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Desvendando a evolução urbana e a dinâmica espacial de Cascavel

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Eixo Temático: Teoria, métodos e técnicas

Desvendando a evolução urbana e a dinâmica espacial de Cascavel

Resumo. Este artigo explora a evolução urbana de Cascavel, um município brasileiro localizado na região oeste do estado do Paraná, empregando uma metodologia que integra análise histórica, exame demográfico e investigações espaciais avançadas. A pesquisa começa destacando a evolução histórica de Cascavel, enfatizando marcos desde o final da década de 1910, incluindo a fase transformadora na década de 1930 impulsionada pela imigração. Central à exploração está a aplicação da teoria de sintaxe espacial, utilizando mapas axiais e de segmentos para desvendar os atributos geométricos e topológicos que moldam a forma urbana da cidade. Utiliza um conjunto de variáveis como área do sistema, número de linhas/eixos, comprimento médio de linhas/fusos, número de segmentos, comprimento médio de segmentos, compactidade a: número de linhas/eixos por km² e compactidade b: comprimento de linhas/eixos por km², conectividade, integração global (rn), integração local (r3), sinergia, inteligibilidade, nain e nach. O estudo acompanha essas variáveis ao longo de vários pontos temporais (1959, 1975, 2008 e 2019) para capturar a natureza dinâmica da expansão urbana de Cascavel. Em conclusão, o artigo analisa a evolução urbana de Cascavel como uma narrativa dinâmica, transcendendo métricas estatísticas. A identidade espacial da cidade se adapta, integra e tece uma narrativa através da história, cultura e contornos naturais.

Palavras-chave. evolução urbana, dinâmica espacial, sintaxe espacial

Unraveling Cascavel's urban evolution and spatial dynamics

Abstract. This paper delves into the urban evolution of Cascavel, a Brazilian municipality located in the western region of the state of Paraná, employing a methodology that integrates historical analysis, demographic examination, and advanced spatial investigations. The research begins by highlighting Cascavel's historical evolution, emphasizing milestones since the late 1910s, including the transformative phase in the 1930s driven by immigration. Central to the exploration is the application of space syntax theory by employing axial and segment maps to unravel the geometric and topological attributes shaping the city's urban form. It utilizes a set of variables such as system area, number of lines/axes, average length of lines/spindles, number of segments, average segment length, compactness a: number of lines/shafts per km² and compactness b: length of lines/shafts per km², connectivity, global integration (rn), local integration (r3), synergy, intelligibility, nain and nach. The study tracks these variables across multiple time points (1959, 1975, 2008, and 2019) to capture the dynamic nature of Cascavel's urban expansion. In conclusion, the paper glances Cascavel's urban evolution as a dynamic narrative, transcending statistical metrics. The city's spatial identity adapts, integrates, and weaves a narrative through history, culture, and natural contours.

Keywords: urban evolution, spatial dynamics, space syntax.

1. Introduction

Cascavel, a city located in the state of Paraná, Brazil, has undergone significant transformations over the years, shaped by various socio-economic factors and urban development initiatives. It has evolved from a small settlement to a thriving urban center, experiencing rapid population growth and infrastructural expansion. The city's strategic location, favorable climate, and rich agricultural resources have contributed to its emergence as a key economic hub in the region. Over the years studied, including 1959, 1975, 2008, and 2019, Cascavel has witnessed waves of migration, industrialization, and urbanization, which have left a profound imprint on its spatial organization and socio-cultural fabric.

This paper delves into Cascavel's history and examine its configurational characteristics through spatial analysis techniques, particularly focusing on space syntax methodology. By mapping and analyzing the city's urban structure, street networks, and spatial configuration, it aims to uncover underlying patterns of accessibility, connectivity, and segregation within the built environment. The space syntax variables considered in analysis include System Area (km²), Number of Lines/Axes, Average Length of Lines/Axes, Number of Segments, Average Segment Length, Compactness A, Compactness B, Connectivity, Global Integration, Local Integration, Synergy,

Intelligibility, NAIN (Normalized Angular Integration), and NACH (Normalized Angular Choice).

The analysis of Cascavel's urban evolution, spanning from 1959 to 2019, provides a comprehensive understanding of how the city's socio-economic dynamics have shaped its spatial configuration over time. By examining historical records, tracing the progression of settlement borders and patterns, it sheds light on the intricate interplay between human activities and urban form. Using spatial analysis techniques, including axial and segment mapping, it dissects the city's spatial organization and evaluates key variables.

The findings offer insights into Cascavel's urban landscape, revealing patterns of development that have emerged over the decades. By elucidating the underlying socio-economic drivers of urban morphology, the analysis provides an understanding of the complex relationships between socio-economic factors, spatial configuration, and urban functionality for Cascavel and similar urban contexts.

Through a multidisciplinary approach that integrates historical research, and space syntax theory, the paper seeks to deepen the understanding of Cascavel's urban evolution and contribute to ongoing debates on urban morphology, and socio-spatial dynamics in the context of growing cities in Brazil and beyond.

