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SPACE SYNTAX IN A NATIONAL SCALE:

A case-study on inter-urban network transportation in Brazil

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ABSTRACT

Social interactions occur inside cities in daily activities, but they are also present in relations between cities, for different reasons such as tourism, family visits or business. This research aims at expanding the usual application, for it aims at the city network of the Brazilian nation, focusing on relations among cities. The application includes the Brazilian road network, the Brazilian domestic air transportation network and the main waterways, all of them working in an integrated system to connect 5570 Brazilian cities. In spite of the large territory and high number of cities, the historic origins of these cities reveal how relations among the latter are concentrated among the main Brazilian metropolis and the coastal towns. Therefore, in this research the cities were grouped into regions representing urban centres and agglomerations, so it was possible to study relations between these regions, not the daily urban trips. With Spatial Syntax Theory we identify relevant issues for the national planning of transport infrastructures and services and try to know if the necessary social needs among cities are met. The global integration map calculated for this network proved to be an important indicator of the availability and potential of infrastructure. An analysis related to transport data revealed that most regions with high integration present a high demand for interurban transportation, but we can also identify some regions that need improvements in services or infrastructure for interurban transportation. Another result of this research was the high correlation noted between global integration and GDP for groups of cities. It allowed us to develop an econometric model to estimate the potential of local economic growth as a result of new transport services or infrastructures, such as air services and highways. A combined indicator, between global integration and the average time travel among cities was proposed. The results of this indicator and the high correlation to the manifest transport demand revealed more accuracy than the previously calculated integration measure, what makes it appropriate for studies in large scale places, such as in this case study. Finally, this research concludes that analysis of large regions with the Spatial Syntax Theory is possible, and that the interpretation of its results can be more interesting when combined with data and indicators of the transport network.

KEYWORDS

Space syntax, interurban transportation, transport network, national planning

1. INTRODUCTION

The interpretation of different aspects of places allows the evaluation of performances and contributes to the evolution of the knowledge of its configurations, helping the planner in its decisions. According to Holanda (2007), each place as architecture from the sociological point of view implies different

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configurations of full and empty elements (volumes and voids). These components are evident in any scale: buildings (surfaces, volumes, spans), cities (streets, squares, buildings) or the natural scale (mountains, valleys). From this perspective, the scale and limits of the analysed object are defined by the analyst, and it are justifiable as long as relationships are identified among the people of the society under study.

Taking this aspect of architecture, a non-orthodox scale is proposed for the planner: to analyse Brazilian national territory as a space system similar to a city, with a main focus on the sociological aspects of the people who are located and moving around the place. There are similarities between the city and the country that justify this proposal, despite the difference in size. Interurban trips - between cities or urban agglomerations - are carried out to meet social and economic relations, just as urban trips meet the population's needs that live in different neighbourhoods of the city. Therefore, if there is a need for society's interrelationship, there is a similarity between inter-urban networks and urban networks.

When we zoom out to a country like this, the full and empty spaces of cities and urban agglomerations are merged into points of origin and destination, and the infrastructures and transport services that connect cities, such as highways, airways, waterways, terminals roads, ports and airports, become the "empty spaces" that make movement possible. The "full" on this scale are the regions that are not permeable by transportation options, that is, barriers that do not allow the interrelations between people from different cities.

Looking at this perspective, it is possible to apply theories of urban architecture as a subsidy to the planning of long-distance transport. For example, it is possible to evaluate if the full and empty spaces that determine the possibilities of movement in this network are related to the needs of the population in different aspects, and also to identify what needs to be satisfied to guarantee this convergence. This work considers that Space Syntax Theory (henceforth SST) is a theory that can reveal the integration levels of a transport network that interconnect cities of a country. Moreover, the crossing of this information with socioeconomic characteristics and demand for transportation indicators reveals the semantics behind the choices of society, as well as the historical choices made by government and people that result in the actual configuration of the transport network. Therefore, the analysis of the intercity network as urban networks is a approach for diagnostic, identification of potentialities, and solutions, which can result in more efficient investments in transport infrastructures.

This paper studies the relationships of people travelling between different cities, choosing Brazil as a case-study, considering its cities, urban agglomerations, infrastructures and transportation services. The hypothesis of this work is to evaluate if SST as applied at a national scale can reveal factors that are not explicit in traditional transport planning. The traditional approach applies models as the four-step one (Bruton, 1979), for example, with predominance in quantitative methods and supply design to meet a future demand (Ortúzar and Willumsen, 2011).

To test the hypothesis, this paper begins with a brief history of the occupation of the Brazilian territory, that is relevant to the understanding the formation of cities and their present relations in the interurban network. Next, the elements of the interurban network are described. Finally, an analysis of this network is made by means of SST (Hillier and Hanson, 1984) and a cross-referencing with transport information and concepts of sociological architecture is carried out (Holanda, 2007), which permits the findings and conclusions in the last section of this paper.

2. CITIES OF BRAZIL AND THE INTER-URBAN NETWORK

Historical aspects of the formation of cities in Brazil's territory and their connections are relevant for understanding the current network of inter-city trips; after all, the configuration of the architecture depends on cultural values, and whether or not there was "planning" – i.e. *top-down* processes – in play (Holanda, 2013). In summary, Table 1 consolidates some relevant facts that have interfered in the design and use of the Brazilian inter-urban network.

Table 1: Main historical facts of the formation of cities and the Brazilian interurban network.

Period	Relevant events
Before Portuguese colonization (before 16th century)	Indigenous tribes inhabited Brazil. They were scattered and nomadic. There were no established cities (Moraes, 2001). The interference in the territory was practically null.
16th century, 1570s	After the Portuguese colonization, there began the search for lands to planting sugar cane along the coast. By the coast were developed the captaincies of São Vicente (that includes part of the current states of São Paulo, Rio de Janeiro and Paraná) and of Pernambuco (Moraes, 2001).
16th and 17th century	Occupation and settlements by the coast gave rise to villages that would later consolidate as State Capitals in Southeast and Northeast regions. The city of Maranhão arose in Brazil's Northeast, founded by the French, while the Portuguese expanded their territory along the coast from Ceará to São Luís and Belém, which was founded by the Spanish. Belém was the starting point for the occupation of the Amazon region.
End of the 16th century	Beginning of the occupation of the interland.
First half of the 17th century	Beginning of the missions, or Bandeirantes, also contributing to internalization. Establishment of livestock in areas not suitable for growing sugar cane far from the coast (Linhares, 1995).
17th century	Discover of gold and beginnings of mining activity, forming more cities in the interior, mainly in Minas Gerais, Goiás, Mato Grosso and Mato Grosso do Sul.
End of the 17th century and beginning of the 18th century	There begins the densification of the metropolis, with the expansion of coffee economy and the first impulse of industrialization (Brito, 2006). Some cities appear in the interior, but always polarized by the metropolis. Rio de Janeiro, capital of the Republic at that time, and São Paulo, comprised 50% of the population of other capitals, consolidating a trend of centrality.
20th century	Growth of the main metropolises, relative decay of the rural population and most of the cities of the interior. The migration breaks familiar ties, observable until today.
20th century, 1950s	The expansion of the road infrastructure and foundation of the new capital: Brasília. From there, we have a mobility network that fosters greater national integration, with a government strategy to expand the development of the Southeast region throughout the territory.
End of the 20th century	Expansion of tourism, mainly domestic tourism (Fonseca et al., 2001), boosting the expansion of infrastructure and inter-urban transport services.
Early 21st century	Deregulation of air transport, which caused fare reductions, popularization of its use and expansion of demand. Road transport, however, still manifests itself as the main mode of transportation for small and medium distances. Brazil has now 5,570 cities, with population concentrated in capitals and a road network that covers practically all national territory. Waterways transportation, however, is still used almost exclusively in the Amazon region.

