A Space Syntax Approach: Covid-19 and Socio-Spatial Inequalities in Bogotá, Colombia

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Abstract

Over the past three years, governments across the globe have enacted various public policy measures to mitigate the multifaceted effects of the Covid-19 virus since its official declaration as a pandemic by the World Health Organisation (WHO) in March 2020. This exploratory study aims to comprehend the impacts of Covid-19, considering urban socio-spatial patterns and socio-economic disparities in Bosa and Chapinero, two boroughs of Bogotá, the capital city of Colombia, South America. Using the socio-economic characterisation provided by the Colombian Statistics Office, National Administrative Department of Statistics (DANE), and consolidated data on mortality rates, infection levels, and intensive care unit usage from the Bogotá Mayor's Office, this study aims to assess the impact of Covid-19 in these two distinctly different boroughs in terms of socio-economic status and urban planning for safe and equitable mobility. Utilising Space Syntax as a methodology, we can examine urban morphology and understand social behaviour, connectivity, integration, and urban planning in a major metropolis of the Global South such as Bogotá. Through the lens of a syndemic concept, this study analyses the interplay of multiple health conditions intensified by social inequality. It underlines the amplifying effect of social inequality on the Covid-19 impact, especially in densely populated urban areas with high poverty levels and poor health conditions and infrastructure. This research suggests that urban density and mobility might affect the efficacy of lockdown measures, thus potentially worsening pre-existing health inequalities. The authors conclude this case study and suggest potential avenues for future research in Colombia and beyond.

Keywords: space syntax; urban planning; income inequality; good health & wellbeing

Abordaje desde la sintaxis espacial: Covid-19 y desigualdades socio-espaciales en Bogotá, Colombia

Resumen

Durante los últimos tres años, gobiernos de todo el mundo han implementado diversas medidas de política pública para mitigar los efectos multifacéticos del virus Covid-19 desde su declaración oficial como pandemia por la Organización Mundial de la Salud (OMS) en marzo de 2020. Este estudio exploratorio tiene como objetivo comprender los impactos de Covid-19, considerando los patrones socioespaciales urbanos y las disparidades socioeconómicas en Bosa y Chapinero, dos distritos de Bogotá, la ciudad capital de Colombia, Sudamérica. Utilizando la caracterización socioeconómica proporcionada por la Oficina de Estadísticas de Colombia, el Departamento Administrativo Nacional de Estadística (DANE), y datos consolidados sobre las tasas de mortalidad, niveles de infección, y uso de unidades de cuidados intensivos de la Alcaldía de Bogotá, este estudio pretende evaluar el impacto de Covid-19 en estos dos distritos marcadamente diferentes en términos de estatus socioeconómico y planificación urbana para una movilidad segura y equitativa. Utilizando la Sintaxis Espacial como metodología, podemos examinar la morfología urbana y entender el comportamiento social, la conectividad, la integración, y la planificación urbana en una gran metrópolis del Sur Global como Bogotá. A través de la lente de un concepto de sindemia, este estudio analiza la interacción de múltiples condiciones de salud intensificadas por la desigualdad social. Subraya el efecto amplificador de la desigualdad social en el impacto de Covid-19, especialmente en áreas urbanas densamente pobladas con altos niveles de pobreza y condiciones e infraestructuras de salud deficientes. Esta investigación sugiere que la densidad urbana y la movilidad podrían afectar la eficacia de las medidas de confinamiento, empeorando así potencialmente las desigualdades de salud preexistentes. Los autores concluyen este estudio de caso y sugieren posibles vías para futuras investigaciones en Colombia y más allá.

Palabras clave: space syntax; planificación territorial; desigualdad de ingresos; salud y bienestar

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1. Introducción

The Covid-19 pandemic has hit countries and regions worldwide at different times, intensities, and levels of preparedness. There are not only differences in the impact of the pandemic between but also within countries and metropolitan areas. Pandemics are not socially neutral, and poverty-stricken parts of cities have been particularly affected (Ellis et al., 2021). Nevertheless, although we can theorize the linkages between the severity of Covid-19 and socio-economic and socio-spatial characteristics and patterns (Cash & Patel, 2020), few studies have analysed empirical data and evidence, especially in Latin American metropolises (Guzman et al., 2021).

Therefore, we employ the concept of a syndemic, which captures 'how social environments, especially conditions of social inequality and injustice, contribute to disease clustering and interaction as well as to vulnerability' (Singer et al., 2017, p. 941). Syndemics are characterized by the presence of two or more health conditions that interact negatively with each other and whose impact is accentuated by the inequalities experienced by individuals (Sharma, 2017). The risks and effects of Covid-19 have been most significant in high-density cities, particularly in those urban sectors with substantial levels of poverty, environmental degradation, and poor health conditions (UN-Habitat, 2020).

Furthermore, urban boroughs as a unit of analysis are highly relevant to understanding crisis management, providing healthcare through the availability of intensive care unit (I.C.U.) beds and public policy responses. Often, local authorities are directly held responsible for the soundness of formulating effective public policies in times of health emergencies.

Recent studies have focused on cross-referencing urban data to determine or spatially understand the impacts of the virus. For example, Hananel et al. (2022) study the neighbourhood relationship and its homogeneity in the urban structure, while Hunter (2021) analyses urban fragility and resilience from a social policy and governance approach. On the other hand, Yao, Shi, Zhang, Liu, & Luo (2021) recently discussed the effects of the built environment on Covid-19. Other studies focus on green spaces according to their importance in the city, whether due to their distribution and accessibility or the importance of location for citizens (Pan et al., 2021; Noszczyk et al., 2022). However, these studies do not match social factors with the spatial dimension to further our understanding of the spatial behaviour of Covid-19 cities.

This exploratory study seeks to understand the impacts of Covid-19, considering urban differences and the context of socio-economic inequalities in the two boroughs of Bosa and Chapinero of the Colombian capital city of Bogotá. An exploratory study is "constructive for theorizing empirical material at an early stage, and which has a purpose to help […] to decide whether to conduct a full study or not" (Swedberg, 2018, p. 3).

Thus, this study contributes to our understanding of the multiple drivers and factors, emphasizing the regional socio-economic dimension and spatial aspects to explain disparities between the two boroughs subject to this research. Concerning public policy and urban planning decisions, our exploratory study suggests providing more hospital I.C.U.s closer to large agglomerations and foci of social behaviour and interaction.

