



Space syntax as a tool for analyzing urban occupation: A study in southern Brazil

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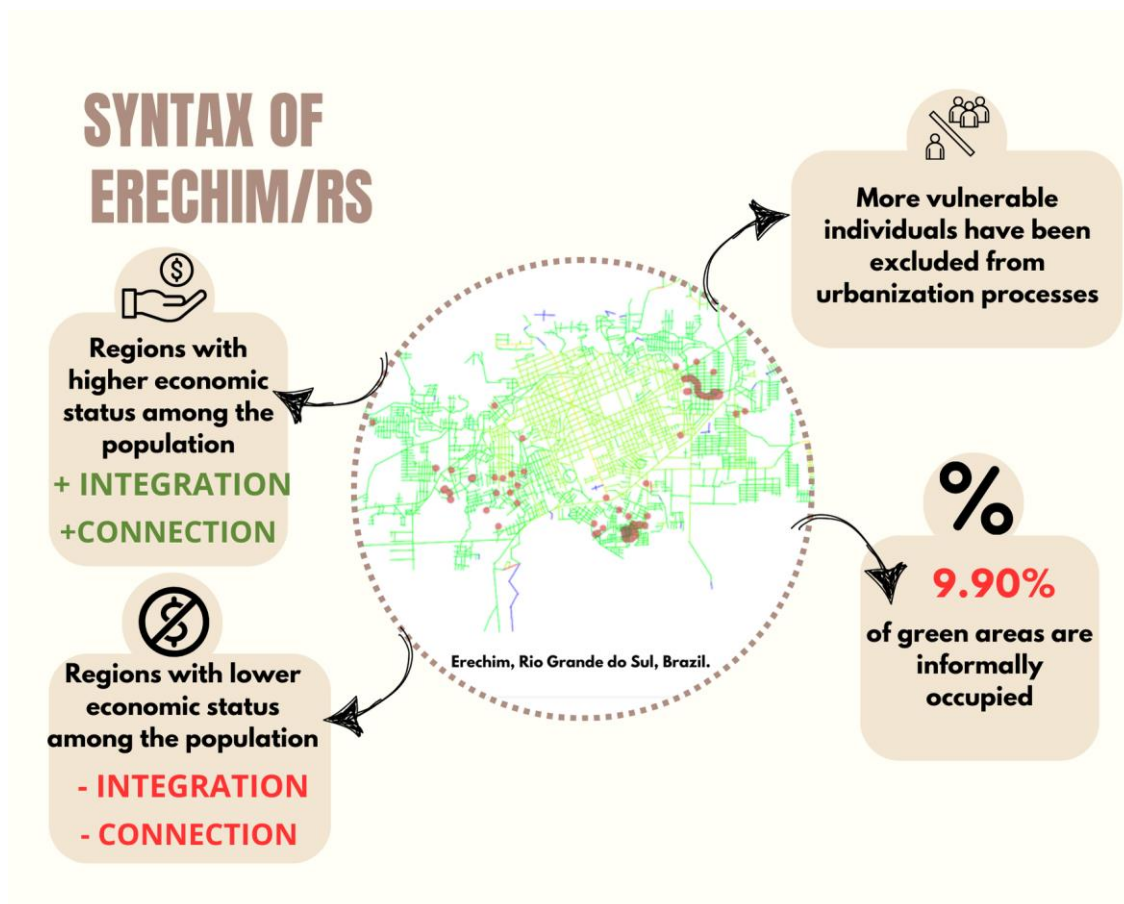
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ABSTRACT

The lack of planning and effective housing policies has encouraged the search for housing in informal settlements, generally located on the outskirts of cities and segregated by urban sprawl. Space syntax is an important tool for analyzing urban configuration, allowing us to understand the geographical space as a whole, with its limitations and potential, capable of understanding the levels of integration and segregation, improving its flow and connectivity possible. This article analyzes connectivity and integration, using the spatial syntax of vulnerable occupation areas in the city of Erechim/RS (southern Brazil). This study was divided into five stages: a) bibliographical research; b) identification of the areas of occupation in Erechim; c) preparation of an axial map of the city; d) axial analysis using the Detphtamp 0.50 software and, finally; e) cross-referencing the information using the Qgis software. We identified the presence of occupations in green areas, mostly on the outskirts of the city, segregated to the other regions of the city, with a general average integration of 1.514 pixels, where the areas with the best economic value (between 1,720.01 and 5,231.01 reais) have the best connectivity.