This brief account shows economic relations between cities, family ties, migrations, and tourist flows. Reasons for travel were are also verified in surveys on the main modes of public inter-urban transportation at present: business, family visits and leisure / tourism (ANTT, 2011, SAC & EPL, 2015). Together, such reasons account 95% of air travel and more than 86% of interstate passenger road transport.

Inter-urban flows manifest in different ways in the Brazilian territory, due to the different social, economic, historical and geographical characteristics. Transport is generally classified as public or private, by its mode (road, air, water, rail), its political-administrative dimension (semi-urban, inter-municipal, interstate, international etc.), or its regularity (regular, eventual, charter etc). These classifications are reflected in distinct economic activity markets, as well as in management, regulation and planning systems performed by different institutions. However, from the perspective of a citizen who travels between cities, it is a single system, with the same main function and different ways and options of transport.

As a consequence of institutional segregation, the planning of inter-urban transportation in Brazil is not integrated. Each mode of transportation has its regulatory agency in the federal sphere and each state manages its internal transports. The result is an inefficient network and isolated investments that do not generate good results in terms of integration, connectivity and accessibility for the population.

Recently, the former Secretariats of Ports and Civil Aviation of the Presidency of Republic merged with the Ministry of Transport. The three extinguished ministries became the Ministry of Transport, Ports and Civil Aviation through Law 13,341 (Brazil, 2016). With a new structure and attributions, there is a tendency of integration in planning and formulation of national public policies among modes of transportation. However, each State continues with its institutions for the management of intercity transport systems, without explicit integration with national plans. In total, there are more than fifty institutions with attributions on planning, management or regulation of infrastructure and inter-urban transportation services in Brazil.

Historical practice of disintegrated planning of intercity transport and institutional limitations are not considered in this paper; we rather focus on the perspective of the people who use it. This approach is in line with two aspects of architecture according to the Holanda (2007): the functional aspect, which analyses whether the place satisfies the practical requirements of daily life in terms of the type and quantity of spaces for the activities, and their interrelationships; the sociological aspect that assesses whether space implies desirable ways for individuals and groups of individuals to locate and move with desired conditions for encounters and gatherings of people.

To study these aspects, some definitions and considerations about the object of analysis are necessary:

1. Definition of the inter-urban network: an intercity transport network was considered for the analysis: road connections between Brazilian cities, regardless of jurisdiction (federal, state or municipal); the main Brazilian waterways with passenger transportation services in the northern region; the routes of commercial air services (regular and non-scheduled). All networks per mode are interconnected by points representing airports and ports connected to highways at the local level when this occurs.

2. Urban agglomerations: In order to analyse the movement between cities or urban agglomerations, and not urban journeys, we adopted the Units for Territorial Planning (UTPs) defined by the Ministry of Transport, Ports and Civil Aviation (2017), which are regions derived from those defined by IBGE in the study of population arrangements and urban agglomerations (IBGE, 2015), in which the main urban agglomerations in Brazil are concentrated. UTPs also include tourism regions according to the Tourism Regionalization Program (MTur, 2016) and strategic areas for guaranteeing accessibility to the population, such as municipalities that have aerodromes. There are 772 UTPs that group most of the Brazilian municipalities. The municipalities that remain outside do not represent significant amounts of population or activities.

3. Demand: A multimodal matrix built by the Ministry of Transport, Ports and Civil Aviation (2018) with information from different regulatory agencies, management bodies and research institutions was considered for the demand for inter-urban transport between UTPs. The total annual volumes of this matrix are shown in Table 2, by mode of transportation. We can observe that almost 1 billion people move annually between cities or urban agglomerations in Brazil.

Table 2: Modal split of inter-urban movement of people between UTPs in Brazil.

Mode of transportation		Demand (millions of people / year)	Subtotal (millions of people / year)	% of collectives modes	%
Collectives	Air transportation (commercial and general aviation)	100.31	390.92	26%	11%
	Coach transportation (interstate and intermunicipal)	285.88		73%	31%
	Rail transportation	1.31		0%	0%
	Waterway transportation	3.42		1%	0%
Private	Car	543.96	543.96	-	58%
Total		**934.88**	**934.88**	**100%**	**100%**

Source: Civil Aviation Master Plan of Brazil [*Plano Aeroviário Nacional - PAN 2018/2038]. Ministério dos Transportes, Portos e Aviação Civil*, 2018. Data base: 2017

Figure 01 shows a map with annual volumes of inter-urban flows in Brazil. The largest inter-urban flows are concentrated in the São Paulo/SP connections. The long-distance connections with São Paulo include Recife/PE, Salvador/BA, Brasília/DF, Belo Horizonte/MG, Goiânia/GO, Rio de Janeiro/RJ, Curitiba/PR, Florianópolis/SC and Porto Alegre/RS, justified by the economic influence of this metropolis on these State Capitals.

The inter-urban flow between São Paulo/SP and Santos/SP UTPs is the largest in the matrix, and is justified by tourism (Guarujá) and economic issues, because there is located the Port of Santos, responsible for the largest volume of imports and exports of Brazil.

There are also high regional flows between urban agglomerations on State of São Paulo, outside the capital, and between North-eastern and Central West capitals with nearby agglomerations.