Furthermore, space syntax analysis serves as a methodology to understand the social behaviour of urban mobility (Jiang & Huang, 2021). Since safe and equitable urban mobility is one of the main factors in the study of public health (Corazza et al., 2021; Xu et al., 2022; Cresswell, 2010), this approach is considered appropriate when analysing spatial phenomena concerning socio-economic data. Thus, the focus of urban morphology on connectivity and Integration is relevant (van Nes & Yamu, 2021; Pafka et al., 2020): 'Connectivity is a static local measurement accounting for all direct connections each street has to other streets in its immediate vicinity' (van Nes & Yamu, 2021, p. 36). Integration describes 'how a street relates to all other streets in a predefined spatial system and represents how a public urban space connects to other public urban spaces' (van Nes & Yamu, 2021).

2. Background

In the wake of the Covid-19 pandemic, countries worldwide have become increasingly preoccupied with limiting mobility, increasing distance, and prioritizing the well-being and health of societies (Martínez & Short, 2021). The Covid-19 pandemic has profoundly and perhaps to some degree permanently changed social behaviour and mobility, imposing distancing measures and prioritizing public healthcare provision. Although these measures would make for safer and more resilient cities, in the absence of more effective measures, lockdowns and social distancing have been assumed to be the most immediate and impactful measures to contain the virus and its subsequent variants.

The global health crisis caused by the SARS-CoV-2 virus moved its epicentre to Latin America, with cities showing high poverty rates, segregation, and overcrowding (Encinas et al., 2021; Marino et al., 2021). Recent studies have focused on the socio-spatial aspects of Covid-19 according to specific urban conditions and found an increasing trend of deaths in the region mainly located in municipalities with high social vulnerability (Castro et al., 2021; Andrade et al., 2022), indicating a correlation between access to public spaces, health facilities and public transport clustering of contagions in the local level areas (Marino et al., 2021; Encinas et al., 2021).

Healthcare capacity has proven to be an incredibly crucial component of the public policy toolbox in the Covid-19 pandemic, where limited I.C.U.s can easily and quickly be overwhelmed by many cases requiring admission in a short time. If patients cannot benefit from timely access to this specialist and crucial resource, then fatalities are far more likely to rise. At the same time, highly connected and urbanized areas had higher incidence rates, which could impact their critical healthcare response, even with potentially high healthcare capacity compared to more rural areas (Cuadros et al., 2020). Recent studies have shown that in the case of Bogotá (the boroughs of Teusaquillo, Suba and Kennedy), proximity to health service infrastructure, public spaces, and connectivity with the rest of the city are essential variables in explaining the differential infection rates between different localities. Thus, it seems that high population density coupled with weak socio-economic conditions are the aspects that could be most directly correlated with the high number of infections in these sectors (Marino et al., 2021). Thus, poorer socio-economic conditions, fragmented crisis management, and unequal allocation of I.C.U. beds in different boroughs of Bogotá, and patterns of human activity in urban areas may have driven the greater or lesser prevalence of the virus. There appears to be a greater probability of people being infected with Covid-19 in lower socio-economic strata or urban areas less developed in urban infrastructure (Guzman et al., 2021; Soja, 2013).

Access to I.C.U. beds in the public health hospital network was critical to the city's response because the disease disproportionately affected the vulnerable patient population. The health secretary of Bogotá carried out plans to expand significantly intensive care capacity. An Emergency and Urgent Care Regulatory Centre was formed to control the evolution and monitor the occupancy rate of I.C.U.s. The hospitals that attend to the positive or suspected Covid-19 patients in the emergency services and define whether the patients require an Intermediate or Intensive Care Unit must immediately contact the Emergency and Urgent Care Regulatory Centre of the District Health Secretariat of Bogotá, which will direct the patients to the healthcare system selected according to territorial criteria or with greater availability of the required service. The public health authorities published an overall I.C.U. occupancy rate as an indicator that has also been monitored during the pandemic, which took as a permanent theoretical denominator the maximum number of I.C.U.s available in Bogotá to care for Covid-19 patients, 1,882 ICU beds.

3. Methodology

3.1   Socio-economic data

Bogotá, Colombia's capital, is the country's most significant economic and industrial centre. The city is home to more than 8 million inhabitants, generating about 26% of the national gross domestic product and the lowest proportion of labour informality in 2020 and 2021, with an average of 42.5%.

Barbosa Brandão, V. A. et al.

The urban structure of Bogotá is dense and compact and features multiple levels of socio-spatial segregation (Guzman and Bocarejo, 2017). Across Colombia, residential land is classified according to official household socio-economic strata (S.E.S.), which classifies households into six categories' (Guzman et al., 2021), with S.E.S. 1 corresponding to the lowest and S.E.S. 6 to the highest strata. Socio-economic strata are a way of classifying households and neighbourhoods based on their level of income and quality of housing. The system also helps policymakers understand patterns of inequality and development across the city. The city has received the most significant flow of Colombia's internally displaced people and international migrants (mostly from Venezuela) and ex-pats and contains the most important industrial and manufacturing park in the country's central region.

Moreover, it encompasses the nation's largest urban centre, which poses other health and social challenges marked by profound economic disparities. Politically, Bogotá is divided into 20 boroughs, 19 urban and one rural, which enable the internal management of aspects such as security, education, and health services provision. These divisions reveal different productive dynamics and communities with different socio-economic capacities and lifestyles.

We include measures of socio-economic differences between boroughs using the latest available data. We focus on: the Gini coefficient, monetary and extreme monetary poverty, and socio-economic strata (S.E.S.). The poverty measures described above indicate a lack of quality of life. For example, the poverty line per capita in Colombia in 2018, 2019 and 2020 stood at COP$316,815 (US$79.20), COP$327,674 (US$81.92) and COP$331,688 (US$82.92) per capita, respectively. Extreme monetary poverty refers to the percentage of people below this level.

Concerning hospital infrastructure, the health ministry published an overall I.C.U. occupancy rate, for which 1,882 ICUs were projected to be available for Covid-19 cases. For this research, we calculate the number of Covid-19 hospital beds per borough. We also consider an open dataset of communicable diseases provided by the Bogotá Health Observatory (Table 1).

