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Residential densification and urbanities; from urban form in collective housing complexes in Córdoba, Argentina Densificación residencial y urbanidad; análisis desde la forma urbana en conjuntos de vivienda en Córdoba, Argentina

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ABSTRACT The performance of residential densification and the potential to generate conditions for urbanity in public space are investigated. The objective is to identify the interrelationships between density ranges, residential types, and spatial conditions leading to different urbanities. The analysis methodology addressed two scales: the building scale and the sectoral urban scale with their respective indicators processed in QGIS and Deepthmap, based on closed-perimeter collective housing complexes with different residential densities in Córdoba, Argentina. The results explain that the performance of residential densification in terms of urbanity depends on the modification of urban form components. If their behavior is understood, densification has the potential to generate conditions of urbanity.

RESUMEN Se investiga el desempeño de la densificación residencial y el potencial para generar condiciones de urbanidad en el espacio público. El objetivo es identificar las interrelaciones entre rangos de densidad, tipos residenciales y condiciones espaciales que conducen a diferentes urbanidades. La metodología de análisis aborda dos escalas: la edilicia-edificación y la urbana-sectorial con sus respectivos indicadores, procesados en QGIS y Deepthmap, a partir del estudio de casos de conjuntos de viviendas colectivas de perímetro cerrado con diferentes densidades residenciales en Córdoba, Argentina. Los resultados explican que el desempeño de la densificación en términos de urbanidad depende de la modificación de los componentes de la forma urbana. Si se comprende su comportamiento, la densificación tiene el potencial de generar condiciones de urbanidad.

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KEYWORDS urban density, urban morphology, urbanity, urban transformations, collective housing

PALABRAS CLAVE densidad urbana, morfología urbana, urbanidad, transformaciones urbanas, vivienda colectiva

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1. Introduction

Urban growth through residential densification is a systemic, complex, and multi-scalar process, in which urban form and building structure are modified based on urban planning indicators and the project decisions of architects, urban planners, designers, and others. Therefore, the properties and indicators of urban morphology impose limitations on residential density values (Berghauser Pont and Haupt, 2023), along with contextual factors: social, economic, geographic, cultural, political, and institutional urban management aspects (Moudon, 1997). This process alters the spatial framework where urbanity is manifested.

The latter concept is understood as the integration and social interaction that occurs within a material spatial framework (Netto, 2013; Siebel, 2018), which is shaped by temporal, social, and cultural conditions that give it identity (Berghauser Pont and Haupt, 2023; Boudreau, 2010; Netto, 2013; Siebel, 2018). Urbanity is thus presented as a socio-spatial category (Marcus, 2010; Netto, 2013), capable of explaining how urban form influences social behaviour, particularly in practices of interaction and sociability in public spaces (Duhau and Giglia, 2004). To conduct this analysis, the interrelationships between residential density, building types, and various variables of urban morphology are examined.

Studies on densification in relation to urban form provide evidence to evaluate the performance of this process in terms of urban liveability (Martino et al., 2021; Sim, 2019), residential quality, and resulting urban forms (Marengo, 2018; Marengo and Lemma, 2017), as well as levels of urban economy and efficiency (Berghauser Pont and Haupt, 2007; Boyko and Cooper, 2011). These studies also explore the potential to create conditions in (public and/or private) spaces that can accommodate and promote social interaction (urbanity or urbanities)[1] (Avalos, 2023; Duhau and Giglia, 2004; Netto, 2013; Souza Ribeiro and De Holanda, 2013). This latter approach focuses on understanding how urban form influences daily life. In the words of Gehl (2014), it is about the human dimension, considering urban life and people in public space, which should play a central role in city planning and design.

The interrelationship of the analytical elements of urban form largely shapes ground floors and public street spaces. Thus, it is essential that the planning and design of building bases and facades in residential densification contexts take into account eye-level perspectives, where urban dwellers experience the city (Karssenberg et al., 2016).

In this regard, locating diverse daily activities near residences, ideally on highly connected routes, alongside proximity to these activities, can positively support residential and population densification. According to Lozano (2013), certain density thresholds can generate sufficient social interactions to support specific urban functions. This relationship suggests that urbanity represents the potential for interaction among a number of people with activities and institutions. Thus, "density is both cause and effect of densely grouped human habitats" (Lozano, 2013, p. 400). From this perspective, high densities would have greater potential for urbanity and urban dynamism. However, the relationship is not linear; rather, it appears to be the result of a process of urban management, planning, and design within a social, cultural, temporal, and geographical context, where form components are manipulated to achieve different residential density ranges. The interrelation of these variables will then impact the potential to create spatial conditions for urbanity in relation to urban form (Avalos, 2023).

In contemporary times, the concept of urbanity has been redefined compared to previous periods. The consolidation of fragmented, segregated urban models with varying residential density levels in Latin American cities, marked by enclaves or closed-perimeter developments, is part of this change. In Brazil, they are called *condominios fechados* (Caldeira, 1997), and in Argentina, they are known as *countries*, gated communities, or garden towers (Liborio, 2019; Welch Guerra and Valentini, 2005). All these cases reference the gated communities of the United States. Functionally, these are collective housing units organized in various forms (blocks, strips, towers), with diverse density levels and housing sizes, controlled access, perimeters enclosed by walls or fences, covered common-use spaces (gyms, multipurpose rooms, barbecue areas, etc.), and open spaces for recreation and leisure. In some cases, commercial spaces are exclusively available for the residential community (Avalos, 2022; Marengo and Lemma, 2017). A substantial transformation of this typology compared to earlier stages is evident in the organization of the parcel, its location within the urban structure, building forms, and the methods used to segregate or integrate the development with its surroundings.

In this context, the focus is on the role of residential densification and its potential to create spatial conditions for social interaction in public street spaces. This is examined through an analysis of housing complexes in closed-perimeter towers in Córdoba. The study investigates to what extent residential densification generates spatial conditions for urbanity. To achieve this, the correlations between density and urban-building form are examined. The objective is to identify the interrelationships between density levels, residential types, and spatial conditions capable of fostering conditions for urbanities.

The study considers quantitative dimensions defined by the relationships between physical space, plot area, lot occupation form, building intensity, and the number of open spaces (public or private). It is assumed that the configurations resulting from densification can influence

[1] In the article, the term *urbanities* and *urbanity* are used to encompass the diversity of forms of urbanity based on the social, cultural, and geographic aspects of the term. The singular does not exclude the plurality of urbanities.

social interaction in street spaces. These dimensions are based on urban morphology theory, using a type-morphological approach, through which three main variables are analysed, as proposed by Moudon (1997):

1. Physical form: defined by building types, open spaces, plot structure, block pattern, and road network.
2. Scale: including both the urban-sector and building scales.
3. Temporal variable: identifying the process of land occupation and urban densification over the past three decades.

