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RESEARCH ARTICLE

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THE DUALITY OF URBAN MOBILITY AS A HETEROGENEOUS PHENOMENON IN THE CONSTRUCTION OF SUSTAINABLE LIVING SPACE IN CITIES: A LOOK AT THE INFERENCE OF POVERTY IN THE CITY OF CAMPINA GRANDE, BRAZIL

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ABSTRACT

The use of statistical and georeferenced tools helps to explain the differentiation of urban mobility given the pre-existing urban configuration in cities. The city of Campina Grande-Brazil, object of this study, is characterized by the prevalence of dual elements such as the growing demographic explosion and the new layout of urban strata in terms of the smart cities concept. That said, the on-screen analysis comprises the existing mobility system, demonstrating how the current space influences the potential for movement in different social strata through the Theory of Spatial Syntax. The research used the Geographic Information System-GIS, processed through Depthmap® and QGIS in the production of spatial syntactic measures in neighborhoods combined with socioeconomic variables. In this study, it was concluded that the method identified in the central areas, with a high concentration of middle and upper income, a format more conducive to the use of the car, while in the neighborhoods with a higher concentration of vulnerable population, a system that favors walking predominates and the use of bicycle and motorcycle. The public transport system could have a more efficient coverage, since it presents itself as a restrictive factor of circular cause of local poverty, although it has the potential to be a driver of the local economic dynamism to favor the increase of income in the most vulnerable and spatially segregated.

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INTRODUCTION

This study aimed the relationship between urban mobility and poverty in the configuration of urban spaces delimited by neighborhoods. The object of this research is the city of Campina Grande-Brazil, located in the northeast region of Brazil. The aspects that guide the study refer to low mobility in geographic areas where the low-income population is concentrated and the implications for overcoming the causes of the circle of poverty. Income is a variable that measures aspects related to poverty, however, it is important to note that although it is an attribute to be considered in social categorization, it is not enough to explain the multidimensional poverty present in the class structure of Brazilian society. Different perspectives on the same phenomenon are important considerations in environmental studies in Brazilian society, as they highlight aspects of social inequality in the same living space in cities. It is necessary to consider these idiosyncrasies in the population as a whole to understand the parts that make up the whole of the object of observation and to identify the latent characteristics that permeate the apparent problem.

This look allows us to understand the nuances of the problem and its different impacts on the social structure. The concept of sustainable development would be understood as a process that, on the one hand, would generate wealth and well-being, but which would also promote social cohesion and prevent the destruction of the environment. This understanding appears, therefore, as a counterpoint to the traditional view of development, mentioned above. The city of Campina Grande became a strong economic influence, and the bulge of this birthplace was its irregular urbanization process due to the period of the cotton cycle and the arrival of the railway in the years 1940-1950. In the 1980s there was physical expansion with the construction of the *Malvinas complex*; and recently there was a new expansion with the *Aluisio Campos complex*. Unlike other cities in the northeast region, its urbanization process was consolidated in the 1960s and 1970s, converging more than 90% of the population living in urban areas. Therefore, for the sake of understanding, Urban Morphology was used, which is multidisciplinary in nature, as an explanation of the environmental debate on sustainable development, given that there is a shift from the conservationist focus - which denied the possibility of reconciling development and healthy environment — for the

sustainability approach, which seeks to reconcile economic growth with principles such as social justice, improving the quality of life in more dignified and healthier environments, with an optimistic outlook for the future. There are three degrees of poverty: extreme (or absolute) poverty, moderate poverty and relative poverty. In the first, families are not able to meet basic survival needs; in the second, basic needs are met, but with difficulty; and in the third, it is characterized by a family income below a certain proportion of the national average income (Sachs, 2005). In order to define, identify and explain the low level of income in poor nations, Nurske (1957) and Myrdal (1968), Economic Development theorists, studied these mechanisms and proposed some theoretical solutions to overcome their causes and reach a virtuous circle of economic growth. Economic progress could be achieved by underdeveloped nations through increasing the level of income, through actions directed by the State and supported by society, as a way to overcome the vicious circle of poverty. The State must provide institutional guarantees and incentive policies that allow society to act to overcome the vicious circle of poverty. The essential objective of public finance is not a modification of the interpersonal distribution of income, but an increase in the proportion of national income through domestic market development programs aimed at capital formation (Nurske, 1957). The identification of cumulative circular causations as explanations of development was one of the constants in the plans of the nations of the Americas, trying to absorb as much as possible the time gap between pre-industrial models. The main hypothesis of a supposedly more realistic economic theory should seek to contemplate circular causation among all the factors of the social system (Myrdal, 1968). These circular causations¹ are fostered by regressive effects that limit the action of the driving effects in the country's socioeconomic structure, which are both a consequence and a cause of the low level of development. Low levels of social mobility and education are obstacles to the propelling effects of an expansionist movement based on greater national integration and the reduction of internal inequalities (Myrdal, 1968). The issue of mobility in large urban agglomerations is difficult for the poorest populations², since the most dynamic area of the economy in cities is found in the central regions, while significant portions of the low-income population are found in the surroundings of the urban area. This fact is aggravating the access to better employment and income opportunities for these more vulnerable social segments (Pero & Mihenssen, 2013).