Table 1. **Borough data of Bogotá within the public health context**

| Bogotá Borough	Population (in thousand)	Cases	Cases / Population (%)	Deaths / Population (%)	Deaths / Cases (%)	Covid Hospital Beds	Gini	Monetary Poverty
La Candelaria	24	2398	9.96	0.21	2.13	0	0.57	8.25
Chapinero	140	13007	9.31	0.19	2.05	242	0.51	3.61
Santa Fe	110	9065	8.24	0.22	2.65	n/a	0.63	8.04
Puente Aranda	258	20238	7.84	0.2	2.58	28	0.42	3.89
Teusaquillo	153	11378	7.44	0.17	2.3	243	0.43	2.2
Usaquén	502	35492	7.07	0.13	1.85	337	0.53	3.06
Los Mártires	99	6809	6.87	0.19	2.76	199	0.46	4.13
Antonio Nariño	109	6935	6.35	0.2	3.16	47	0.41	2.33
Rafael Uribe	374	23633	6.31	0.18	2.88	40	0.43	4.21
Fontibón	395	24220	6.14	0.12	1.97	73	0.51	3.41
Engativá	887	53304	6.01	0.14	2.3	151	0.44	2.6
Tunjuelito	199	11886	5.96	0.17	2.88	103	0.48	10.62
Kennedy	1088	63593	5.84	0.13	2.28	171	0.46	4.06
Suba	1219	70384	5.78	0.11	1.97	77	0.54	3.01
San Cristóbal	405	23221	5.74	0.15	2.62	119	0.43	5.72
Bosa	673	37276	5.54	0.12	2.16	6	0.41	4.95
Barrios Unidos	243	10412	4.28	0.11	2.67	111	0.48	2.96
Ciudad Bolívar	734	30373	4.14	0.1	2.39	5	0.41	6.87
Usme	457	17517	3.83	0.09	2.36	n/a	0.44	12.08
Sumapaz	7	12	0.18	n/a	n/a	n/a	n/a	n/a
Total	**8077**	**471153**	**5.83**	**0.13**	**2.29**	**1952**	**0.48**	

Source: Authors' elaboration.

This dataset displays daily information on the clinical status of the registered cases: infected, deaths from Covid-19 in different urban boroughs and the percentage of available Covid-19 beds. Finally, it needs to be pointed out that temporal and regional (borough-focused) lockdowns were imposed on boroughs at various times during 2020 impeding traffic and the flow of people.

Nevertheless, lockdowns did not always overlap in the various Bogotá boroughs as the pandemic situation was deemed sufficiently different among the totality of the 20 boroughs. The statistical analysis used Power Query, Power B.I., and Space Syntax, using the database of Covid-19 infected cases in Bogotá from March 06th, 2020, to December 31st, 2020.

We propose a methodological design to compare two very different Bogotá boroughs, Bosa with predominantly low S.E.S. and Chapinero with predominantly high S.E.S. (see Figure 1, Figure 2, Figure 3). According to the Economic Development Observatory of Bogotá, Chapinero has the third lowest informality rate in the city (33.2%), after Teusaquillo (26.8%) and Usaquén (33.1%). On the contrary, according to DANE, Bosa had one of the highest rates of informality, with 54% in 2018 (DANE, 2023; ODEB, 2023).

Figure 1. **Socio-economic Strata Bogotá**
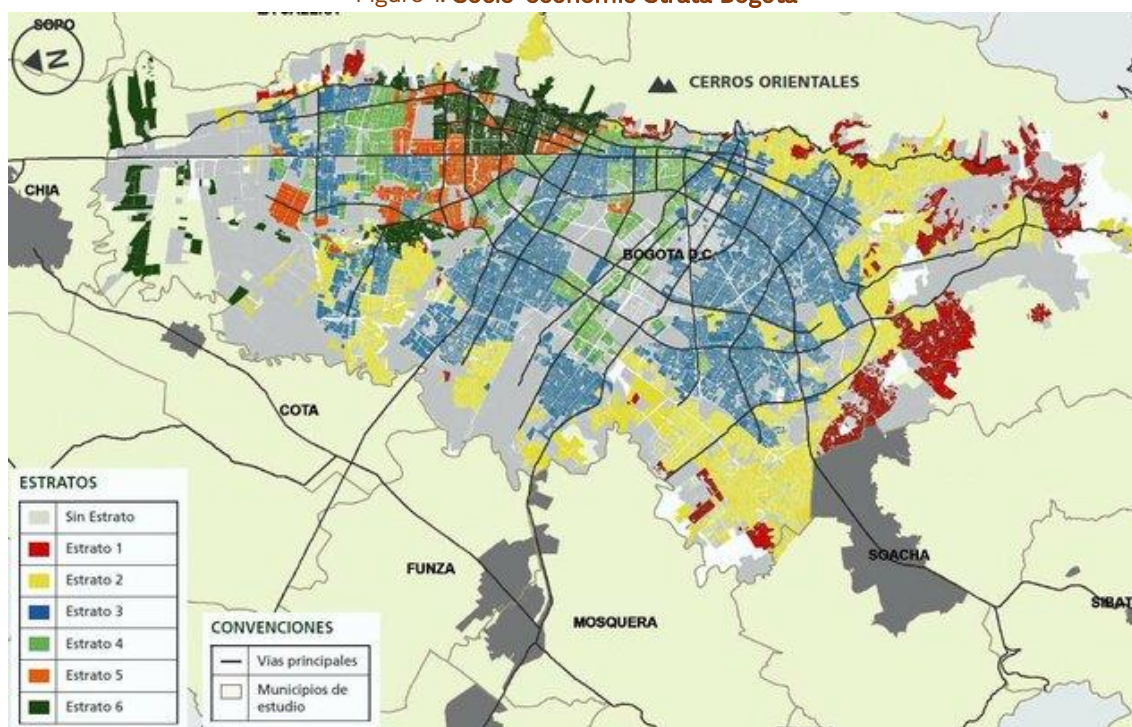
Source: Bogotá Urban Planning Secretary.

Both boroughs, Bosa and Chapinero, were selected due to the dynamics of available public health infrastructure and the number of available I.C.U. beds, the number of Covid-19 infected people, and the mortality rate. Bosa counts 673,000 inhabitants (128 per km2), and Chapinero has a population of 140,000 (348 per km2). In Bosa, 5.54% of the inhabitants were counted as Covid-19 cases (Figure 4), and in the Chapinero borough (Figure 5), almost 10% were counted as Covid-19 cases. Bosa represents one of the lowest rates of Covid-19 cases in Bogotá, whilst Chapinero features one of the highest rates.

Equally, the Covid-19-related death rate in Bosa was 0.12%, whereas, in Chapinero, the rate stood at 0.19%. Finally, monetary poverty in Bosa is just over 20%, whereas, in Chapinero, the corresponding figure is only 6.29%.

These figures show the evolution of the number of I.C.U. hospital beds assigned for Covid-19 over time throughout the analysed period of Covid-19 cases by borough. Regarding hospital beds specifically allocated to Covid-19 patients, Chapinero, with the highest socio-economic strata (S.E.S.), was one of the best-equipped districts in Bogotá. Therefore, throughout 2020, sufficient beds were always available to Covid-19 patients in Chapinero. However, the situation in Bosa, among the lowest S.E.S., reads very differently.

