GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 14, n. 91, 2026

Urban Density: assessment of the built stock and its potential

Lina Corrêa
Master's Degree in Architecture and Urbanism - PPGAU/UFF, Brazil
linacorrea@id.uff.br
ORCID iD https://orcid.org/0000-0002-5984-5708

Felix Carriello
Professor, PhD in Geography - PPGAU/UFF, Brazil
felixcarriello@id.uff.br
ORCID iD https://orcid.org/0000-0001-6436-1671

Rubens M. R. Carvalho
Professor, PhD in Architecture and Urbanism - PPGAU/UFF, Brazil
rubens_carvalho@id.uff.br
ORCID iD https://orcid.org/0000-0002-0352-4622

Submissão: 12/09/2025
Aceite 17/11/2025
CORRÊA, Lina; CARRIELLO , Felix; CARVALHO , Rubens M. R. Densidade Urbana: avaliação do estoque construído e seus potenciais. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 14, n. 91, p. e2525, 2026.
DOI: 10.17271/23188472149120266208. Disponível em: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/6208

GC Revista Nacional de Gerenciamento de Cidades
National Journal of City Management

ISSN 2318-8472, v. 14, n. 91, 2026

Densidade Urbana: avaliação do estoque construído e seus potenciais

RESUMO

Objetivo – Análise da Densidade Urbana, avaliando a capacidade de atendimento às necessidades habitacionais em áreas urbanizadas, sem expansão, para a preservação de ambientes naturais.

Metodologia – Avaliação de medidas variadas da Densidade Urbana, com o mapeamento de dados populacionais (IBGE, 2010) e das áreas construídas das edificações existentes (Data Rio/IPP/2013), sobre área urbanizada do Rio de Janeiro (IBGE, 2015). A partir desta análise, foram feitas projeções de adensamento.

Originalidade/relevância – Os debates sobre a intensificação no uso de áreas urbanizadas, objetivando a redução da expansão urbana e das emissões de gases de efeito estufa (GEE), ganharam força com a urgência da crise climática. A relevância deste artigo está no desdobramento de uma metodologia de avaliação da Densidade, para o desenvolvimento de projeções de adensamento, pouco empregadas em pesquisas científicas.

Resultados – As projeções de adensamento resultaram em um potencial para alocação de mais 300.000 unidades habitacionais, cerca de 50% do conjunto total das necessidades e futuras demandas por moradia da cidade, em uma área correspondente a 5% de seu território; demonstrando que ambientes urbanizados podem receber incrementos demográficos, contribuindo para redução da expansão urbana.

Contribuições teóricas/metodológicas – A exploração de cenários possíveis, resultantes do método de projeções de adensamento, tem importante contribuição para estratégias do Planejamento Urbano de combate a causas das mudanças climáticas.

Contribuições sociais e ambientais - O conhecimento sobre o território das cidades, através da análise da Densidade e das projeções de adensamento, pode indicar caminhos para a gestão urbana, com instrumentos do Planejamento que direcionem o atendimento às necessidades habitacionais, nos espaços existentes, com maior igualdade social e preservação ambiental.

PALAVRAS-CHAVE: Densidade Urbana. Déficit Habitacional. Expansão Urbana.

Urban Density: assessment of the built stock and its potential

ABSTRACT

Objective – Analysis of Urban Density, assessing the capacity to meet housing needs in urbanized areas, without expansion, for the preservation of natural environments.

Methodology – Evaluation of various measures of Urban Density, mapping population data (IBGE, 2010) and existing built areas (Data Rio/IPP/2013), over the urbanized area of Rio de Janeiro (IBGE, 2015). Based on this analysis, densification projections were made.

Originality/Relevance – Discussions about intensifying the use of urbanized areas, aiming to reduce urban expansion and greenhouse gas emissions (GHG), have gained momentum with the urgency of the climate crisis. The relevance of this article lies in the development of a methodology for Density assessment, unfolding into densification projections, which are rarely employed in scientific research.

Results – Densification projections resulted in a potential for allocating additional 300,000 housing units, approximately 50% of the total needs and future demands for housing in the city, in an area corresponding to 5% of its territory; demonstrating that urbanized environments can accommodate demographic increases, contributing to the reduction of urban expansion.

Theoretical/Methodological Contributions – The exploration of possible scenarios, resulting from the density projection method, has an important contribution to Urban Planning strategies to combat the causes of climate change.

Social and Environmental Contributions – Knowledge about the urban territory, through the analysis of Density and densification projections, can indicate pathways for urban management, with Planning tools that guide the meeting of housing needs in existing spaces, with greater social equality and environmental preservation.

KEYWORDS: Urban Density. Housing Deficit. Urban Expansion.

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National Journal of City Management

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Densidad urbana: evaluación del parque edificado y su potencial

RESUMEN

Objetivo – Análisis de la Densidad Urbana, evaluando la capacidad de atender las necesidades habitacionales en áreas urbanizadas, sin expansión, para la preservación de los entornos naturales.

Metodología – Evaluación de diversas medidas de la Densidad Urbana, con el mapeo de datos poblacionales (IBGE, 2010) y de las áreas construidas de los edificios existentes (Data Rio/IPP/2013), sobre el área urbanizada de R io de Janeiro (IBGE, 2015). A partir de este análisis, se realizaron proyecciones de densificación.

Originalidad/Relevancia – Los debates sobre la intensificación en el uso de áreas urbanizadas, con el objetivo de reducir la expansión urbana y las emisiones de gases de efecto invernadero (GEI), han ganado fuerza con la urgencia de la crisis climática. La relevancia de este artículo radica en el desarrollo de una metodología de evaluación de la Densidad, en proyecciones de densificación, poco empleadas en investigaciones científicas.

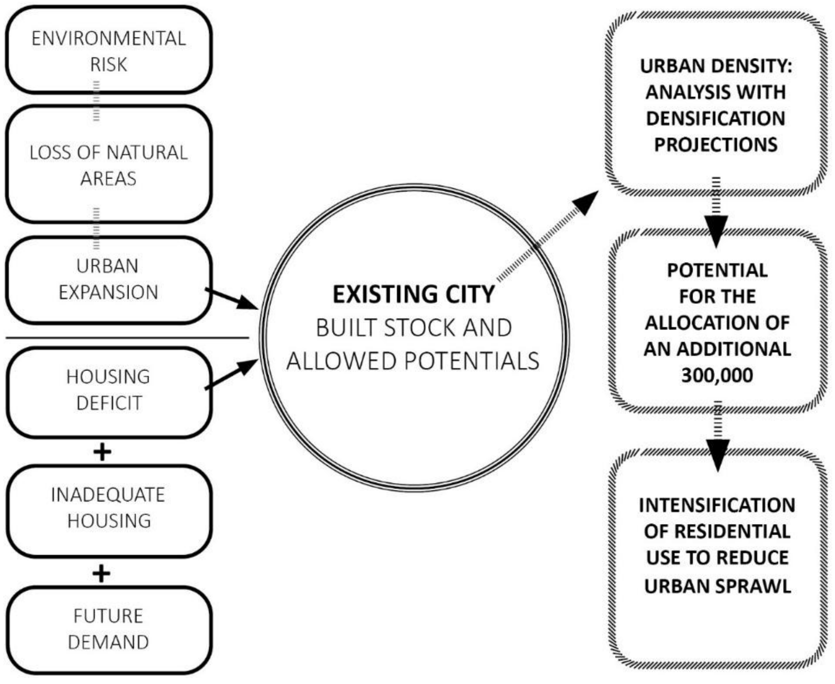
Resultados – Las proyecciones de densificación resultaron en un potencial para la asignación de más de 300,000 unidades habitacionales, cerca del 50% del total de las necesidades y futuras demandas de vivienda de la ciudad, en un área correspondiente al 5% de su territorio; demostrando que los ambientes urbanizados pueden recibir incrementos demográficos, contribuyendo a la reducción de la expansión urbana.

Contribuciones teóricas/metodológicas – La exploración de escenarios posibles, resultantes del método de proyecciones de densificación, tiene un importante aporte a las estrategias de Planificación Urbana para combatir las causas del cambio climático.

Contribuciones sociales y ambientales – El conocimiento sobre el territorio de las ciudades, a través del análisis de la Densidad y de las proyecciones de densificación, puede indicar caminos para la gestión urbana, con instrumentos de Planificación que orienten la atención a las necesidades habitacionales, en los espacios existentes, con mayor igualdad social y preservación ambiental.

PALABRAS CLAVE: Densidad Urbana. Déficit Habitacional. Expansión Urbana.

GRAPHIC SUMMARY



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1 INTRODUCTION

This article summarizes the results of a master's research whose main objective was to analyze Urban Density, assessing the capacity to meet housing needs within already urbanized areas—without further expansion—in order to preserve natural environments. The study aimed to contribute to the debates on Urban Density as an analytical tool for guiding Urban Planning, focusing on the city of Rio de Janeiro, where social inequality and housing shortages are clearly visible in the territory (Corrêa, 2023).

Urban Density represents the relationship between a statistical indicator—population, housing, jobs, among others—and a delimited area, which can be a block, a neighborhood, a city, a region, a country, etc. (Merlin & Choay, 2015). There are no standardized measures of density, but some are widely used, such as: demographic or population density, expressed in inhabitants per unit of area; housing density, expressed in housing units per unit of area; and built density, which indicates the total built-up area per unit of surface. The most common surface unit is the hectare, equal to 10,000 m².