KEYWORDS: Space syntax. Informal occupations. Spatial segregation. Urban expansion.

GRAPHICAL ABSTRACT



1 INTRODUCTION

Many countries, like Brazil, experienced accelerated urbanization, especially at the end of the 20th century, as a result of the migration of the rural population to urban areas. This phenomenon was mainly due to inadequate living conditions in rural areas (Davis, 2006). The lack of planning and effective housing policies has resulted in occupying peripheral land, often clandestine, in environmentally vulnerable areas (Maricato, 2000). These settlements are largely located in areas lacking urban infrastructure and public services, which intensifies social exclusion (Rolnik, 2015).

It is important to remember that analyzing and understanding urban connectivity is crucial for planning and development. They significantly interfere with mobility and access to services and opportunities often found in areas of economic interest. (Jacobs, 1961; Harvey, 1973; Rolnik, 2015). In addition, the lack of access to these central areas interferes with the social partitioning of the residents of the more remote regions, impeding the economic and social opportunities of a city, such as access to a decent job and specific medical specialties, which are far from the individual's residential location (Sen, 2000).

This understanding, the space syntax technique designed by Bill Hillier and Julienne Hanson (1984), allows for the analysis of analyzing spatial configuration and its relationship with human behavior (Hillier; Hanson, 1984). This theory uses computational tools to analyze the metrics of integration, choice and depth, making it possible to understand the accessibility and connectivity of cities (Sintax Limited, 2001).

According to Hillier (1996), urban configuration directly impacts the distribution of economic and social activities, including economic issues and socio-spatial inequality (Harvey, 2006). Given this, applications of space syntax in the analysis of occupations can reveal the connectivity patterns of a city (Holanda, 2013), which proves important for developing tools/policies for spatial equity (Villaça, 2001). The aim is to analyze the connectivity and integration, using the space syntax tool, of the areas of vulnerable occupation in Erechim/RS, a medium-sized city located in the northern part of Rio Grande do Sul. In addition, the aim is to identify the barriers and potential of the spatial configuration of these areas, comparing them with other regions. This analysis is important for the development of more equitable urban policies.

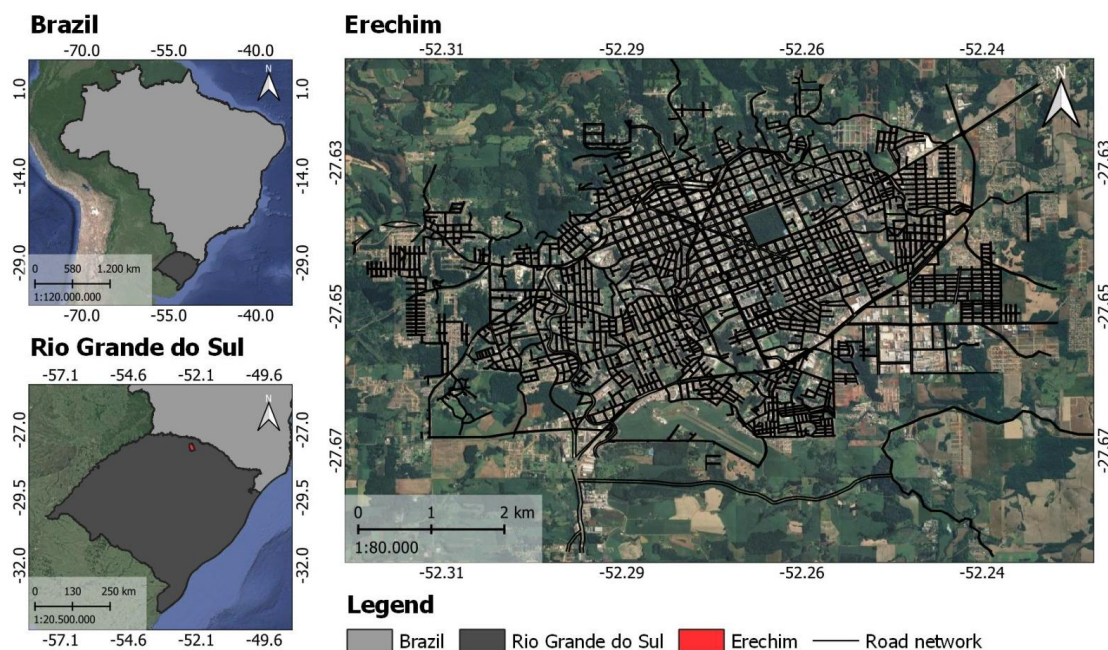
This article, with an exploratory approach, was divided into five stages: a) bibliographical research, which covered the layout of the city of Erechim and its expansion, focusing on the implementation of social housing and the resulting occupations, as well as investigating the importance and methodology of space syntax; b) identification of the areas of occupation in Erechim; c) preparation of the axial map of the city, tracing the linear representation of the urban network provided by the Erechim City Hall (2024) in the AutoCAD program. It was exported in Data Interchange File (DXF) format; d) Depthmap software, version X5.0, was used to apply the axial analysis and the radius and integration variables; e) the information obtained from the axial analysis was cross-referenced with the vulnerable occupations identified.