2. Background

Urban development is a dynamic interplay of historical legacies, socio-economic forces, and spatial configurations that shape the fabric of cities over time. Understanding the intricate relationship between urban form and historical evolution is fundamental to unraveling the complexities of urban landscapes. In this context, space syntax theory offers a powerful analytical framework that elucidates the spatial organization and structure of cities, providing insights into how they evolve and function. Meanwhile, the city of Cascavel stands as a microcosm of urban development, its history intricately intertwined with Brazil's socio-economic and political landscape. By delving into the historical evolution of Cascavel alongside space syntax theory, it is possible to explore how urban morphology reflects historical processes and informs contemporary urban planning and design strategies. This section aims to synthesize existing knowledge on Cascavel's history and space syntax theory, setting the stage for a deeper understanding of the interplay between urban form, historical context, and urban development.

2.1 Historical evolution of Cascavel

Cascavel, a city situated on the intersection of the three basins in the Paraná state of Brazil (see figure 1), witnessed a historical evolution deeply intertwined with the socio-economic and political landscape of the nation. Its rise from a mere stopping point between coastal cities and eastern towns to a thriving urban center reflects the complex dynamics of Brazilian history, characterized by colonization, economic shifts, and political transitions.

According to Sperança (2007), the region where Cascavel is situated originally served as a resting point between the coastal cities along the Paraná River and those in the east, such as Guarapuava, Lapa, and Curitiba. During the early colonial period, from around 1532 until the onset of the African slave trade, this area primarily provided indigenous labor for the large latifúndia, or plantations, established by the Portuguese. The economic activities of the Portuguese settlers in the region were constrained by the lack of access to the wealth derived from sugar cane cultivation, cattle ranching, and other lucrative ventures in other parts of Brazil. Consequently, they turned to the capture and enslavement of indigenous peoples through bandeiras, or expeditions, to supply labor for their expanding plantations. Despite the influx of bandeiras to the region starting in 1558, Portuguese settlers did not attempt to establish permanent colonies in the area. Instead, the economic landscape remained focused on exploiting indigenous labor for agricultural and other labor-intensive activities.



Figure 1. Location of Cascavel: The precise location of Cascavel within its municipality, state, and country. (source: author's elaboration)

Additionally, the abolition of slavery in Brazil in 1888 marked a significant turning point in the region's economic and demographic history. With the end of the slave trade, plantation owners faced a shortage of labor. In response, the Brazilian government sought to attract immigrants to fill the labor gap and colonize the interior regions, particularly those with disputed or undefined borders. Italy, grappling with its economic challenges, emerged as a key source of immigrants for Brazil's labor replacement plans. Italian immigrants, along with others from Europe and neighboring countries, began to arrive in the region, drawn by promises of land and opportunity. The colonization efforts intensified following the establishment of settlements in the Iguaçu River delta by foreign immigrants. These early pioneers laid the groundwork for further exploration and settlement of the interior regions, including Cascavel (SPERANÇA, 2007).

Table 1. Urban and Rural Population in Cascavel (1960-2010) based on data from IBGE Censo 2010. (source: author's elaboration)

Settlement	1960	1970	1980	1991	2000	2010
Rural	34.324	54.960	39.761	15.224	16.696	16.156
Urban	5.274	34.961	123.698	177.766	228.673	270.049
Total	39.598	89.921	163.459	192.990	245.369	286.205

Obs. The demographic trends revealed by the data underscore a consistent rise in the total population across the specified years, indicative of sustained overall population growth. Notably, the urban population has witnessed substantial expansion, most prominently observed in the transformative period from 1960 to 2010. In contrast, the rural population has exhibited fluctuations, with certain years marked by a decline, such as 1980 and 1991, while others registered a modest increase. This dynamic interplay between rural and urban demographics underscores a widening gap over the years, underscoring prevailing urbanization trends that have shaped the population landscape.

In the late 19th and early 20th centuries, Cascavel began to emerge as a focal point of development in the region. The presidential elections of 1929 signaled the end of the traditional political arrangement known as "coffee-with-milk," which alternated power between São Paulo and Minas Gerais. The election of Júlio Prestes from São Paulo led to discontent among the elite in Minas Gerais and other regions, culminating in the rise of the Alliance Liberal and the election of Getúlio Vargas. The Tenentismo movement, characterized by military rebellions against the established political order, played a significant role in shaping Brazil's political landscape in the 1920s. The Coluna Prestes, led by figures like Luis Carlos Prestes, traversed the region, leaving a mark on local communities and contributing to political instability (Dias et al., 2005).