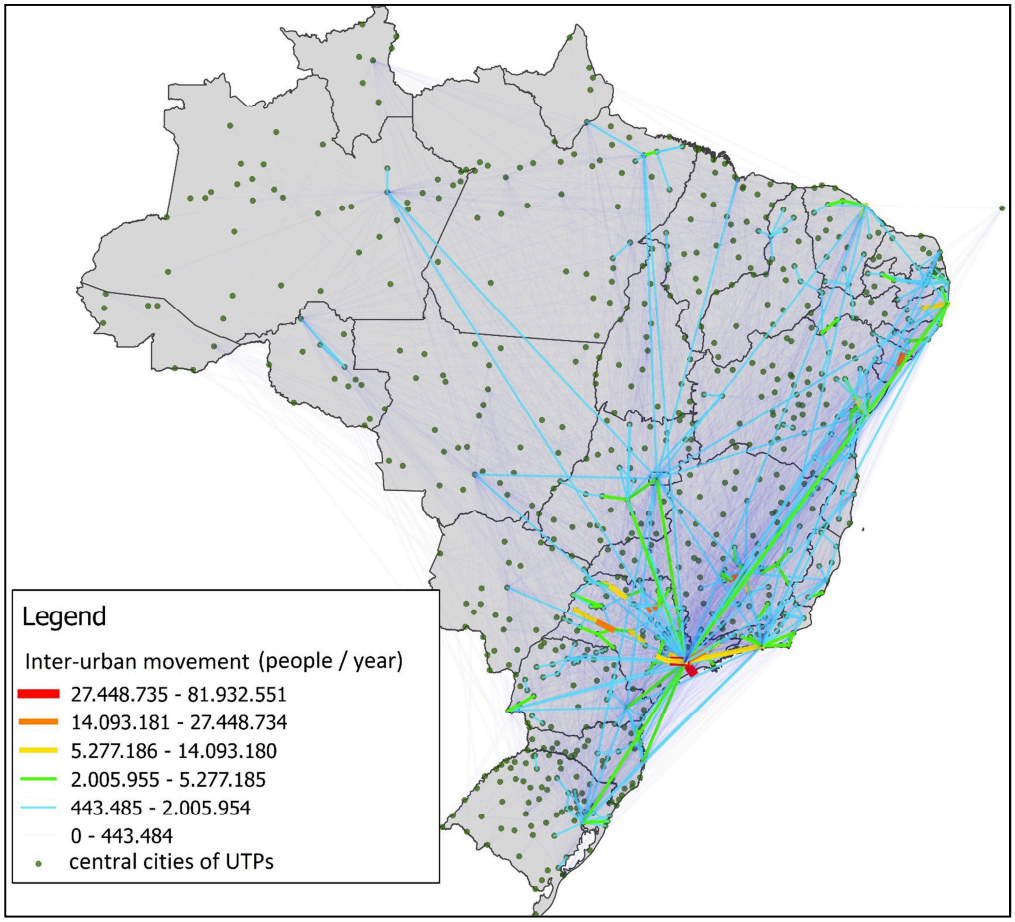


Figure 1: Annual people flows between urban agglomerations (UTPs) in Brazil

3. APPLICATION OF SPACE SYNTAX IN THE NATIONAL SCALE

Spatial Syntax Theory was developed by Bill Hillier and Julienne Hanson (1984) seeking to understand the integration of physical aspects and all social interactions that occur in the spatial domains of cities and buildings. According to Pereira et al. (2011), the spatial structure of cities is understood as "urban configuration", involving the set of barriers and permeabilities constituent of the physical structure of space, in which the arrangement of these elements provides more or less difficulties for the movement of people and the performance of their activities, representing obstacles to movement or "open systems".

Adopting this concept and considering the possibility of architectural analysis in places of any scale, it is evident the possibility of application of the SST in a network of inter-urban trips, considering as permeabilities the physical structures, services and transportation facilities, which make feasible the movement between urban agglomerations or cities.

There are references of application of the Space Syntax in questions related to the transport and also in scales greater than a city or metropolitan region. We highlight some works such as Jales' (2009), which uses Spatial Syntax to estimate traffic volumes in the city of Fortaleza; Pereira et al. (2011), who study the relationship between theory results and urban transport performance; Ugalde and Rigatti (2016) and Altafini (2018), which extrapolate the analyses beyond the metropolitan regions in a vision of regional integration. However, it is not common to advance the application of SST on a national scale, except for some works as Hanna et. al (2013), which applies SST in European

countries and generates results closes to those presented below in this work. Law & Versluis (2015) also studied the relationship between spatial syntax and the spatial configuration of regional flows in the UK. the results presented good correlations, but the study shows as a limitation the need to consider an integrated intermodal transportation network for large scales, which is also approached in this work.

There are also criticisms about spatial syntax in papers that assess its potential in transport studies, such as Maha (1997), who states that the representation of the road network in axial maps makes it difficult to identify specific properties of each street (such as capacity, for example); or Alves (1999), who compares the theory with traffic allocation techniques, concluding that the allocation methodologies consider the elements more segregated, and therefore, would lead more accurate results for allocation purposes. About this type of analysis, it is important to observe some relevant questions to this work: first, the SST initially developed by Hillier and Hanson did not intend to explain all the characteristics of a circulation system, therefore any application outside the original objective is an experiment that requires application, testing, evaluation of results and criticism; second, a group of indicators always explains an object better than a single indicator. Each indicator represents a specific characteristic that it proposes to represent and extend this representation beyond its possibilities involves risk. Graph theory, for example, presents indicators of connectivity, accessibility, centrality and efficiency to represent a transport network, and the interpretation of the whole network performance depends on the analysis of all attributes together (TAAFFE et al., 1996). From this perspective, this work focuses on the evaluation of the results of SST combined with other information.

Although SST incorporates segment analysis, angular and metric integration measures, it is understood that smaller scales, associated with pedestrian traffic, are more sensitive to this type of measurement. Thus, we chose to measure the global axial integration measure (radius "n") for a first application on the national scale. Although it is possible to simulate different radius for an analysis of axial integration in a complex network of highways, for example, limiting the number of conversions makes the results more akin to national integration then local or regional integration.

Global integration measure calculates the potential for movement from one point to another, identifying locations with less or more integration into the territory. Bringing this theory to transport planning field, by concept, the measure indicates an offer of the possibility of movement of the whole network in an integrated way, which is not confused with quantitative indicators of infrastructure's supply in terms of measuring the processing of the demand. Therefore, global integration indicates potential and availability, and requires other indicators, such as demand, for analysis about the use of the integration potential in the current scenario.

Depthmap® software was used to calculate the integration, and spreadsheets and QGIS software were used for visual processing and cross-referencing. The preparation of the databases was also carried out taking care of, for example, the "unlinking" in the air links that fly over highways and waterways. With this, the possibilities of integrating air transport mode to the others in inter-urban movements, are limited to the places with airports.

The importance of planning the Brazilian inter-urban transport network in an integrated way was evident at the beginning of the application of the theory. When calculating global integration for road, air and waterway networks separately, high and low integration levels occur in different regions of the map, as can be seen in Figure 2. However, none of the separate networks brings the real perception of territorial integration. Airports, for example, do not serve a single city, but a region, according to studies about airport catchment areas (De Paula et al., 2017), and thus the integration of the immediately connected road or waterway segments to airports are influenced by the integration of long-distance (air transport) connections into a segment that may be at the other side of the territory.