The study area is in the northwest sector of the city of Córdoba, characterized by vacant land on large parcels with sufficient services and infrastructure to support increased residential and population density. In these parcels, local urban management promotes densification by modifying building heights, total construction capacity, and land occupancy values. This has encouraged major local real estate companies to develop housing complexes (towers or blocks) with closed perimeters, controlled access, private open spaces and/or commercial areas, and shared-use spaces (gyms, pools, tennis courts, covered spaces, wine cellars, etc.). This research analyses nine housing complexes planned and built between 2001 and 2020, located along Colón Avenue and in adjacent areas between the El Tropezón traffic hub and Zipolí Avenue (Figure 1).

While studies on the relationships between density and urban form have several precedents (Berghauser Pont and Haupt, 2023; Boyko and Cooper, 2011; Lozano, 2013), the correlation with the notion of urbanity in the context of closed-perimeter housing complexes of high and medium density, embedded in urban structures that simultaneously spread and densify, provides a significant contribution to the discussion on this topic. These housing complexes are often seen as the “antithesis” of the urban due to their physical enclosure. However, this study aims to challenge that claim. Thus, it is crucial to examine how the relationship between building form and urbanity is addressed in various closed tower housing projects, considering the relational space between public and private spheres.

The article is structured into five sections. It begins with a theoretical-conceptual review of density, urban form, urbanities, and their interrelationships. This is followed by a contextualization of Córdoba, the cases studied, and the methodology. The analysis and results align with two scales of approach: building and urban. Subsequently, the results are discussed in relation to the literature presented, and two forms of densification are described based on the characteristics of the urban fabric. The conclusion explains how the analysed building types present different density ranges, where physical form does not act as a dependent variable. The performance of residential densification in relation to urbanity conditions is largely based on the modification of form components, design solutions at the ground-floor base, road connectivity, and mixed-use integration.

2. Interrelations between Residential Density, Urban Form, and Urbanity

Different forms of residential densification can provide various ranges of population density, transforming urban form and, consequently, modifying urban life and urbanity (Berghauser Pont and Haupt, 2023; Siebel, 2018). This transformation is rooted in the social performativity of urban form, which explains how spatial design and planning influence social behaviour (Hillier, 2007).

Berghauser Pont and Haupt (2023) argue that urbanity is a highly flexible concept theoretically, suggesting it be studied through sub-properties of urban form, focusing on physical-spatial characteristics. Physical factors like the urban interface (the relationship between buildings and the street network), building footprint, layout characteristics (block sizes), and street profile (width, height, and proportion of public and private space) are relevant descriptors of urbanities. Additional sub-properties include “the intensity of users and activities, road connectivity, and the interaction with buildings at ground level” (Berghauser Pont and Haupt, 2023, pp. 201-202).

This interpretation of urbanity is based on the physical-spatial analysis of urban space, particularly public open spaces (streets, parks, plazas, sidewalks, etc.) (Berghauser Pont and Haupt, 2023; Lozano, 2013; Siebel, 2018), where social interactions of urban life are often visualized (Duhau and Giglia, 2004). In this context, Monnet (1996) points out that urbanity is a "complex" of relationships that a society establishes, defining the urban way of life. This concept should be interpreted in two ways: as the "art of coexistence" (referring to good manners and courtesy) and as a way of life in the city. We concur with Monnet, affirming that urbanities illustrate the different ways of living in cities over time.

For Lefebvre (1974), this vision of urbanity refers to an observable level of the concept, operationalized through the process of urbanization (in cities). A more general level of analysis suggests that urbanity is ontological to the society that produces it. Therefore, it is recognized as historical and geographically situated, partly structuring and representing daily life (Boudreau, 2010; Lefebvre, 1974).

Thus, a globalized and univocal definition of the term would incur a contradiction, as "urbanities" are recognized as products of the diverse social worlds from which they emerge, characterized by the idiosyncrasies that identify and differentiate them (Avalos, 2023; Boudreau, 2010; Netto, 2013). The urban space serves as the medium for supporting and integrating the social (Lefebvre, 1974; Netto, 2013). Therefore, physical space acquires particular relevance as a generator of practices and activities within buildings and in open areas, serving as social modalities of interaction and encounter (Berghauser Pont and Haupt, 2023; Netto, 2013).

This approach supports Marcus's (2010) idea that urbanity can be understood as a socio-spatial category resulting from the performativity of urban form and social behaviour. In this context, variables such as accessibility to residential density, population density, and diversity in land use can inform methodologies for analysis.

In this vein, Lozano (2013) suggests that the relationship between density and urbanity is based on thresholds established through measuring population density and building intensity[2]. For example, thresholds ranging from 350 to 700 inhabitants per hectare represent high densities and building intensities capable of promoting urbanity (Berghauser Pont and Haupt, 2023). When residences are located near everyday services and facilities, this can enhance urban dynamism. However, these levels can also reduce diversity and generate negative outcomes from densification, such as a lack of open spaces, traffic congestion, environmental pollution, a lack of privacy, and insufficient parking, among others (Lozano, 2013). This becomes more detrimental if building intensity increases alongside height and ground floor occupancy, adversely affecting optimal natural lighting values and resulting in a lower proportion of open space per inhabitant.

In an intermediate range, thresholds above 130 to 260 inhabitants per hectare, with nearby and accessible facilities and services, would enable the creation of urbanity spaces. Thresholds between 20 to 130 dwellings per hectare represent a wide range, which can progressively increase by combining different types of housing: single-family homes, duplexes, row houses, and even low-rise buildings (up to three stories). Density will also increase if the types are attached (Campoli and MacLean, 2007). At this point, building types such as low- and medium-rise buildings can contribute to density thresholds ranging from 40 to 70 dwellings per hectare, while taller buildings (more than ten stories) with elevators and attached units can raise this value to up to 150 dwellings per hectare. These thresholds can generate a wide variety of easily accessible activities for each residence, due to the proximity and population density created by the housing (Lozano, 2013). In contrast, a range of 20 dwellings per hectare (40 inhabitants per hectare) and below will hinder the provision of facilities and the diversity of nearby activities or services, as the low population level is insufficient to sustain such activities.

Campoli and MacLean (2007) assert that a density value does not capture the complexity of building and urban form. What truly matters is the street layout, parcel subdivision, building arrangement, presence of trees, sidewalks, etc. All these parameters are functions of urban design.

