Marcia Regina Werner Schneider Abdala
(Organizadora)

Impactos das Tecnologias na Engenharia Civil 3

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APRESENTAÇÃO

A construção civil é um setor extremamente importante para um país, e como tal é responsável pela geração de milhões de empregos, contribuindo decisivamente para os avanços da sociedade.

A tecnologia na construção civil vem evoluindo a cada dia e é o diferencial na busca da eficiência e produtividade do setor. A tecnologia permite o uso mais racional de tempo, material e mão de obra, pois agiliza e auxilia na gestão das várias frentes de uma obra, tanto nas fases de projeto e orçamento quanto na execução.

A tecnologia possibilita uma mudança de perspectiva de todo o setor produtivo e estar atualizado quanto às modernas práticas e ferramentas é uma exigência.

Neste contexto, este e-book, dividido em dois volumes apresenta uma coletânea de trabalhos científicos desenvolvidos visando apresentar as diferentes tecnologias e os benefícios que sua utilização apresenta para o setor de construção civil e também para a arquitetura.

Aproveite a leitura!

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MOBILITY MEASURED BY THE URBAN FORM PERFORMANCE OF THE CITY

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ABSTRACT: This work investigates how urban mobility can be impacted by the urban form of the city. For this, it is necessary to analyze the evolution of the urbanization process. For that, the city of Brasilia - Brazil was used as a case study for the methodological application. The purpose of this method is to determine if the procedures adopted provide an accurate assessment and allows the identification of variables that have statistical correlation. The theoretical concepts are fundamental for the analysis of the data in an Integrated Urban Model. This allows you to obtain thematic maps as a result of the intersection of the city's spatial information. The variables identified in this study make a statistical correlation of the spatial configuration with the urban mobility system. Thus, it is possible to measure the performance of the urban form, for the promotion of mobility in a city transit system. This complex system can be visualized by Space Syntax, and can be easily replicated with the combination of other variables in several cities of the world.

KEYWORDS: Urban Form, Space Syntax, Walkable City, Transit System, Spatial Configuration.

MOBILIDADE MEDIDA PELO DESEMPENHO DA FORMA URBANA DA CIDADE

RESUMO: Este trabalho investiga como a mobilidade urbana pode ser impactada pela forma urbana da cidade. Para isso, é necessário analisar a evolução do processo de urbanização. Para tanto, a cidade de Brasília – Brasil, foi utilizada como estudo de caso para a aplicação metodológica. O objetivo deste método é determinar se os procedimentos adotados fornecem uma avaliação precisa e se ele permite a identificação de variáveis que possuem correlação estatística. Os conceitos teóricos são fundamentais para a análise dos dados em um Modelo Urbano Integrado. Isso permite obter mapas temáticos como resultado da interseção das informações espaciais da cidade. Neste estudo as variáveis identificadas da configuração espacial são correlacionadas estatisticamente com o sistema de mobilidade urbana. Assim, é possível medir o desempenho da forma urbana, para a promoção da mobilidade em um sistema de transporte público. Esse sistema complexo pode ser visualizado pela

Sintaxe Espacial e pode ser facilmente replicado com a combinação de outras variáveis em várias cidades do mundo.
PALAVRAS-CHAVE: Forma Urbana, Sintaxe Espacial, Cidade Caminhável, Transporte Público, Configuração Espacial.

1 I INTRODUCTION

Urban mobility is one of the greatest problems in contemporary cities, as seen in Vasconcellos (2014), and which is worsening in Brazil due to the lack of adequate planning and projects to follow the evolution of the urbanization process, as emphasized by Holanda (2002). Although the literature describes several theories, methodologies and techniques to point out the problems of large cities, the empirical repertoire to measure the performance of mobility is still a complex subject and difficult to understand, especially when we take into account the welfare and quality of population life.

The purpose of this research was to analyze the relationship between the configuration of urban space and the main variables that affect the performance of urban mobility, such as density, compactness, integration and connectivity, using the city of Brasilia - Brazil, as a case study. The objective of this study was to identify if the urban configuration is a determining factor for the use of the automobile, the bicycle, for the promotion of the road, or for the use of public transport. In order to do so, it was tried to verify if the method adopted here, statistically, provides results that approximate or not the real values obtained in-loco, and the complex models of Transport Engineering.

