Road hierarchy and speed limits in Brasília/Brazil

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Abstract: This paper aims at exploring the theory of the Social Logic of Space or Space Syntax as a strategy to define parameters of road hierarchy and, if this use is found possible, to establish maximum speeds allowed in the transportation system of Brasília, the capital city of Brazil. Space Syntax – a theory developed by Hillier and Hanson (1984) – incorporates the space topological relationships, considering the city shape and its influence in the distribution of movements within the space. The theory's axiality method – used in this study – analyses the accessibility to the street network relationships, by means of the system's integration, one of its explicative variables in terms of copresence, or potential co-existence between the through-passing movements of people and vehicles (Hillier, 1996). One of the most used concepts of Space Syntax in the integration, which represents the potential flow generation in the road axes and is the focus of this paper. It is believed there is a strong correlation between urban space-form configuration and the way flows and movements are distributed in the city, considering nodes articulations and the topological location of segments and streets in the grid (Holanda, 2002; Medeiros, 2006). For urban transportation studies, traffic-related problems are often investigated and simulated by assignment models – well-established in traffic studies. Space Syntax, on the other hand, is a tool with few applications in transport (Barros, 2006; Barros et al, 2007), an area where configurational models are considered to present inconsistencies when used in transportation (cf. Cybis et al, 1996). Although this is true in some cases, it should not be generalized. Therefore, in order to simulate and evaluate Space Syntax for the traffic approach, the city of Brasília was used as a case study. The reason for the choice was the fact the capital of Brazil is a masterpiece of modern urban design and presents a unique urban layout based on an axial grid system considering several express and arterial long roads, each one with 3 to 6 lanes, which stimulates high speeds. This feature fosters many problems such as car crashes and pedestrian accidents. In order to perform a comparative analysis, the basic guidelines to regulate speeds in urban streets in Brazil, including the Brazilian Traffic Code and the Brazilian Association of Technical Rules, and the results for the maps of the so called Pilot Plan of Brasilia were taken into account to verify the possibilities of use of Space Syntax to define speeds. Findings indicate that some important axial lines correspond to those roads of higher speed limits, however in some cases correlation is not valid. Therefore, it is possible to infer that Space Syntax seems to play a relevant role in defining road hierarchy, but not directly as a speed definition tool. It has a complementary importance in the planning and decision support both for engineers and architects, helping to better understand how flows and movements are developed in the urban system network.

1. INTRODUCTION

The inordinate growing number of vehicles in the city centers and the lack of transport planning have caused serious problems, such as traffic jams in the last decades. Ways of solving and reducing such problems have been studied for many decades. In this regard, some initiatives such as the speed limits have been developed, as in the Brazilian Traffic Code – CTB (2001) when it determined basic outlines for speed limits regulations both in countryside areas and urban ones, the latter being the focus of this paper.

To avoid problems in traffic, whether with vehicles, pedestrians or even cyclists, it is ultimate that some kind of hierarchy in the road system exist, so that it becomes more organized and that the ones who use the road system are provided with more comfort.

Due to this hierarchical structure, Space Syntax is highly regarded amongst the tools existing nowadays as it is responsible for the application of traffic engineering, integrating hierarchical aspects of the urban system network with the flow and movement generation potentials in urban areas.

The Space Syntax – theory developed by Hillier & Hanson (1984) – incorporates the topological space relations and its influence on the location of the movements within its circulation space by considering the shape of the city. The axial method of the theory analyses the accessibility relations with the road system by means of the integration of its system, which is one of its explicative variables in terms of co-presence or potential co-existence of the passing movement of pedestrians and vehicles.

Therefore, it was agreed to test the Space Syntax variable, which has been currently used in other areas (architecture, urbanism, economy, sociology, archeology, etc), as a parameter of the road system hierarchy, so as to verify its efficiency.

2. PREMISES

2.1 Road Hierarchy

The road system has different flow patterns, with some roads designed for faster flow and others designed for slower flow.

The master plans anticipate that the roads of a town must have a functional hierarchy (Estatuto da Cidade, 2001 [*The statute of cities*]). This hierarchy is named according to its function, such as: slow moving roads are called local roads; roads which collect the flow from the local to the arterial ones are called collector roads; the roads which distribute the flow are known as arterial; and the faster roads are called express roads.

As to exemplify the structure mentioned, the roads of the Brasilia Pilot Plan (DF) – object of this study – can be seen at *Table 1*.

The road functional classification corresponds to the traffic mobility and the access allowed to them. It is constituted by three different road systems: Express and Arterial; Collector; and Local (CTB, 2001).