Berghauser Pont and Haupt (2023) describe how the properties and indicators of urban morphology components (layout, buildings, open spaces, etc.) impose limitations on residential density values. They argue that cities are constructed within a context of constraints, in diverse yet interconnected realms. Designers create buildings and urban developments based on ideas derived from various theories that can define geometric and physical aspects influencing human behaviour, which are collective restrictions. The remainder largely consists of social restrictions (urban regulations, social and economic aspects, etc.) specific to the geographic location and a particular temporal framework. Therefore, the ranges of residential density are related to such constraints, some of which establish the amount of buildable area (m^2), the form and amount of construction occupancy on the ground floor, the height, and the density of the road network.

With the aim of quantifying the relationships, three main variables[3] are proposed for analysis:

1. Total Construction Coefficient (CC): This is the number of times the surface area of the plot or block can be built upon (the ratio is total covered area divided by the area of the plot or block).
2. Land Occupancy Coefficient (COS): This measures the level of occupancy on the ground floor in relation to the total area of the plot or block.
3. Road Network Density (N): This refers to the concentration of roads in an area. It is defined as the length in linear meters (ml) of the road per square meter (m^2) of the area it occupies (ml/m^2), and it is calculated as the sum of the entire internal network plus half of the length of the used road network, divided by the study area.

[2] FSI (Floor Space Index) - This term is used in most of Europe to denote the capacity to build on a plot or block. An FSI of 2.2 to 4.4 represents high densities, FSI 2 represents a medium range, and FSI 0.30 indicates a low value. In Argentina, this indicator is referred to as the Total Occupation Factor (FOT), which defines the total building capacity (covered area) of a plot or lot.

[3] In the European and North American context, the variables correspond to the following translations: FSI (Floor Space Index) and GSI (Ground Space Index).

These variables enable the formulation of derived indicators that help describe the spatial properties and the potential of densities for social interaction. The indicators are[4]:

- L: This is the coefficient determined by the ratio between the total construction capacity and land occupancy (CC/COS). If the CC value increases without changing the footprint, L will also increase. If the goal is to maintain a constant height, then both CC and COS must increase.

- Open Space Coefficient (CEA): This indicates the pressure on the unbuilt space. As the total built area increases with the same land occupancy area, the number of people using the unbuilt space would also increase. This means there would be less (m^2) free space per person for interaction. The unit of CEA is m^2/m^2.

The interrelationships between residential density and urban form partially explain the dependence of ranges and building types based on the modification of components of urban morphology (road network, land occupancy forms, height, building types, urban location, road hierarchy, etc.). The components and indicators of urban form are defined by regulations (plans, projects, ordinances, etc.), which govern construction, the shape of buildings, and the spaces between constructions. Ultimately, urban form depends on contextual, cultural, and disciplinary aspects that modify the configuration of public space and the potential for hosting social interactions.

3. Methodological Design

The aim of the research was to investigate how residential density, in interaction with urban morphology, establishes spatial conditions that promote social interaction, based on the analysis of closed-perimeter housing complexes in Córdoba.

3.1. The Case Studies: Collective Housing in Closed Perimeters

The city of Córdoba, Argentina, is the second most populous city in Argentina[5] (National Institute of Statistics and Censuses, 2023). With a Mediterranean location, it features a radial road structure that connects it to other cities in the country. Residential density is high in the centre (< 400 dwelling units per hectare) and decreases towards the peri-central and peripheral areas[6]. In the latter, the residential fabric is dispersed with low density, and to a lesser extent with medium and high density, resulting from urbanizations concentrated in specific areas or blocks designated for densification.

The study area is in the intermediate-peripheral zone, to the northwest of the city. The analysed sector is bounded by Avenida Colón, Zípoli Street, and the El Tropezón Road Junction (Figure 1). In particular, the Colón corridor is characterized as a peripheral extension area, with a mixture of urban-scale commercial use and high residential density. The sectors adjacent to the corridor are identified by low residential density (between 20 to 60 dwelling units per hectare), with a mix of neighbourhood-scale uses along the main primary and secondary roads (Ordinance 8256, 2015). This sector is significant due to the establishment of closed-perimeter residential complexes built by the main local real estate companies (GAMA, GNI, and Grupo Canter) over the past 20 years.

Between 2001 and 2020, vertical densification processes were carried out primarily along the Colón corridor on large plots of land, some of which were unoccupied, while others were set for redevelopment (for commercial and industrial uses). Before the start of this process, the sector was characterized by low density, lower commercial intensity, and low building heights. Subsequently, the urban profile transformed, intensifying the commercial role, with specific interventions on some plots and blocks featuring residential typologies in the form of towers and individual or clustered blocks. This created a unique situation within the urban structure. In the words of Abramo (2012), it generated a configuration that simultaneously compacts and diffuses or diffuses and compacts.

For this study, we have selected nine cases, located within the presented sector, which are relevant due to their urban-building form, density, and building intensity (Table 1). Additionally, they represent a "novel" typology in the local context, characterized by height and organization into towers or blocks on large, enclosed plots with shared-use spaces inside. These resemble "fortified" enclaves that, in part, aim to address the security, tranquillity, and social distinction requirements of certain population segments (Avalos and Sosa, 2024).

The rise of these typologies is associated with the economic recovery following the 2001 crisis in Argentina, when agro-export sectors for commodities played a major role in driving the construction industry. The increase in international demand for raw materials, along with their high prices (in dollars), positively impacted the sector, with profits being redirected toward housing construction due to distrust in the banking system. The exchange rate (Argentine peso and U.S. dollar) favoured new construction projects. Urban land prices had fallen in dollar terms compared to previous periods, labour costs were lower in pesos, and there was high demand with income available for real estate investment (Avalos, 2022; Liborio, 2019). Although these conditions were not constant, they persisted until 2015.

In a context of economic growth, local management promoted building intensification in certain urban sectors through various means, including the Urban Densification Plan, amendments to the land use ordinance (Ordinance 8.256, 2015), and by raising occupancy and buildability intensity indicators in special and strategic areas, such as the Avenida Colón corridor. Subsequently, an ordinance on Urban Agreements was enacted to regulate public-private agreements, allowing modifications to land use and occupancy indicators in

[4] The original designations for the height coefficient are maintained with the letter L, as proposed by Berghauser Pont and Haupt (2023). The indicator "open space ratio" is modified to "Open Space Coefficient."

[5] 1,565,112 inhabitants according to the 2022 population census.

[6] In the central area, residential density is around 410 to 680 dwellings per hectare, in the pericentral area 130 to 230 dwellings per hectare, in the intermediate sector 60 to 130 dwellings per hectare, and in the periphery 20 dwellings per hectare (Pre-census of Housing, National Institute of Statistics and Censuses, 2022).

exchange for investments and improvements in city infrastructure (Ordinance 12077, 2012).