Figure 2. **Socio-economic Strata Bosa**
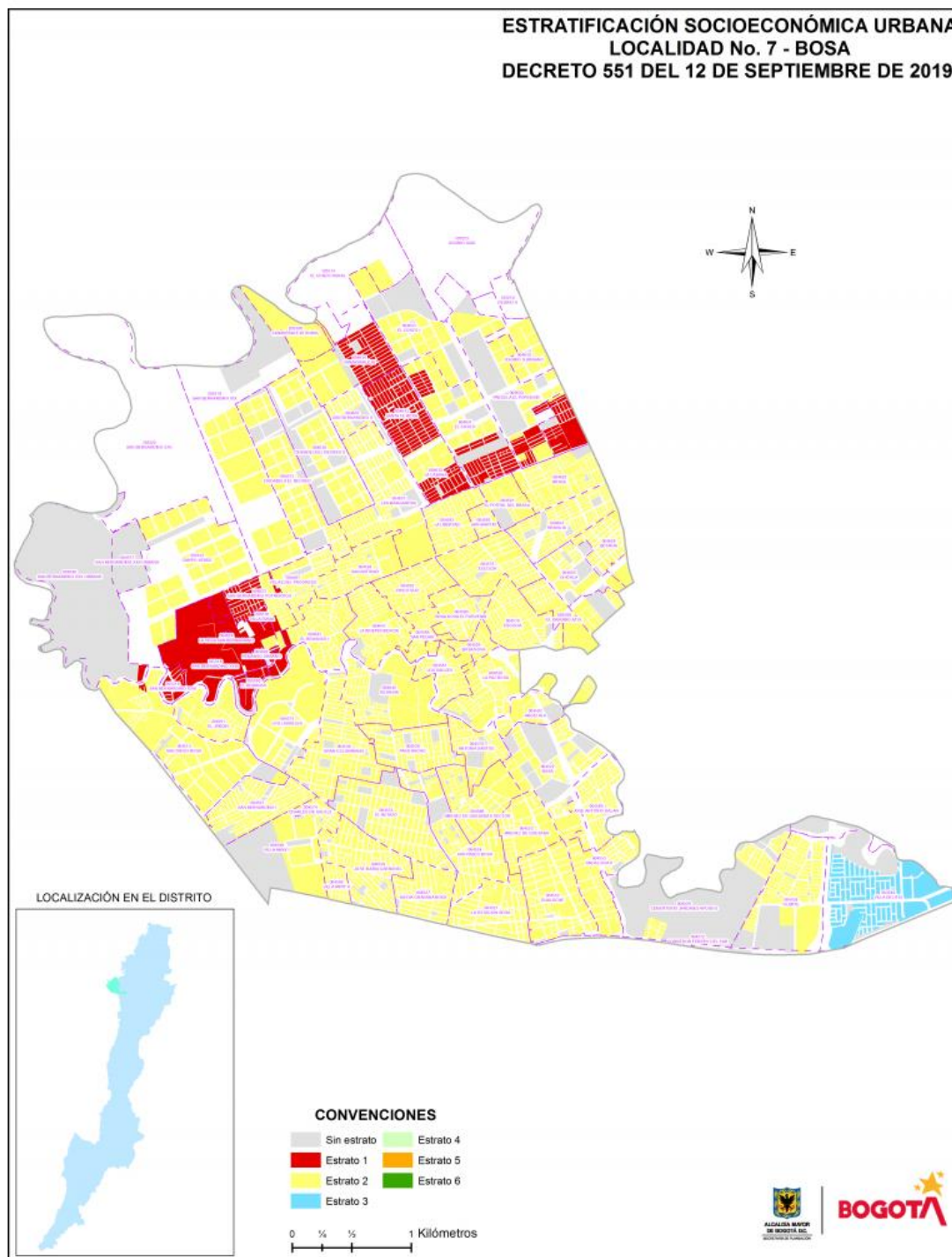
Source: Bogotá Urban Planning Secretary.

Only six hospital beds were allocated for Covid-19 patients in hospitals in Bosa in 2020, which suggests that Covid-19 patients from Bosa were either not treated or treated in boroughs differently.