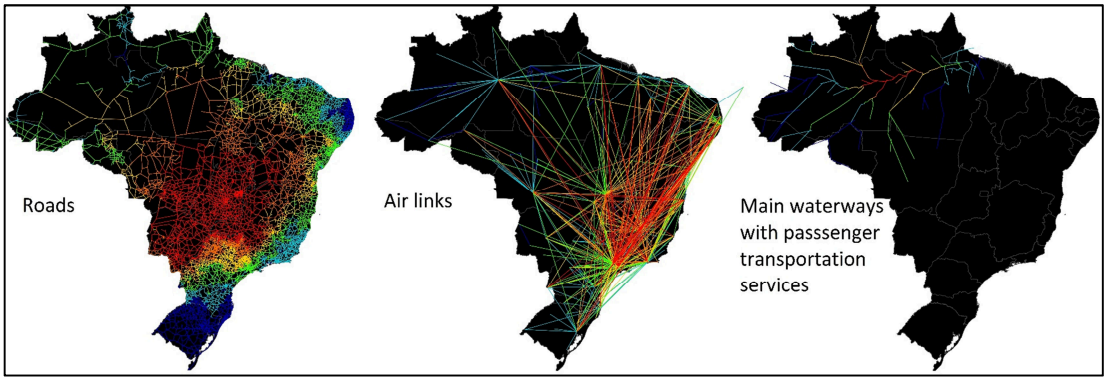


Figure 2: Map of global integration by mode of trasnportation (non-integrated network)

Considering the need for integrated planning between different modes of transport, the axial bases were treated to ensure intermodal connections. Subsequently, the global integration for this intermodal network was calculated, which generated geographically different results, shown in Figure 3.

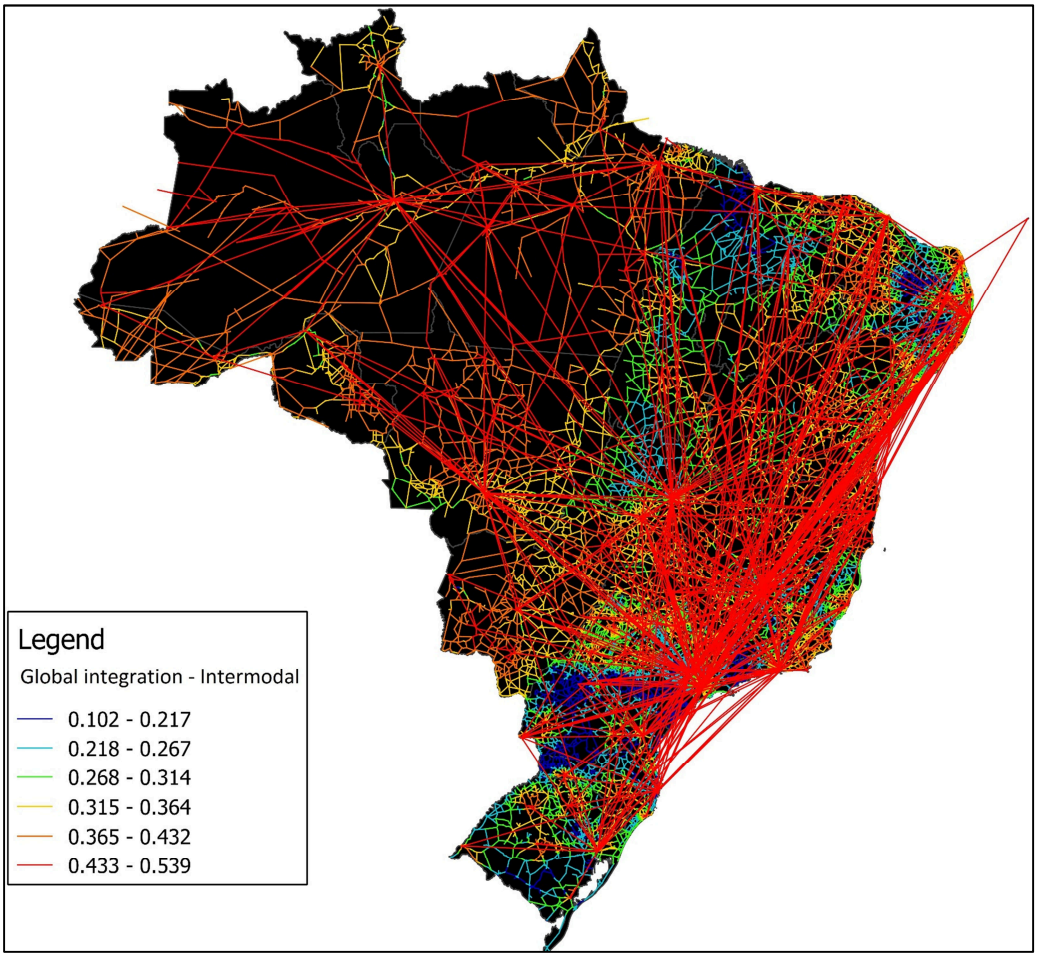


Figure 3: Map of global integration for Brazilian intermodal trasnportation inter-urban network

The results demonstrate the role of air transport in national integration. Roads and waterways linked to points of origin and destination of commercial flights present high rates of global integration. From these points, there is loss of integration when the road network configuration is more complex. The measure of global integration is consistent with one of the main characteristics of air transport, since distances are not characterized as relevant impedances to the movement, but rather the number of connections.

The air transportation connections present the highest integration rates of the network, forming trunks fed by other modes of transportation. These axes concentrate on São Paulo/SP connections with the

capitals along the eastern coast, in addition to being evident the interconnection hubs with Brasília/DF, Manaus/AM, Belo Horizonte/MG and Campinas/SP.

Considering that the integration measure is associated with the potential and availability of infrastructure and services that facilitate inter-urban movement, it is natural to imagine that there is a relation between demand for transportation and integration. This should occur in efficient networks: where there is demand for transport, there should be infrastructure and services. However, as previously seen, the Brazilian inter-urban network has its planning and management segregated institutionally, with public policies and investments that seek to change a bottom-up condition of centrality (for example, the changed of the capital versus the historical centrality of São Paulo and Rio de Janeiro). This process reveals some inefficiencies such as high integration (indicating high potential and availability) where there is low demand, or low integration in regions with high demand. Therefore, the analysis of the correlation between these variables and the identification of the geographical location of the discrepancies helps a more efficient planning.

The correlations between populations, GDP, integration and demand for transport tend to be high, both for the role of transport in economic development, and for development for other reasons that generate demand for transportation. The availability of infrastructure affects the economic development and well-being of society (Santos and Aragão, 2004 and Barat, 2007), and the identification of these correlations can help planners to predicting future impacts of transport investments.

Hillier explains the relation between the (urban) configuration, the movement generated by it and, consequently, the development cycle constituted by the concentration of the movement and the installation of attracting activities in the most favourable places (Hillier et al., 1993 *apud* Medeiros, 2006), which reinforces the need to quantify these relationships.