Population and housing densities can be gross or net: the former considers the entire area of the settlement, including streets, public spaces, and other uses, while the latter includes only lots reserved for residential use. Density measures are an important reference for guiding decisions regarding the expansion of urbanized areas or the intensification of urban land use, influencing infrastructure costs and the provision of public and private services (Acioly & Davidson, 1998).

Throughout the history of cities, Urban Density has at times been used to indicate problems and at other times to prescribe ideal concentrations. Its conscious use, however, as a tool of urban planning, began in the second half of the 19th century as a response to the economic and demographic growth of industrialized cities, where population concentration was seen as the cause of fires, diseases, and social disorder (Pont & Haupt, 2009). From the 1960s onward, however, criticisms of the modernist model and the impacts of low-density urban expansion became consolidated, and the potential benefits of urban concentration began to be publicized.

Jane Jacobs, in her book The Death and Life of Great American Cities, published in 1961, defined high residential density as one of the necessary conditions for the flourishing of urban life. Other authors, like Jacobs, highlighted the vitality and diversity achieved in dense urban environments, as well as the need to increase density in already urbanized areas to reduce city expansion (Jacobs, 2000; Rogers, 2001; Acioly & Davidson, 1998; Cheng, 2010; Chakrabarti, 2013). High and low densities, however, lack precise definitions, varying according to cultural and social contexts and factors such as the form and use of urban space (Acioly & Davidson, 1998; Cheng, 2010).

Discussions on Density within the field of Urban Planning have been ongoing for more than a century, but debates about intensifying the use of urbanized areas—with the aim of reducing urban expansion and greenhouse gas emissions (GHG)—have gained momentum in recent decades amid the urgency of the climate crisis. Urban expansion over natural surroundings poses environmental risks, considering that climate change and the increase in global temperature are strongly linked to biodiversity loss, observed in nearly all ecosystems

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and caused mainly by land-use changes, largely driven by agriculture and urbanization (IPBES, 2019). According to the IPCC (Intergovernmental Panel on Climate Change), ensuring livable environments for all in the future requires limiting global warming. Therefore, it is essential to conserve and restore natural forests, as well as reduce carbon dioxide (CO_2) emissions (IPCC, 2022).

Currently, cities concentrate more than half of the world's growing population, and by 2050, according to a United Nations (UN, 2019) report, they are expected to house 68% of the global population—about 6.7 billion people—absorbing all the world's population growth. In general, cities are expanding twice as fast as their population growth rates. Larger urban land areas result in higher CO_2 emissions, contributing to the worsening of the greenhouse effect (Angel et al., 2011).

In Brazil, 85% of the population lives in urban areas (IBGE/PNAD, 2015), where expansion is often driven by the creation of new areas for real estate investment, supported by the State (Maricato, 2017). Maia, Lage, and Leonelli (2019) observed the transformation of rural areas into urban ones, promoted by the private real estate market with public-sector support, in the municipality of São José do Rio Preto, in São Paulo. The study demonstrates the formation of a dispersed and fragmented territory, with the urban perimeter expanding to accommodate new subdivisions in response to market demand. The expansion of cities increases distances, making it nearly impossible to provide quality urban services throughout the territory.

Housing deficit and inadequacy amount to approximately 30 million urban households in the country, predominantly affecting the poorest populations, whose monthly income is limited to up to three minimum wages (FJP, 2020, 2021). This income range is the least served by public housing programs and ignored by the real estate market. With no alternatives, this large segment of the population is forced to self-build their homes in areas of no value to the formal market—far from city centers, lacking infrastructure, or in environmentally fragile zones such as hillside slopes, where settlements are at risk (Maricato, 2017). It is important to note that housing deficit and inadequacy calculations do not consider future housing demand, which is based on demographic projections, housing supply, and the economy. It is estimated that approximately 13 million new urban housing units will be needed between 2023 and 2040 (UFF, 2018).

The promotion of Social Housing (HIS, which stands for "Habitação de Interesse Social" in Portuguese) predominantly occurs in areas distant from urban centers in Brazil, as verified in a study on the city of Londrina, Paraná. According to the analysis, the legislation for implementing the municipal Master Plan, approved in 2022, perpetuates the model of spatial segregation by reserving peripheral locations for HIS (Bertini et al., 2024). In Brazil, the densification of urbanized areas equipped with infrastructure should aim to serve the portion of the population associated with most housing shortages, contributing to the reduction of urban expansion linked to the exclusion of the poor.

Densifying urban environments alone cannot solve issues such as housing deficits or urban sprawl. However, analyzing density can guide efforts to meet housing needs within existing spaces, contributing to the efficient use of land and infrastructure, with greater social equity, while preserving natural environments.

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2 OBJECTIVES

The main objective of this study was to assess the capacity to meet housing needs in urbanized areas of the city of Rio de Janeiro. This city was chosen as the place of interest due to its history of urban expansion and the size of its territory, which creates difficulties in providing infrastructure across its entire extent and results in long daily commutes for its residents, especially for home–work–home trips. Rio de Janeiro represents a central hub both at the metropolitan and national scales. In addition to being the second most populous city in the country, it served as the capital of the colony during the Gold Cycle in Minas Gerais, the seat of the Empire after Brazil's independence, and the capital of the Republic following its proclamation. The analyses focused on a Study Area corresponding to 12% of the city's urbanized territory, centrally located and comprising 26 neighborhoods with a good supply of jobs, services, and infrastructure, including mass transit networks.

Two complementary objectives were defined in pursuit of the main goal. The first, based on the analysis of the Study Area, aimed to assess the balance between population and built densities, examining the extent to which urban spaces are being utilized. This assessment was guided by studies on the relationship between density and urbanization costs, whose results indicated a strong correlation between increases in urban density and reductions in the per-user cost of building and maintaining urban networks and services (Mascaró, 1979; Rodrigues Da Silva, 1990; Pushkarev & Zupan, 1980).

The second objective was to estimate the capacity to absorb new residents in specific regions delineated within the Study Area. These regions were designated as Subareas of Study and together represent 5% of the city's urbanized surface. Densification projections were conducted in two stages: the first calculated how many housing units could be implemented within the existing built stock, and the second assumed the partial renewal of that stock, considering local zoning restrictions and the construction potentials outlined in Complementary Bill 44/2021[1], which was under review in the Rio de Janeiro City Council at the time of the research.

The projections indicated a capacity for the allocation of 300,000 additional residential units, approximately 50% of the total housing deficit combined with the inadequacy of existing dwellings (FJP, 2013) and future housing demand in the municipality (UFF, 2018). This demonstrates that urbanized, and often densely built, environments can accommodate demographic increases. This can be beneficial not only to meet current shortages and future demands but also to bring vitality and diversity to underused or seasonally occupied areas, while preserving the natural surroundings of cities, as mentioned above.

3 METHODOLOGY

[1] RIO DE JANEIRO. **Complementary Bill No. 44/2021.** Provides for the urban and environmental policy of the municipality, establishes the review process of the Sustainable Urban Development Master Plan of the City of Rio de Janeiro, and makes other provisions. Rio de Janeiro, RJ: Municipality of Rio de Janeiro, [2021]. Available at: https://planodiretor-pcrj.hub.arcgis.com/documents/projeto-de-lei-complementar-n%C2%BA-44-2021-revis%C3%A3o-do-plano-diretor/explore. Accessed on: 13 October 2022.

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The main research method involved mapping population data from the 2010 Census (IBGE), using the 2015 urbanized area base of Rio de Janeiro (IBGE), information on buildings (Data Rio/IPP) obtained from files resulting from the restitution of 2013 satellite images, as well as the zoning proposed in Complementary Bill 44/2021. At the time the research was conducted, these were the most recent available datasets. However, after the defense of the master's dissertation, the 2022 Census and the revision of the Master Plan (Complementary Law No. 270 of January 16, 2024[2]) were published. Nevertheless, the relevance of this work should be considered, given the significance of the results obtained. Furthermore, the methodology developed can be applied and updated in future research, serving as a reference for scientific production in the field of Architecture and Urban Planning.

The Study Area (Map 01) of this research was delineated based on two main works. One was produced by the Municipality of Rio de Janeiro and included an analysis of the municipal territory, mapping built and population densities (Rio de Janeiro, SMU, 2016). The other was the "Access to Opportunities" Project, developed by the Institute for Applied Economic Research (IPEA), which generated estimates on access to jobs, schools, healthcare services, and Social Assistance Reference Centers (CRAS) in the twenty largest urban centers in Brazil (Pereira et al., 2020).

Map 01 – Delimitation of the study area over the municipal boundary, subdivided into Planning Areas (Rio de Janeiro, IPP, 2018) and Google Satellite imagery.

Source: Authors' elaboration based on data from Data Rio/IPP (2018) and Google imagery.

The Study Area includes neighborhoods located in the central and the northern zones of the city—regions with the highest concentration of services and employment opportunities, good infrastructure provision, and high built densities compared with the city as a whole. Therefore, the potential of the existing built stock in these regions deserves particular attention.

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[2] RIO DE JANEIRO. **Complementary Law No. 270 of January 16, 2024**. Provides for the Urban and Environmental Policy of the Municipality, establishes the review process of the Sustainable Urban Development Master Plan of the City of Rio de Janeiro, and makes other provisions. Rio de Janeiro: Municipality of Rio de Janeiro [2024].