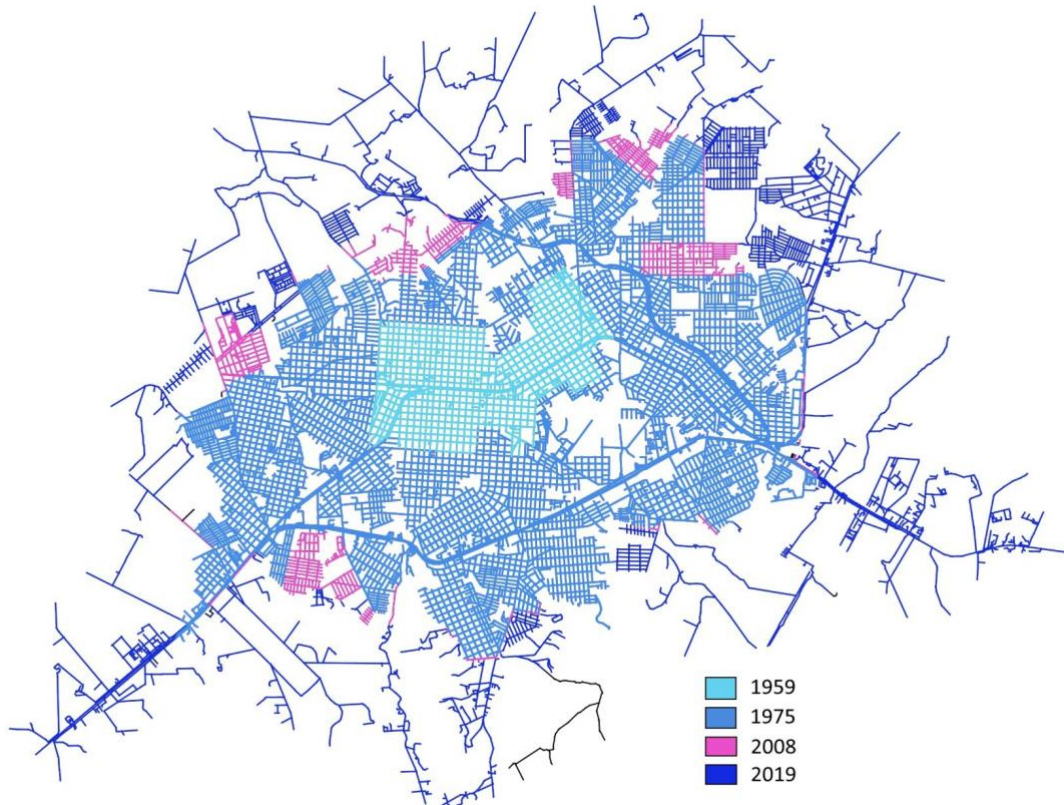


Figure 2. The evolution of Cascavel city settlement over the years 1959, 1975, 2008, and 2019, adapted from data obtained from Cascavel's Planning and Urbanism Secretariat - SEPLAN (2019). (source: author's elaboration)

In addition, according to them, Cascavel's evolution into an industrial and commercial hub during the mid-20th century was underpinned by a confluence of factors, including waves of immigration that infused the city with diverse cultural influences and skilled labor. European immigrants contributed to the city's demographic mosaic, bringing with them expertise in various trades and professions. This influx of human capital (see table 1) not only enriched Cascavel's social fabric but also fueled economic growth and innovation. Furthermore, Cascavel's strategic location served as a catalyst for its economic ascendancy, providing a gateway for trade and commerce in the region. Situated at a crossroads of transportation routes and surrounded by fertile lands conducive to agriculture, timber, and livestock production, the city emerged as a pivotal center for economic activity. Its proximity to key markets and logistical networks facilitated the exchange of goods and services, fostering a dynamic business environment that attracted economic activities. As Cascavel's economy diversified and expanded, fueled by these strategic advantages and the ingenuity of its inhabitants, the city solidified its position as a thriving urban center with a vibrant economy and promising prospects for continued growth and development (see figure 2).

This historical narrative underscores Cascavel's administrative metamorphosis, reflective of broader socio-economic and political developments. The administrative formation of Cascavel traces a timeline marked by legislative enactments and territorial adjustments, emblematic of its transition from a district to a fully-fledged municipality within the state of Paraná, Brazil.

According to Dias et al. (2005), the initial establishment of Cascavel as a district occurred under the Decree-Law State No. 7,573 on October 20, 1938. At this juncture, Cascavel operated under the jurisdiction of the municipality of Foz do Iguaçu. This administrative arrangement persisted through subsequent territorial delineations until July 1, 1950. Cascavel's elevation to municipal status transpired through the State Law No. 790 on November 14, 1951, leading to its detachment from Foz do Iguaçu. The former district of Cascavel became the municipal seat, and the

municipality initially comprised only the Cascavel district. Its official establishment as a municipality occurred on December 14, 1952.