The Municipality entered into two agreements in the Colón corridor for the Ciudad GAMA development by GAMA S.A. and the Alto Panorama tower project by Propietarian S.A. GAMA was granted an increase in height (from the permitted 36 meters) for two towers (140 meters and 80 meters) and an increase in the total occupancy factor (FOT) from two to two and a half. For Propietarian S.A., the allowed height was raised from 12 meters to 77,80 meters and 29,50 meters. Additionally, the total occupancy factor (FOT) was increased more than threefold, from 2 to nearly 5,5.

3.2. Method of Analysis, Building and Urban Scale

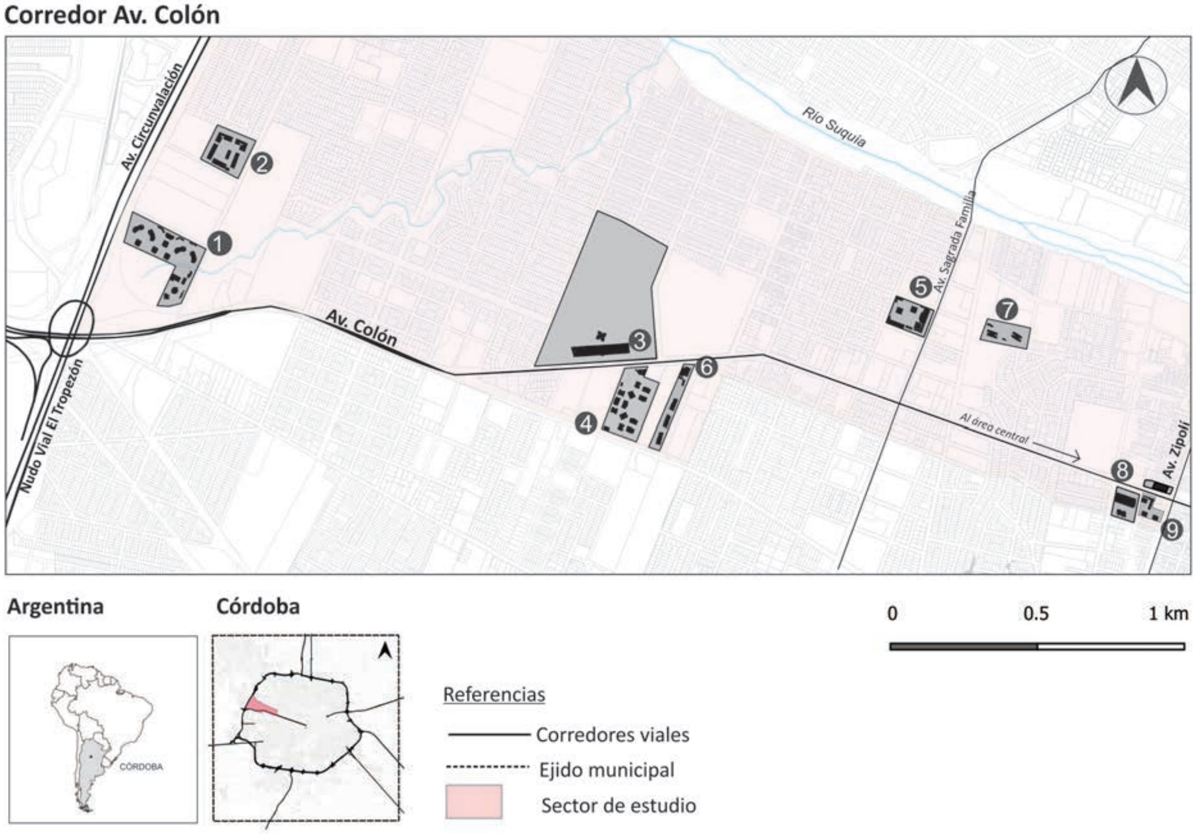
The analysis was conducted using an experimental quantitative methodological design at two scales: building and urban-sectoral, with respective indicators defined through a literature review, detailed in Table 2.

Data and information for the analysis came from primary and secondary sources, including public agencies (Córdoba Cadastre, Urban Planning Department of the Municipality of Córdoba) and freely accessible online databases. In addition, on-site documentary and photographic data collection was conducted. Information such as lot dimensions and constructed covered areas was obtained from the Province of Córdoba Cadastre. Building heights, number of residential units, and constructed areas were cross-referenced with information provided by the development companies available online. To determine the built areas occupied on the ground floor, a survey was conducted using Google Earth satellite images.

The calculation of the following indicators: 1) Net Residential Density (NRD), 2) Land Occupancy Ratio (COS), 3) Buildability Ratio (CC), and 4) Open Space Ratio (CEA) was processed using QGIS and Excel, based on the data presented in Table 1. To visualize the results (Figures 3 and 4), heat maps were created using Google Colab with Python programming codes. These graphs display the maximum, intermediate, and minimum indicator values for each set, addressing the objective of comparison and seeking correlations among them.

The urban scale analysis was based on the construction of three indicators: 5) Use Mix Ratio (CMix), 6) Public-to-Private Space Ratio (CEPu/CEPri), and 7) Road and

Figure 1: Localización de casuística. Planeamiento Urbano y Catastro de Córdoba (2024)



N°	Housing complex	No. of towers/ blocks	Gb+No. of floors	Height (m)	N° of dwellings	Net lot area (m²)	Total building intensity (m²)	Land occupation (m²)
1	Altos de Villa Sol	9	20	50	1.170	41.300	110.000	7.587
2	Harmonie Chateau	5	4	16	266	20.755	21.400	5.476
3	Ciudad GAMA	1	17	65	4.000	160.000	400.000	28.900
4	Villa Sol	12	8	21	834	31440	40.000	6.315
5	Terra Forte 1	3	16	40	450	14565	18.0000	4.846
6	Terra Forte 2	3	16	40	477	12600	31.0000	3.279
7	Milénica V Sagrada Familia	2	18	46,8	97	12.635	23.100	1.622
8	La Diva de GAMA	1	21	60	122	8626	28.800	3.155
9	Cardinales Alto Panorama	4	23	70	560	8200	45.300	2.380

Table 1: Data and information of the case studies. Own elaboration (2024) based on the Cadastre of Córdoba, real estate companies, and personal surveys.