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Population and built density measurements were spatialized through the production of maps using QGIS, a free and open-source geoprocessing software. This software is one of the platforms of Geographic Information Systems (GIS), computational tools that create georeferenced databases structured in layers (Francisco, 2014). At this stage, the Study Area—equivalent to 7,158 hectares and comprising 26 neighborhoods—was divided into two parts, Areas 001 and 002, in order to reduce the amount of data being geo-processed simultaneously.

Map 02 – Delimitation of Areas 001 and 002 on Google Satellite Imagery.

Source: Authors' elaboration based on data from the IBGE census sector grid (2010) and Google imagery.

3.1 Cell-based Density

The method employed for analyzing Urban Density in the Study Area—divided into Areas 001 and 002—used a rectangular grid with cells measuring 100 (one hundred) meters by 100 (one hundred) meters, equivalent to 1 (one) hectare (ha). Data on the total built-up areas of buildings and the number of inhabitants from census sectors were aggregated into this rectangular grid, generating density grids by cell matrix.

Each density map was produced with three classes, whose values were established based on research addressing the efficient and economic use of urban infrastructure. Among these are: Mascaró's habilitation thesis (1979), in which the author found a drastic reduction in

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the average cost of urban networks[3] per dwelling as density increased, and Rodrigues da Silva's dissertation (1990), which analyzed the influence of population density on motorized public passenger transport (buses) in medium-sized hypothetical cities. The latter concluded that increasing densities to around 300 inhabitants per hectare (ha) would significantly reduce public transport costs.

In addition, Chakrabarti's research (2013), drawing on Pushkarev and Zupan (1980), indicates the need for a minimum housing density of 75 dwellings per hectare to ensure the economic viability of rapid mass transit systems such as subways. The study by Pushkarev and Zupan examined various rail-based transport modes, considering their operational performance. According to the authors, since most of the costs of a rail line are fixed, when travel volume is low, the cost per service unit tends to increase, considering factors such as passenger waiting time, labor, energy consumption, land, and capital investment (Pushkarev & Zupan, 1980).

According to the studies, 300 inhabitants per hectare represents a gross population density threshold above which urban infrastructure becomes economically viable at lower per capita costs. Based on this reference, value ranges were defined for low, medium, and high population densities, which were then converted into corresponding ranges of built density values (Table 01).

Table 01 – Density classes. Value ranges of population and built densities as conceptualized in this research.

Population density	Built density	Concept	Justification
Up to 100 inhabitants/ha	Up to 2,800 m²/ha	Low density	Costly infrastructure
Above 100 inhabitants/ha up to 300	Above 2,800 m²/ha up to 9300 m²/ha	Medium density	Non-economic infrastructure; greater difficulty in enabling mass transit systems.
Above 300 inhabitants/ha	Above 9,300 m²/ha	High density	Economical infrastructure; feasibility of mass public transport.

Source: Authors' elaboration.

The conversion of population densities into built densities followed criteria related to floor plan efficiency[4] and the average size of housing units. These parameters were determined based on the analysis of five architectural projects of multifamily housing[5] and on references to the minimum usable areas of residential units and standard areas of real estate developments, as specified in municipal and national regulations (Simplified Building and Construction Code of

[3] Paving, rainwater drainage, water supply, sanitary sewage, piped gas distribution, and electricity supply
[4] Ratio between gross private areas (habitable area) and gross built residential area, based on the method proposed by Angel, Lamson-Hall, and Blanco (2021).
[5] The projects vary in size, height, and location across different zones of the city. Two of them are social housing projects, and their designs were provided by the authors' offices (INSITE Architects and LZD Architects). The others were obtained from the websites of Cité Arquitetura and Revista Projeto.

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the Municipality of Rio de Janeiro[6]; Ordinance No. 959 of May 18, 2021[7]; and Brazilian Standard No. 12,721 of April 9, 2007[8]).

Two tables were prepared to estimate the average size of housing units—one based on architectural projects and another on regulatory standards. In this article, Table 02 is presented as an example of the estimation based on the sizes of units surveyed in the architectural projects. In addition, a share of 30% was established for social housing or units with reduced area.

Table 02 – Average size of housing units. Estimated average size of housing units.

	Percentage	Gross area of housing unit (m²)
Social Housing or Small Units (30%)	5	31.00
	13	46
	12	55
Residential units of various sizes	20	65
	22	75
	20	85.00
	6	105.00
	1	135.00
	1	165.00
Average size of housing unit		68.80 m²

Source: Authors' elaboration.

According to the values established for the classes, population and built density grids were generated. These grids were then combined into a single grid, referred to as a *bivariate grid*, aggregating data from both variables (population and built area), based on the method proposed by Joshua Stevens (2015). The purpose of producing these maps was to visualize and identify areas with the highest built densities and the lowest population densities—that is, areas where the existing building stock could accommodate higher population densities but currently does not, due to factors related to land use or housing unit size, which will be discussed in the results section.

Kazuo Nakano examined the disconnection between built density and demographic density in residential real estate developments in the municipality of São Paulo between 1998 and 2008. The author found that the increase in built density was not accompanied by demographic densification. The expansion of the residential built area without population growth does not promote optimized land use, leading to a "hollow city"[9] rather than a "compact city" (Nakano, 2018).

Based on the mappings of Areas 001 and 002, four Study Subareas were selected for an assessment of Urban Density in a larger scale, following the analytical method of density

[6] RIO DE JANEIRO. **Complementary Law No. 198 of January 14, 2019.** Establishes the Simplified Building and Construction Code of the Municipality of Rio de Janeiro – COES. Rio de Janeiro, RJ: Municipality of Rio de Janeiro, [2019].

[7] BRAZIL. Ordinance No. 959, of May 18, 2021. Establishes the requirements for the implementation of housing developments under the subsidized housing acquisition program for new properties in urban areas, part of the Casa Verde e Amarela Program. **Official Gazette:** Section 1, Brasília, 93th ed., p. 155, May 19, 2021.

[8] BRAZILIAN ASSOCIATION OF TECHNICAL STANDARDS. **NBR 12.721:** Assessment of unit construction costs for real estate development and other provisions for building condominiums – Procedure. Rio de Janeiro, 2007.

[9] According to Nakano, he first heard the expression "hollow city" when participating in a panel discussion with architect Nabil Bonduki, who used it to describe the construction densification promoted in the city of São Paulo through the proliferation of apartment buildings, without corresponding demographic densification.

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components developed by Angel, Lamson-Hall, and Blanco (2021). The detailed results of this analysis fall beyond the scope of this article, which summarizes a master's research. However, based on these results, densification projections were developed and will be presented later, given their relevance to the overall findings. These projections considered urban legislation, respecting the preservation areas defined in the city by different public authorities.

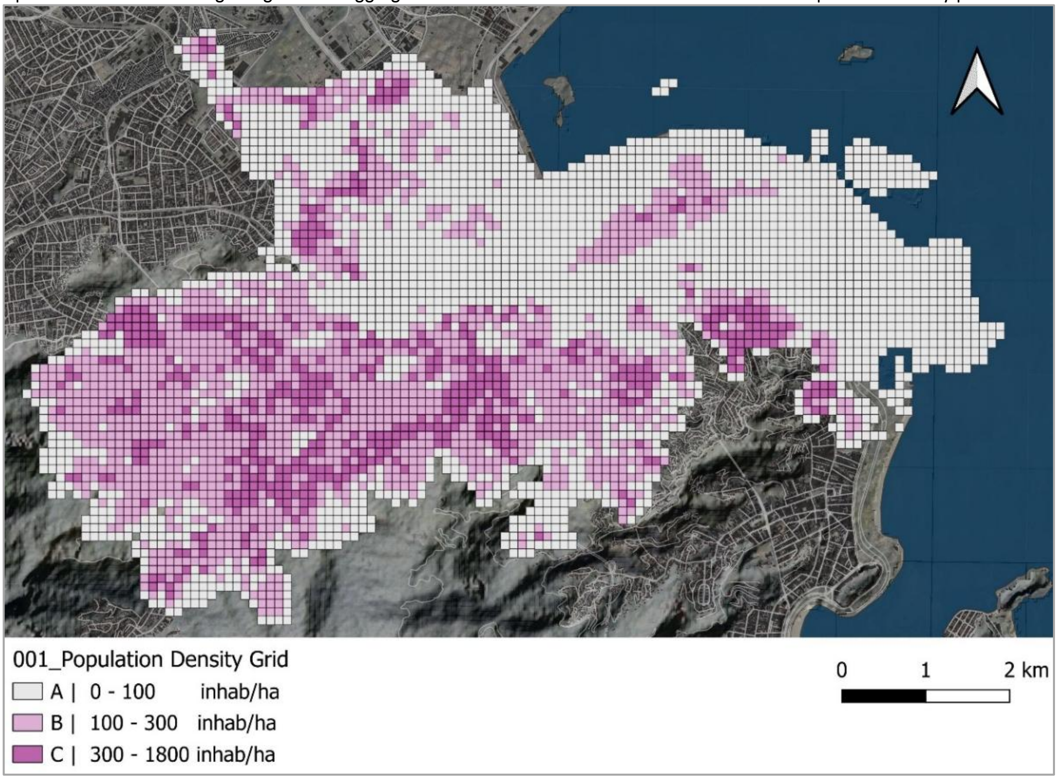
The next section will explore the cell-matrix density mappings of Area 001 only, as they are sufficient to illustrate the results of this stage, considering the similarities between Areas 001 and 002. This will be followed by a brief analysis of the four Study Subareas and, subsequently, the presentation of the densification projections for them.