This paradox suggests that there might exist factors going beyond socio-economic variables that could explain the difference in outcomes between Bosa and Chapinero.
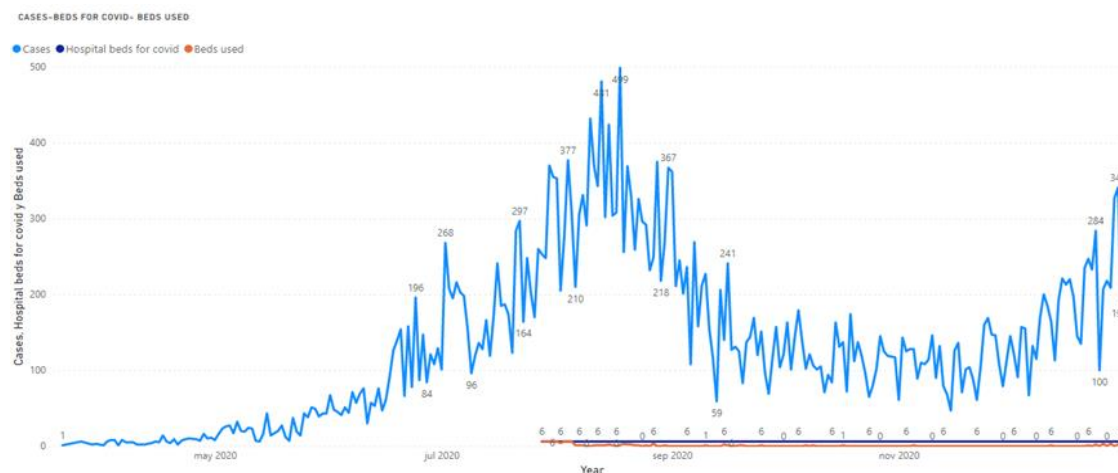
Figure 3. Socio-economic Strata Chapinero
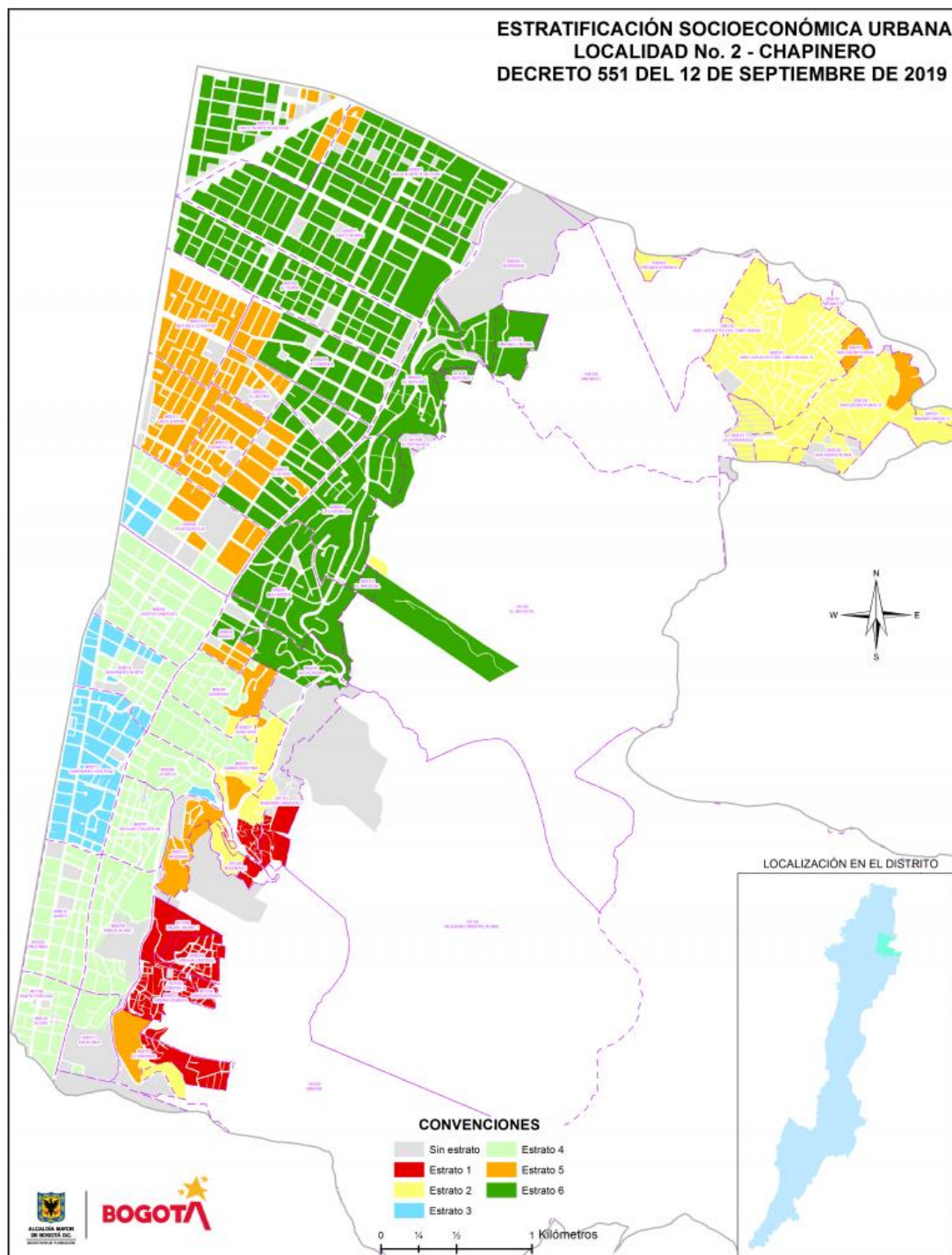
Source: Bogotá Urban Planning Secretary.

Therefore, we examine the urban morphology variables of Integration and connectivity to capture and explain the different results in comparing the two boroughs.

Figure 4. Bosa borough: cases and hospital beds

Source: Authors' elaboration.

Figure 5. Chapinero borough: cases and hospital beds

Source: Authors' elaboration.

3.2   Urban morphology data

The two boroughs present different characteristics of urban organization and distribution, as well as their functionality concerning the entire urban area of Bogotá. Moreover, the population density in Chapinero is about 2.7 times as high as in Bosa.

The Chapinero borough is located on the city's east side and in an urban transition zone, a north-south spatial corridor. In this area, higher socio-economic strata are located (Figure 6).

The Bosa area is located on the southwestern edge of the city. It features more significant urban irregularity (Figure 6).

In view of the continuity of the urban network, the figure below shows the built-up area of each neighbourhood, which is the element being considered in the spatial analyses. Due to this spatial, socio-economic, and public health infrastructure differentiation, these two boroughs were selected to understand possible differences, divergences, commonalities, and interrelationships.

Figure 6. Chapinero (left) and Bosa (right)

Source: Aerial photo by Google Earth.

Space syntax tries to understand the social movement of urban space (Hillier, 2009; Penn et al., 1998). Therefore, starting from the principle of the importance of urban mobility and accessibility as the main factors underlying the pandemic, the application of this method in spatial study is considered advantageous and promising (Alalouch et al., 2019; Schwarz et al., 2022). Furthermore, the urban structure, as currently organized and distributed, provides data on spatial topological relationships that allow for an interpretation of urban space behaviour in the city.

For the study of space syntax, the importance of urban form is of central importance; as such, the association of the road axes that make up the network and, therefore, the urban structure assumes a spatial significance for understanding the socio-spatial behaviour of Covid-19 in these two areas of study (Can & Heath, 2016; Huang et al., 2020; Jiang et al., 2000).

For this reason, the connectivity and spatial Integration parameters were chosen as they most promisingly represent the possibility of understanding this central research topic. This study applies parameters such as connectivity and spatial Integration. These spatial measures best represent the urban space as its morphological structure (McCormack et al., 2021).

Connectivity is defined in space syntax theory as the number of nodes that connect directly to a given node in the dual graph. Space syntax considers the accessibility of space as a critical determinant of its spatial interaction, and its analysis is based on an implicit graph-theoretic view of the dual graph. In graph theory, the space syntax connectivity (Equation 1) of a node is called the 'node degree':

$$\text{Connectivity}(i) = \deg(i) = \sum_{j=1}^{N} (A_G)_{ij}$$

The Integration (I) of an axial line i is a function of its depth related to all the other axial lines (how many steps are distant from all others). The latter (Equation 2) is "calculated by assigning a depth value to each space according to how many spaces it is away from the original space, summing these values and dividing by the number of spaces in the system less one, where n is the number of axial lines in the urban street area considered, is the shortest distance (least number of steps) between two axial lines i and j":

$$Integration\ l_i = \frac{2\left(n\left(log_2\left(\frac{n+2}{3}\right)-1\right)+1\right)/(n-1)(n-2)}{2\left(\left(\frac{\sum_{j=1}^{n} d_{ij}}{n-1}\right)-1\right)/(n-2)}$$

According to urban morphology, the connectivity parameter allows us to understand spatial patterns and possible urban mobility behaviours, obtaining a probability of the frequency of these same human behaviours. Finally, the integration parameter intends to understand the urban system as a spatial whole and determine possible spatially consolidated urban areas. A spatial model of the two study areas is designed to apply and calculate these syntactic measures, representing the city axes of the entire urban road structure (Figure 7).