Pedestrian Connectivity (CX). To measure use mix (CMix), the area of everyday supply businesses (grocery stores, drugstores, veterinary services, supermarkets, bakeries, etc.), as well as offices and professional services within the complexes and adjacent areas within a 300 m radius[7], was surveyed. The indicator formula was then applied (Table 2), and a rating was assigned on a scale from 1 to -1. A value of 1 indicates purely residential use; a value of 0 suggests a proportional balance between residential and other uses; and a value of -1 indicates a predominance of non-residential uses, excluding residential (van den Hoek, 2008).

For determining the Public-to-Private Space Ratio (CEPu/CEPri), the surface areas of sidewalks corresponding to the complex and adjacent open public spaces were measured[8]. The formula for this indicator (Table 2) was then applied. This data is relevant for understanding the amount of public space available for pedestrian movement and social gatherings. The higher the ratio, the greater the availability of public space per housing unit (Berghauser Pont and Haupt, 2007; 2023; Vicuña Del Río, 2015).

Finally, the road connectivity for each complex location was measured following spatial syntax theory (Hillier, 2007), based on graph theory and road network topology. The Depthmap software was used to analyse cumulative local connectivity, reflecting the degree of node integration within the analysed network[9]. This evaluates node or intersection density, as well as the continuity and permeability of the road network.

Connectivity visualization was processed in Depthmap along with QGIS, using a numerical scale from one to eight, where colours range from blue (lowest values) to red (highest connectivity). For this analysis, road network data from Córdoba Urban Planning, available on Mapas Córdoba (www.mapascordoba.gob.ar), was used.

4. Results: Densification, Urban Form, and Urbanity
4.1. Building Scale

The variables analysed at this scale were: net residential density, land occupancy ratio, buildability ratio, and open space ratio. The analysis reveals that density acts as an independent variable of the building form and is dependent on the properties of urban form components. These include the building and occupancy capacity of the lot or block, building height, and setbacks regulated by urban planning norms. The analysed residential density ranges from 70 to 700 dwellings per hectare, projected in tower and block types (Figure 3).

It was observed that high-rise buildings, such as *Altos de Villa Sol and Milénica V Sagrada Familia*, do not necessarily result in high residential density values but rather in intermediate and low ranges. This can be associated with dwelling sizes, lot sizes, urban zoning, and respective indicators that influence design decisions. In this regard, the highest values of net residential density correlate with high buildability ratios and lower land occupancy. For instance, Alto Panorama has 682,92 dwellings per hectare, a buildability factor of 5,52 times the lot area in built-up surface, and nearly 29% land occupancy. These correlations are often seen in towers where the open space ratio (CEA) is higher partly due to lower land occupancy as building height increases (Figure 3). However, this correlation does not imply a direct, linear relationship.

[7] The feasible walking radii for daily needs range between 300 to 500 meters (Gehl, 2014).

[8] Spaces located at the front, side, or rear of the parcel of the complex are considered.

[9] Depthmap determines this measure by performing mathematical operations, summing the integration of the node in relation to the network of nodes (in mathematical terms, this refers to the depth of nodes in the connection graph). It measures the average number of segments (paths) that must be crossed to reach all other nodes in the network.

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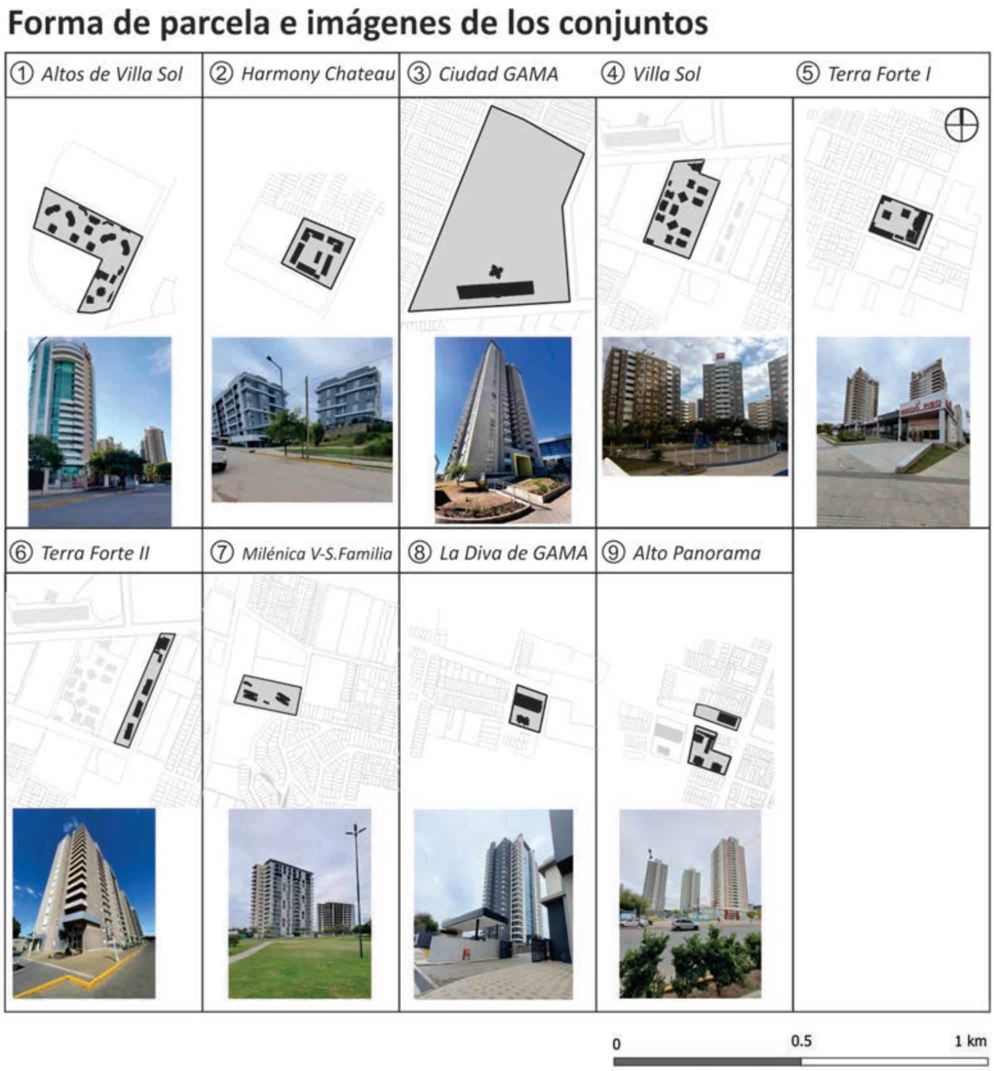

Figure 2: Shape and occupation of plots and images of housing estates. Own elaboration based on data from Urban Planning and Cadastre of Córdoba (2024)

In the case of Milénica V Sagrada Familia (7), the lowest residential density was observed (76 dwellings/ha) across 18 floors. This development represents high construction intensity (almost twice the lot area) but low land occupancy. This results in a high open space ratio (CEA) because the number of units developed is low, with each unit being relatively large compared to the other complexes analysed. Here, it is evident that building height acts independently of building type and density, as compared to the Harmonie Chateau complex (2). The latter has 120 dwellings/ha in four-story blocks, resulting in higher ground floor land occupancy and lower construction intensity, with more open space within the complex.