4 RESULTS

4.1 Cell-Based Density Maps

Cell-based density maps were produced by aggregating data on the number of inhabitants and the built-up area into a rectangular grid. In Area 001, as shown in Map 03, 87% of the territory has medium or low population densities and therefore lacks the capacity to ensure the economic maintenance of infrastructure and mass transit networks.

Map 03 – Area 001. Rectangular grid with aggregated information on the number of inhabitants. Population Density per 1 ha cell.



Source: Authors' elaboration based on data from IBGE (2010) and Data Rio/IPP (2022).

In Map 04, based on recommendations from the Institute for Transportation and Development Policy (ITDP, 2017) and the Inter-American Development Bank (IDB, 2021) regarding the influence areas of transit lines, the train, metro, BRT (Bus Rapid Transit), and LRV

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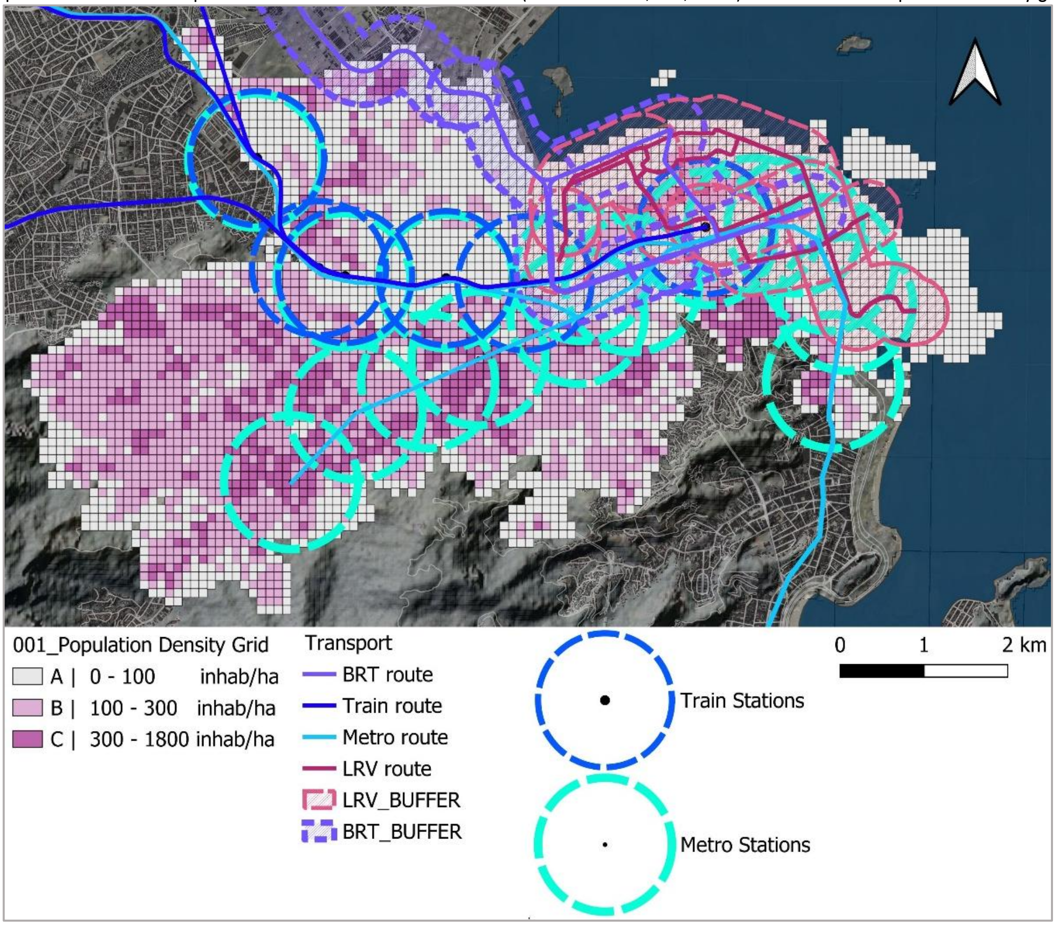
(Light Rail Vehicle) lines were overlaid on the population density grid. A radius of 800 meters was delineated around each train and metro station. Due to the lack of available data on BRT and LRV stations, the influence areas of these systems were defined using a 400-meter buffer, as done in the ITDP (2017) mapping of BRT stations in Rio de Janeiro.

The overlay of influence areas on the Area 001 grid shows that public transport services are largely provided in areas with low and medium population densities, where infrastructure maintenance is costly or, at best, not economically efficient.

Map 04 – Area 001. Transportation lines extracted from Data Rio (Rio de Janeiro, IPP, 2015) overlaid on the Population Density grid.



Source: Authors' elaboration, based on information from IBGE (2010) and Data Rio/IPP (2015).

Areas with low and medium population densities are not necessarily those with low built densities, as shown in Map 05 (cell-based built density). This map shows that, in much of Area 001, the built densities are sufficient to accommodate high population densities and to support the economic maintenance of infrastructure networks. However, the predominance of nonresidential land uses results in spaces that are sparsely populated, thus preventing the full utilization of the built infrastructure. Depending on the use of these areas, densities may rise at certain times of the day or week but, being temporary, leave infrastructures underused during off-peak periods.

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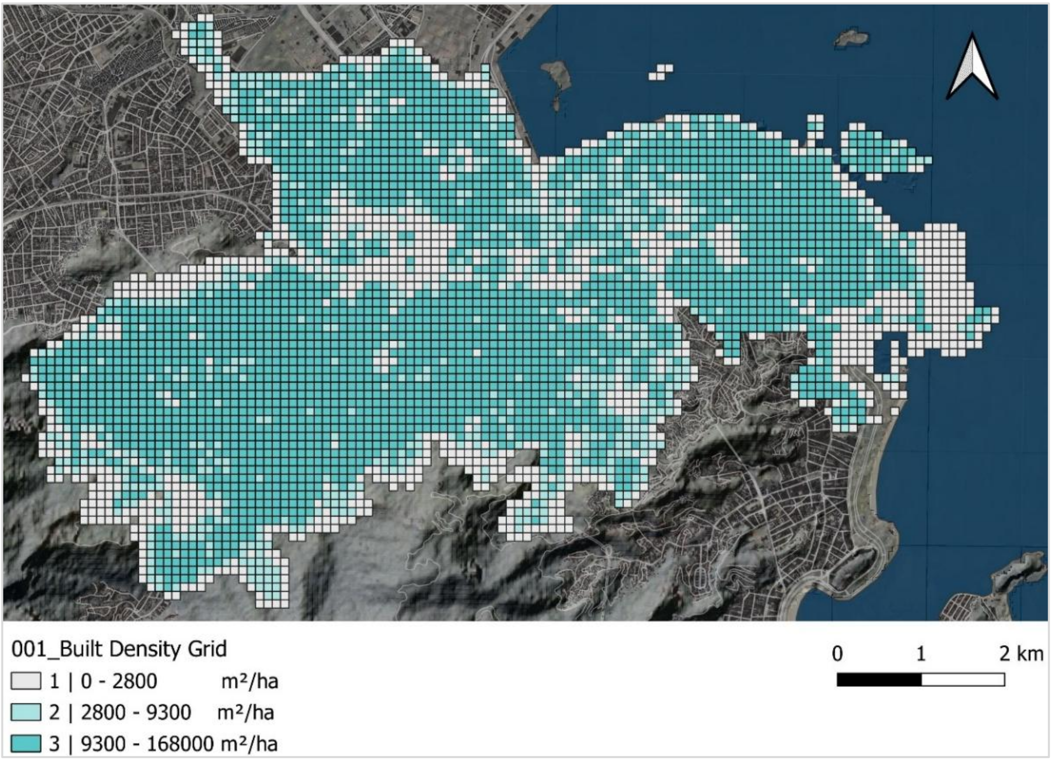
Map 05 – Area 001. Grid with aggregated total-built area information. Built density per 1ha cell.



Source: Authors' elaboration, based on information from Data Rio/IPP (2022).

In Map 06, residential and informal settlement (slums or *favelas*) areas were overlaid on the population density grid, highlighting the low population densities of nonresidential zones, where maintaining infrastructure becomes expensive.