Space Syntax was used as a methodology of Hillier and Hanson's (1984) in the social logic of space theory to analyze the effects of spatial configuration on urban mobility, according to Dayan (2018), with data, indicators and indexes being collected in the main research bodies in a single Integrated Urban Model. Thus, the construction of thematic maps through multicriteria analysis was performed with QGIS software, and significant variables were selected through statistical correlations, according to Casella and Berger (2002).

As a result of this configurational evaluation of the space, it was possible to establish objective criteria to evaluate the existing conditions in an automatic and simplified way (DAYAN, 2018). As a result, it was identified, for example, that 68% of the most integrated roads in the Federal District's road system are part of the bus route of the transit system, as well as measuring the performance of bus routes, that do not offer accessibility to 17% of the urban population of the Brazilian capital. It was also identified that urban density is directly linked to spatial configuration and urban mobility, where constructive choices and land uses define the distances of transit stops, allowing or not the people's walkability, and consequently, alternative to the car.

Thus, the spatial configuration or physical organization of the territory, supported by an integrated network of transport alternatives, transit systems, pedestrian circulation and cycling, maximizes affordability and urban mobility of the city, reducing dependence

on the car.

2 I THEORETICAL FOUNDATION

This work supposes that the quality of the mobility and the conditions existing in the big cities are related to the urban configuration, that is, they are not independent, it is a complex system that, according to urban form, mobility, can have a better or worse performance. In other words, it is assumed that the urban configuration is the determining factor for the use of the car, the use of the bicycle, the promotion of the road, or the use of public transport. Thus, spatial configuration and urban mobility were defined to establish the theoretical basis of this paper.

2.1 Spatial Configuration

The spatial configuration is studied through The Social Logic of Space Theory or simply Space Syntax, defined by Bill Hillier as an architectural theory of the city. Space Syntax is a theoretical model of human space: how it is structured, how it works, how it is understood and how it is part of what we call society, commonly considered as a set of techniques to analyze the architectural and urban space to predict functional results (HOLANDA, 2002).

Space Syntax is a science-based approach that investigates relationships between spatial configuration and a series of social, economic, and environmental phenomena with a focus on people. These phenomena include patterns of movement, awareness and interaction; density, land use and land value; urban growth and social differentiation; distribution of security and crime.

The spatial configuration, in turn, is understood here by the formal, geometrical aspects and their hierarchical relations, that is, how urban spaces articulate each other. This definition is important to understand the fundamentals of this study, which makes a reading of the city under topological bias, as a complex set of relations between formal and spatial elements (HOLANDA, 2012). Topological bias refers to the relationship of the elements that constitute the city with the way of articulation between them, that is, it is a reading of the urban relations of interdependence between the parties.

The shape of the city, investigated through syntactic analysis of space, is an approach to spatial configuration, which was presented in the 1970s by Prof Bill Hillier, Prof Julienne Hanson and colleagues at The Bartlett School of Architecture, University College London. Today, Space Syntax is used and developed in hundreds of universities and educational institutions as well as professional practices around the world. Based on quantitative analysis and geospatial computer technology, Space Syntax provides a set of theories and methods for the analysis of spatial configurations of all types and at all scales (AL_SAYED et al., 2014).

To evaluate the effects of urban design, Hillier and Hanson's Space Syntax (HILLIER; HANSON, 1984), relates the configurational syntactic properties and enables

attributes of the morphological configuration to be mathematically measured and graphically visualized by means of axial maps and tables, thus revealing morphological logic of the urban fabric and the conformation of the city (MEDEIROS, 2013).

The word *morphology* is derived from the Greek *morpho*, which means "study of form," and from the German *morphologie*, originated by Goethe in 1822, which adds the meanings of the meanings of position and pattern, associating etymologically with the word *configuration*, understood as arrangement, organization, ordering, composition, structure, adjustment, position, articulation or allocation of things in a particular order.

Research using the spatial configuration approach showed how patterns of movement are powerfully shaped by urban design (PEREIRA et al., 2011), how patterns of safety and insecurity are affected by form, and how this relationship shapes the evolution of centres and centralities (COELHO, 2017), making cities capable of living. There are other studies (VILLAÇA, 2012) that reveal how spatial segregation and social inequality are related in cities. Scoppa and Peponis (2015), defend the thesis that recent commercial literature has shown that commercial uses are subject to the attraction of the network of distributed routes and according to the syntax of network connectivity.

Since then, a variety of research areas and practical applications have grown around the world, including archeology, criminology, information technology, urban and human geography, anthropology, and cognitive sciences. For Medeiros (2013), topological and geometric approaches are the key to understanding the diversity that characterizes the built urban space.