In a road system, the greater the accessibility of a road, the less flow (mobility) it has and the greater the flow, the less accessibility it has (*Figure 1*). This means that, in roads with a greater capacity of generating trips (express and arterial roads) its access is easier. However, at some moments during the day its capacity to allow traffic flow is reduced, which makes it slower. And in roads with a smaller capacity of generating trips (local roads) its access is reduced and, thus, its capacity to allow traffic flow is much greater.

Table 1. Roads used for this study

Classification: Roads	Pilot Plan Roads
Fast Traffic Roads	Eixão
Arterial Roads	L2, W3 e L4 Roads
Collector Roads	L1, W2 (Roads In Between Superblocks)
Local Roads	Roads in the Superblocks

The city consists of a physical structure which needs links to connect the parts (neighborhoods, towns etc). These connections, which are made by the roads or by the axis, can happen in a local or global scale, that is, a neighborhood scale or a city scale.

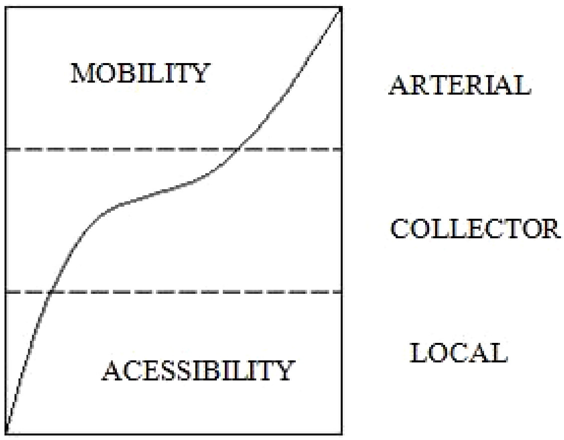

Figure 1. Mobility x accessibility graph [Source: adapted from ABNT (1976)].

These connections can be measured and there are studies which estimate the connection and accessibility potentials, as for instance Space Syntax.

2.2 Space Syntax

Space Syntax is defined as a theoretical and methodological approach in this present work. It consists of different measuring techniques which attempt to understand how the built space, that is, the city shape or parts of it, interferes on the moving patterns by means of its topological relations, not only its geometry.

"Topology is understood as a study of the spatial relations which are independent in terms of shape and size (they depend on the articulation between parts). On the other hand, geometry is the precise description of the physical elements which compound it, regarding dimensions, proportions, scales etc." (Medeiros, 2003)

It means to say that the way the parts – roads and built spaces – relate to each other and with the whole of the urban system network is carefully analyzed in the topological process. Besides that, how these distinctions in terms of articulation interfere on the social relations developed in this space – mainly regarding the flows and potential movement generation, when the urban space is taken into consideration.

The Space Syntax technique adopted by the present work is the axiality. Its production of the so-called axial maps consists of four stages, which are:

2.2.1 Linear Representation (Axial Map)

From a cartographic raster base (aerial photographs or satellite images) or a vectorial one (*.dwg *.dgn files, etc) of the area under study, the smallest number of the longest straight lines are drawn onto the road beds. For this stage, creation/editing programs which allow the use of graphic representation must be used, for example: ArcView®, AutoCad®, Microstation®, amongst others.

Computerized Analyses of the Representation (Mathematic Matrix Calculation)

After the map is produced, it is analyzed by means of special designed programs for analyzing the syntax of the space (Axman®, Ovation® or Orange Box® for computers Macintosh®, and Spatialist®, Axwoman® or MindWalk® for PCs). They can calculate mathematically the numeric potentials for each axis of the system, considering the collectiveness of the urban grid – the accessibility potential of each line through Space Syntax algorithms (Hillier & Hanson, op. cit.). That is, they inform how accessible these segments are considering the system as a whole.

Amongst the variables of the analyses there is connectivity, which is similar to accessibility in terms of traffic engineering. Accessibility is the physical articulation of a road to another, that is the number of connections that a road has when it is "linked" to others.

On the other hand, the way of calculating the integration on a global scale (n radius – Rn) or on a local scale (radius 3 – R3 or superior, for example) is the number of conversions that a user, in this case vehicles and people, does from a particular beginning line (a starting road) to all the other lines (other destination roads) in relation to the urban system as a whole (other destinations), in this case a traffic assignment from n to n. The number of conversions is called integration radius, according to the initial definition of Hillier & Hanson (op. cit.). This radius varies from 1 to n (total number of lines, in this case, roads of the road system). The integration numeric value can be converted into a color scale ranging from warm colors to cool ones, going through red, orange, green, light blue up to dark blue. Another possible alternative would be using a scale with shades of gray, in which black corresponds to red, a very dark gray corresponding to orange, dark gray to green; light blue and light gray to dark blue. The more intense the color or the gradation of gray of an axis, the more integrated this will be in relation to the system as a whole.