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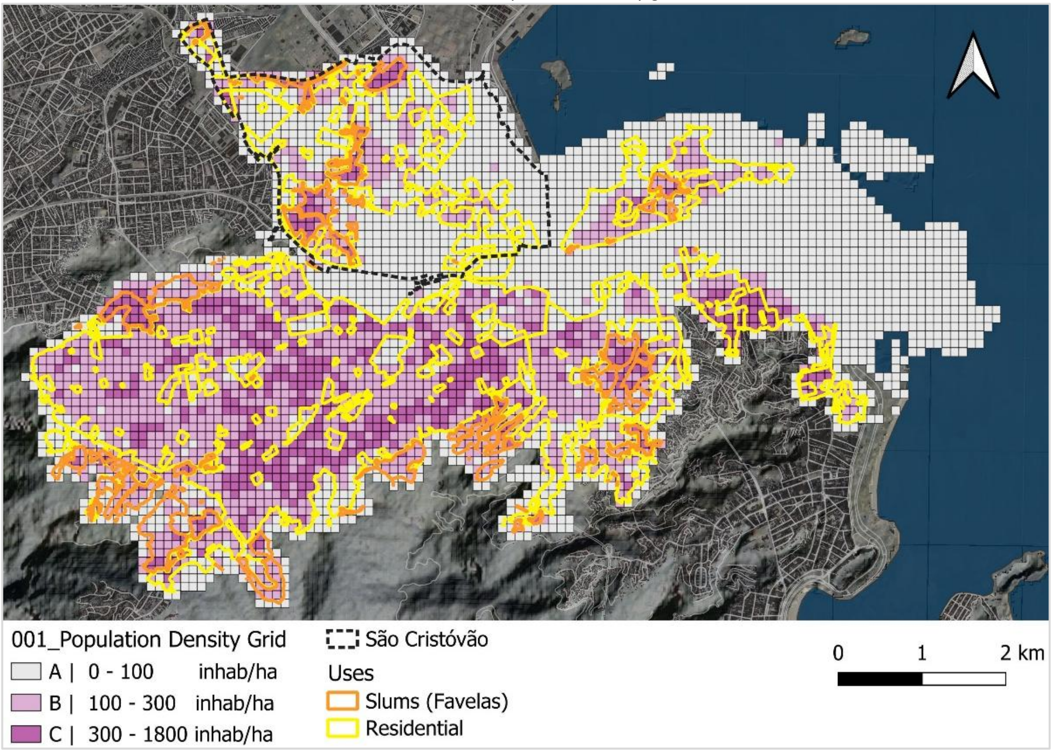
Map 06 – Area 001. Residential and Favela uses extracted from Data Rio (Rio de Janeiro, IPP, 2021) overlaid on the Population Density grid.



Source: Authors' elaboration, based on information from IBGE (2010) and Data Rio/IPP (2021).

Even within residential zones, low population densities account for a significant portion of the territory—34% of the area—while medium densities represent 48%, and high densities only 18%. In the São Cristóvão subdistrict, highlighted in Map 06, high densities were found only in areas classified by the City Hall as favelas, where self-construction became the housing solution for those wishing to live in the region, revealing the subdistrict's housing shortages.

In Area 001—a territory of approximately 4,223 hectares, comprising 19 neighborhoods—only 548 hectares (13% of the area) have high population densities, capable of ensuring the economic maintenance of infrastructure. However, about 60% of the existing building stock has high built densities that could accommodate high population densities but do not, largely due to the low share of residential use in some regions or because of large housing units occupied by few residents, as found in the analysis of Urban Density in the Subareas.

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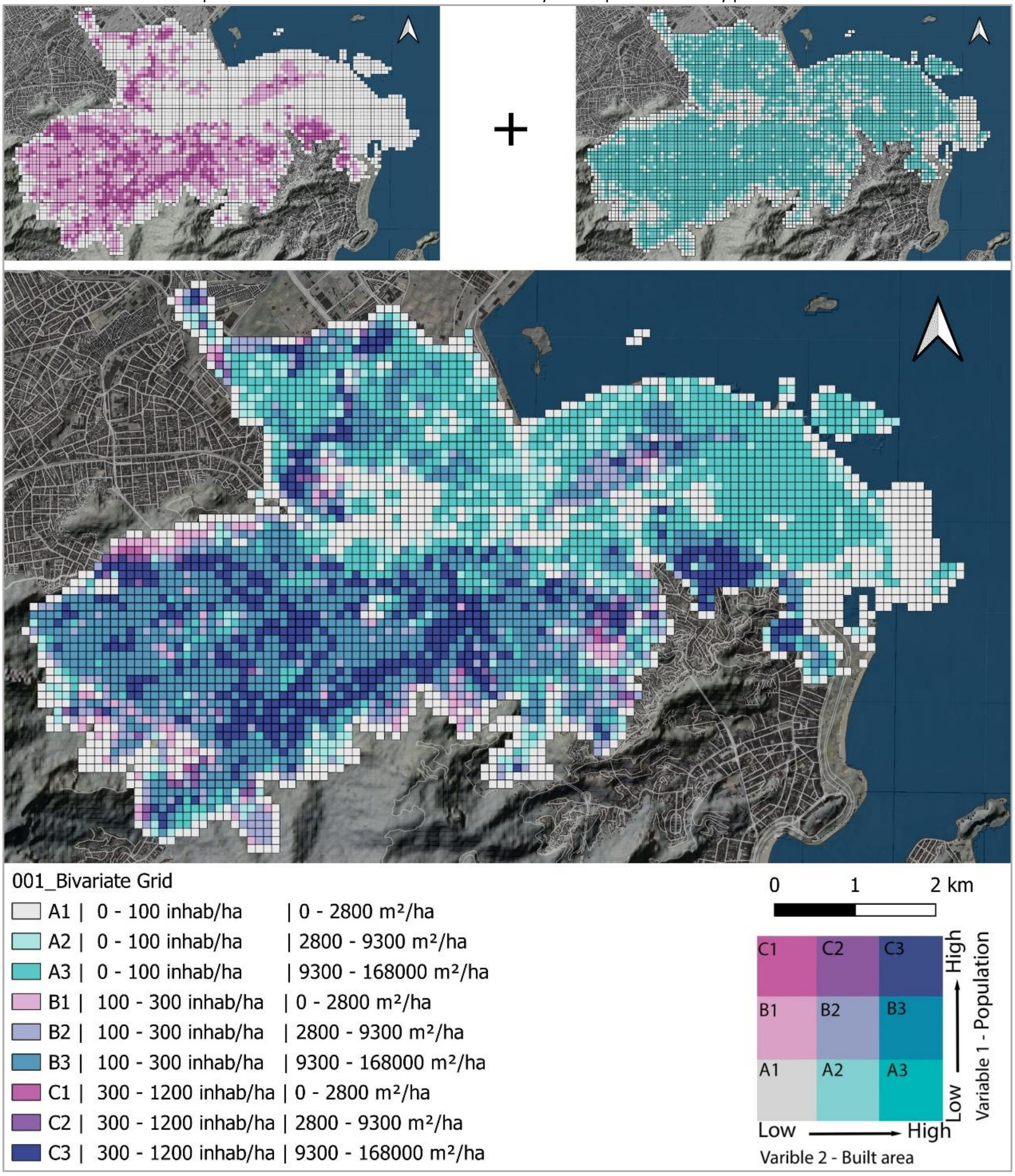
4.2 Bivariate Maps

The bivariate maps allowed the relationship between variables to be visualized, showing their concordances—high population densities coinciding with high built densities—represented by cell C3, and discordances—high built densities coinciding with low population densities—represented by cell A3.

Map 07 – Area 001. Bivariate Grid. Built Density and Population Density per 1 ha cell.



Source of maps: Authors' elaboration based on data from IBGE (2010) and Data Rio/IPP (2022).

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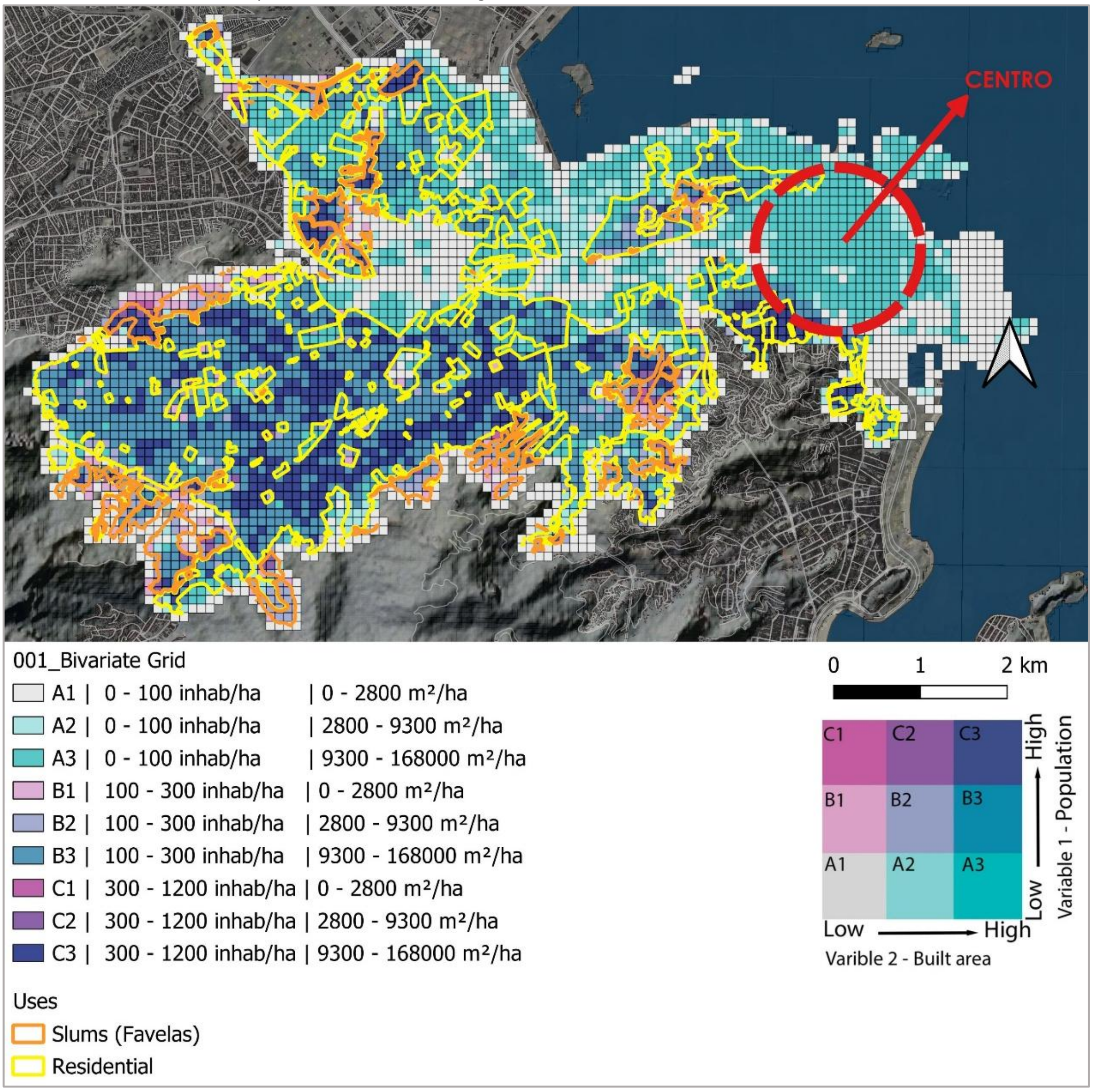
It is noteworthy that, in the bivariate grid, the lowest population densities combined with the highest built densities—the discordances—highlight areas of low population density that could accommodate more residents at higher densities if there were an increase in residential use of the existing built stock.