2 MATERIAL AND METHODS

2.1 Identification of the object of study

Erechim (Figure 1), located in the northern part of Rio Grande do Sul, has a territorial extension of 429.164 km² and a population of 105,705 inhabitants, totaling 246.30 inhabitants per km². Erechim was designed in 1914 by the then engineer and Director of the Land Commission Carlo Torres Gonçalves and was elevated to the category of municipality in 1918 (Aver, 2008).

Figure 1 - Location of the city of Erechim in Rio Grande do Sul (Brazil).



Source: Prepared from the IBGE database (2024).

The occupation of areas in the municipality dates back to the construction of the first farm called “Chácara para indigentes” in the late 1930s. Located outside the urbanization of the city, this was not only a way of providing housing for workers but also of expelling the poor from areas of economic interest, which not only reinforced the positivist concepts that inspired the creation of the city (Funfgel, 2004; Aver 2008) and which historically prioritized rational urbanization without considering the social context of the city (Villaça, 2001), but also the hygienist/sanitarist ideals of the time, which marginalized the population with lower financial conditions in order of hygiene, by building hygienic villas for them, which they believed were responsible for idleness and the proliferation of diseases (Almeida, 2007).

In the 1951s, a village was built in the city for the city's workers, and at the end of its construction, all the garden areas were taken over (Aver, 2008). In the latter case, the invaded areas were regularized by City Hall over the decades (Erechim, 2024). However, the greatest volume of occupation of green areas occurred in the areas destined for social allotments, set up

in the 1990s. Between 1991 and 2000, 10 areas were set up for social housing, all located on the margins of the urban network, reflecting the organic development of the city (Psldonik, 2019).

In addition to the areas, the 1990s were marked by the use of the areas near the railroad. With the decommissioning of the railroad section, many people began to establish their homes in the remaining areas of the railroad line, and there are currently around 230 families living within the railroad's domain (Tochetto and Almeida, 2023). However, since 2015, there have been no reports of new occupations, with only consolidated nuclei being used (Psldonik, 2019).

2.2 Space syntax

Every landscape can change over time, depending on its economic, cultural, political, and social context (Lynch, 1996). According to Harvey (2006), two fundamental tools for analyzing urban transformations are the social imagination and the spatial imagination. In general terms, the “spatial imagination” is related to the organization and use of space, considering the social, economic, political space, considering the social, economic, political, and cultural factors that shape this place. In contrast, the “social imagination” is related to the ability to connect personal experiences with social issues.

Space syntax is an important tool for analyzing the urban context, as it allows us to understand the space in its entirety, its limitations, and its potential, allowing us to improve its flow and connectivity (Hillier and Hanson, 1984), which mainly affects peripheral areas. According to Medeiros (2014), the most economically affluent areas are distanced from the most vulnerable, exacerbating socio-spatial segregation and hindering access to urban facilities, which in most cases are invested in the prime regions of cities, while the others remain indifferent to the eyes of public policies (Rolnik, 2018).

This dichotomy in access to certain services, as well as quality urban infrastructure, is related to the capital market, where land is a high-cost product, which consequently becomes unattainable for specific classes, resulting in a lack of mobility and connectivity for people who live far from the areas with the highest economic values (Villaça, 2001).

In this sense, the technique used by Hillier and Hanson in the 1980s, in their book “The Social Logic of the Space” (1984), makes it possible to identify the patterns of integration and segregation of spaces quantitatively. From this, it is possible to obtain the relationship between the spatial configuration and the social behavior of a given location (Jiang *et al.*, 2014).