In order to understand the complex relationships within the urban space, the processes of attraction and dispersion that shape and differentiate its territory, it is necessary to investigate the relations between its parts, how they are organized, how they are structured, and the principles that govern this organization. For this reason, it is necessary to understand the isolated parts, which are continually renewed, in order to understand the whole as a whole, in its various scales: national, regional and local, since total space is indivisible (SANTOS, 2014).

2.2 Urban mobility

The concept of urban mobility is associated with the desire to reach a destination and the individual's ability to move. Brazilian Law No. 12,587 / 2012, which instituted the National Urban Mobility Policy, defines urban mobility as the condition in which people and loads are displaced in urban space. The purpose of this federal law is to contribute to universal access to the city, foster and concretize the conditions that contribute to the implementation of the principles, objectives and guidelines of urban development policy, through the planning and democratic management of the National System of Urban mobility.

Here we do not intend to explore the vehicular movement as object of study of Transport Engineering. But to understand the possibilities of movement of people

in the urban space, in the different modes of transport, according to the established spatial configuration. The aim is to understand the affordability relationships of transit with walking mobility, and equity in citizens' access, based on bus routes and the geo-referenced position of existing stops. In addition, it seeks to identify the more or less integrated and connected ways that promote efficiency, effectiveness and usefulness in the movement of people in urban areas.

In this way, the concept of urban mobility discussed here, is embedded in the fundamentals not contained in art. 5º of the Law, which is related to the urban morphology and its topological issues, in the offer of universal accessibility; sustainable development of cities, socioeconomic and environmental configurations; equity in citizens' access to collective public transport; in the fair distribution of the benefits and rights of use of the different modes and services; equity in the use of the public space of circulation, roads and streets; The efficiency, effectiveness and usefulness of urban traffic.

For Jones (2017), one of the main drivers of the pedestrian movement around cities is the structure and connectivity of the streets. These are the spaces that people occupy and move, and where we come into contact with each other. This form of contact is essential for social interaction and for economic transactions. The configuration of space, the result of the urban and architectural project, is therefore very important for the relationship between people, companies and communities.

The Space Syntax allows to perform the modeling of the road system in the context of this toolkit, and is used to analyze the connections of streets and probable patterns of movements of vehicles and pedestrians (BARROS, 2014). In this way, it can also be used to predict the impact, on flows, of changes in a project. Thus, the evaluation of space syntax leads to a new understanding of the fundamental relationship between urban design, infrastructure, urban mobility, use of public space and long-term social outcomes.

However, the conventional models of Transport Engineering consider mainly the geometrical aspects of a system, and disregard the topological aspects, consecrated by the configurational models (BARROS, 2006). According to Barros (2006), the high cost of performing source-destination research is a crucial factor to stop using this model. Considering the above, Space Syntax does not need this data for its analysis, since it allows to obtain very relevant information, simply with a digital map. Holanda (2002), also pointed out how the theory of Space Syntax has a revealing role of socioeconomic relations in the investigation of origin and destiny, simply by the movement of individuals in the territory.

Space Syntax methods can be used to analyze the structure of the road system, showing which roads and paths are most important, both for urban mobility and for trade and social interactions. This spatial analysis method considers geometry and road connectivity as independent variables in the assessment of pedestrian and vehicle transport. And it only observes the configuration of the road system, to obtain very

significant results. Other factors, which may encourage or discourage foot or motorized displacement, are not examined, which simplifies the process.

In this way, the conditions of urban mobility are deeply linked to the structuring of the urban space in the territory. But the dynamics of urbanization are expressed by spatial decentralization and the need for people to move, which is only possible thanks to the development of transport and communications networks (VASCONCELLOS, 2014). Thus, transport networks are the result of a potential set of origins and destinations, motivated by activities developed in space, which generate spatial flows and interactions (SANTOS, 2014).

3 I METHOD, TECHNIQUES AND PROCEDURES

3.1 Integrated Urban Model

Cities are complex combinations of physical forms, infrastructure systems, interpersonal relationships, and economic activities. Physical changes in the city can have unexpected impacts on these systems and on the day-to-day running of the city. In order to anticipate the unexpected impacts of urban planning on spatial configuration and urban mobility, Space Syntax developed the methodology of gathering all information into a single model, which we call the “Integrated Urban Model” (IUM).