2.2.2 Correlations

At this stage the mathematical rates obtained from the previous stage are correlated. Variables such as integration, with other different variables observed (secondary data) or collected (primary data) such as the land use (use density), the existence of public transportation (calibration variable), vehicles and pedestrian movements (amount and/or speed) and others.

2.2.3 Simulations

The site simulations are made from the construction of new axial maps by inserting or removing axes that can represent a desired situation. One example would be the creation of axes simulating the future growth of an area, and based on this, areas or axes which would be potentially more integrated or with a greater potential of movements are simulated. That could also incorporate commercial and service areas.

It is essential to highlight that, regarding the procedures, some studies have demonstrated that there is a strong correlation between the found potentials and those which were measured in field reality, for example, the correlation between the use of the land (Medeiros e Trigueiro, 2001) and others, in terms of “magnets” (Holanda, 2002).

However, it is important to point out that, as for any method or tool, the Space Syntax and particularly the axial maps have showed some restrictions which bespeaks the need for an oriented outlook by the researcher or technician, so as to make the best use of the instrument. The full knowledge and the skill of what is being worked on is a must for the success of the simulations, which – as far as it is concerned – is a promising field regarding transport studies.

3. METHODOLOGICAL PROPOSAL

The functional hierarchy of the road system is based on the level of importance the roads represent to the road system as a whole. This importance can be associated with the number of traffic lanes, with the position of the roads or with the accommodation potential of vehicle flow, for example. Space Syntax approaches this capacity of accommodating the flows by using the localization and the connections between the roads in its road system as an investigation parameter. According to the localization and articulation – or connection – some roads tend to play a more important role as traffic generators, while some others don’t. it is claimed that by means of Space Syntax it is possible to estimate the characteristics of the traffic flow.

Therefore, the methodology proposed in this present work aims at relating the road hierarchy, which is translated by the colors within the axial maps, with the speed limits. After that, Space Syntax potential to define the road hierarchy parameters is evaluated. For that the study of the systems integration is done in two ways: firstly analyzing Federal District as a whole, afterwards, analyzing Pilot Plan only. For comparison reasons, the articles 60 and 61 of the Brazilian Traffic Code (2001) about urban roads characteristics have been used.

4. CASE STUDY

4.1 Area Description

The area under study is Pilot Plan, located in the city of Brasilia which, in its turn, is located in the Federal District (*Figure 2*). The urban site, planned in correspondence to the orientations of modernist thinking, presents strong characteristics of spatial segregation resulted from, it seems, its very civic and administrative character. The road hierarchy in the system of Brasilia presents considerably peculiar characteristics. The EPIA (Estrada Parque de Indústria e Abastecimento – Industry and Supply Parkway – the thicker dark gray line) is a fast traffic road (express) and has quite a significant flow of vehicles, in view of it being the main access to the city. Two other expressways (Monumental Axis and Road Axis, North and South – in black) practically separate the city in north/south and east/west, what greatly restricts the access by pedestrians between the Wings (*Figure 2*). The North and South Wings, in turn, present well-defined road hierarchy levels, in which arterial roads are represented by roads L2 and W3, collector roads by the roads in between blocks, and, finally, by the roads inside the blocks.