METHODOLOGY

The methodological tool used was the Spatial Syntax, which sought to understand the configuration of urban space and the pre-established social relations of flows and movements, having multidisciplinary as an approach for connectivity, accessibility and global integration (Al-Sayed et al., 2018). The cost of the distance between two-line segments with the smallest (geometric) angular change in a street network and the criterion for ranking the roads is measured by the sum of the angular changes that are made in a route, assigning a weight to each intersection proportional to the angle of incidence of two-line segments at the intersection (Hillier & Iida, 2005). Weight is set so distance gain is 1 when swiveling at right angles or 90°; 2 if the angular rotation is 180° and 0 for the angular distance gain if two segments remain straight, according to the equation (Al-Sayed et al., 2018):

$$\omega(\theta)\alpha\theta(0 \leq \theta < \pi), \quad \omega(0) = 0, \quad \omega\left(\frac{\pi}{2}\right) = 1 \quad (1)$$

¹The approaches of these theorists converge and present possible complementarities. The observation of the existence of weak propelling effects defined by Myrdal (1968) would be one of the components that would help to explain the permanence of the vicious circle of poverty defined by Nurske (1957). The positive chain effects of the cumulative circular causations highlighted by Myrdal would be a potential means of overcoming the vicious circle of poverty and reaching development (CARDOSO, 2012).

² According to Gomide, Leite and Rebelo (2006), urban transport is an important variable in the urban mobility system in the fight against urban poverty, and deprivation for the poorest may result in a barrier to social inclusion. The study points out that this phenomenon can be generated by inability to pay, unavailability of the service and difficult access in poorer areas.

Where θ is the angle of incidence between two segments, π is the measure of the radius and ω is the weight assigned at each intersection.

This angular cost can be applied as a weighting function to measures of centrality called Normalized Angular Integration AIN_{θ} :

$$AIN_{\theta} = (\sum_{i=1}^n d_{\theta}(x, i))^{-1} \quad (2)$$

Where d_{θ} is the length of a shortest path between vertices x and i . Integration is based on centrality and proximity (closeness). It indicates the best way to get from one point of the city to another (to-movement potential) (Hillier, 2009). This facility is based on the set of segments that minimize the topological distance of change of direction to other points in the city. The choice is based on the centrality of crossing (betweenness) when considering the possibility of crossing a specific segment from all other points of origin and destination. It is calculated by generating the shortest paths, with the lowest angular cost, between all pairs of segments in the system. The flow through each segment is then added up according to how many trips are made through each segment and divided by the total number of possible trips (Turner, 2007), defined as follows:

$$ACH_B = \frac{\sum_{i=1}^n \sum_{j=1}^n \sigma(i, x, j)}{(n-1)(n-2)/2}, \text{ com } i \neq x \neq j \quad (3)$$

Where $(i, x, j) = 1$ if the shortest path from i to j goes through x , and 0 otherwise. To allow a better understanding of the syntactic properties of the measures between cities of different sizes, Hillier, Yang and Turner (2012) proposed the normalization of two of the main measures: Integration (Normalised Angular Integration – NAIN) and Choice (Normalised Angular Choice – NACH). The two measures correspond to the two basic elements of any trip: selecting a destination from an origin (Integration) and choosing a route, and thus the spaces to be covered between the origin and the destination (Choice). Normalized Angular Integration is defined by

$$NAIN_{\theta} = \frac{(n+2)^{1.2}}{(\sum_{i=1}^n d_{\theta}(x, i))} \quad (4)$$

and $NACH_B$ Normalized Angular Choice is defined by:

$$NACH_B(x) = \frac{\log(\sum_{i=1}^n \sum_{j=1}^n \sigma(i, x, j) + 1)}{\log(\sum_{i=1}^n d_{\theta}(x, i) + 3)} (i \neq x \neq j) \quad (5)$$