In order to be able to evaluate this approach, we grouped the results of the global integration (in this case, "national integration") by Unit for Territorial Planning - UTP (grouping of municipalities as explained in the previous section). The global integration assigned to a UTP is the sum of the integration values of infrastructures and intercity transport services with origin or destination in each UTP area, as can be observed in the procedure described in Figure 4.

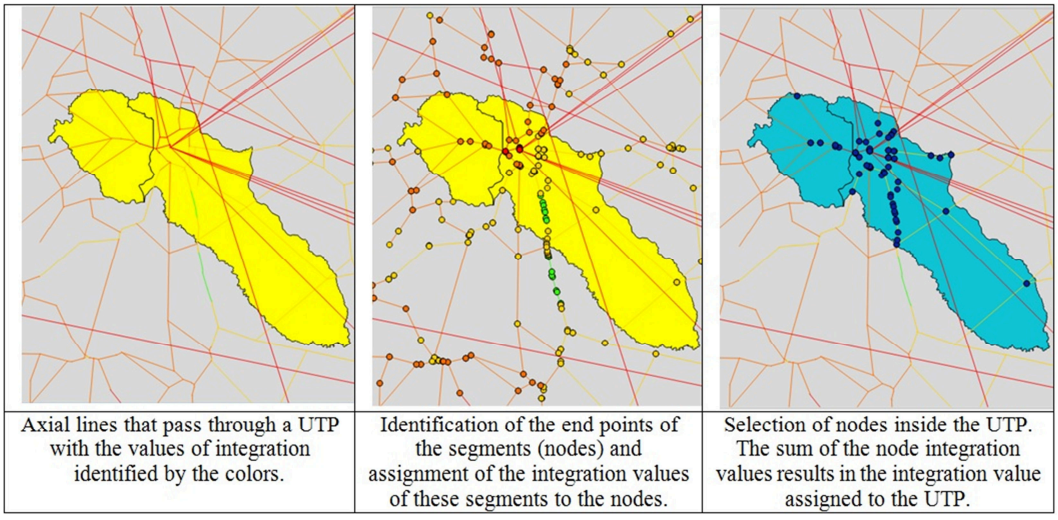


Figure 4: Example of determining national integration values for a UTP

Population, GDP (Gross Domestic Product) and demand for inter-urban transport were also grouped by UTP. The correlations between these variables are shown in Table 3. They were measured using the Correlation Coefficient (R^2), which evaluates if a pair of variables approaches to a linear distribution.

Table 3: Correlation coefficients between National Integration, Demand, Population and GDP by UTP.

	Integration	Demand	GDP	Population
Integration	1			
Demand	0.787356	1		

GDP	0.779067	0.898786	1	
Population	0.82034	0.890412	0.977437	1

The correlation analysis indicates:

- There is high compatibility between Population and GDP with demand - that is, the UTPs with the largest populations and GDP are also those with the greatest demand for inter-urban transport. The fact is commonly found in transport modelling (Hensher and Button, 2000), and indicates the possibility of development of travel generation models for inter-urban transport in Brazil with this database.
- The high correlation between Population and Integration indicates that the potential and availability of infrastructure and services for inter-urban transport followed the population growth efficiently.
- The correlation between Integration and GDP indicates the possibility of developing econometric models to estimate the potential of economic development when infrastructure and transport services are available, as we can see in Equation 1, developed from data grouped by UTP.

$$GDP_{UTP} = -22{,}530{,}867.99 + 1{,}103{,}041.58 \sum_1^n Int \quad \text{(Equation 1)}$$

  - Where:
    - GDP_{UTP}: Gross Domestic Product estimated for the UTP (or an urban agglomeration);
    - *Int*: Value of global integration (Radius n) of each vertex of the segments, from 1 to n, with nodes within the UTP area, calculated according to the spatial syntax methodology and considering the intermodal inter-urban network.
    - The R^2 of the equation is 0.77; Standard error: 32,767,818.82; Simple linear regression by least squares method (MMQ).
  - This model can be used in transport planning: from the current inter-urban network, for example, it is simulated axial lines that represent air connections from an airport, or segments representing new highways integrated into the network, in a region that wants to invest new infrastructures or transport services. In this new network, SST can be applied again to calculate global integration, and the "*Int*" variable of the econometric model is updated to estimate the new GDP (in R$, nominal values) for the region after the investment. The results are useful for cost-benefit analyses, and it helps quantify expected development for a region that receives investments in transportation. In addition, this may assist Public Authorities to prioritizing and directing resources.
- The correlation between network integration and demand, although high from the statistical point of view, indicates that there are differences that can be identified geographically to guide infrastructure planning in order to meet demand.

The maps on Figure 5 shows the geographical distribution of integration measures and the demand for inter-urban transport, respectively, by UTP. Classes with lower values were hidden for better visualisation. The amplitude of each class observed in the distribution was defined by natural breaks method (Jenks). This method seeks to identify the clusters formed by groups with more similar values (that concentrate a smaller standard deviation in each cluster).

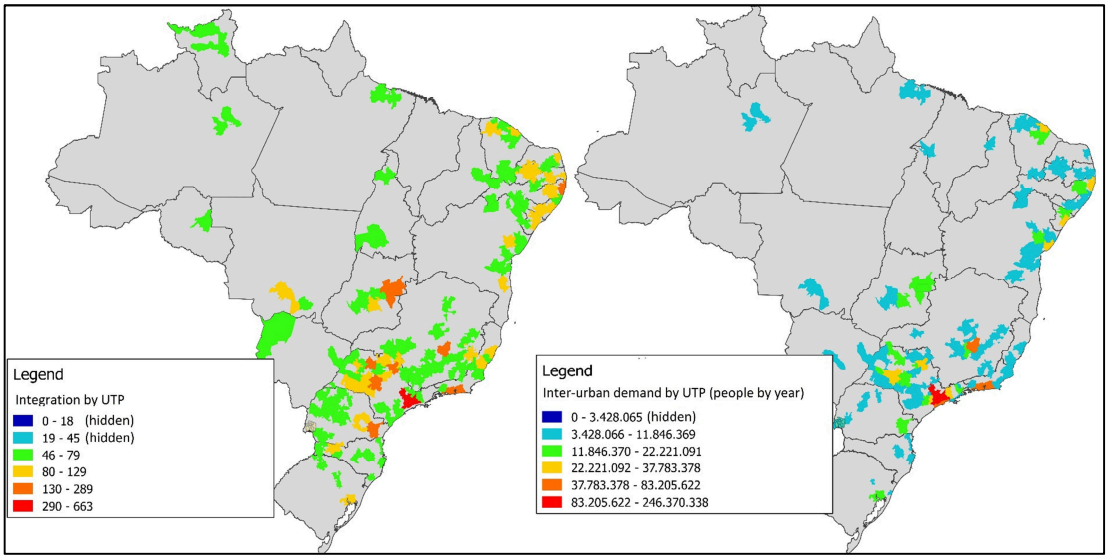


Figure 5: Integration and Inter-urban demand by UTP - regions with highest values

The visual similarity of the maps in Figure 5 shows that most UTPs with medium or high demands for inter-city transport have good or very good integration with the national territory, in a correspondence between availability and potential, measured by integration, with their use.