Academic researchers have identified links between the spatial configuration and the social, economic and environmental performance of places (HOLANDA, 2002; MEDEIROS, 2013). Thus, as the first procedure adopted was the set of data that involve an urban form, the movement of pedestrians, cyclists and vehicles, the road system, land use, as well as population data, such as socioeconomic conditions, housing and work, and income.

From the moment all the data were spatialized in a single integrated urban model, the geoprocessing procedures for the interpolation of the Space Syntax information were developed to the data of areas, population distribution, urban dispersion, and the transport to the analytical output.

Based on the spatial data statistics, the maps for visualization and presentation were generated as variables for the statistical processing of no IBM SPSS Statistics V.22 software, for a verification of the main tests, and thus, to validate or reject as hypotheses of coordination of results.

3.2 Correlations between Variables

Analyzing only the scatter plot leads to subjective conclusions. There is a need to define a measure that objectively quantifies the rate of relation between variables. Thus, a measure of the degree of linear relationship between two variables is given by Pearson’s Coefficient of Correlation (for quantitative data).

Pearson’s population correlation measures the degree of linear association

between two random variables with normal distribution. Pearson's theory assumes that if the joint distribution is bivariate normal, then the Pearson correlation coefficient corresponds to the rho Maximum Likelihood Estimator (VIEIRA; HOFFMANN, 1989). Maximum Likelihood is a statistical method for estimating parameters of a distribution that best explains the sample, maximizing the probability of obtaining the observed values. Thus, the null hypothesis Ho assumes that there is no linear association between the variables, and when we reject Ho, we identify that there is a linear association between them.

In cases of non-compliance with the data normality assumption, Spearman's job correlations (VIEIRA; HOFFMANN, 1989) were verified, which were applied as a Pearson correlation formula in the positions of the variables that do not normal distribution.

3.3 Statistics

All the results obtained by the variables related to the spatial configuration, geometric and topological, as well as by the variables of urban mobility, were published in the IBM SPSS Statistics V.22 Software for the purpose of processing the statistical tests, thus identifying the representative variables with statistical significance. For this, the first step was the processing of descriptive statistics, suppressing the variables that do not have significant correlations.

The descriptive statistics adopted follow the procedures of the extensive bibliography of Casella and Berger (2002), when defining the concepts and theories applied to statistical methods established in the literature. From here on, all the concepts and methods adopted in the statistical tests must be consulted in the specific literature (CASELLA; BERGER, 2002), since the focus of this paper is not the explanation of the theory of each test performed, but of its application validation and identification of significant variables.

The Kolmogorov-Smirnov and Shapiro-Wilk Normality Test were applied, with the first test being corrected for the significance correlation of Lilliefors, in order to identify variables whose data are normally distributed. Using 5% as a level of significance, and null hypothesis Ho that the data follow a normal distribution, it was possible to identify that only the variables "Income per capita" and "Unattended population" do not follow a normal distribution, since the null hypothesis Ho, was rejected for these two variables.

4 I RESULTS AND DISCUSSION

The results obtained by the effects of population density and employment are confronted with the distance from the collective transit stations, besides the zoning, land use and the bicycle system.

The interactions between the variables indicate the effects of Space Syntax on the identification of more integrated and connected routes, which are more susceptible

to trade and which, theoretically, should have greater accessibility to public transport, greater correspondence to the bicycle system, and consequently, possess the population. Figure 1 shows the bus lines of the Federal District transit system, where there are overlapping routes when passing through the same route, and are therefore considered to be united in this model, that is, routes are not computed in duplicate when lines are superimposed.

