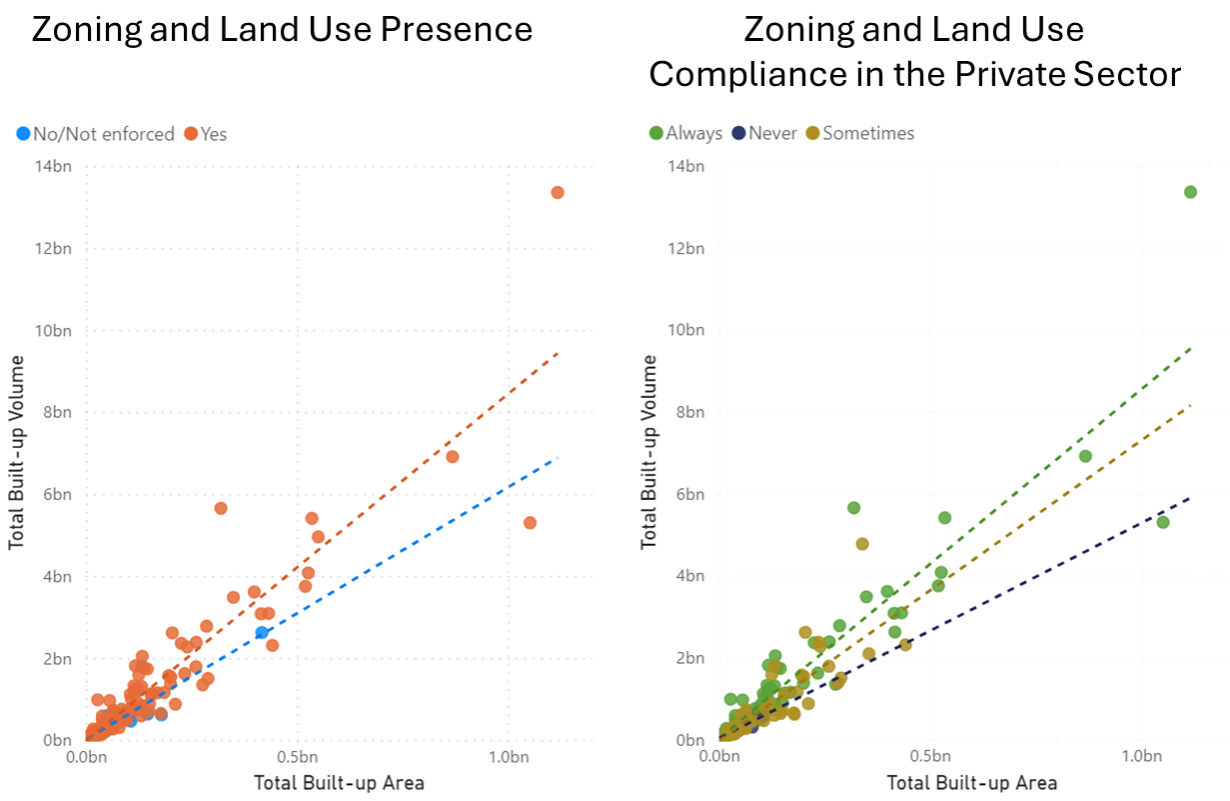
infrastructure metrics, planners can gain insights into the adequacy of infrastructure provisions within urban areas, aiding in the formulation of effective development strategies.

Figure 4. Average vertical height of cities and total length of primary roads.



Integrating the innovative dataset with planning regulations provides novel insights into the intricate interplay between urban morphology and the regulatory framework. This analysis illuminates the ways in which planning regulations shape the physical characteristics of urban spaces. Specifically, we investigate the influence of zoning laws and land use plans, assessing their effectiveness and the degree to which they are adhered to in promoting built-up volume and vertical height. Our findings indicate that cities that rigorously adhere to zoning and land use regulations tend to exhibit greater built-up volume and corresponding height, even when total built-up areas are comparable. Moreover, a significant correlation emerges, demonstrating that higher levels of zoning compliance are associated with increased volume and heights within urban structures, as depicted in Figure 5. These findings underscore the importance of planning regulations in shaping the built environment and highlight the potential for targeted regulatory interventions to influence urban morphology in desired directions.