This model is called an axial map. It is always more analytically appropriate to have a spatial area larger than the administratively delimited area, which allows for a more effective spatial analysis. The urban axes network in colour identifies the boundaries of the built-up area of each neighbourhood, namely Chapinero and Bosa.

Figure 7. Urban axes of Chapinero (left) and Bosa (right)

Source: Elaborated by authors from an aerial photo by Google Earth.

4. Results and discussion

By applying space syntax to interpret the urban morphology, the axial maps (Figure 8) of the connectivity parameters (Figure 8: A, B) and Integration (Figure 8: C, D) are obtained as results of the boroughs subject to this research, that is, Bosa and Chapinero (Table 2).

Regarding connectivity (Figure 8: A, B), in the case of Chapinero, the values obtained are higher than in the case of Bosa; that is, the average value in Chapinero is 4.2 compared to the average value of 3.7 in Bosa. In Chapinero, three urban roads are the principal axes with the highest values crossing the entire study area: one longitudinal and two transversal ways.

Figure 8. **Axial maps of Chapinero (left) and Bosa (right) boroughs with the spatial variables: (a, b) connectivity and (c, d) integration global (H.H.)**
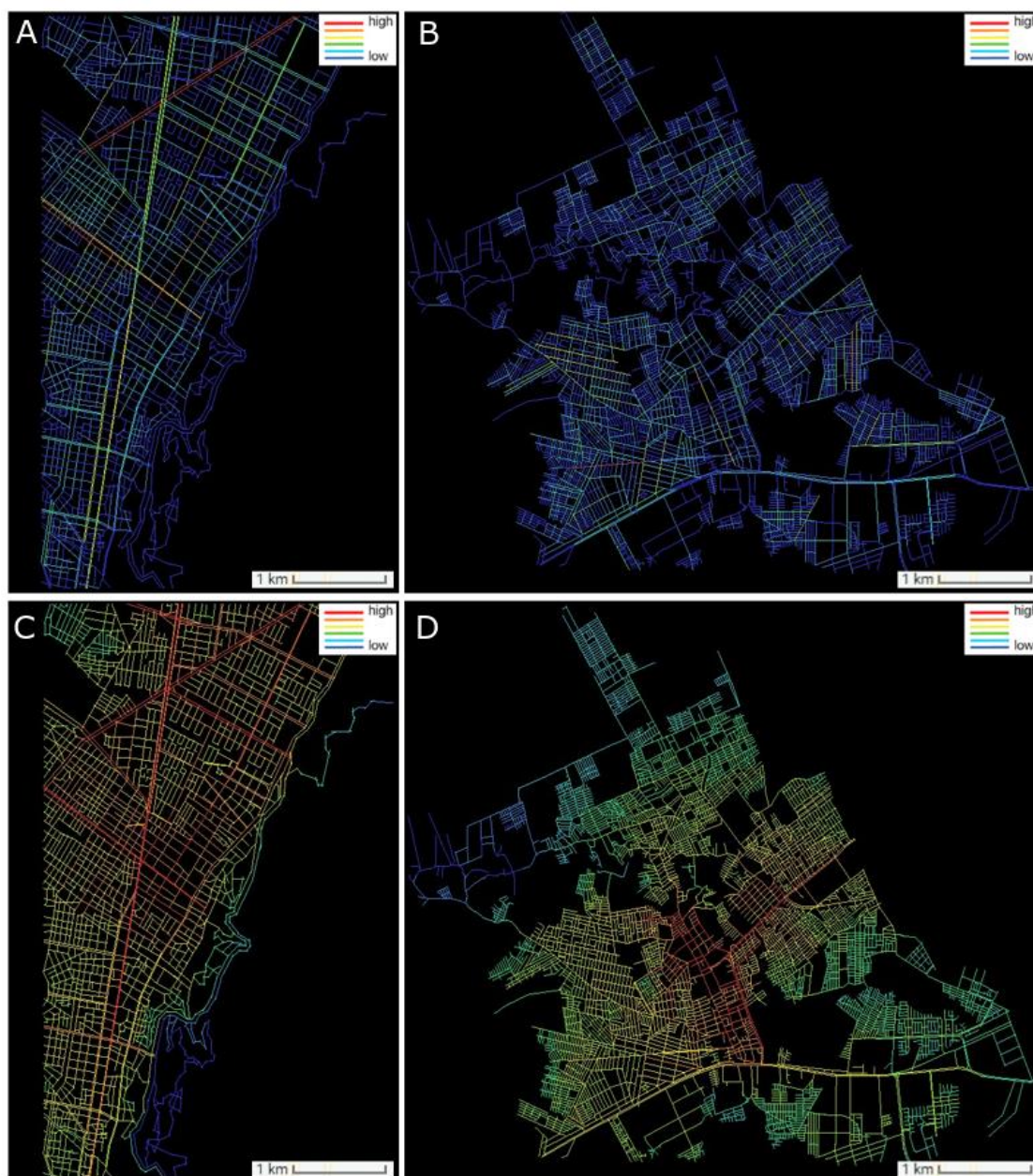
Source: Elaborated by authors.

Since the connectivity variable is related to the probability of urban flow, Chapinero has a more significant number of roads with higher values and identified in light colours, which means an urban area with a high value of interconnection between its urban roads. On the contrary, in the case of Bosa, and with most roads coloured blue, this, in turn, indicates a low connectivity value. Thus, urban mobility is hampered by its spatial configuration.

From Integration Global (H.H.), which refers to the organization and spatial configuration, the result shows a higher value in Chapinero and is visualized by the more significant number of pathways with light colours (red and yellow). There is a central area with greater homogeneity of these nuclei in the central zone and a more significant number of lanes when compared to Bosa. On the other hand, according to the result for Bosa, there is a more significant number of roads with dark colours throughout its peripheral zone, highlighting urban areas with complex spatial Integration.

Following the space syntax approach through the depth map and R Studio, statistical measures were obtained concerning six spatial variables, providing a global observation of the spatial characteristics of the urban form of these two Bogotá boroughs. We highlight the choice variable, which assumes the route with the highest probability to be chosen; connectivity, which indicates the urban route with the highest probability of flow and global Integration (H.H.), which refers to the formal organization of the urban structure and what is its integration measure in the urban space of the city.