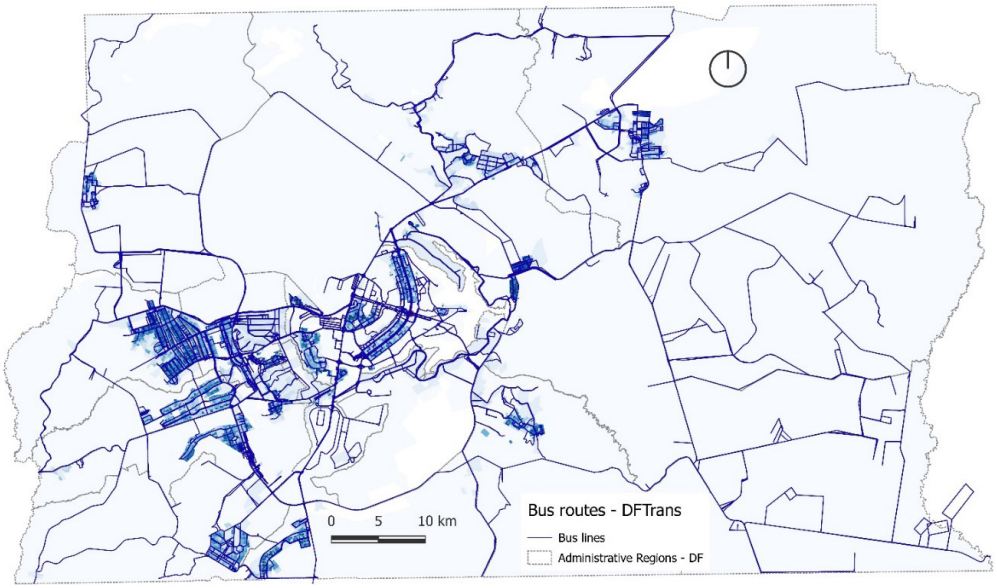

Fig.1 - Bus Routes of the public transportation system of the Federal District

Source: Prepared by the authors

Through the mapping of the bus lines, the Federal District transit system (Fig. 1), identified the areas that are not covered by this service. This result was obtained from the correlation between the coverage area of the DFTrans Company bus routes and the stopping points, with the urban area of each Brasilia sub-district.

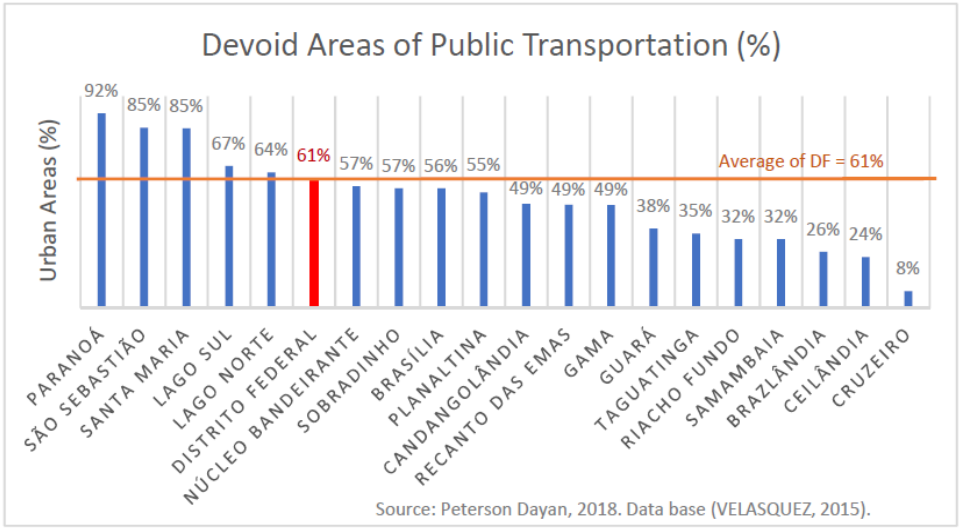

Fig.2 - Devoid Areas of Public Transportation in each sub-district of Brasilia

Source: Prepared by the authors

Figure 2 shows that, on average, 61% of the urban area of the Federal District does not have access to public transportation, a maximum radius of 400 meters, or a 5-minute walk to bus stops (DAYAN; RIBEIRO, 2018). Likewise, the population not served by the public transportation system of the Federal District was identified. This result was obtained from the correlation between the coverage area of the DFTrans Company bus routes and the stopping points, with the urban population of each sub-district of Brasilia (Fig. 2).

It was identified that, on average, 17% of the urban population of the Federal District does not have access to public transport, a maximum radius of 400 meters, or a 5-minute walk to bus stops. The most critical places, where more than 40% of the population does not have accessible public transportation, are in the Lago Norte and Sobradinho, demonstrating the inefficiency of the bus system, especially in these regions.

The reflection of this lack of accessibility to transit is directly related to the availability of commerce and services to the population. Scoppa and Peponis (2015) show that the measures that describe the syntax of the network of roads have a significant relation with the commercial facade density, based on an analysis of the spatial database of the city of Buenos Aires, which has a plan of radial street with regular blocks and a well-defined central place, identifying the impact of the attraction of the Central Business District - CBD.