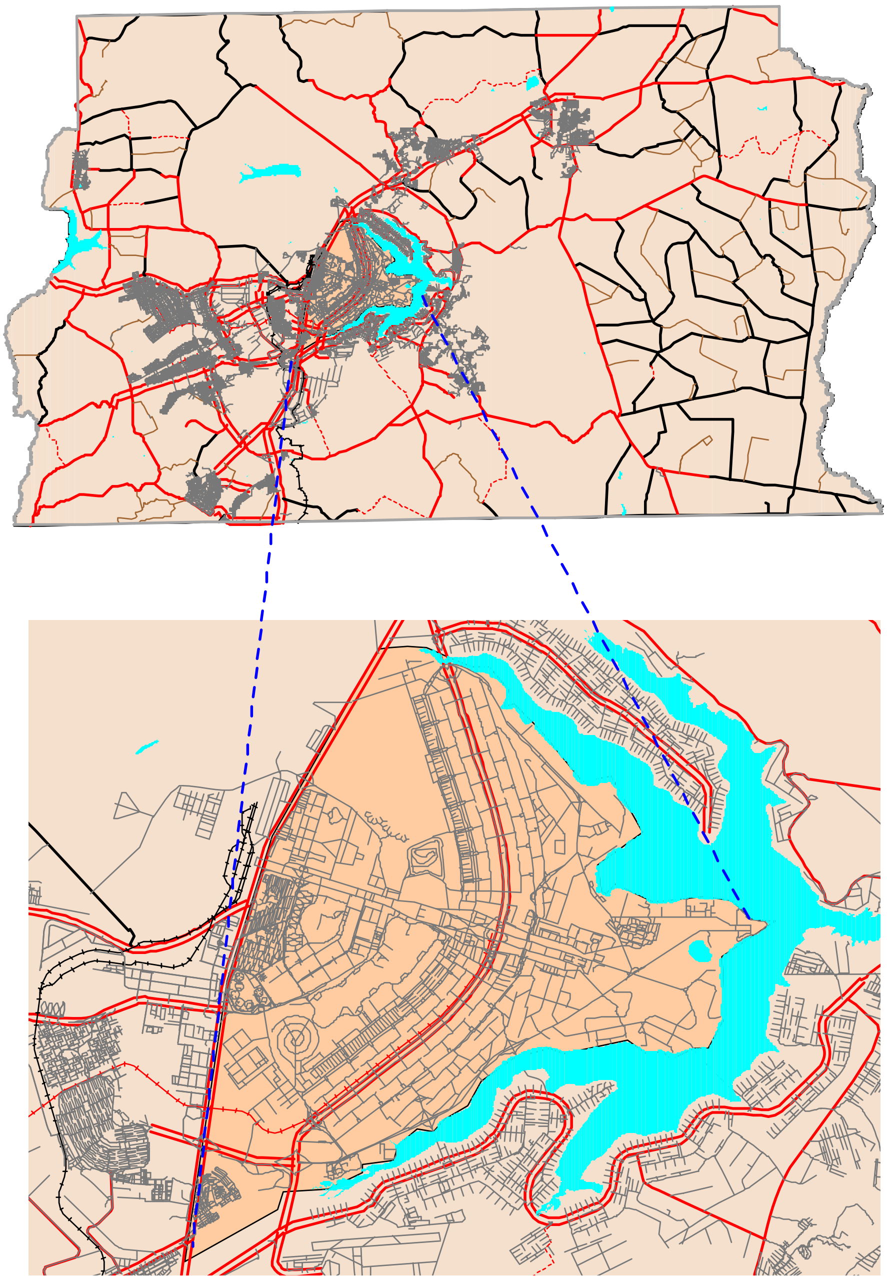

Figure 2. Federal District (above) and Pilot Plan (below) maps.

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4.2 The use of the methodology

4.2.1 Correlations

By analysing the Pilot Plan within the Federal District, it is noted that it is an eccentric area in relation to the Federal District since its beginning, according to Holanda (2002), because the predominant colors are dark gray (60%) and light gray (40%), what translates the little integration of Brasilia (average) with the global road system (*Figure 3*). The average integration of the system is of 0,623, with a maximum of 1,062 and a minimum of 0,310.

The EPIA (Estrada Parque de Indústria e Abastecimento – Industry and Supply Parkway), the EPTG (Estrada Parque Taguatinga – Taguatinga Parkway) and the road that passes through Setor Gráfico (Press Sector), represented in black (100%) in (*Figures 4 and 5*) are the axes which are most integrated in the system (with integration values equivalent to 1,0204; 0,9590 and 0,9146, respectively), granted that trips taken towards the Pilot Plan, in most cases, are taken through them

Monumental Axes, in its turn, presents three levels of integration (*Figure 5*). Its first stretch – in black (100%) – due to its proximity to EPIA (Estrada Parque de Indústria e Abastecimento), concentrates a significant flow of vehicles which should be distributed to SMU (Setor Militar Urbano – Urban Military Sector), Sudoeste and Cruzeiro, besides the other areas of the Pilot Plan (integration value 0,9605). The following stretch – in very dark gray (80%) – shows a decrease in vehicle flow distributed on the following stretch, as well as a flow which should be distributed among the Wings (integration value 0,8182). And the final stretch – in light gray (40%) – presents the little integration of the Esplanade of Ministries with the system, once access to other areas of the city don’t necessarily have to pass through it (integration value 0,7488).

By analyzing the Pilot Plan isolatedly, not considering further cities of the Federal District, it is observed that the system integration is altered. The most integrated roads in that situation are: Monumental Axes (integration value 1,1546, against the system average 0,8191) and Eixão North (integration value 1,2257, *Figure 6*). This is different from the previous analysis, in which only a part of Monumental Axes was highly integrated.