For Hillier (2007), *natural movement* explained by the results of SST is the proportion of movement of each line determined by the network structure, without considering attractor activities installed in the places. In fact, the only input data for the application of SST is the network topology. Therefore, it is surprising (positively) the coincidences of high integration with the poles attractors and producers of inter-urban movements in the analysis performed. However, there are ways to increase the correlation between these variables. Analyzing the data in detail, we identified 41 of the 772 UTPs, which have considerable demands for inter-city transport, but in regions with low integration. These regions can be observed in Figure 6, with emphasis on the UTPs of Santos/SP, São Roque/SP, Votuporanga/SP, Itaúna/MG, Fernandópolis/SP, Guariba/SP and Guaratinguetá/SP, with demands at higher levels, in descending order.

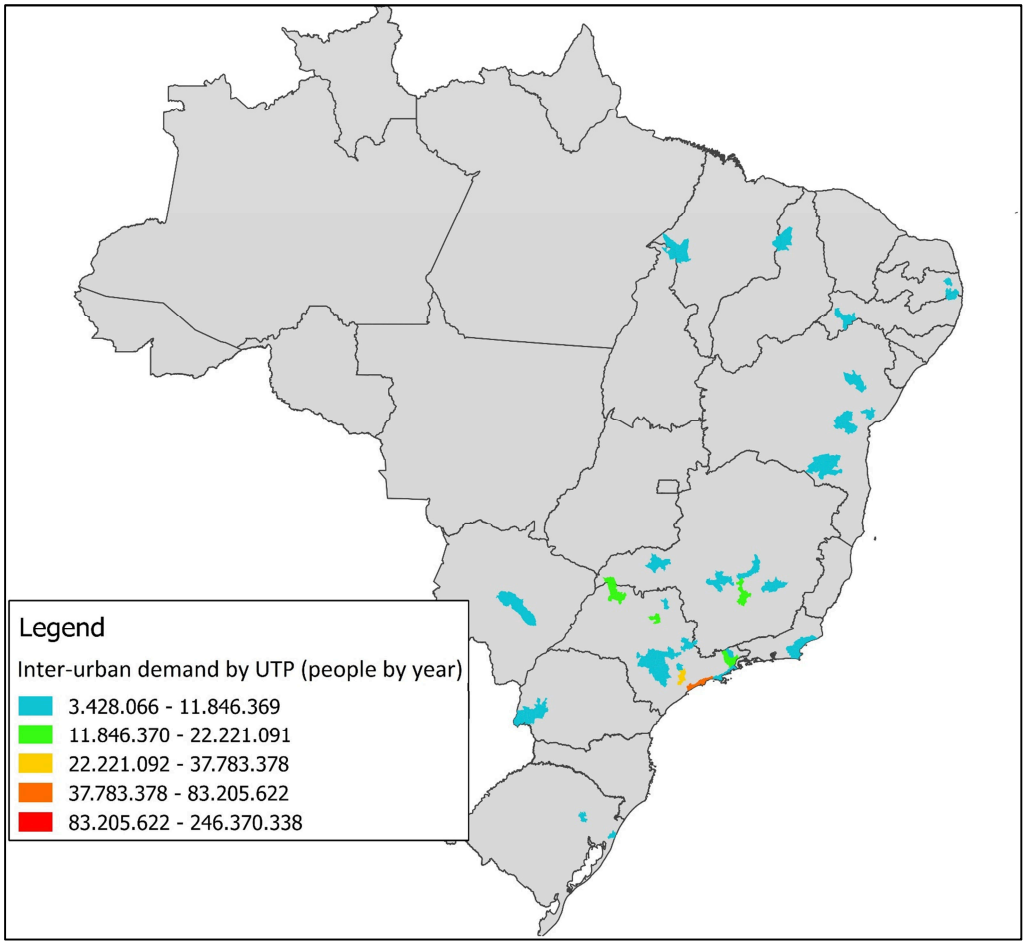
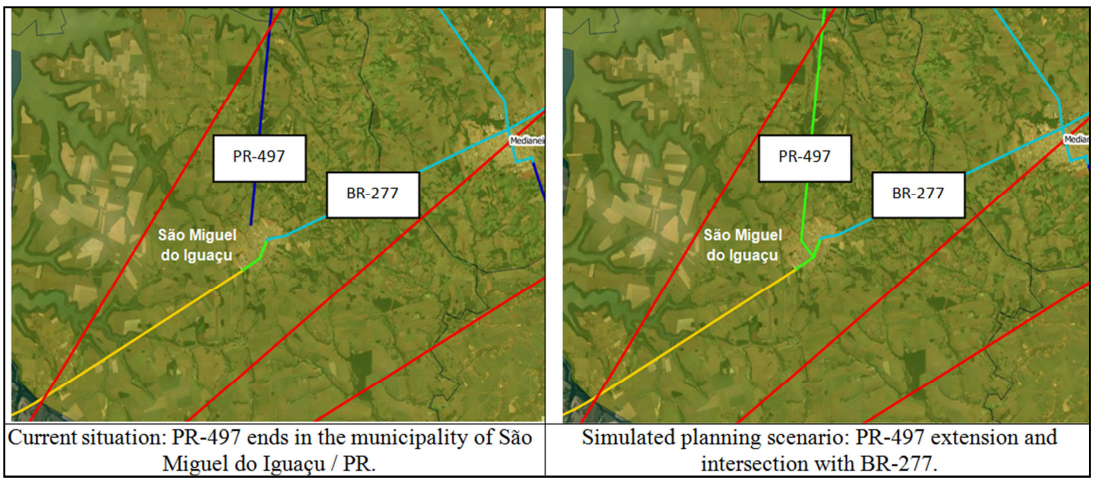


Figure 6: UTPs with high demand for intercity transport and low national integration

The UTPs identified in Figure 6 may be subject to a closer look by the planner, to seek ways to increase integration by providing infrastructures and transportation services. To demonstrate the potential use of this method as a planning tool, we take a hypothetical example of one of the UTPs of Figure 6, which groups ten municipalities on west of the State of Paraná, whose pole is the municipality of Medianeira/PR. It was simulated the possibility of extending the PR-497 highway, bypassing the municipality of São Miguel do Iguaçu/PR, until it meets the BR-277 highway, according to Figure 7.



Current situation: PR-497 ends in the municipality of São Miguel do Iguaçu / PR.

Simulated planning scenario: PR-497 extension and intersection with BR-277.