They also report the following years, as Cascavel experiencing territorial reconfigurations, reflecting demographic shifts and administrative reorganizations. The creation of new districts, such as Corbélia by State Law No. 3,356 on October 9, 1957, and Formosa by State Law No. 4,311 on January 6, 1961, expanded Cascavel's administrative boundaries. However, subsequent legislative acts, notably State Law No. 4,382 on June 10, 1961, resulted in the separation of Corbélia and Formosa from Cascavel, elevating them to independent municipalities. Conversely, the integration of new districts like Cafelândia by Municipal Law No. 166 on December 7, 1961, and Nova Aurora by State Law No. 177 on September 26, 1961, augmented Cascavel's administrative structure. Further territorial adjustments occurred with the renaming of Cafelândia to Cafelândia do Oeste by State Law No. 4,668 on December 31, 1962, and the subsequent creation of districts like Santa Tereza by State Law No. 5,263 on January 13, 1966, and São João d'Oeste by State Law No. 5,536 on September 24, 1967.

The year 1976 witnessed the incorporation of Lindoeste by State Law No. 6,851 on February 13, followed by the establishment of Rio do Salto and Juvinópolis as districts in 1977 by State Laws No. 6,921 and No. 6,925, respectively. These developments culminated in Cascavel's administrative composition of seven districts by January 1, 1979 (Dias et al., 2005). This expansion of urban subdivisions in the 1970s contributed to the formation of urban voids, despite a relatively low population density. This indiscriminate expansion generated high infrastructure costs and the dispersion of scarce financial resources (Figueiredo et al, 2018).

Dias et al., (2005) continue to record the developments with subsequent legislative acts, such as State Law No. 7,292 on December 28, 1979, led to the detachment of Cafelândia, which attained municipal status, and the creation of new districts like Sede Alvorada by State Law No. 7,440 on December 29, 1980. The territorial evolution of Cascavel continued with the emancipation of Lindoeste and Santa Tereza into independent municipalities by State Laws No. 9,006 and No. 9,008, respectively, on June 12, 1989. According to Figueiredo et al. (2018), the 1980s were characterized by an insufficient housing policy, leading to an increase in informal settlements. In response, an Urban Development Plan was drawn up in 1986-1987, aiming to organize the city's development in a more structured manner.

By 1993, Cascavel comprised five districts, namely Cascavel, Juvinópolis, Rio do Salto, São João d'Oeste, and Sede Alvorada, a configuration that persisted through subsequent territorial assessments (Dias et al., 2005). During the 1990s, the focus shifted to rationalizing land use, economic strengthening, and modernizing public administration. The 1996 Master Plan proposed densification of already urbanized areas, prioritizing the city center and sub-center (Figueiredo et al., 2018).

According to Figueiredo et al. (2018), rapid growth continued in the 2000s, with Cascavel assuming characteristics of a metropolis, branding itself as the "MERCOSUL Metropolis". The approval of the City Statute in 2001 and emphasis on public participation in urban decisions reflected a change in urban planning approach. Urban densification was encouraged through instruments like Transfer of Development Rights and Land Use Change. This led to vertical growth in the city, driven by investment in basic sanitation and demand for housing.

For the 2010s, they also mention the creation of the Metropolitan Statute and the Cascavel Metropolitan Region bringing new guidelines for urban planning, focusing on regional integration and integrated development. The new 2017 Master Plan established structuring and densification macrozones, aiming to discourage uncontrolled expansion and promote efficient use of urban space.



Figure 3. In 2019, the city of Cascavel, along with its urban perimeter and primary roads linking it to the surrounding environment, was depicted using data accessed from <https://geocascavel.cascavel.pr.gov.br:8181/geoserver/web/?2> (source: author's elaboration)

In summary, over these decades, it is possible to understand that Cascavel undergoes a significant process of urban transformation, marked by a mix of disorderly growth, real estate speculation, densification policies, and modernization of urban planning, reflecting the complex dynamics of urban development in specific regional contexts, as it takes its current form (see figure 3).

2.2 Unveiling historical narratives through space syntax analysis

Space syntax theory, introduced by Hillier and Hanson in 1984, provides a robust framework for dissecting the spatial configurations and dynamics of urban environments, allowing for a nuanced exploration of how spatial development intertwines with historical evolution. By leveraging a multitude of measures and variables, space syntax unveils crucial insights into the historical trajectory of urban fabric, reflecting shifts in culture, society, and historical forces. This analytical lens enables researchers to delve into the historical layers embedded within the city's spatial structure, offering invaluable context for understanding its developmental narrative (HILLIER; HANSON, 1984).

Axial lines, axial maps, and segment maps constitute foundational components of space syntax theory, facilitating the analysis of spatial structure, movement dynamics, and connectivity patterns in urban landscapes. Axial lines delineate primary pathways or axes of movement within the city, comprising streets, pathways, or corridors essential for the flow of people and vehicles across urban areas (see figure 4). Axial maps visually represent these primary movement axes, aiding in the identification of major routes and interactions within the cityscape, thereby elucidating key pathways crucial for urban accessibility and connectivity (HILLIER, 1999; Turner et al., 2005; HILLIER, 2007; MEDEIROS; HOLANDA, 2005).