In cases where the open space ratio (CEA) is low and residential densities are high, construction pressure increases, which tends to reduce spaces that foster urban qualities, as seen in Alto Panorama (9) (682,92 dwellings/ha) (Figure 4).

The density ranges between 140 and 380 dwellings/ha (Figure 4) are represented in towers, each exhibiting different levels of building intensity and land occupancy. The cases of Villa Sol (4) and Terra Forte I (5) reflect intermediate densities with appropriately sized units, ranging from 45 to 80 m^2, according to the Building Code. This corresponds to lower land occupancy levels and, therefore, more open space in comparison to the entire sample. This suggests that these locations may have better conditions for fostering social interaction both inside and outside the complexes. Notably, Villa Sol (4) features numerous commercial spaces and green areas within its premises compared to Terra Forte

Scale	Ítem	Indicators	Formula	Observations
Buildings	1	Net residential density DRN	Net dwellings/lot area (dwellings/ha)	Indicates the number of dwellings distributed over the net area of the lot.
	2	Land Cover Coefficient COS	Lot area/ Land use area	Indicates the number of times the area of the plot is occupied by covered building area at ground floor level. The closer it is to 1, the higher the occupancy.
	3	Total constructability coefficient CC	Total area covered/plot area	Indicates the number of times the plot area is included in the total built-up area. The higher the value, the greater the built-up area.
	4	Open Space Coefficient CEA	(1– COS)/ CC	It indicates the ratio between the covered built-up area and the land occupation. The higher the open space coefficient, the lower the pressure on the unbuilt.
Urban	5	Coefficient of mixed use over residential CMix	(Built-up area for residential use - Built-up area for other uses) / (Built-up area for residential use + Built-up area for other uses)	Ratio between residential and other uses in terms of total built-up area (considers all floors). The closer the value is to '1', the higher the proportion of residential to other uses. If the value is closer to '-1', other uses are in higher proportion.
	6	Ratio of public to private space CEPu/CEPri	Sup. of public space/ Number of dwellings	Determines the area of public space corresponding to each dwelling. Pavements and public open spaces are included. The higher the coefficient, the greater the amount of public space per dwelling.
	7	Road and pedestrian connectivity CX	Depthmap analysis 1) Density; 2) Continuity ; 3) Permeability	Density indicates the number of connections between roads in a given area; the greater the number in a continuous and permeable regular orthogonal fabric, the greater the possibilities for connectivity and social encounters. Continuity indicates the prolongation of the fabric without breaks, at least over 1 km, which affects its permeability. Connectivity is represented by values 1 to 8, the higher the higher the connectivity.

Table 2: Indicators of analysis at the building and urban scale. Authors, (2024), based on Berghauser Pont and Haupt, (2007; 2023), and Vicuña Del Río, (2015).

I (5). However, the latter exhibits significant commercial activity, with storefronts featuring terraces, urban furniture, landscaping, and wide sidewalks along a main urban avenue (Av. Sagrada Familia). The combination of these factors, along with residential density, promotes higher urban connectivity values that positively impact the mix of uses and enhance urban qualities across the sample.

Overall, the analysis indicates how different ranges of net residential density (DRN) correspond to various building types (towers and/or blocks). Height acts as an independent variable in relation to density, while the coefficients for land occupancy (COS), constructability (CC), and open space (CEA) serve as influential factors in determining the ranges of net residential density (DRN). These coefficients are partly governed by urban regulations (zoning, maximum heights, land occupancy factors [FOS][10], total occupancy factors [FOT][11], setbacks, allowable residential densities, types and sizes of collective and grouped housing, etc.) and the design decisions made to ensure compliance. The analysed components define the physical form of the buildings and interconnect with elements at the urban-sectoral scale, as we will examine next.

4.2. Urban Scale

The analysis at this scale addressed three variables: the coefficient of public and private space (CEPub/CEPriv), the mixed-use coefficient (CMix) in adjacent sectors, and road connectivity (CX). Regarding the first, very similar and balanced values were identified for both types of spaces. In this variable, it is observed that the relationship can be positive, in terms of spatial conditions for accommodating urban life, if a greater amount of public space is available in the adjacent sectors, whether sidewalks, squares, or parks. If the value increases, the complexes have a greater amount of public space per housing unit.

In the analysed cases, the highest value corresponds to Milénica V Sagrada Familia (7), which is due to the presence of a large green space (park) in front and the limited number of housing units built in the complex (Figure 5). In contrast, it is observed that in high-density residential complexes with fewer public spaces, the proportion of public spaces per housing unit decreases, as seen in *Cardinales Alto Panorama* (9), which would negatively impact the possibilities of generating conditions for social interaction (Figure 5).

Regarding the mixed-use coefficient (CMix), Figure 6 shows a significant trend toward residential mono-functionality, with values above 90%. Although there are cases where commercial bases are proposed on the ground floor, either internally or externally, the complexes do not manage to increase the intensity and mix of commercial and/or service activities. The projects Terra Forte I (5), La Diva de Gama (8), and Alto Panorama (9) maintain values ranging from 65% to 80% of mix (Figure 6). It is assumed that the location along a main urban road with intensive commercial character influences these values.

10 The occupancy factor is defined by local government regulations (Ord. 8256) as the ratio between the area determined by the building's projection on the horizontal plane at ground level and the total area of the plot.

11 The total occupancy factor, as established by Ordinance 8256, sets the maximum buildable area, defined by the ratio of the total buildable surface to the total plot area.