As can be seen in Figure 3, this is not the reality of the Federal District, where the most integrated highways has few commercial facades of buildings, such as the following roads: *EIXO - Eixo Rodoviário de Brasília – DF 002* (Road Axis of Brasilia); *EPIA - Estrada Parque Indústria e Abastecimento – DF 003* (Road Park Industry and Supply); *EPNB - Estrada Parque Núcleo Bandeirante – DF 075* (Road Park Nucleo Bandeirante); *EPTG - Estrada Parque Taguatinga – DF 085* (Road Park Taguatinga); *EPCL - Estrada Parque Ceilândia – DF 095* (Road Park Ceilandia), on the map (Fig. 3)

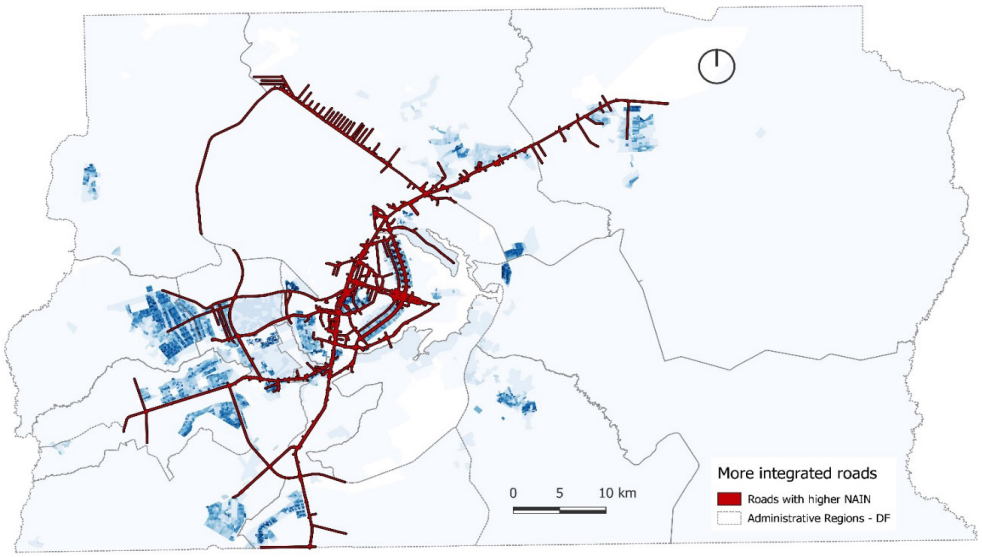

Fig.3 - Roads with Higher Normalized Angular Integration – NAIN

Source: Prepared by the authors

In segment analysis, NAIN is one of the main variables, which indicates the level of integration in the formation of centers and destinations, where these can be more easily achieved from all others in the system. They are in synthesis the structuring segments of the system.

The most integrated routes correspond to only 23% of the area occupied by the bus lines of the entire Federal District (Fig. 3). They are considered more integrated routes, those that correspond to 20% of the streets more accessible spatially (STONOR, 2015). However, 68% of these routes are part of the bus routes belonging to the DFTrans Company system. Since the sections were not counted in duplicate, that is, only the sections where the bus lines were overlapped with the most integrated roadway routes were computed.

Coelho (2017) pointed out that there is a fairly structured network at the global level (NACH), which covers practically the whole territory when the routes with NACH values 20% higher are considered (Fig. 4). When crossing these roads with the bus transportation system of the Federal District, we found a correlation of 69% of these best-choice routes, as belonging to the DFTrans bus route. And in analyzing the coverage of bus routes and the best standardized angular paths - NACH 20%, we identified that the best choices correspond to 46% of the total bus lines. This analysis was done for the Normalized Angular Choice - NACH 20% higher routes, as shown in Figure 4.