Where $(i, x, j) = 1$, if the shortest path from i to j goes through x and 0, otherwise. Also called Spatial Accessibility measure, INCH is an expression of the potential for human movement within urban space resulting from the combination of two measures of centrality, Normalized Integration (NAIN) and Normalized Choice (NACH) (Hillier & Iida, 2005). In the first one understands which spaces minimize distances; and in the second, the potential for crossing, according to the equation:

$$INCH = \left(\frac{ND^{1.2}}{TD+2}\right) * \left(\frac{\log(CH)+1}{\log(TD+3)}\right) \quad (6)$$

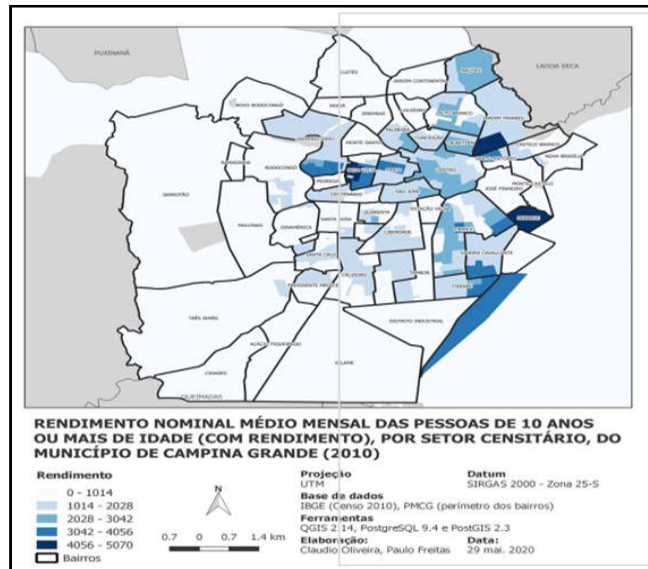
Where ND = total nodes, TD = total depth and CH = choice measure

DISCUSSION AND RESULTS

It was highlighted that the population density in the city, according to data from the 2010 IBGE Census, is 648 inhab./km², and the reference in the literature is that a value of 600 inhab./km² is ideal to make public transport viable. Therefore, the city presented the minimum requirements for the system to operate satisfactorily in relation to passenger demand and economic feasibility. However, according to data presented in Table 1, the public transport system can collapse and compromise sustainability. It is interesting to point out that in the last hundred years, the urban area of the city of Campina Grande – PB has gone from what today corresponds to the region of the expanded center, reaching 43km² more. As for the data from the urban mobility system, the variables observed refer to the

period from 2013 to 2018. The diagrammatic representation in Figure 1, refers to the variable Income by census sector. There is the classification adopted by the IBGE (Family Budget Survey) in the 2010 Census, which considered as the nominal monthly income of people aged 10 or over the sum of the nominal monthly income from work, added to that from other sources, covering all people living in the household, who are over 10 years of age and have some income. To classify social class according to income, the IBGE, 2019, considers Class “E” as individuals earning up to two minimum wages; Class “D”, between two and four minimum wages; Class “C”, between four and ten minimum wages; Class “B”, between ten and twenty minimum wages, and Class “A”, individuals with income above twenty minimum wages. In the map legend, the same color grading methodology was followed: dark blue tones represent a higher income range and light blue tones represent a lower income range. The scale in this research comprises five classes, starting with earnings from BRL³ 0 to BRL 1,014.00 (approximately one minimum wage); from BRL 1,014.00 to BRL 2,028.00 (two minimum wages); from BRL 2,028.00 to BRL 3,042.00 (three minimum wages); from BRL 3,042.00 to BRL 4,056.00 (four minimum wages), and from BRL 4,056.00 to BRL 5,070.00 (approximately five minimum wages).

census tracts with a greater predominance of income up to five minimum wages are located in the following districts: Santo Antônio, Alto Branco, Mirante and Prata. In the specific case, they are geographically united sectors in each neighborhood or between neighborhoods. Of these, the locality of Prata is the only one with excellent Spatial Syntax indices, although the other neighborhoods mentioned in this paragraph are also among the best values identified in the survey for the city. In other words, there is a greater concentration of people earning up to five minimum wages in the city who are located close to the best conditions for urban mobility in the city, especially in the Prata neighborhood. The sectors in which a majority with low nominal income, up to one minimum wage, are concentrated are geographically located in the region far from what is known as the historic center of the city and present smaller syntactic measures. Neighborhoods with better Spatial Syntax measurements are located around what is known as the historic center of the city, so the further away from this point, the more difficult the access to the optimal structures of urban spatial configuration identified through this study. The neighborhoods with income below R\$1,014.00 are: Cuités, Jardim Continental, Louzeiro, Jeremias, Monte Santo, Araxá, Novo Bodocongó, Malvinas, Bodocongó, Serrotão, Três Irmãs, Cities, Acácio Figueiredo, Velame, Monte Castelo and José Pinheiro.