In contrast, segment maps partition the urban environment into distinct spatial segments or units, delineating specific areas such as streets, blocks, neighborhoods, or districts. By segmenting the city in this manner, researchers can analyze the spatial composition and distribution of urban elements while examining connectivity and accessibility patterns between different segments. Together, axial lines, axial maps, and segment maps form integral components of space syntax analysis, providing a comprehensive framework for unraveling the complexities of urban environments (TURNER, 2004).



Figure 4. Axial map representation of Cascavel city. (source: author's elaboration)

Changes in the number of lines and their lengths serve as windows into the historical evolution of the urban fabric, offering nuanced insights into the dynamic interplay between human activity and spatial organization. An increase in the number of lines, coupled with shorter average lengths, paints a vivid picture of urban densification and development. This phenomenon mirrors historical trends towards heightened population density and urbanization, reflecting the evolving needs and aspirations of urban dwellers over time (HILLIER, 1999; Turner et al., 2005; MEDEIROS; HOLANDA, 2005).

Furthermore, shifts in the number and length of segments provide a compelling narrative of how the urban fabric has been subdivided and reorganized across different epochs. These changes reflect historical shifts in urban planning and design strategies, capturing the adaptation of the cityscape to changing societal demands, economic imperatives, and technological advancements (TURNER, 2004).

Variations in line density across diverse topographic areas and eras underscore the intricate relation between natural landscapes and human interventions in shaping urban morphology. These variations illuminate historical settlement patterns and resource utilization, highlighting the symbiotic relationship between human communities and their natural surroundings (HILLIER, 2007).

Moreover, changes in connectivity patterns unveil the historical transformations that have shaped the urban landscape. They offer insights into the evolution of transportation networks, the reconfiguration of land use patterns, and the expansion of urban boundaries, illuminating historical trends in mobility, accessibility, and integration within the city (HILLIER; HANSON, 1984; MEDEIROS; HOLANDA, 2005) .

The historical changes in integration values, synergy values, intelligibility dynamics, NAIN, and NACH values provide a rich tapestry of evolving urban navigation, accessibility, and connectivity patterns. Analyzing these values over time allows for the identification of historical trends in urban development, including shifts in urban morphology and the impact of planning

interventions on spatial accessibility and connectivity. This holistic approach enables researchers to uncover the underlying forces that have shaped the city's spatial dynamics, offering invaluable lessons for informing future urban planning and design endeavors (Hillier et al., 1987; HILLIER, 1996; Hillier et al, 2012; MEDEIROS; HOLANDA, 2005).

Examining these measures within the historical context of a settlement like Cascavel unveils profound insights into the intricate tapestry of urban development, adaptation, and response to a myriad of socio-economic and environmental factors over time. By delving into the historical layers of urban morphology, connectivity patterns, and spatial organization, researchers can unravel the complex interplay between societal aspirations, economic forces, and natural constraints that have influenced the city's trajectory over the years.

Ultimately, the examination not only enriches the understanding of the city's past but also informs contemporary urban planning and design practices. By illuminating the historical dynamics of urban development, adaptation, and response, it is possible to glean valuable lessons for navigating the complexities of modern urban challenges, ensuring that Cascavel continues to evolve as a vibrant, resilient, and inclusive urban landscape for generations to come.

3. Method

The study employed a multi-faceted approach to examine the historical evolution and spatial dynamics of Cascavel. Historical records detailing the city's evolution, settlement borders, and patterns for the years in question were sourced from prior studies and Municipal Government's Planning and Urbanism Secretariat (2010). To augment this data, satellite imagery was employed to validate and enrich the information, particularly for the year 2019, thereby offering a comprehensive perspective on the city's developmental trajectory.

Utilizing Quantum Geographic Information System (QGIS) software, axial maps were meticulously crafted for each study year. Leveraging the Space Syntax module within QGIS, axial lines were generated to delineate the city's spatial structure. Subsequently, the axial and segment maps underwent space syntax analysis to quantify a range of spatial attributes, encompassing system area (km²), number of lines/axes, average length of lines/axes, number of segments, average segment length, compactness, connectivity, global and local integration, synergy, intelligibility, NAIN (normalized angular integration), and NACH (normalized angular choice). These metrics were computed utilizing established algorithms integrated into the space syntax module (see figure 5).

The outcomes of the space syntax analysis were interpreted through the lens of space syntax theory, which offers insights into the intricate relationship between spatial configurations and human behavior. Theoretical constructs such as natural movement patterns, hierarchical access, and spatial cognition guided the interpretation of the findings, providing a better understanding of Cascavel's urban morphology and its underlying dynamics.

Furthermore, the interpreted results were juxtaposed with existing literature on Cascavel's historical evolution. This comparative analysis facilitated a deeper comprehension of Cascavel's urban evolution within the broader theoretical context. Acknowledging potential limitations, including biases in historical data, constraints in obtained settlement border information and inherent assumptions in space syntax analysis, the study considered these factors in the interpretation and discussion of results.