Figure 7: Hypothetical example of infrastructure planning

After considering the new road network situation at the location of the example, we applied SST again, which modified the global integration for all segments, especially those close to the affected

region. Figure 8 shows segments that previously had very low national integration values (dark blue colour), and which were increased in the planned situation (green colour on the right figure).

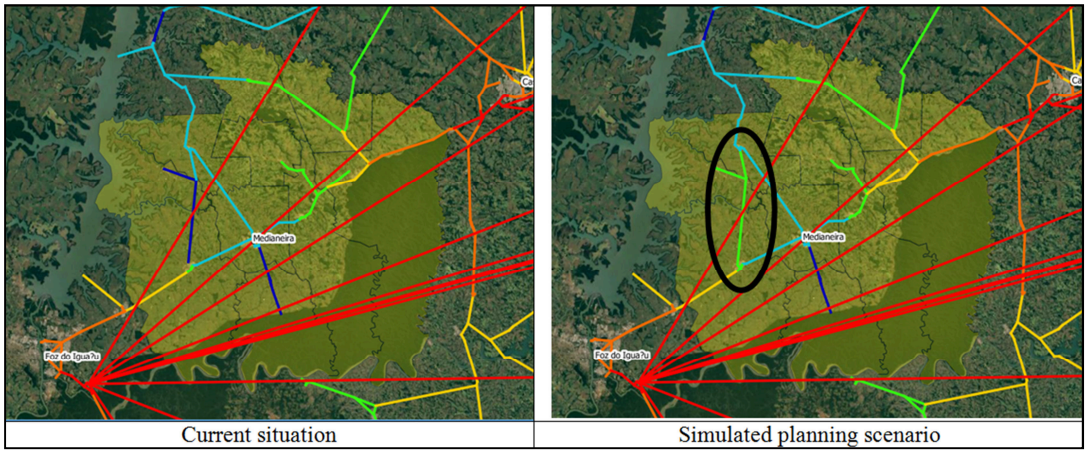


Figure 8: Zoom out on UTP of Medianeira/PR and the impact of the intervention on PR-497 highway

For this example, the UTP's global integration increased from 26.74 to 27.72. Despite the small variation, we apply the model of Equation 1 previously described, which resulted in the projection of a 15% increase in the region's GDP. The same approach can be applied to designing highways or railways between cities, or to evaluate the construction of airports and the start of new commercial flights in strategic level of planning. It may be one of the criteria for prioritizing investments and governmental actions, but detailed studies should be performed to choose the appropriate transportation mode for each region, considering geographical limitations, physical characteristics of the intervention sites, socioeconomic characteristics and demands.

A characteristic of global integration calculated by SST is that each segment has an integration value independent of its extension. At the national scale we observed, for example, that highways without intersections for more than 200 km may have values similar to the short segments, less than 5 km. This situation led the study to consider other impedances to movement in addition to the calculated integration, in order to verify if the combination of indicators can generate more accurate results.

In an analysis considering a transport impedance for each UTP, the average time of inter-urban travel weighted by the demand was calculated, which represents the average inter-urban travel time of the flows with origin or destination in the UTP. The geographic distribution of this measure can be observed in Figure 9. It can be observed that the UTPs located on southeast, centre-west and east coast regions have faster access, while travel times increase stronger in the north of the country.

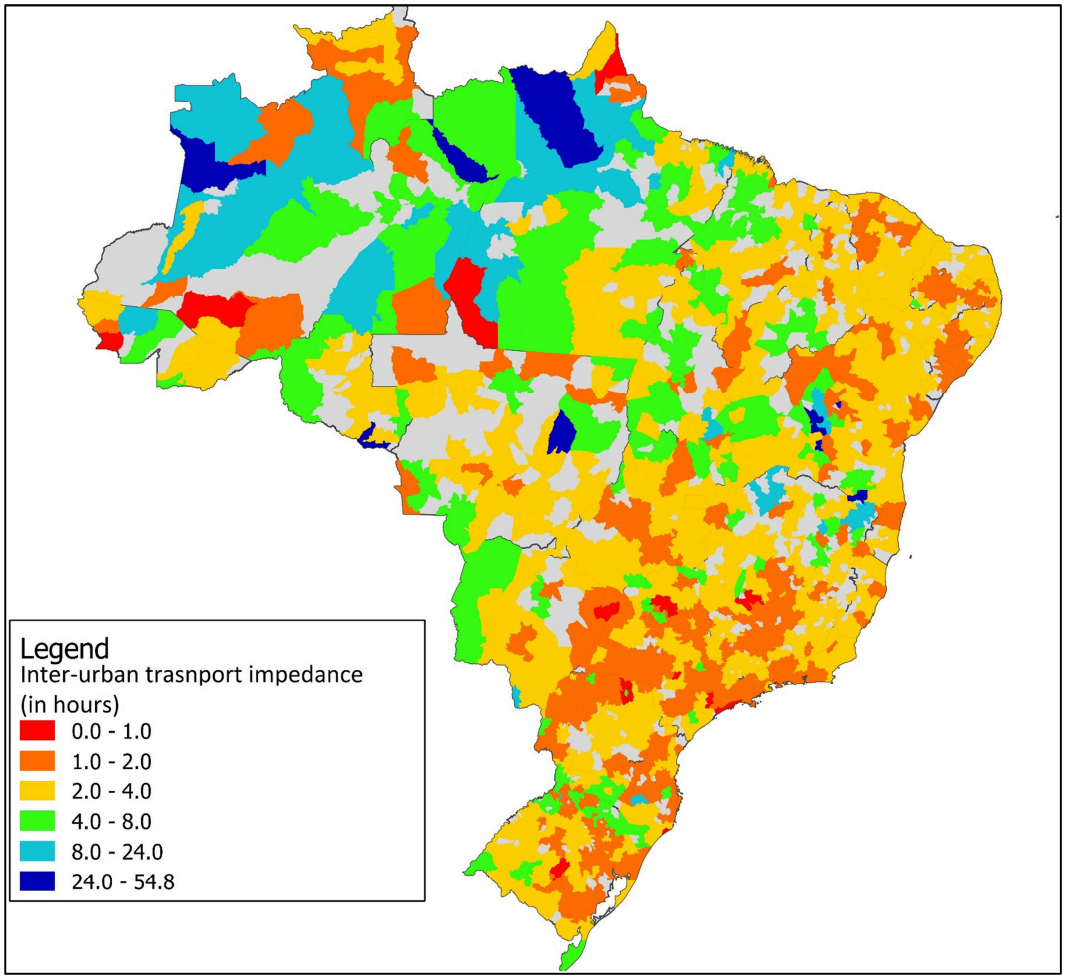


Figure 9: UTP transport impedance - Demand-weighted average inter-urban travel time

While the integration measure represents the availability of infrastructure, average time indicates the use of these infrastructures by means of public transportation (commercial air flights, buses etc) or private ones (cars). In order to create a measure that considers both aspects we divide the UTP global integration values by the impedance measure. Thus, UTPs with high availability of infrastructure, and with high times to access origins and destinations demanded by the population have their value of integration reduced. The calculation approaches the logic of gravitational models of transport (Philbrick, 1971). However, the denominator coefficient of this equation needs calibration.