Table 2. **Descriptive statistics of Chapinero and Bosa boroughs**

Variable	Choice		Connectivity		Entropy		Integration [HH]		Intensity		Mean depth	
Locality	Bosa	Chapinero	Bosa	Chapinero	Bosa	Chapinero	Bosa	Chapinero	Bosa	Chapinero	Bosa	Chapinero
Mean	83,129.11	17,214.89	3.78	4.17	49.18	36.60	0.53	3.14	0.27	0.39	19.76	60.67
Median	5.98	1,487.50	3.00	3.00	48.57	36.55	0.53	0.91	0.27	0.41	18.69	78.26
Mode	0.00	0.00	2.00	2.00	49.07	36.31	0.53	0.92	0.27	0.46	18.96	9.13
Standard deviation	315,451.35	54,622.60	2.84	3.59	45.74	32.65	0.10	7.53	0.04	0.10	19.33	87.37
Variance	99,5 x 108	2,9 x 108	8.04	12.31	2,092.20	1,065.98	0,01	56.72	0.00	0.01	373.5	7,634.1
Skewness	7.38	5.06	2.99	3.45	8.62	9.20	-0.23	9.95	-0.53	-1.85	9.61	7.65
Minimum	0.00	0.00	1.00	1.00	4.28	3.37	0.23	0.13	0.11	0.06	1.32	1.00
Maximum	4,436,978	561,034	34.00	33.00	521.17	398.90	0.79	108.50	0.38	0.56	341.18	990.90
Variation coef. (%)	379.47	317.30	74.98	84.14	93.01	89.21	18.58	239.82	16.68	25.72	97.78	144.00

Source: Authors' elaboration.

These results allow us to demonstrate for the case of Chapinero that connectivity in terms of urban morphology is a spatially hierarchical factor present throughout the study area with medium and high values. In Bosa, however, the results do not show structuring roads with high connectivity, roads that cross the study area, but a set of fractional and short-distance roads in the city.

On the global integration (H.H.) parameter, Chapinero obtains a maximum value of 108 and an average of 3.1, compared with maximum values of 0.8 and an average of 0.5 in Bosa. Spatially, the Integration in Chapinero concerning the urban form is more compact than in Bosa (Figure 8: C, D). In the latter borough, several urban areas are located to the North and South with low integration values, whilst in Chapinero, the peripheral areas present medium values. More urban consolidation is seen in Chapinero than in Bosa regarding spatial Integration of the urban plot.

In Chapinero (Figure 9), the correlation between the parameters Choice and Intensity is evident, that is, the importance of Choice in the urban area, which means that there is a high probability that a high number of urban roads will be chosen for the urban routes of citizens. Another result obtained is that Intensity very much determines the Connectivity data. In this case, the data shows a high intensity of circulation of citizens in several urban streets rather than in only a few urban areas.

In Bosa (Figure 10), we can observe that the Entropy parameter correlates with Intensity in two urban areas. This result shows a fractionation of its spatial area in some urban spaces of less dimension and the Intensity of accessibility of citizens.

From the Choice parameter, the result is correlated with the mean depth, which means a high probability of choosing roads with long distances. However, the reduction of the number of these roads accentuates the probability of concentration of citizen mobility on some roads rather than in the spatial globality of the boroughs that are subject to this research.

Given the results obtained from the more significant number of Covid-19 cases and deaths in Chapinero vis-à-vis Bosa and higher values of connectivity and urban Integration, the functionality and urban context throughout the city should be discussed. Chapinero is a borough with higher socio-economic strata than Bosa, defined as a transition zone, while its urban functionality can justify the high number of cases/deaths.

Figure 9. **Plot descriptive statistics of Chapinero urban space variables: Choice, connectivity, Entropy, Integration (H.H.), Intensity, and mean depth**
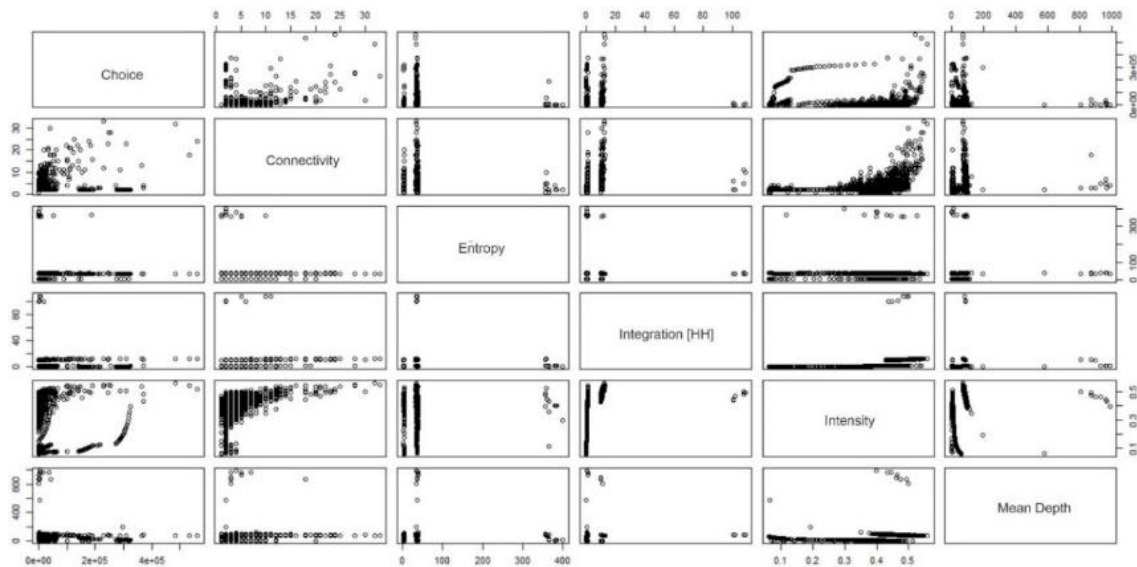
Source: Elaborated by authors.