North Wing presents four levels of integration. The internal roads in the blocks (local) – in dark gray (60%) and light gray (40%) – are the least integrated in the system, owing to the fact that it is necessary to pass through a larger number of roads in order to access them. The roads in-between superblocks (collectors) and roads L2 and W3 (arterials) – in very dark gray (80%) – are in a relatively good integration with the system (very dark gray – 80%), once its integration is only inferior to the roads in black (100%). The road which corresponds to Road Axis ("Big Axis") – in black (100%) – is the most integrated road in the system, which means its access is facilitated by the fact of there being no need to pass through many other roads in order to reach it (*Figure 7*).

Figure 3. Federal District axial map.

Figure 4. EPIA and Press Sector integration.

Figure 5. Monumental axes integration levels.

Figure 6. Pilot Plan axial map.

Figure 7. North Wing axial map (4 levels of integration).

4.2.2 Analysis of Speed Limit Regulation in Urban Roads – Brazilian Traffic Code.

In accordance with articles 60 and 61 of the Brazilian Traffic Code (2001), the maximum speeds permitted in kph according to road classification (*Table 2*) are: fast traffic roads (express) must have a speed limit of 80 kph; arterial roads, maximum speed of 60 kph; collector roads, maximum speed of 40 kph; and local roads must have a limit of 30 kph.

Table 2. Speed Limits Presented by the Brazilian Traffic Code [source: Adapted from Brazilian Traffic Code (2001)]

Road Classification	Speed Limit
Fast Traffic Roads	80
Arterial Roads	60
Collector Roads	40
Local Roads	30

5. RESULTS

Based on the analysis of integration and the guidelines for the regulation of speed limits – accomplished in the previous section – a comparison between the two studies was made (*Table 3*).

According to the table assembled basing on the comparison of the two studies and *Figure 7*, what validates the findings of the syntax is verified:

The local roads (30 kph) – internal roads in the blocks – are little integrated to the system, in dark gray (60%) and light gray (40%);

The collector and arterial roads (40 kph to 60 kph) – L1 (roads in-between superblocks), L2, W3 and L4 – have a relatively good integration with the system, in very dark gray (80%); and finally,

The expressways (80 kph) – Eixão North – are most integrated to the system, for they are presented in black (100%).

A detail that has been observed (*Figure 6*) is Eixão North, which is highly integrated to the system – in black (100%), with an integration value of 1,2227 – and Eixão South, less integrated than the first – in very dark gray (80%), with an integration value of 1,0564. In actuality, there is not a difference between the roles of Eixão North and Eixão South in the road network of the city, what shows that for full analysis, a researcher must ponder, in the results, on diverse aspects that may interfere in the potentiality of an axis to attract movement or not.

Table 3. Comparison of Data

Road Classification	Speed Limit	Colors – Integration with the system	Pilot Plan Road
Fast Traffic Roads	80	Black	Eixão North
Arterial Roads	60	Very Dark Gray	Road L4
Collector Roads	40	Dark Gray	Roads L1, L2 and W3
Local Roads	30	Light Gray	Internal Roads in the blocks

6. CONCLUSION

The map of the Pilot Plan shows that some of the axes correspond to the road speeds, in view that in both cases there is a narrow relation with the road hierarchy of the system. However, in other axes there is no exact correspondence, what indicated that Spatial Syntax seems to act better as a tool for defining parameters in road hierarchy, and not directly as a tool for defining speeds.

As has been noted, such axiality illustrates how much or how little an axis (road) is integrated to the system as a whole; in other words, what is its accessibility or permeability in face of the system. It is also necessary to clarify that its integration depends on a few variables, such as the number of roads that must be taken in order to reach any other in the system; where the system roads are located (close to Trip Generating Centre etc.); what the urban road network design is like, among others

In view of this being an exploratory research that sought to apply the Syntax in the study of Brasilia, it is worth pointing out that the investigated site presents urban design characteristics which are peculiar in relation to the other usual urban settlements in Brazil.

The evident features of intense urban planning in Brasilia may demand higher calibration in the results, or even make them unfeasible. Therefore, it is believed that there is a need to amplify the research scope by incorporating examples of what would be the traditional cities in Brazil: those that, historically, are associated to typical urbanization processes (metropolization, periphery, suburbs), what aggravates the disputes for territory and mobility in urban spaces. Therefore, the validity of the tools must be verified by amplifying the database and the examples explored.

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