Residential and favela zones exhibit a higher degree of concordance. The City Center, highlighted in red on Map 08, is the main example of discordance within the Study Area, which encompasses Areas 001 and 002. This is a location with high built densities but low population densities, due to the predominance of commercial and service uses. The limited availability of housing results in fluctuating infrastructure usage, which remains underutilized outside working hours, at night, and on weekends.

Map 08 – Area 001. Bivariate grid with overlaid Residential and Favela uses.



Source: Authors' elaboration based on data from IBGE (2010) and Data Rio/IPP (2021).

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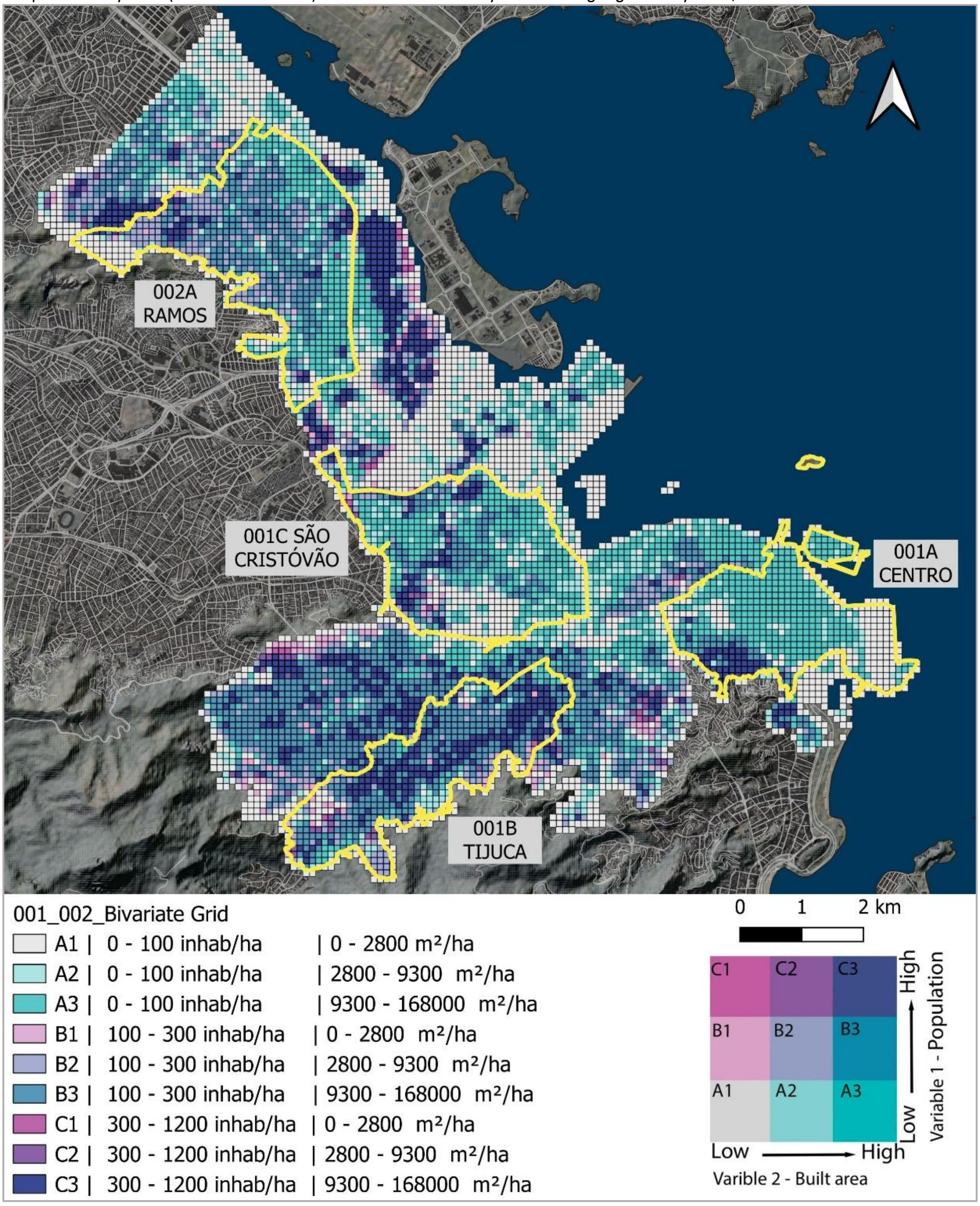
4.3 Study Subareas

The Subareas, delineated after analyzing Areas 001 and 002, have good infrastructure coverage, including mass transit networks. Three of the four Subareas—001A, 001B, and 001C—are located within Area 001, while Subarea 002A belongs to Area 002.

Map 09 – Study Area (Areas 001 and 002) with the selected Study Subareas highlighted in yellow, overlaid on the Bivariate Grid.



Source: Authors' elaboration, based on data from IBGE (2010) and Data Rio/IPP (2022).

The Subareas correspond to neighborhood or subdistrict scales, an approach adopted for the development of densification projections consistent with this research's purpose of

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estimating the magnitude of the built stock's capacity. Future studies, further expanding the scale of work, will be valuable for assessing the impacts of increased density in each locality, considering social, cultural, and historical contexts. Additional studies on the performance of urban environments in relation to built density, using other methods such as the Spacematrix by Pont & Per Haupt (2009), would also be welcome.

In Subarea 001A, which includes the City Center, the highest built densities and the lowest population densities were observed, due to the small proportion of residential use. Subarea 001B, which includes the Tijuca neighborhood, was selected because parts of its "formal" area exhibit high population densities coinciding with high built densities. Subarea 001C corresponds to the neighborhoods of Benfica, Mangueira, São Cristóvão, and Vasco da Gama, which together make up the São Cristóvão subdistrict. Like Tijuca, this area has diverse land uses but a relatively small residential share, resulting, similarly to the City Center, in large zones with high built densities but low population densities.

Subarea 002A (Ramos) includes the neighborhoods of Olaria, Ramos, and Bonsucesso, part of the Ramos subdistrict, which historically hosted many industrial facilities (Abreu, 2008). Following industrial decline, many properties became underutilized, resulting in high built densities combined with low population densities.

An analysis of urban density and its components was carried out in the Subareas, following the method proposed by Angel et al. (2021). One key aspect to highlight is the evaluation of average housing unit size. Except for the City Center (001A), the average size of housing units in the Subareas is significantly larger than the 70 m² average estimated by this research, based on architectural project analysis and municipal and national regulations.

Housing units with excessively large floor areas may not be suitable given Brazil's projected future housing demand. A study published in *Future Housing Demand: Demography, Housing, and Market* (UFF, 2018) estimated a reduction in the average household size from 3.4 persons in 2010 to 2.6 in 2040. Changes in generational behavior—such as fewer children, higher divorce rates, and increased youth financial independence—may contribute to this reduction, directly affecting housing demand. A greater number of housing units will be needed to accommodate a population distributed among smaller households. The decline in average household size is a global trend and was observed in estimates for all Brazilian regions during the analyzed period (UFF, 2018).

Based on the analysis of the Subareas, densification projections were developed.

4.4 Densification Projections in the Subareas – Stage 1

The first stage of the densification projections considered the existing building stock, based on certain densification mechanisms: increasing the residential share through land-use conversion; occupation of unused or underutilized properties; and subdivision of single-family homes or housing units, noting that for the latter, difficulties related to building infrastructure could be greater. These assumptions are based on guidelines of Brazilian urban policy—the City

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Statute[10]—incorporated into municipal legislation, as well as studies on instruments and densification mechanisms implemented in various locations worldwide, such as Soft Densification, defined by Anastasia Touati (2016)[11] .