Figure 10. **Plot descriptive statistics of Bosa urban space variables: Choice, connectivity, Entropy, Integration (H.H.), Intensity, and mean depth**
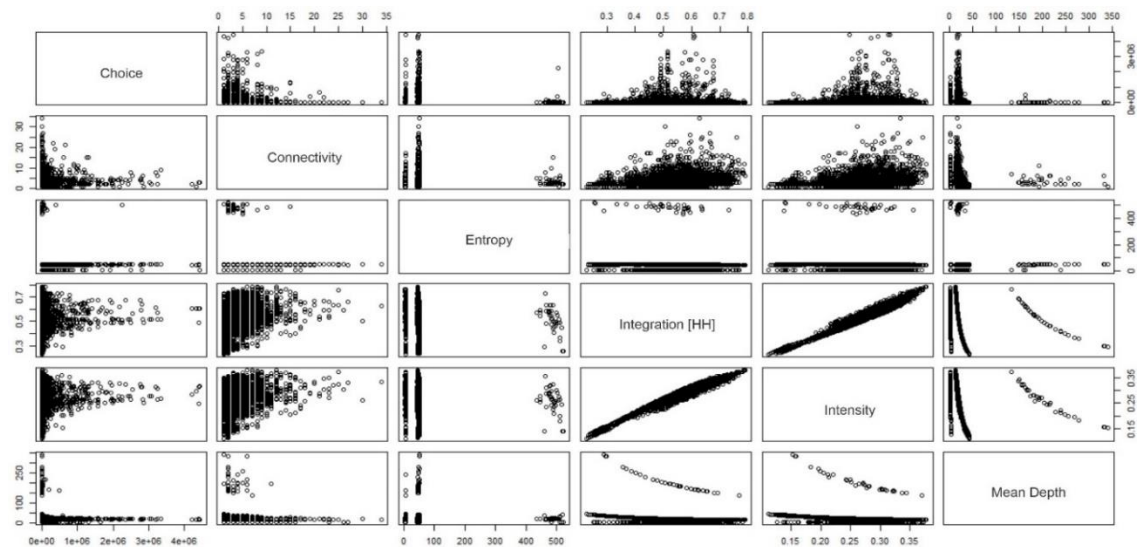
Source: Elaborated by authors.

The spatial conditions of Chapinero facilitate mobility, and the urban structure is more regularly organized than Bosa. Bosa has a peripheral geographic location concerning the city of Bogotá and presents a more irregular urban street network, which can justify the lower number of cases of infection of the disease. Nevertheless, we must stress the enormous socio-economic differences between the two boroughs, with Chapinero receiving much better public healthcare provision as measured by I.C.U.s and much lower poverty levels than Bosa.

Furthermore, this research addresses the effectiveness of the borough-specific lockdown as a public policy tool as decreed by the Bogotá mayor. Our research suggests that spatial heterogeneity across different urban areas is a crucial aspect of Covid-19. Areas with a more compact and cohesive spatial configuration facilitate urban mobility and frequency of circulation and could, therefore, at least to

Barbosa Brandão, V. A. et al.

some extent, shed light on the prevalence of the virus. In addition, the spatial characteristics condition the accessibility of citizens. Thus, the lockdown discussion should consider spatial configuration and urban behaviour.

Infections in Bosa were relatively high during the time studied in this research. At the same time, only six I.C.U. beds were available in the borough of Bosa, and the all-cause mortality of the borough's total population was somewhat astonishingly lower than in Chapinero. Nevertheless, slightly more Covid-19-infected inhabitants of Bosa died than did in Chapinero, which suggests that Covid-19 hit Bosa harder than Chapinero, possibly again highlighting a link between socio-economic precariousness and the ramifications of the pandemic. Thus, this leads us to hypothesize that people suffering from infection either did not seek access to the public health system at all or did so by travelling to another borough of Bogotá, which had some availability of I.C.U. beds that could accommodate individuals flowing in from neighbouring or more distant boroughs.

5. Conclusion

This exploratory study seeks to understand the socioeconomic aspects of Covid-19, considering urban differences and the context of socio-economic inequalities in the localities of Bosa and Chapinero in Bogotá. The results obtained by Space Syntax suggest that Chapinero has an urban area in terms of a more compact and cohesive socio-spatial configuration, which facilitates urban mobility and its frequency. Bosa, by contrast, presents a fractional integration making safe and equitable mobility difficult in its global space and impacts the frequency of circulation of citizens as well as the accessibility to some urban areas only rather than to the spatial whole. These socio-spatial characteristics condition the accessibility of citizens, highlighting some facets of the complexities of the pandemic in a metropolis.

These data demonstrate spatial globality regarding urban mobility in Chapinero, which will likely pose challenges for public policy responses to the Covid-19 pandemic. This research concludes that another aspect to consider is urban density, given the considerable difference between the two boroughs on that score. Chapinero, even though it has a small population, receives a large population to work and study daily. For instance, such flows of individuals streaming into Chapinero from Bosa were supposed to be severely limited by general or more localized lockdown policies across the different Bogotá boroughs.

This research allows us to conclude that these factors of urban behaviour possibly mediate the effectiveness of borough-focused lockdowns. To the extent that Chapinero registers greater cohesion and mobility throughout its space and more Integration with the rest of the city, it is more challenging to guarantee distance in urban mobility. In contrast, in Bosa, fragmented urban areas impose a kind of de facto lockdown, while it is easy to predict where most urban movements occur.

Finally, there was already a situation of dire inequalities regarding public health prior to the pandemic. The public health emergency after the pandemic only exacerbated this situation, resulting in a syndemic. Even before the outbreak of the pandemic in Bogotá, I.C.U.s were perhaps unavailable in the desired quantities and more equitable spatial distribution across the city. Instead of acting mainly on the public healthcare front, that is, raising the supply of I.C.U.s and staff across several predominantly highly populated boroughs, the primary policy response during the high points of the pandemic was the introduction and implementation of lockdowns in all and subsequently only a few boroughs.

6. Recommendations for future research

For future research endeavours, especially in Latin American metropolises, we recommend extending the research focus to broader boroughs within one metropolis or considering several metropolises in several countries should the available data permit this research paradigm.

Moreover, we recommend studying the allocation of I.C.U.s across different spatial entities with a particular focus on Integration, connectivity, safe and equitable mobility, and socio-economic factors. An avenue of future research for the case of Bogotá would be the identification of public policies focused on healthcare that fits the spatial and socio-economic realities of the city rather than simply borrowing policies such as lockdowns from far-flung locations from other parts of the world, which might display very different realities. Finally, in terms of urban planning, introducing more public green spaces and access roads might be studied.

Acknowledgements

Authorship

All authors have made substantial contributions to all of the following: Corresponding Author: R.G.A.; Conceptualization, V.B., U.T. and R.G.A.; methodology, V.B., U.T., and R.G.A., P.A.Ch.; writing—original draft preparation, V.B., U.T. and R.G.A.; writing—review and editing, V.B., U.T., and R.G.A.; supervision, V.B., U.T. and R.G.A. All authors have read and agreed to the published version of the manuscript.

Conflict of interests: The authors of this article declare no competing interests.

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