To analyze space syntax, it is important to consider the spatial network, which treats urban space as a mesh with various “micro” connections. This component uses integration metrics that measure how integrated (accessible) or segregated (inaccessible) a space is. It also analyzes the ease of access between different areas, based on the number of direct connections they have. This data reveals how interconnections within the city affect an individual's movement and their accessibility in certain regions (Hillier, 1996; Turner, 2007; Andrade, 2014).

To identify these metrics, Hillier and Hanson (1984) define mapping as a fundamental element, which creates maps to visualize and analyse these connections, using axial lines to represent the paths within the city grid, delimiting the space by main axes, where greater integration between areas will have greater accessibility between regions (Carmo, Junior and

Nogueira, 2013). To obtain this data, it is necessary to identify the mean depth (MD), the sum of the total depth owed by the number of spaces, subtracted by unit 01.

From the DM value, it is possible to find the relative symmetry (RS), which aims to compare the depth of a node to the others and assess how central or peripheral a space is within a city (Hillier, 1993; Carmo, Junior e Nogueira, 2013). This data makes it possible to quantify the relationship between spatial configuration and social behavior (Jiang *et al.*, 2014), which can be used to understand the dynamics of socio-spatial segregation, which is important for planning city spaces, as well as making them more accessible by optimizing flows and organizing space more efficiently (Hillier & Iida, 2005; Alves *et al.*, 2013). This study followed the following methodological steps:

a) identification of areas of occupation in Erechim: the green areas occupied informally were surveyed at the Erechim City Hall. The data was obtained using the .doc extension, which was then analyzed using the Google Earth program and georeferenced using the Qgis software, which generated maps of points;

b) preparation of the axial map of the city, using a linear representation of Erechim's urban grid, made available by the Department of Works, using Autocad software version 2025;

c) Depthmap software version X5.0 was used to apply the axial analysis and the R3 radius and integration variables. To analyze the integration of informally occupied peripheral green areas with the official urban network planned in 1914;

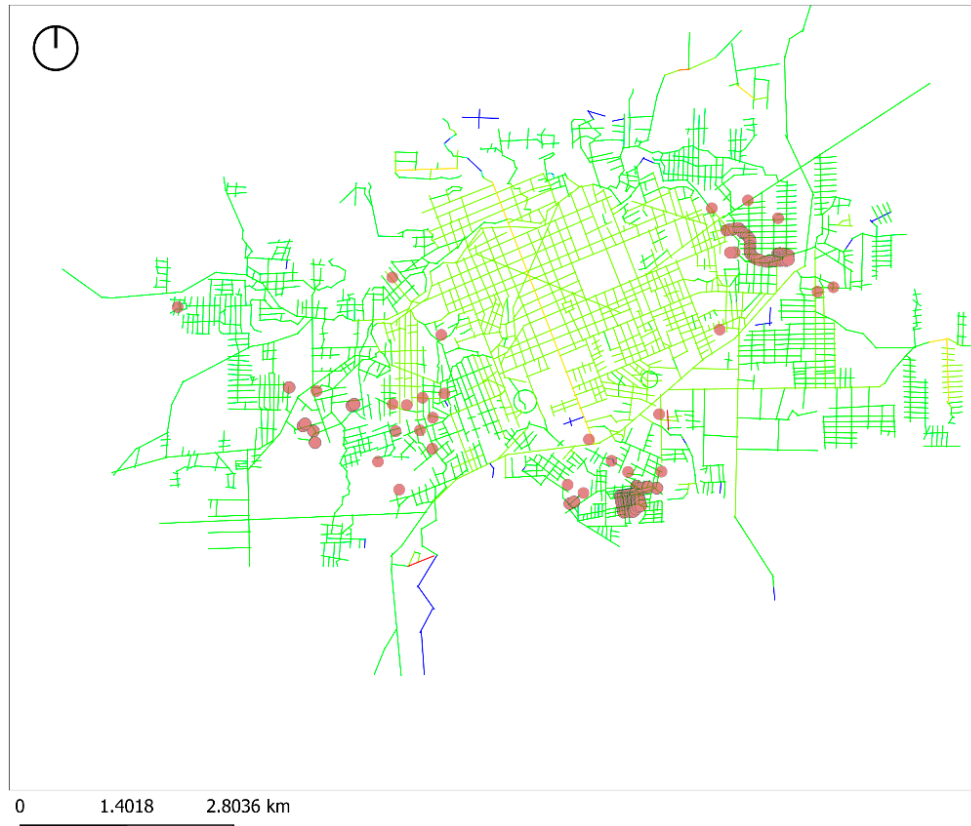
d) Finally, the information obtained in the axial analysis was analyzed and cross-referenced with the vulnerable occupations identified.