The building dataset used as a base is from 2013. Therefore, the projections were performed on an older base, considered valid for this study due to its comparison with Google satellite imagery, which showed no changes significant enough to affect the intended order of magnitude. Furthermore, the methodology developed can be applied to newer datasets in the future and update the study.

The increase in the residential share was determined by creating an average Residential Use Index (RUI), calculated for each area based on the Commercial and Services Indices (CSI) established in Complementary Bill 44/2021. This index highlights the importance of residential intensity in the city. Using the Residential Use Indices, potential residential shares were determined for each Subarea.

The densification projections relied on surveys of urbanized areas, total built-up areas, horizontal projection areas of buildings, and building heights, based on the method proposed by Angel et al. (2021). Using the residential shares, estimated floor efficiency, and average housing unit sizes, the potential number of housing units in the existing stock and the potential population and housing densities were calculated.

According to the calculations, the residential share determined for the existing built stock in the four study Subareas could accommodate approximately 127,700 additional housing units—on top of the 123,837 already present—resulting in a total of about 251,540 units, more than doubling the number of dwellings in these areas. However, the increase in housing and population densities resulting from better utilization of the built stock would not exceed, in the cases of the São Cristóvão and Ramos subdistricts (001C and 002A), the limit of 300 inhabitants per hectare, which would allow for cost-effective construction and maintenance of infrastructure.

4.5 Densification Projections in the Subareas – Stage 2

The second stage of the densification projections consisted of a study on the capacity of the Additional Construction Potential (ACP), measuring the number of housing units that could be implemented, based on the Maximum Utilization Coefficient (MUC) proposed in Complementary Bill 44/2021.

For each Subarea, the average MUC was calculated, as was done for the average RUI, using the zoning data proposed in Complementary Bill 44/2021. Lots with areas larger than the

[10] BRAZIL. **City Statute.** Law No. 10,257, of July 10, 2001. Regulates Articles 182 and 183 of the Federal Constitution, establishes general guidelines for urban policy, and provides other measures. Brasília, Federal District: Presidency of the Republic [2001].

[11] Soft densification is a low-impact model of urban form transformation that has been implemented in single-family suburban areas of France and Canada by homeowners themselves, through the subdivision or extension of their houses to create an additional housing unit for sale or rent. Soft densification differs from large-scale urban intervention projects, which promote densification on a broad scale (hard densification), significantly altering the urban form. The author identified the central role of homeowners in this process, while municipalities exert their influence through urban policy instruments (Touati, 2016).

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minimum lot size for the region or with potential for lot consolidation, if smaller, were selected. Lots containing heritage or preserved buildings were excluded[12].

The ACP was estimated by calculating the Total Buildable Area (TBA) of the selected lots, based on the MUC, subtracting the existing Total Built Area considered in the first stage of densification projections. An additional 20% was added to the TBA to account for areas not counted in determining the Total Built Area.

The resulting housing and population densities from this last projection exceeded the threshold of 300 inhabitants per hectare, necessary for cost-effective construction and maintenance of infrastructure networks. According to the calculations, approximately 187,290 housing units could be accommodated in the ACP of the four Subareas. Adding the results from both stages, it is estimated that these areas have the potential to accommodate an additional 314,990 (three hundred fourteen thousand nine hundred ninety) housing units, beyond the 123,837 existing units, resulting in a total of 438,830 dwellings—more than tripling the current number.

Considering the potential allocation of an additional 314,990 housing units and assuming a residential vacancy rate of 3–5%, necessary for the balanced functioning of the housing market (Shlomo Angel & Patrick Lamson-Hall, 2020), a reduction of approximately 15,000 units in the allocation potential is estimated, resulting in 300,000 residential units. This number is equivalent to 84% of the urban housing deficit, estimated by the João Pinheiro Foundation (2021) for the Rio de Janeiro Metropolitan Region, at 355,000 (three hundred fifty-five thousand) dwellings. The densification projections exceed the municipal housing deficit, estimated at 220,000 (two hundred twenty thousand) housing units (FJP, 2013). It is important to recall that the four Subareas for which the densification projections were made correspond to a portion of the entire Study Area and only 5% of the total urbanized territory of the city of Rio de Janeiro.

In the municipality, in addition to the dwellings counted as deficit, there are another 229,000 inadequate permanent private urban dwellings (FJP, 2013) and a future housing demand[13] estimated at 150,000 units for the 2023–2030 period (UFF, 2018). While the total current and future housing demand amounts to approximately 600,000 units, the studies demonstrate that 5% of the city's urbanized area, with its existing stock optimized and expanded, could accommodate a number of housing units corresponding to 50% of this total. It should be noted, however, that if these areas were densified, the densification would not be exclusively for low-income housing—which accounts for the majority of the deficit and is most affected by inadequate dwellings—but the order of magnitude provided by the calculations confirms the importance of the issue.

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[12] The Municipality of Rio de Janeiro has Environmental and Cultural Preservation Areas (APACs). Lots with such buildings are eligible for densification through the implementation of the Reallocation of Constructive Potential on the Lot, as established in the Master Plan (Complementary Law No. 111/2011). However, at the scale adopted in this study, these lots were excluded.

[13] This demand can be verified through the application developed within the research published in the book "Demanda futura por moradias: demografia, habitação e mercado" [Future Housing Demand: Demography, Housing, and Market] (UFF, 2018).
Fluminense Federal University – UFF. Application "Demanda futura por moradias." Version 1.0. Software developed by Eduardo Martins. Niterói: UFF/Office of Research, Graduate Studies, and Innovation

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5 CONCLUSION

Urban expansion, the environmental risk associated with it, the housing deficit, and the inadequacy of dwellings were the motivating problems of this research, addressed due to their relevance to the topic of Urban Density. The management of Urban Density alone is not capable of preventing expansion into the natural surroundings of cities, hillsides, risk areas, or the loss of arable land. Other urban policy instruments act directly to contain this expansion, such as land-use classifications, the delimitation of urban perimeters, and the establishment of green belts. However, steering city growth toward already urbanized areas may help discourage expansion.

The densification of urban spaces will not automatically reduce the housing deficit, but it can indicate mechanisms for doing so. In Rio de Janeiro, the city on which this research focused, the social exclusion of the poorest segments of the population is visible throughout the territory. In this context, intensifying the use of existing urban spaces may discourage urban expansion driven by exclusion, if part of the existing building stock were allocated to low-income populations—a criterion that should guide urban densification policies.

The cell-based density maps produced in this study provide a diagnosis of the current state of population and built densities, showing that the population residing in most of the territory does not allow for economic construction and maintenance of infrastructure networks, despite built densities being high across much of the area.

Empty industrial zones, commercial and service centers with low housing density, and residential areas where the average size of housing units is excessively large compared to the current average household size, all point to the need for establishing multiple urban densification policies to ensure the efficient use of infrastructure. Throughout the history of cities, the existing building stock has been modified by diverse interests; processes of verticalization and expansion have changed the urban form. Analyses of Urban Density offer a powerful tool to guide future transformations, seeking, as much as possible, to make use of underutilized spaces—without necessarily changing the form or expanding the territory, but rather changing its content.

The results of the densification projections demonstrated that an area corresponding to 5% of the city's urbanized territory, if its existing stock were optimized and expanded, could accommodate a number of housing units equivalent to 50% of the city's total housing needs, both current and future. Building housing complexes for low-income families in distant areas of the city, lacking urban services and opportunities, is a contradiction in light of the knowledge about consolidated centralities, where extensive areas with low population densities make infrastructure maintenance costly and do not provide adequate support for potential improvements.

Places with good infrastructure–including mass transportation, public spaces, and urban facilities–can support population growth, but at the same time, it is precisely these population increases that enable the densities necessary for the economic viability of infrastructure. In Rio de Janeiro, there are people who need a place to live, and there are places that need people.

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6 BIBLIOGRAPHICAL REFERENCE

ABREU, Maurício de Almeida. **A evolução urbana do Rio de Janeiro**. Rio de Janeiro: IPP, 2008.

ACIOLY, Claudio; DAVIDSON, Forbes. **Densidade urbana: um instrumento de planejamento e gestão urbana**. Tradução: Claudio Acioly. Rio de Janeiro: Mauad, 1998. Original title: Density in urban development.

ANGEL, Shlomo; PARENT, Jason; CIVCO, Daniel L.; BLEI, Alexander; POTERE, David. The dimensions of global urban expansion: Estimates and projections for all countries, 2000-2050. **Progress in Planning**, vol. 75, p. 53-107, 2011.

ANGEL, Shlomo; LAMSON-HALL, Patrick. **Anatomy of Density II: A Comprehensive Strategy for Making Room for City Densification**. New York: NYU, 2020. Available at: https://ssrn.com/abstract=3744466. Accessed: 15 November 2022.

ANGEL, Shlomo; LAMSON-HALL, Patrick; BLANCO, Zeltia Gonzalez. Anatomy of Density: measurable factors that constitute urban density. **Buildings and Cities**, Vol. 2(1), p. 264-282, 2021. Available at: https://journal-buildingscities.org/articles/10.5334/bc.91. Accessed: 20 October 2022.

BERTINI, Isabelle Teixeira; MARCOLIN, Nathalia Moraes; ANTONELLO, Ideni Terezinha; VEIGA, Leia Aparecida. Área de Expansão Urbana de Interesse Social em Londrina: Uma resposta adequada ao déficit habitacional?. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 12, n. 86. Available at: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/5320. Accessed: 11 October 2025.