4. Results and Discussion

The analysis across four different time points (1959, 1975, 2008, and 2019) reveals significant trends in the city's spatial configuration and organization. Cascavel experiences notable changes in its urban landscape over the studied period, reflecting shifts in population, infrastructure development, and economic activities (see table 2).

One key finding is the progressive expansion of the city's urban area, growing from 116 km² in 1959 to 2529 km² in 2019. This expansion accompanies a substantial increase in the number of

lines/eixos within the urban network, rising from 356 in 1959 to 6515 in 2019. Similarly, the number of segments within the urban network also sees a significant uptick, growing from 1567 in 1959 to 17355 in 2019.

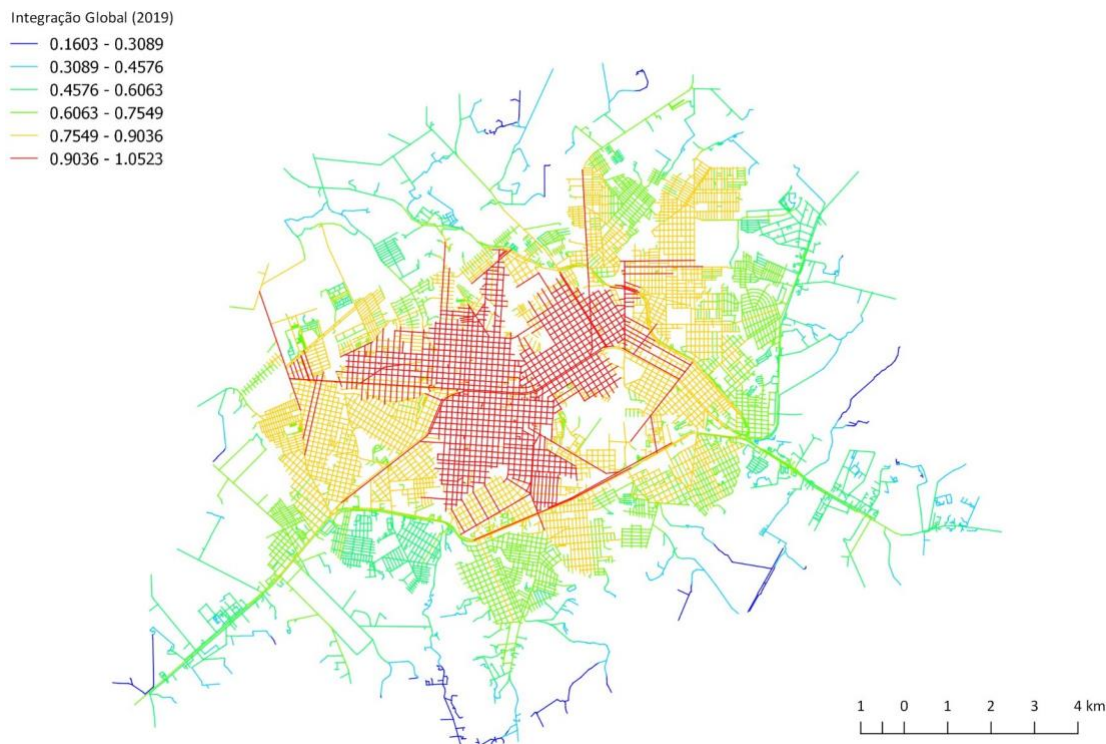


Figure 5. Global integration map of Cascavel. The lines are color-coded from red to blue, with red indicating areas of higher integration and blue representing lower integration levels. (source: author's elaboration)

Despite the expansion of the urban area and network, there is a noticeable decreasing trend towards the average length of lines/axis and segments. Additionally, while the number of lines/axis per km² exhibits a slight decrease over time, the compactness measures (compactness a and compactness b) remain relatively stable across the studied period.

Connectivity measures such as connectivity, global integration, and local integration show relatively consistent values over time, suggesting a stable level of urban connectivity and integration. However, there is a slight decrease in these measures, potentially reflecting changes in the city's spatial structure and network configuration.

Finally, measures related to spatial perception and navigation, including Synergy, Intelligibility, NAIN, and NACH, display varying trends over the studied period, indicating potential shifts in the city's spatial legibility and navigability.

The historical evolution of Cascavel from a small transit point to a thriving urban center is reflected in the significant expansion of the system area over time. In 1959, the area was relatively compact, indicative of a nascent urban settlement. However, by 2019, the substantial

increase to 2529 km² signifies extensive urban growth and territorial expansion, mirroring Cascavel's transformation into a metropolis. Likewise, the increase in the number of lines also reflects the progressive development and densification of Cascavel's urban network. During the years considered, the number of lines rose from 356 to 6515, indicating a substantial shift in urban connectivity and mobility.

Table 2. Yearly change of the configurational measures (source: author's elaboration).