3 RESULTS AND DISCUSSION

To identify the connectivity of informally occupied green areas, 444 areas were mapped. Of these areas, 44 are occupied by primarily vulnerable housing. These areas are concentrated in the city's peripheral neighborhoods, with a lower concentration of income, ranging from 615.46 to 1070.00 reais (IBGE, 2024), such as Petit Village, Progresso, Presidente Vargas, Cristo Rei, São Vicente de Paulo, Aeroporto, among others.

To identify the connectivity of the city's occupied green areas, we used the axial map (Figure 2), which topologically analyzes urban integration combined with the normalized global choice (NHC) segment map. The site's connectivity was calculated using Depthmap software. To draw up the connectivity map, two radius levels were considered: R3, which represents the level of local connectivity, and global integration R, for a macro analysis of the urban system. The integration indices were represented using colors, with shades closer to blue representing the most segregated areas, while colors closer to red refer to the most integrated regions.

Figure 2 - Analysis of the overall integration of Erechim from the perspective of informal occupations in green areas.

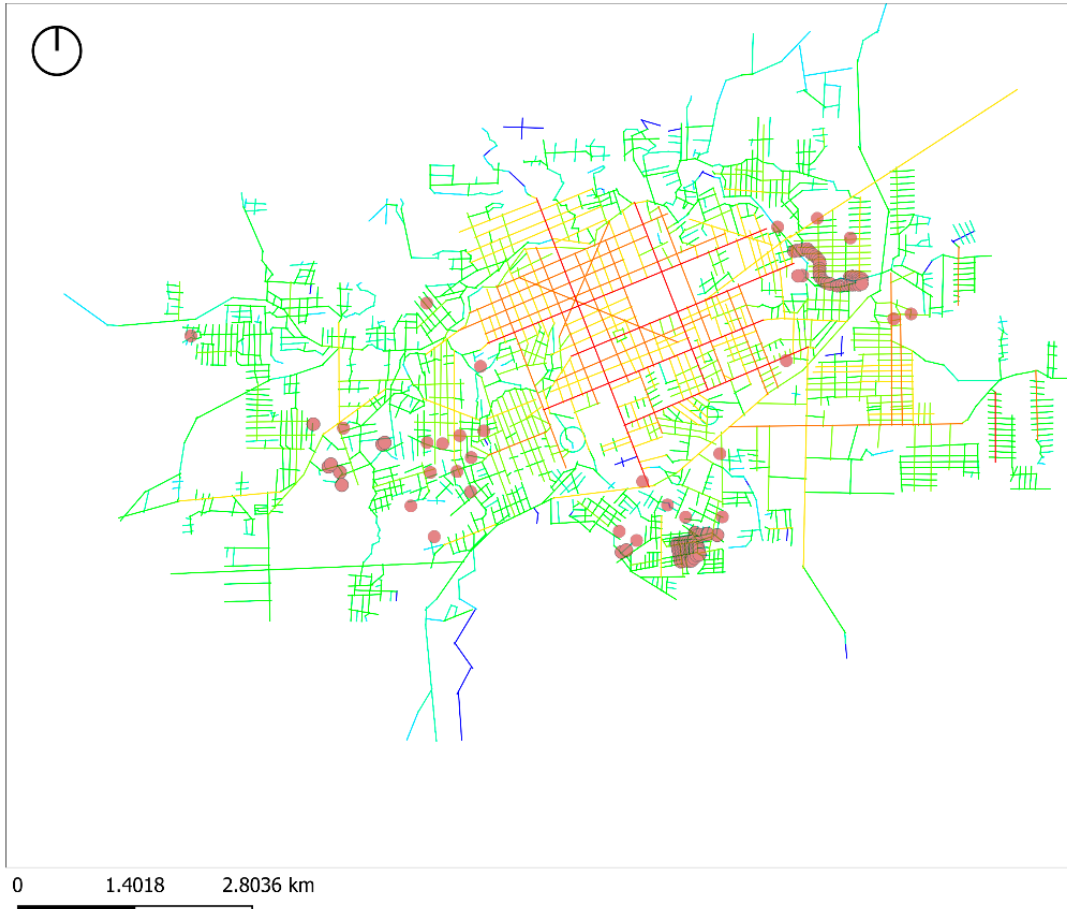


Source: Prepared by the authors (2024).