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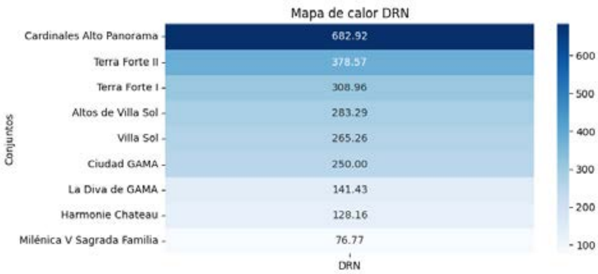


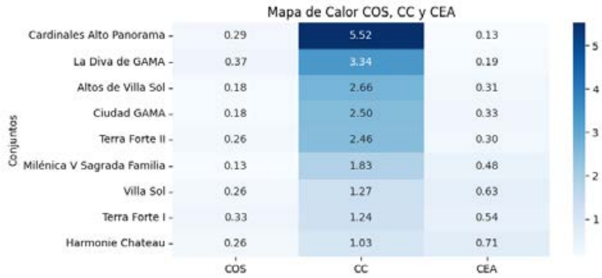


Figure 3: DRN net residential density ranges of clusters from highest to lowest. (2024)
Figure 4: Building variables from highest to lowest from the CC constructability coefficient. (2024)

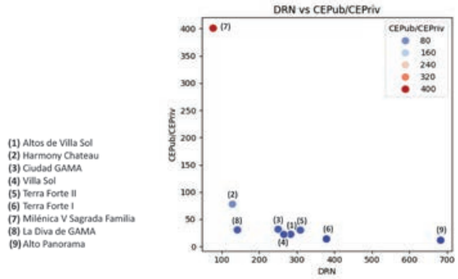
The measurement of road connectivity (CX) shows how the layout, composition, and hierarchy of the road network play a predominant role in creating urban conditions in residential densification processes. The location, connectivity of activities, and mixed uses also play a key role in the placement of urban spaces. However, the dispersion between residential density and connectivity (Figure 6) suggests a low positive linear correlation. In other words, it cannot be asserted that greater road connectivity results in higher levels of density; rather, it would be associated with other factors such as layout characteristics, size, and shape of parcels. This is illustrated in Figure 7, which presents connectivity ranges from one to eight, with the highest values being the most positive. Generally, low to medium values are identified in the analysed complexes, which are associated with the physical characteristics of the layout, given the low density of nodes and the low continuity and permeability of the roads. In situations where the blocks are irregular, with large dimensions and edge fabrics, the values decrease considerably, as seen in the cases of Altos de Villasol (1), Ciudad GAMA (2), and Harmonie Chateau (9). Meanwhile, intermediate values are observed in areas where the fabric is continuous, permeable, with regular orthogonal blocks, which enhances connectivity, as in the case of Terra Forte I (5) (Figure 7).

5. Discussion

The results allow us to understand that residential densification, understood as the ranges of values between housing units and surfaces, provides extremely limited information for analyzing how this form of growth can (or cannot) create conditions for urbanity. It is identified that these ranges must be interrelated with building type, physical form, and other components of urban form (such as the road network, parcels, blocks, and buildings). Such ranges influence the formation of public space and the behaviour of people on the street, thereby generating conditions for urbanity. To this end, some reflections are presented on the interrelations between density and urban form. The analysis results show how the interaction of residential density with urban and building form modifies the fabric with different effects. Three situations are observed in this interrelation:

1. Net residential density acts as an independent variable from building type, physical form (block or tower), and height. High-rise towers can be developed with very low density, or high density in low-rise blocks. This aspect is influenced by the size and type of housing (collective, grouped, etc.).
2. The components of urban form, such as the road network, blocks, parcels, buildings, and public open spaces, are modified based on the forms of residential densification, where the indicators are altered to facilitate this process. Total buildability, land occupation area, the arrangement of mandatory setbacks, and the street profile, among others, are modified. These are dependent on local urban regulations and the design resolutions of architects, designers, and planners. Ultimately, the transformation of urban form components within the framework of urban processes such as densification influences the spatial configuration of urbanity.
3. The potential to generate urbanity through residential densification can achieve better performance if located along roads with hierarchy (main, secondary) with intermediate and high connectivity values. This can create conditions that favour commercial and service density, which would reduce residential mono-functionality. Additionally, greater conditions for urbanity can be generated if ground floor designs include furniture and spaces for people to linger and/or transit.

The aspects of densification outlined have their counterpart in the urban fabric, with two particular cases observed:



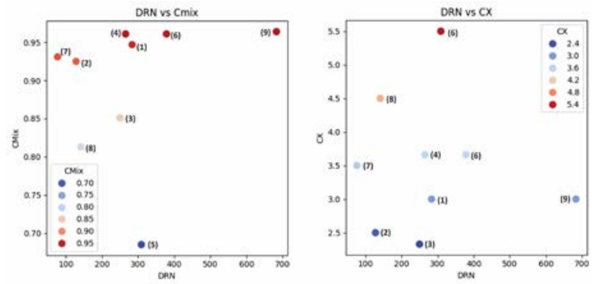


Figure 5: Scatter plot between DRN and CEPub/CEPriv. (2024)
Figure 6: Scatter plot between DRN and CMix, and DRN and CX. (2024)

5.1. Densification in Regular and Orthogonal Fabric with Mixed Uses and Greater Connectivity

The proposed aspects of densification correlate with the urban fabric, particularly observed in two cases: Residential densities between 250 to 400 dwelling units per hectare, with building coefficients (BC) ranging from two to two and a half and land occupancy below 35% of the lot's surface, tend to increase the potential generation of public and private spaces for social interaction. This would have positive effects on a continuous, regular, orthogonal fabric (for example, square or rectangular blocks with walkable distances) and along hierarchical roads (main, secondary, etc.) capable of incentivizing greater everyday activities. If the sidewalks are wide and the design of the ground floors (with businesses) is permeable or inviting for people to linger, the conditions of spatiality could enhance the possibilities of urbanity.

The Terra Forte I tower complex (Figure 8) partly illustrates these aspects. Although it has a closed perimeter, it features a commercial base accessible to the public along the main road (Av. Sagrada Familia), which, as analysed, promotes values with greater mixed uses. This case demonstrates how the consolidation of the fabric influences achieving "positive" effects for densification.

5.2. Densification in Irregular, Discontinuous, and Monofunctional Fabric

Residential complexes with densities exceeding 400 dwelling units per hectare, with building coefficients ranging from two to two and a half times the lot area, developed at great heights, over discontinuous fabrics, and located on roads with limited connectivity, reduce the conditions for hosting urbanity in public spaces. This is partly due to the size and shape of the plots or blocks. For example, in situations where the plots or blocks are large, exceeding four hectares, and have irregular shapes, they tend to fragment the urban fabric. The location in relation to the urban structure can diminish urbanity conditions if situated in peripheral areas with limited road connectivity. This leads to greater monofunctionally, resulting in poor performance of residential densification in terms of urbanity. This condition worsens if there are no activities or businesses on the ground floor that invite people to transit or linger in the public realm.