Source: Oliveira (2020b) based on IBGE data (2010).

Fig. 1. Income map of the municipality of C. Grande (2010)



Source: Oliveira (2020b) based on IBGE data (2010).

Fig. 2. Correlation matrix cutout

Six dark blue census tracts stand out due to the predominance of income above five monthly minimum wages. It is evident that low-income sectors are located in all parts of the city. There is less presence of these representative sectors of low nominal income in the region known as the historic center of Campina Grande, but the socio-spatial pattern of the city is quite complex and heterogeneous. These

Of the 50 districts, 16 have low income in most census sectors. The prominent correlations were those of the income variables with the average length of the segments (segment length), which ranged from 40% to 42%, indicating that sectors of the municipality where higher-income residents live tend to have larger blocks. The “income” variable was verified according to the four types of income presented by the 2010 Census. A significant correlation was found, in which the best correlations between the NAIN, NACH and INCH measures by

³1 BRL above 0,19USD

Table 1. Variables on the mobility system of Campina Grande

Ano	Motorcycle Fleet	Δ%	Bus travel	Δ%	Motorcycle Accidents	Δ%	Car fleet	Δ%	Car accidents	Δ%
013	52.744		35.037.525		1.828		142.277		3.131	
2014	54.787	4	35.680.282	0	2.503	27	149.975	5	3.298	5
2015	58.792	7	33.483.906	-7	2.394	-5	159.179	6	3.023	-8
2016	64.692	15	31.387.331	-14	2.624	5	168.963	6	3.280	9
2017	67.443	19	28.067.633	-27	2.286	-9	175.261	4	2.789	-15
2018	70.245	22	25.140.160	-42	2.049	-22	182.241	4	2.520	-10
2013-2018		33		-28				28		19

Source: Oliveira (2020a)

neighborhoods and the income variable were 0.29, 0.30 and 0.31, respectively. This indicates a positive relationship according to which where and when income grows there is a better mobility structure. We tried to quantify the trips made by the city's urban public transport system correlated with the segments that present the highest number of daily trips. Graph 1 shows the quantity of trips by number of segments. The first bar of Graph 1 corresponds to 67% of the space segments, with the best Integration and Choice concentrate only from 1 to 102 trips, while 21 segments (0.5% of the total segments) concentrate from 1,122 to 2003 of the range of trips daily. The evidence of this disproportion demonstrates that the journeys of the urban public transport system itinerary in the city still favor reduced routes represented by the avenues that cut the city along its longitudinal axis.

CONCLUSION

Initially, the urban design of the city was investigated over time, passing through the inseparable processes of the constitution of the old Campina to the modern and technological Campina, but which still presents great economic and social disparities: practically two cities coexisting in the same territory; a modern, dynamic and organized one; still another with medieval aspects, such as lack of basic sanitation, income disparity and an urban layout that favors immobility and urban violence. Aspects that should be considered, however, regarding the study, as they can interfere with the flow of vehicles and pedestrians. Although a road presents a good Integration and Choice score, this characteristic may not necessarily be interesting for the city in terms of mobility and accessibility, as it is necessary to have other parallel roads as alternative routes for pedestrians and cyclists. Given the urban configuration of the city of Campina Grande, it is possible to conclude that the neighborhoods that present a set of better Integration and Choice, present a combination of attributes that favor mobility, in which it is possible to access the best attractive points of the city's centrality.

Conversely, peripheral neighborhoods, according to these syntactic variables, are segregated from the mobility system. According to the radiocentric configurational design — since all roads lead to the center — presented in the results, it is possible to infer that the peripheral neighborhoods present a more restrictive characteristic regarding the movement of people in the city. In the regions of the expanded center, there is a more favorable pattern for the mobility of citizens who use individual transport on the main roads. The system presents a very cohesive and efficient structural network in the central part, while, in the more distant regions, there is still a lack of coverage of the system to the population, compromising the mobility of low-income population segments. Most high-income neighborhoods have a structure that is favorable to mobility through automobiles, as they are endowed with large blocks and well-structured roads that provide access to various parts of the city, in addition to public transport that also facilitates commuting. Neighborhoods with the highest concentration of low-income sectors have the worst indicators of syntactic measures, as they depend on a mobility model based on urban public transport, and on the use of bicycles and motorcycles. In the perspective of strengthening the city's economy, the theoretical approaches of Myrdal (1968) and Nurske (1957) can be considered regarding measures to strengthen the internal market that favors the expansion of income in peripheral regions, making mobility efficient for these localities, would change

what is currently characterized as a limiting factor, into a circular causation of development and strengthening of local markets.

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