The axial map in Figure 3 shows that the urban grid corresponding to the 1914 plan is more integrated than the roads established organically over time, especially on the main axes located in the city center. This configuration aligns with the theory of natural movement proposed by Hillier *et al.* (1993), which argues that the urban fabric, when well structured, attracts people to move around spontaneously, generating a natural flow that defines the vitality of urban spaces. The centrality of this area is, therefore, a manifestation of the social logic of space, where the distribution of integrations reflects the potential for accessibility and use of space.

This greater integration in the center suggests that Torres Gonçalves of 1914 effectively created an urban structure that favors social interaction and circulation, in line with the idea that urban form directly influences movement patterns and, consequently, the city's social life. One notable aspect is the integration of the peripheral areas, which remain connected to the original layout, in contrast to the local scale R3, represented in Figure 3.

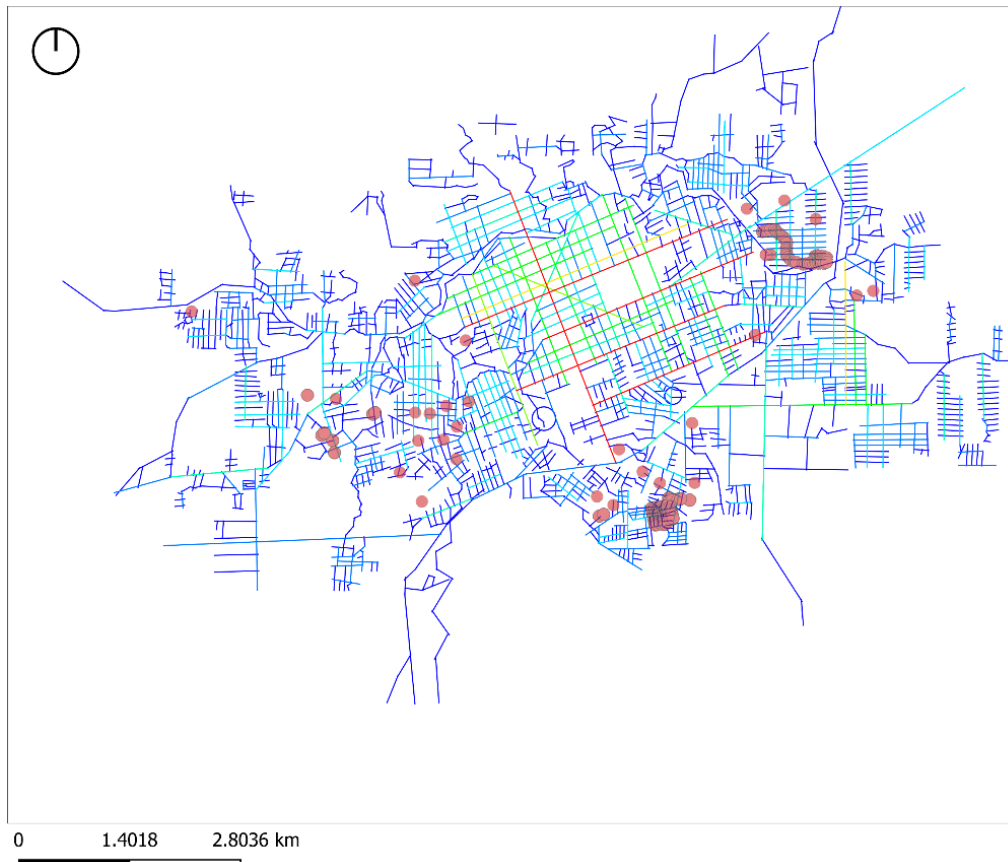
Figure 3 - Analysis of Erechim's local integration from the perspective of informal occupations in green areas.



Source: Prepared by the authors (2024).

With regard to local integration, the scale varies from -1.0 to 4.2474 pixels, with the highest value being associated with the north-south axis of the urban network. The average local integration in the city is 1.514 pixels. These values indicate an uneven distribution of accessibility, where peripheral areas, especially those with a higher concentration of vulnerable occupations in green areas, are more segregated (Figure 4) or less accessible compared to other regions. According to space syntax, this segregation reflects a condition of spatial marginalization, where low integration is associated with fewer opportunities for social interaction and reduced access to urban resources.