Variables	Years			
	1959	1975	2008	2019
System Area (km ²)	116	921	1019	2529
Number of Lines/Axes	356	3541	3927	6515
Average Length of Lines/Axes	504.197	362.963	360.067	289.536
Number of Segments	1567	11932	13304	17355
Average Segment Length	107.691	101.995	101.060	102.460
Compactness A	3.06	3.84	3.85	2.58
Compactness B	4.34	0.39	0.35	0.11
Connectivity	5.12	4.14	4.18	3.47
Global Integration (Rn)	1.47	0.95	0.96	0.64
Local Integration (R3)	2.04	1.88	1.93	1.63
Synergy	0.85	0.53	0.50	0.56
Intelligibility	0.34	0.14	0.14	0.15
NAIN	1.66	1.15	1.15	1.02
NACH	1.07	0.95	0.95	0.92

These trends correlate with the city's historical narrative, which emphasizes its evolution into a commercial and industrial hub, attracting population influx and necessitating the expansion of road networks. The growth in both variables signifies the complexity of Cascavel's urban fabric, highlighting its transition from a small settlement to a multifaceted urban center.

On the contrary, the decrease in the average length of lines can be seen as a result of urban infill, where new developments or changes in land use lead to the creation of shorter, more interconnected routes. From 1959 to 2019, the average length decreased from 504.197 to 289.536, indicating infrastructural improvements and urban planning interventions aimed at enhancing urban accessibility and livability. This also aligns with the historical narrative, which mentions efforts to rationalize land use and modernize public administration, reflecting a shift towards more efficient urban development strategies.

Additionally, the increase in the number of segments reflects the proliferation of urban arterial roads and the emergence of a more extensive street network. During the period analyzed, the number of segments rises from 1567 to 17355, indicating the city's spatial complexity. This correlates with Cascavel's transformation and its focus on development and regional integration. In comparison to other measures such as the number of lines and system area, the growth in the number of segments signifies the granularity and complexity of Cascavel's urban streetscapes, underscoring the city's urbanization and spatial evolution.

The relatively stable values of the average length of segments over time also suggest a consistent pattern of street network design. Despite urban expansion and densification, the average length remained relatively unchanged, reflecting a balanced approach to street network design and urban form. This also verifies the mentioned urban planning interventions aimed at enhancing urban functionality before. Comparatively, while other measures such as the number of segments and system area exhibit growth, the stability of the average length of segments underscores Cascavel's focus on maintaining a cohesive and designed urban fabric.

Compactness A indicates the density of street lines or axes per square kilometer of the urban area. The decrease in compactness over time (from 3.06 in 1959 to 2.58 in 2019) suggests a reduction in street density relative to the urban footprint. This trend correlates with the urban expansion over the years. The decreasing compactness implies that as the city grew, its street network did not expand proportionally, potentially leading to lower connectivity and accessibility in certain

areas. Comparing with other measures, while the system area and number of lines increased, the decrease in compactness highlights the spatial dispersion and sprawl (see figure 6).

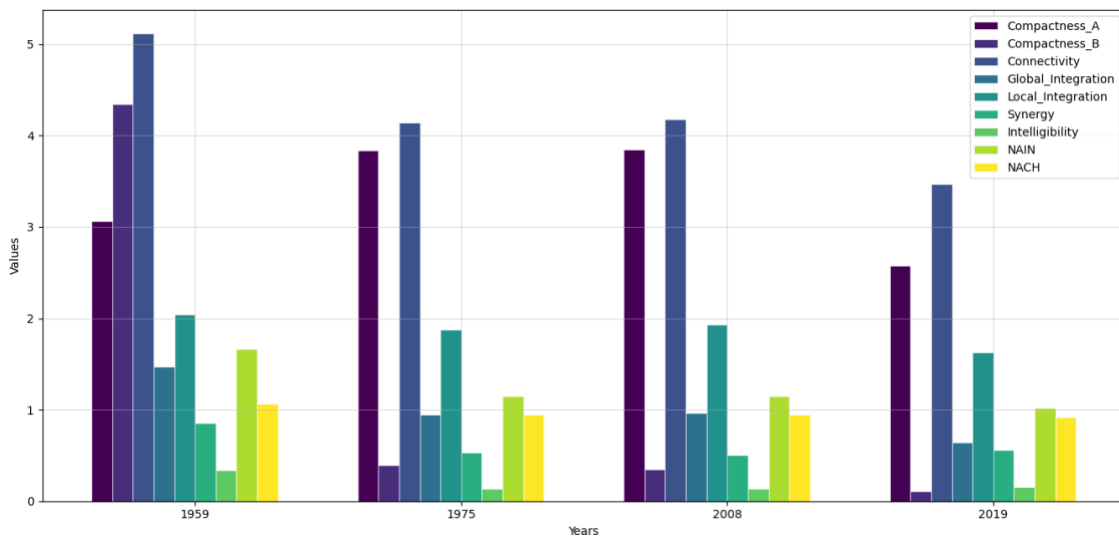


Figure 6. Bar chart illustrating yearly change of selected configurational measures. (source: author's elaboration)

Compactness B, on the other hand, represents the total length of street lines or axes in kilometers, reflecting the extent of street infrastructure within the urban area. The substantial decrease in compactness over time (from 4.34 in 1959 to 0.11 in 2019) suggests a significant reduction in the total length of street infrastructure relative to the urban area. This trend contrasts with the overall increase in system area and number of lines, indicating changes in the spatial distribution and configuration of street networks over time. The decreasing compactness signifies changes in urban morphology, such as the emergence of less efficient or compact street layouts.