BID. **Desenvolvimento orientado ao transporte: como criar cidades mais compactas, conectadas e coordenadas: recomendacões para os municípios brasileiros**. Jason Hobbs, Carolina Baima, Mario R. Durán Ortiz, Dalve Alves, Karisa Ribeiro, Renata Seabra (editores). BID, 2021. Available at: https://publications.iadb.org/pt/desenvolvimento-orientado-ao-transporte-como-criar-cidades-mais-compactas-conectadas-e-coordenadas. Accessed: 17 February 2023.

CORRÊA, Lina Motta. **Densidade Urbana: avaliação do estoque construído e seus potenciais**. 2023. 185 f. Dissertação (Mestrado em Arquitetura e Urbanismo)—Programa de Pós-Graduação em Arquitetura e Urbanismo, Escola de Arquitetura e Urbanismo, Universidade Federal Fluminense, Niterói, 2023.

CHAKRABARTI, Vishaan. Building Hyperdensity and Civic Delight. **Places Journal**, June 2013. Available at: https://doi.org/10.22269/130613. Accessed: 18 April 2025.

CHENG, Vicky. Understanding Density and High Density. *In*: NG, Edward (org.). **Designing high-density cities for social and environmental sustainability**. London, UK: Earthscan, 2010. p. 3-16.

FRANCISCO, Cristiane Nunes. Sistemas de Informações Geográficas - Estudo Dirigido em SIG. *In*: **SIGCidades: Mapeamento de Áreas Protegidas**. Niterói: UFF, Instituto de Geociências, Departamento Análise Geoambiental, 2014.

FUNDAÇÃO JOÃO PINHEIRO. **Déficit Habitacional Municipal no Brasil – 2010**. Belo Horizonte: FJP, 2013.

FUNDAÇÃO JOÃO PINHEIRO. **Inadequação de domicílios no Brasil 2016 – 2019**. Belo Horizonte: FJP, 2020.

FUNDAÇÃO JOÃO PINHEIRO. **Déficit habitacional no Brasil – 2016-2019**. Belo Horizonte: FJP, 2021.

IBGE. **Censo Populacional 2010**. Rio de Janeiro: IBGE, s/d.

IBGE. **Áreas Urbanizadas do Brasil 2015**. Rio de Janeiro: IBGE, s/d.

IBGE/PNAD. **Pesquisa Nacional por Amostra de Domicílios 2015**. Rio de Janeiro: IBGE, s/d.

IPBES. **Summary for policymakers of the global assessment report on biodiversity and ecosystem services**. New York: United Nations, 2019.

ISSN 2318-8472, v. 14, n. 91, 2026

IPCC. Summary for Policymakers. *In*: PÖRTNER, H.O; ROBERTS, D.C.; TIGNOR, M.; POLOCZANSKA, E.S.; MINTENBECK, K.; ALEGRÍA, A; CRAIG, M.; LANGSDORF, S.; LÖSCHKE, S.; MÖLLER, V.; OKEM, A; RAMA, B. (org.). **Climate Change 2022: Impacts, Adaptation and Vulnerability**. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge University Press, Cambridge, UK and New York, NY, USA, 2022. p. 3–33.

ITDP. **Guia de implementação de políticas e projetos de DOTS**. [*S. l.*]: ITDP Brasil, December 2017.

JACOBS, Jane. **Morte e vida de grandes cidades**. Tradução: Carlos S. Mendes Rosa. São Paulo: Martins Fontes, 2000.

MAIA, Amanda Carvalho; LAGE, Selena Duarte Lage e; LEONELLI, Gisela Cunha Viana. O impacto da legislação urbanística de São José do Rio Preto – SP: crescimento urbano espraiado, fragmentado e excludente. **Revista Nacional de Gerenciamento de Cidades**, *[S. l.]*, v. 7, n. 47, 2019. Available at: https://publicacoes.amigosdanatureza.org.br/index.php/gerenciamento_de_cidades/article/view/2096. Accessed: 11 October 2025.

MARICATO, Ermínia. **O impasse da política urbana no Brasil**. Petrópolis, RJ: Editora Vozes, 2017 – Digital edition.

MASCARÓ, Juan Luís. **Custos de infra-estrutura em cidades de porte médio: um ponto de partida para o desenho econômico**. 1979. Tese (Doutorado em Arquitetura e Urbanismo) – Faculdade de Arquitetura e Urbanismo, Universidade de São Paulo, São Paulo, 1979.

MERLIN, Pierre; CHOAY, Françoise. **Dictionnaire de l’urbanisme e et de l’aménagement**. Paris: Presses Universitaires de France, 2015.

NAKANO, Anderson Kazuo. A produção da “cidade oca” nos padrões recentes de verticalização e adensamento construtivo do município de São Paulo. **Oculum ensaios**, nº 15 (1), p. 33-50, 2018. Available at: https://periodicos.puc-campinas.edu.br/oculum/article/view/3373 . Accessed: 17 April 2025

PEREIRA, Rafael H. M. et al. Desigualdades socioespaciais de acesso a oportunidades nas cidades brasileiras – 2019. **Texto para Discussão 2535**. Brasília: IPEA - Instituto de Pesquisa Econômica Aplicada, 2020.

PONT, Meta Berghauser; HAUPT, Per. **Space, Density and Urban Form**. Rotterdam: NAI010 Publishers, 2021.

PUSHKAREV, Boris; ZUPAN, Jeffrey. **Urban Rail in America: An Exploration Criteria for Fixed-Guideway Transit**. Washington, DC: U. S. Department of Transportation, 1980.

RODRIGUES DA SILVA, Antônio Nélson. **Densidades Urbanas econômicas: a influência do transporte público**. 1990. Dissertação (Mestrado em Transportes)—Escola de Engenharia de São Carlos, Universidade de São Paulo, São Paulo, 1990.

ROGERS, Richards. **Cidades para um pequeno planeta**. Barcelona: Editorial Gustavo Gili, AS, 2001.

RIO DE JANEIRO. Prefeitura da Cidade do Rio de Janeiro. **Data Rio/Instituto Pereira Passos**. Rio de Janeiro: IPP. Available at: https://www.data.rio/. Accessed: 10 January 2023.

RIO DE JANEIRO. Prefeitura da Cidade do Rio De Janeiro. Secretaria Municipal de Urbanismo. Análise qualitativa das densidades construídas em regiões da cidade do Rio de Janeiro. *In*: **Evolução da Ocupação e Uso do Solo 2014 – 2015 – 2016**. Rio de Janeiro: SMU, 2016. Available at: http://www.rio.rj.gov.br/dlstatic/10112/4236391/4184113/RELATORIOCOMPLETO.pdf. Accessed: 27 December 2021.

STEVENS, Joshua. Bivariate Choropleth Maps: A How-to Guide. *In*: Joshua Stevens’s Blog. **Joshua Stevens**. S./l.: 18 fev. 2015. Available at: www.joshuastevens.net/cartography/make-a-bivariate-choropleth-map/ . Accessed: 23 November 2022.

TOUATI, Anastasia. The "hidden mechanisms" of land use policies: the case of socio-spatial impacts of suburban densification. **Territoire(s)**, nº 5, Jul. 2016. Available at: https://www.researchgate.net/publication/311301631. Accessed: 25 April 2023.

ISSN 2318-8472, v. 14, n. 91, 2026

UFF. **Demanda futura por moradias: demografia, habitação e mercado**. Gustavo Henrique Naves Givisiez, Elzira Lúcia de Oliveira (org.). Niterói, RJ: UFF, 2018. ISBN: 978-85-94029-11-9. Available at: https://app.uff.br/riuff/bitstream/1/21478/1/Livro%20Demanda%20%28HR%29.pdf. Accessed: 10 September 2022.

UN. **World Urbanization Prospects: The 2018 Revision (ST/ESA/SER.A/420)**. New York: United Nations, 2019.

STATEMENTS

CONTRIBUTION OF EACH AUTHOR

- **Study Concept and Design**: Lina Corrêa.
- **Data Curation**: Lina Corrêa.
- **Formal Analysis**: Lina Corrêa.
- **Acquisition of Financing**: There was no.
- **Investigation**: Lina Corrêa.
- **Methodology**: Lina Corrêa, Felix Carriello e Rubens M. R. Carvalho.
- **Writing - Initial Draft**: Lina Corrêa.
- **Writing - Critical Review**: Lina Corrêa, Felix Carriello e Rubens M. R. Carvalho.
- **Review and Final Editing**: Lina Corrêa.
- **Supervision**: Felix Carriello e Rubens M. R. Carvalho.

DECLARATION OF CONFLICTS OF INTEREST

We, Lina Corrêa, Felix Carriello, and Rubens M. R. Carvalho, hereby declare that the manuscript entitled "**Urban Density: evaluation of the built stock and its potential**":

1. **Financial relationships**: Has no financial relationships that could influence the results or interpretation of the work. No institution or funding entity was involved in the development of this study.
2. **Professional relationships**: Has no professional relationships that could impact the analysis, interpretation, or presentation of the results. No professional relationship relevant to the content of this manuscript has been established.
3. **Personal conflicts**: Has no personal conflicts of interest related to the content of the manuscript.