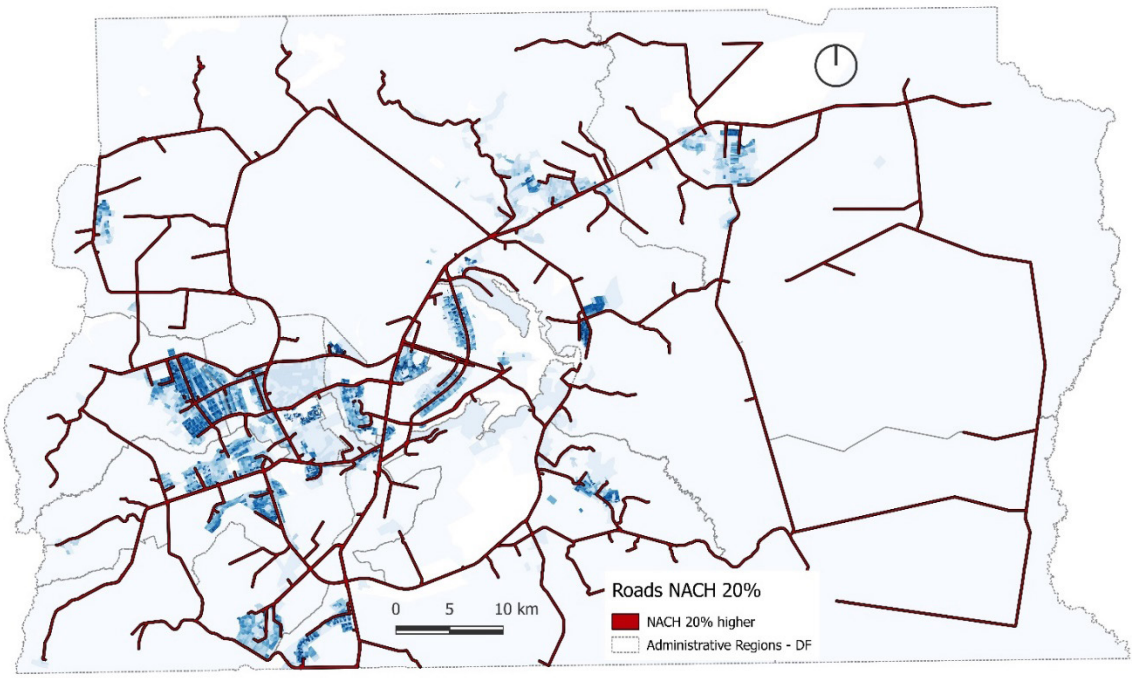

Fig.4 - Map with Normalized Angular Choices - NACH 20% higher

Source: Prepared by the authors

This variable is particularly useful for pointing out the main driving axes that cross the entire urban system as more likely routes of use. Hence the importance of crossing

the bus routes with NACH (Fig. 4). One can identify if the transit system performs well, when the lines are optimized to the best routes of the system, that is, when a compatibilization of the two variables is obtained.

When analyzing the conditions in which people move daily, one can understand the metropolitan dynamics and its impacts on the quality of the commuting movements. It can be seen, therefore, that the conditions of urban mobility existing in large metropolises play an important role in shaping the well-being and quality of urban life.

Through the correlation between the bicycle system of the Federal District and the more integrated and better-chosen routes, it was identified that only 43% of the cycle paths are inserted in the best angular standardized pathways. In other words, 57% of the bicycle lanes in the Federal District are located in areas with the worst route to access the main localities, shown in Figure 5. Included were the cycle routes that were already built and those that were in the project in 2015.

It was identified, however, that only 31% of the most integrated areas have cycle lanes, that is, the bicycle system is no longer meeting 69% of the most accessible regions. This is a cause for concern, since it demonstrates the inefficiency of the cycle system in the Federal District, even considering all the cycle routes built and those that were in the project.