Furthermore, the decreasing trend in connectivity values during the years researched (from 5.12 to 3.47) suggests a reduction in overall network connectivity over time. This trend aligns with the historical reality, which includes urban expansion and the emergence of disconnected and fragmented urban spaces. Thus, the decrease in connectivity impacts accessibility and mobility within the city, reflecting challenges in urban planning and design. Comparatively, while the number of segments and system area exhibit growth, the decrease in connectivity underscores the evolving spatial configuration of Cascavel's urban fabric.

Similarly, the decreasing trends in both global and local integration values suggest changes in the hierarchical organization and accessibility of urban streetscapes over time. The decrease in integration values reflect alterations in urban morphology, land use patterns, and transportation infrastructure, influencing the overall functionality and efficiency of the urban environment.

Moreover, decreasing synergy values suggests a decline in overall network integration, potentially leading to disjointed or fragmented urban spaces. Similarly, the stable or slightly decreasing trend in intelligibility values indicates consistent or slightly reduced spatial clarity and navigability within the urban environment. These trends also reflect changes in urban

morphology, land use patterns, and transportation infrastructure over time, impacting the overall coherence and legibility.

Both NAIN and NACH values suggest changes in the angular configuration and accessibility of urban streetscapes over time. Decrease in these values also reflects alterations in street layout, land use patterns, and transportation infrastructure, influencing the overall spatial organization and functionality of Cascavel's urban environment.

In essence, each space syntax measure outlined above provides valuable insights into the spatial evolution of settlements, shedding light on trends such as urban expansion, density, connectivity, and spatial organization over time. These measures offer complementary perspectives that

contribute to a comprehensive understanding of the complexities of urban development, thus informing future urban planning and design efforts.

By examining various aspects of urban morphology, these measures offer a holistic view that enables policymakers, urban planners, and researchers to grasp the intricate dynamics of the settlement. This comprehensive understanding allows for the identification of key trends and patterns, facilitating informed decision-making.

Correlating space syntax measures with Cascavel's historical evolution provides crucial context for interpreting urban changes over time. Understanding how the city's spatial characteristics have evolved alongside historical events, economic shifts, and policy interventions enhances the depth of analysis and supports proactive planning and policy responses.

Moreover, the analysis of space syntax measures enables the identification of long-term urban trends, such as expansion, densification, connectivity changes, and spatial fragmentation. These insights offer valuable guidance for planning and policy-making, allowing for targeted interventions to enhance urban functionality, accessibility, and livability.

These measures have practical applications in urban planning and design interventions. By pinpointing areas of low connectivity, inefficient spatial layouts, or fragmented urban spaces, policymakers and planners can prioritize interventions such as infrastructure upgrades, transportation improvements, and strategic land use policies.

Lastly, the analysis of space syntax measures can inform strategies for sustainable urban development in Cascavel. By promoting compact, connected, and efficient urban layouts, policymakers can encourage resource-efficient land use, minimize environmental impacts, and enhance the city's resilience to future challenges.

5. Conclusion

The space syntax analysis conducted across four different time points (1959, 1975, 2008, and 2019) reveals significant trends in Cascavel's spatial configuration and organization. Notable changes in the city's urban landscape over the studied period reflect shifts in population, infrastructure development, and economic activities.

One key finding is the progressive expansion of Cascavel's urban area. This expansion is accompanied by a substantial increase in the number of lines within the urban network. Similarly, the number of segments within the urban network also sees a significant uptick. The average length of lines and segments decreases steadily over the years. Measures related to spatial perception and navigation display varying trends, indicating potential shifts in the city's spatial legibility and navigability.

Compactness measures indicate changes in street density and infrastructure extent relative to the urban area, highlighting spatial dispersion and sprawl. Connectivity values suggest a reduction in overall network connectivity over time, impacting accessibility and mobility within the city. Similarly, decreasing trends in integration values indicate changes in hierarchical organization and accessibility of urban streetscapes.

The space syntax analysis in Cascavel reveals crucial insights for urban planning and development. It emphasizes the need for proactive interventions to accommodate urban growth while maintaining spatial efficiency and connectivity. Thus, continuous monitoring is essential to anticipate emerging challenges and opportunities. Future research can delve deeper into specific drivers of urban expansion and densification and explore their impacts on social equity, environmental sustainability, and economic resilience. In addition, comparative analyses with other cities can provide valuable insights into broader urban trends and guide innovative approaches to urban development. Overall, this analysis informs strategies for creating more resilient, livable, and equitable cities in Cascavel and beyond.

6. References

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