Figure 4 - Analysis of the connectivity of Erechim's urban network.



Source: Prepared by the authors (2024).

Figure 4 shows a dispersion in the city's connectivity, highlighting that the areas with the highest concentration of connectivity correspond to the service axes and the regions with high-income levels (between R\$1,720.01 and R\$5,231.01). From the perspective of the configuration of the urban fabric, it can be seen that the neighborhoods where the social allotments were set up in the 1990s, such as Progresso, Cristo Rei, Pettit Village, Copas Verdes, and São Vicente de Paulo, have less connectivity compared to the central areas. This shows spatial segregation where higher-income residents are concentrated in the more central areas of the city, reflecting Erechim's socio-spatial segregation.

From the point of view of space syntax, this configuration is not surprising. Hillier (1996) argues that the urban form is a reflection and, simultaneously, a producer of social inequalities. The central areas, which are more integrated and connected, tend to concentrate on the higher social strata, while the peripheries, with less connectivity, are associated with lower-income groups. Frederico Holanda also addresses the issue of segregation, suggesting that the structure of urban space can either intensify or mitigate social inequalities, depending on how connections and accessibility are distributed. In addition, the peripheral location of the social allotments contributed to the formation of informal occupations near these areas. The urban expansion resulting from this process occurred in an organic and unplanned manner, reinforcing segregation and perpetuating the conditions of socio-spatial inequality.

4 CONCLUSION

This article aimed to identify the levels of integration and connectivity of areas occupied by housing in green areas in the city of Erechim. It is important to note that this study does not aim to discuss the legality of these areas but rather to identify the levels of integration with the other regions of the city. From this, it was observed that the city expanded from the Plan drawn up in 1914 by Torres Gonçalves, with the north-south axis, drawn in the center of the project, being the most integrated area of the city. This central region also corresponds to the commercial sector and the areas with the highest concentration of income, which demonstrates a correlation between spatial accessibility and the accumulation of capital, in line with Hillier's (1996) theories on the influence of urban form on social and economic patterns.

In addition, the checkerboard grid designed in the initial plan (1914) remains connected to the spatial configuration of Erechim, suggesting that the original urban design successfully established a structuring base that continues to this day. Another important aspect identified was the role of the railroad, which at some points along its route acts as a constraint on urban integration, creating physical barriers that hinder connectivity between different parts of the city.

The city's peripheral growth, driven mainly by the implementation of social allotments (1990-2000), occurred disorderly, resulting in an expansion that proper planning. The lack of control over the remaining areas encouraged the formation of informal occupations, many inhabited by vulnerable populations. The poor integration and connectivity of these peripheral areas have contributed to their residents feeling segregated and marginalized, a condition that can be understood through the lens of space syntax due to an urban structure that does not offer equal accessibility and opportunities for all. Given this, a morphological understanding of the city is crucial to identifying the challenges of urban planning, especially in formulating policies aimed at integrating under-served regions into the city's spatial configuration.

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STATEMENTS

EACH AUTHOR'S CONTRIBUTION

When describing the participation of each author in the manuscript, use the following criteria:

- **Study conception and design:** Fernanda Tochetto and Guilherme Peterle Schmitz
 - **Data Curation:** Fernanda Tochetto
 - **Formal Analysis:** Fernanda Tochetto
 - **Research:** Fernanda Tochetto
 - **Methodology:** Alcindo Neckel
 - **Writing - Initial Draft:** Fernanda Tochetto
 - **Writing - Critical Review:** Caliane Christie Oliveira de Almeida
 - **Proofreading and Final Editing:** Alcindo Neckel
 - **Supervision:** Alcindo Neckel
-

DECLARATION OF CONFLICTS OF INTEREST

We, Fernanda Tochetto, Alcindo Neckel, Caliane Christie Oliveira de Almeida and Guilherme Peterle Schmitz, declare that the manuscript entitled “Space syntax as a tool for analyzing urban occupation: A study in Southern Brazil”:

1. Financial ties: We have no financial ties that could influence the results or interpretation of the work.

2. Professional Relationships: We have no professional relationships that could have an impact on the analysis, interpretation or presentation of the results.

Personal Conflicts: We have no personal conflicts of interest related to the content of the manuscript.