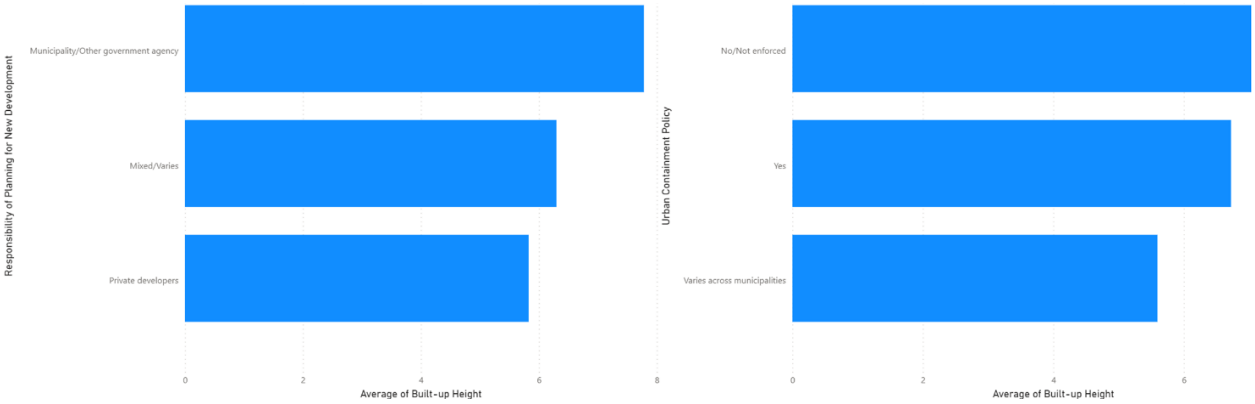
Figure 5. Zoning and Land Use Presence (left) and its compliance by the private sector (right)



Further assessment is undertaken to deepen our understanding of institutional roles and specific policies that facilitate vertical layering within urban environments. This examination allows for a detailed scrutiny of the various stages involved in the transition of land to urban use, delving into the responsibilities of entities tasked with designing street layouts and subdividing land into plots, as depicted in Figure 6 (left). The findings underscore the pivotal role of municipal authorities in ensuring the realization of dense and efficient urban development practices, suggesting that effective institutional management is essential for enhancing efficient land use. Moreover, the analysis unveils the ineffectiveness of urban containment policies in promoting efficient urban land use, as illustrated in Figure 6 (right), highlighting a disconnect between such policies and their ability to improve vertical layering within urban areas. These findings emphasize the importance of refining urban policies to

better align with the goals of vertical layering and efficient land use, thus contributing to the sustainable development of urban spaces.

Figure 6. Average built-up height of cities upon planning and regulatory framework.



4. Discussion

4.1. Vertical dimension of urban development

The incorporation of the vertical dimension as a new indicator to assess urban morphology and structure represents a significant advancement in urban planning and research. Traditionally, assessments of urban form have predominantly focused on horizontal spatial arrangements, such as land use mix and street layout. However, by introducing the vertical dimension, we gain a more comprehensive understanding of urban spaces and their utilization. Vertical indicators, such as building height and floor area ratio, provide valuable insights into the intensity of land use, population density, and the efficiency of urban development. Moreover, considering the vertical dimension allows for a more nuanced analysis of urban density patterns, infrastructure provision, and the relationship between built form and environmental sustainability. By recognizing the importance of the vertical dimension in urban assessments, planners and policymakers can make more informed decisions to promote sustainable, resilient, and livable cities.

4.2. Impact of Planning Policies on Urban Morphology

The findings from our analysis highlight the significant impact of planning policies on shaping the physical form of urban spaces. By examining the dynamic interplay between zoning regulations, land use plans, and their levels of compliance, we have elucidated how these policies influence the built-up volume, height, and overall development patterns within cities. This underscores the critical role that effective planning strategies play in sculpting urban morphology and underscores the importance of aligning policy objectives with the goals of sustainable and efficient urban development.

4.3. Institutional Roles and Policy Effectiveness

Our examination of institutional roles and specific policies enhancing vertical layering has provided valuable insights into the mechanisms through which urban development is guided. We found that municipal authorities play a pivotal role in ensuring dense and efficient urban development, underscoring the importance of effective institutional management in promoting efficient land use. Additionally, our analysis revealed the limitations of urban containment policies in improving vertical layering within urban areas, highlighting the need for policy refinement to better align with the objectives of efficient urban land use.

5. Conclusions

The utilization of innovative data and methodologies to assess the impact of planning policies and regulatory frameworks has played a crucial role in unraveling the intricacies of urban morphology. The empirical evidence garnered from these analyses underscores the pivotal importance of effective planning policies in sculpting the physical structure of urban spaces. By closely examining the dynamic interplay between zoning regulations, land use plans, and their compliance levels, these insights emphasize the necessity for thoughtful and well-crafted planning strategies.

The capacity to quantify and visualize the influence of planning policies on built-up volume, height, and overall urban development establishes a tangible foundation for advocating and implementing sound planning practices. This empirical evidence not only informs ongoing discussions on urban development but also serves as a compelling call to prioritize and refine planning policies, ultimately contributing to the creation of sustainable, livable, and resilient cities.

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