As expected, results of this new "reduced integration" by the impedance of movement to/from each UTP increased the correlation with inter-urban demand from 0.78 to 0.83, showing that regions with availability of infrastructure but with difficulties for access tend to result reduced demands. The reduced integration measure has generated coherent results of availability of infrastructure and services. While the global integration previously calculated indicated high values, for example, in UTPs in the Amazon (Figures 3 and 5), due the fact that there were regular air transport flights, the same was not verified in the reduced integration measure, since time of access to those regions is high. Finally, Figure 10 shows the result of this measure.

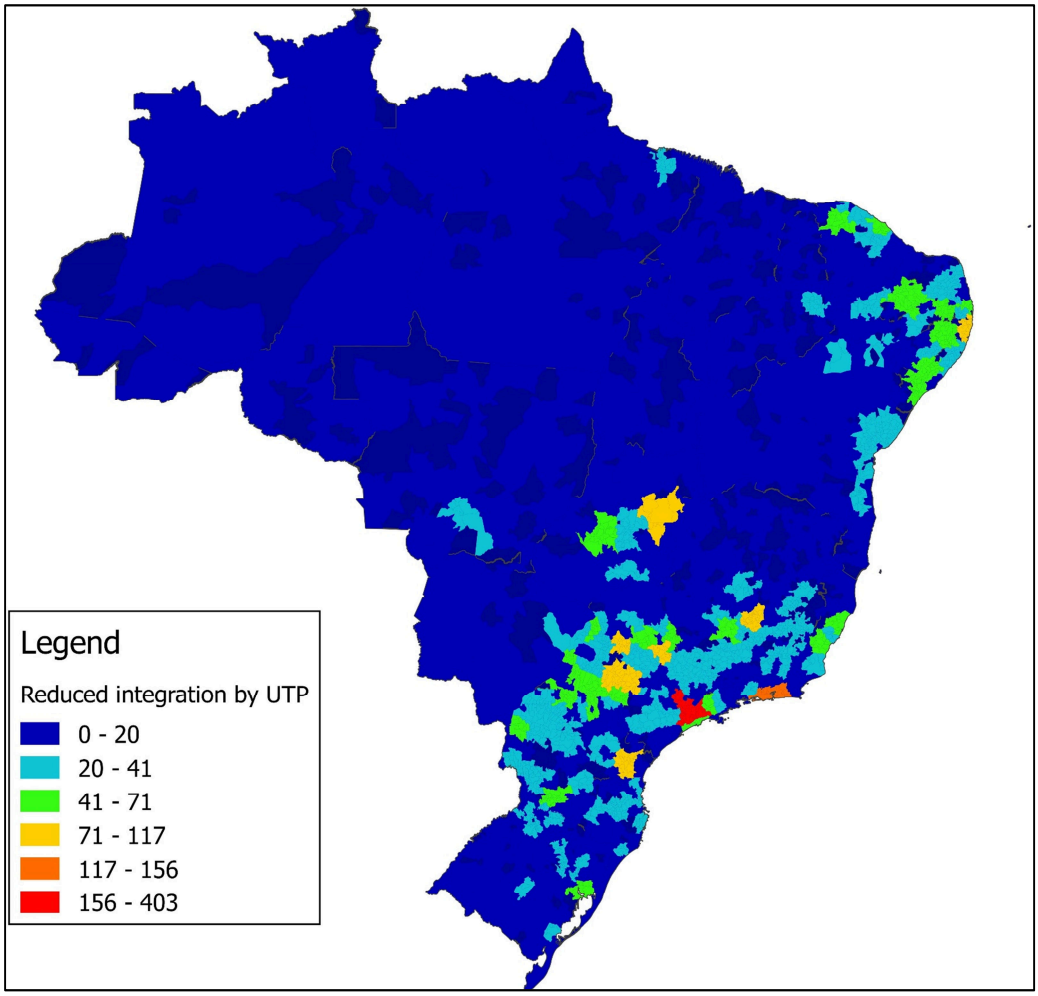


Figure 10: Global integration reduced by inter-urban impedance to/from each UTP

4. CONCLUSIONS

In this paper, it was observed that a network between Brazilian cities demonstrates characteristics of an architecture as a dependent variable (adopting Holanda's concept, 2007) in the long run of its formation history. This means that its configuration is a result of natural determinations of the environment, society, and the economic evolution of regions. Architecture enters as an independent variable only in planned actions in the recent past (1950s) when it was officially intended to bring development into the interior of the country through the planned new capital of Brasília and the expansion of the road system. Current network is a reflection of both actions, and generates a configuration that was evaluated in this paper through SST. Despite recent intentions of internalization, the application of the theory has shown that integration, as well as the demand for inter-urban transport, remains concentrated in the natural poles of the State capitals of the south-east and the capitals of the northeast coast. Despite exceptions in the interior of the country, such as Brasília, this does not create a continuum of integration throughout the territory.

It was verified that the inter-urban network meets a great part of the social needs of relations between the urban agglomerations or cities; therefore, it performs well in the sociological aspect, allowing the demand of trips related to tourism, family visits and business (fairs, conventions, official meetings etc.).

The network of inter-urban movements coincide in large part with the demands manifested by transportation, as well as with demographic distribution and economic production. The analysis of integration with other data, such as the impedance to movement, makes it possible to conclude that infrastructure, services and transportation facilities are relatively adequate to the needs of the population, but detailed studies are also necessary for evaluation of some regions with repressed demands.

Finally, the hypothesis was corroborated by the evidence: application of SST on a national scale proved possible, and revealed lacunae of classical models of transport planning, e.g. as an objective way to quantify the potential and availability of all transport infrastructures and services. Another example was the econometric model developed, by adding SST tools to traditional ways of forecasting economic development as a function of planned changes in the network (Equation 1).

A relevant consideration that can be worked out when using Spatial Syntax in large places, and for evaluation of transport networks purposes, is the combined analysis of integration measures with other data, or even the possibility of testing new measures. Global axial integration, for example, does not consider the extent of the segment in its value. If the segment represents an air transport line, this makes sense, since the extent (and consequently the time) do not imply significant impedances for transport. However, if we apply this logic to waterways in opposite flows of the rivers, the length and travel time interfere strongly in the workings of integration. A proposal to develop this issue in future works is to generate new values of the depth measurement of the segments using gravitational models (such as in Philbrick, 1971). A first attempt of this idea, grouped by UTP was presented at the end of the last section in this paper; however, it is probable that a segmented analysis can generate better results.

Finally, this papers suggests directions of a joint development in the fields of Spatial Syntax Theory and of transportation planning, a combination that improves systemic approaches towards the distribution of cities and their integration on a national scale.

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