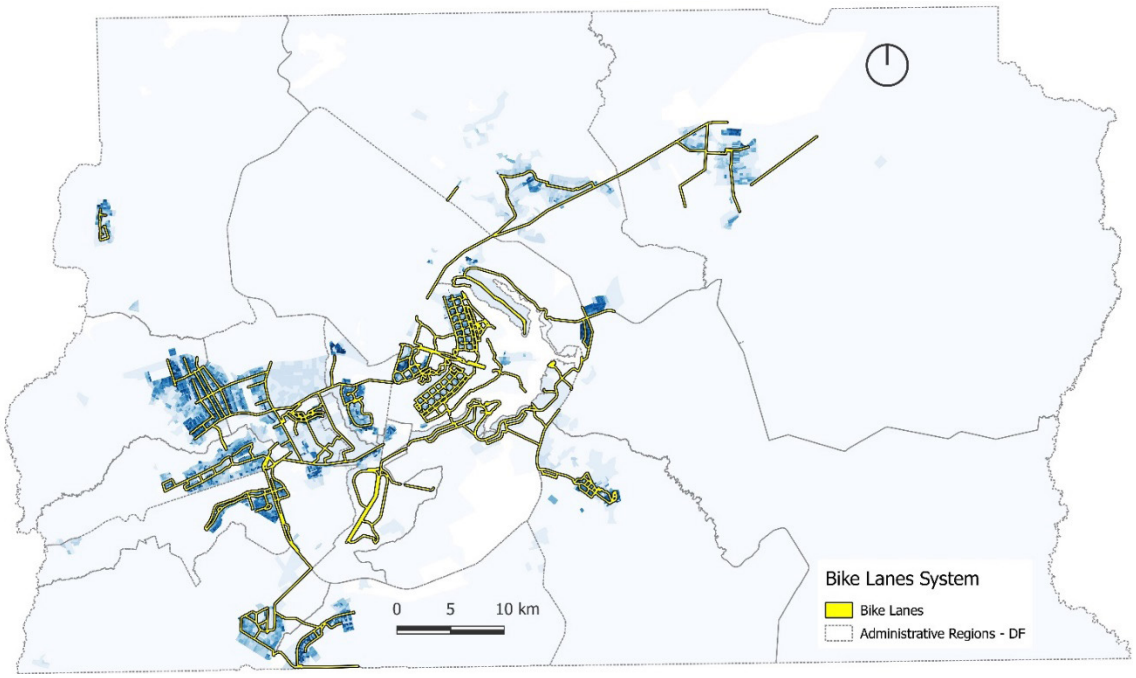

Fig.5 - Bike lanes system built and in project for the Federal District in 2015

Source: Prepared by the authors

When a more accessible route does not have bicycle lanes, we could imagine that this is because it has no attractiveness to the circulation of people, and this would not justify the construction of bicycle lanes (Fig. 5). This hypothesis is rejected because it is the most accessible routes, those that exercise the function of centralities, and consequently, has a greater concentration of people, and at the same time demand for

bike paths.

Therefore, this study shows how poor urban planning can lead to the inefficiency of a city's public transportation system. As well as done in this work, it can be measured by the Space Syntax and statistical correlations on the urban form of the streets of the city.

5 I CONCLUSION

The main result obtained with the development of this paper was the understanding of how the spatial configuration impacts urban mobility and affects the urban population of the cities, bringing information different from those usually known in Transportation Planning and Urban Planning, contributing with a pragmatic approach, and proven by statistical tests.

This study allowed to identify some urban planning guidelines that provide a better performance of the urban mobility from the spatial configuration. The first one concerns urban density, we saw that there is a more compact occupation of the ground, around 600 hab / ha, to make transit and non-motorized modes possible. Another measure, identified in the literature, is the search for the occupation of urban voids and consequent reduction of intra-urban distances, thus optimizing the displacements of public transport, through a network of more integrated and connected roads.

Identifying these variables allowed us to correlate the effects of spatial configuration on the performance of urban mobility in the Federal District, which are applicable both for urban planning and transport planning, allowing to indicate the priority measures to be implemented as public policies at different levels of government, and thus, fulfilling the objectives of this study.

Thus, urban density is directly related to the spatial configuration and urban mobility, since the constructive choices and land uses define the distances of transit stops, allowing or not the walkability of the people, and consequently, alternative to the car. In this way, the spatial configuration, or physical organization of the region, supported by an integrated network of transport alternatives, transit systems, pedestrian circulation and cycling, maximize affordability and urban mobility of the city, reducing dependence on the automobile.

It has been proven in all studies that the Federal District needs a better occupation and densification with a variation between 300 hab / ha and 600 hab / ha. Since it is unacceptable that the average density of the third largest city in urban extension of Brazil is in around 21 hab / ha, while the lowest economically feasible density is above 200 hab / ha (RODRIGUES DA SILVA, 1990). Translating, we can say that the urban sprawl and the spreading of the cities provoke the degradation of the environment, waste of resources, increase of the commuting displacements, dependence of the car and congestion, diminution of the market competitiveness and loss of the quality of life.

All Brazilian cities have urban densities far below the desirable minimum, as

shown by the study of urban areas in Brazil, carried out by Embrapa (FARIAS *et al.*, 2017). This is due to economic viability, infrastructure, housing, the road system and the transit system. It is necessary to promote compactness, complexity, efficiency and social stability through the mixing of land uses. In this way, it generates a greater balance of uses of public spaces, enhancing community life and, consequently, reduces the use of the car.

The inefficiency of transit in Brasília was evident when it failed to meet 17% of the population and absent itself from coverage of service provision in 61% of the urban area of the Federal District. It was verified the importance of density and morphological aspects in the diachronic interpretation of the city, to understand its urban dispersion process, being these the main factors that influence the urban mobility.

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