The residential complex Alto Panorama illustrates how high residential density ranges are not synonymous with greater potential for urbanity (Figure 9a). The same is true for Altos de Villa sol (Figure 9b), where the peripheral edge location leads to a decrease in urbanity. In the case of Harmonie Chateau, also located on the peripheral edge, it has wide sidewalks and landscaping designed for transit; however, the absence of activities and furnishings (due to its recent construction) results in fewer opportunities to generate urbanity (Figure 10).

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6. Conclusions

The performance of residential densification processes related to conditions for social interaction (urbanity) in public spaces is a little-explored approach in the Latin American context. This article aimed to contribute to this regard by analyzing closed-perimeter residential complexes in intermediate and peripheral cities, specifically in the city of Córdoba. With this goal, the study sought to identify the interrelationships between density levels, residential types, and the spatial conditions that promote urbanity in public spaces, such as streets.

It was noted that residential density values, by themselves, do not provide sufficient information to analyse the quantitative performance derived from increased buildability. Even less so regarding the effects on public spaces and conditions of urbanity. To do this, it is necessary to analyse and understand the behaviour of the components of urban and building form in relation to different residential density values. The characteristics of the fabric (size, shapes, etc.), the hierarchy of the roads, the level of connectivity, the location within the urban structure, urban indicators (such as building coefficients, land occupancy, maximum height, quantity and type of housing, etc.), and the design resolutions between the ground floors and the street are extremely important aspects for creating (or not) conditions of urbanity.

According to the theoretical review, higher connectivity indices (vehicular and pedestrian) can influence elevated levels of urbanity and are associated with high population density, which is sufficient to energize urban areas with everyday activities (Lozano 2013; Berghauser Pont and Haupt, 2023). However, this will depend on the characteristics of the fabrics in which they are located. Therefore, it is important for the promotion of quantitative densification processes to incorporate analyses of urban form and derived indicators to understand the impact on urbanity conditions.

The review of closed-perimeter complexes serves as examples of concentrated residential densification on a plot or block in low- to medium-density areas. This building type (in blocks and towers), due to its separation from the street, seemingly shows a decrease in levels of integration and opportunities for social encounters in public spaces, especially in locations with limited road connectivity and low mixed-use values. Nonetheless, the analysis of the cases also shows that certain complexes, despite their closed-perimeter condition, propose forms of integration within the implantation sector. For example, in the cases of Terra Forte I, La Diva de Gama, and Alto Panorama, they incorporate low-height commercial bases (6m) with concessions of private space translated into terraces, ramps, and areas extending to the businesses. This generates spatial conditions for social interaction, that is, spaces for urbanity. In these cases, the importance

Figure 7: Analysis of connectivity in the study housing estates. (2024)

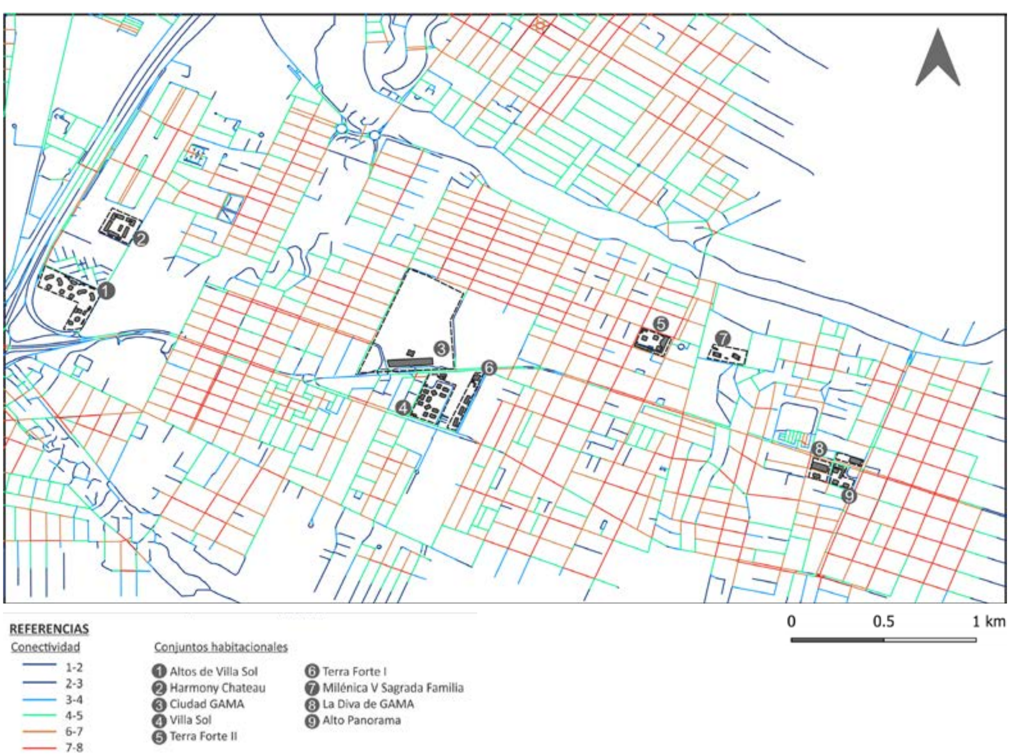

Figure 8: Terra Forte I complex, ground floor with commercial plinth as a potential urbanity conditioner. (2024)

of location within the urban structure of densification processes is emphasized. If densification occurs on roads with good connectivity, within consolidated, regular, and continuous fabrics, social and commercial exchange would be favoured.

If location is not taken into account, an unintended consequence of implementing policies for the intensification of urban fabric will be the deepening of processes of monofunctionally, fragmentation, and urban segregation. This could be more detrimental in locations with limited connectivity, on peripheral edges, or where the layout is configured with irregular blocks that are large and have low residential and population density. This will tend to produce counterproductive effects in terms of urbanity.

From this perspective, densification as a regulated process promoted by the state and carried out by private agents can play a key role in creating conditions that encourage urbanity in public space. To achieve this, it is necessary to reconceptualize residential density as a dependent variable on the behaviour of urban and building form, framed within a temporal and geographical context, with social and collective restrictions, where the street as a space between buildings is defined based on these actions.

We conclude that the process of residential densification has the potential to generate conditions of urbanity if the interrelationships with the components of urban form are understood. The methodology and the cases presented are part of an exploration of the topic. Future research could advance in studying this process in urban fabrics in central and pericentral locations to observe the behaviour of population and residential density in the performance of urbanity.

Conflict of Interests. The author declare no conflict of interests.

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Figure 9: Tower densification on discontinuous and edge urban fabrics tends to lower urbanities. (2024)

Figure 10: Block densification on discontinuous urban fabrics with little building consolidation. (2024)

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