

Intelligibility in Large Spatial Systems Ref 119

The Case of Porto Alegre Metropolitan Region

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Abstract

In 2006, almost 1,500 Brazilian municipalities, with population over 20,000 people or located in metropolitan areas approved or reviewed their master plans, influenced by new law requirements and principles such as the social function of property, urban sustainability, popular participation and democratic public management. At this moment, urban transportation debate went over and above its limits as a public service to be provided and reached an urban mobility approach. The discussion crossed different points of view. However, the influence of the urban grid on pedestrian and vehicle movement has been seldom referred to. Urban space structuring is seen as a generic process in public transportation policies, described by abstract center/periphery models where costs are often related exclusively to metric distances.

Consequent problems from this incomplete approach, under a spatial point of view, become worse in Brazilian metropolitan areas, once recent master plans of metropolitan municipalities brought out difficulties in understanding themselves as parts of the metropolitan whole. This was expressed not only in the number of spaces which didn't join up to form coherent continuities but also in the lack of spaces selected to provide a wider mobility system in considerable large sectors of these cities, parts of the conurbation.

Based on Space Syntax theory and methodology, in GIS environment, this investigation aims to evaluate integration and intelligibility (integration/connectivity correlation) in Brazilian metropolitan areas in order to contribute to the discussion about spatial navigation in large urban spaces. The study case about Metropolitan Region of Porto Alegre shows how excessive axial fragmentation, high spatial depth and environmental factors are influencing intelligibility. At the end, elements are proposed and considerations are made suggesting another approach on space intelligibility, based on the macro structural metropolitan grid configuration. The investigation is part of a developing research about spatial configuration and conurbations, taking place at our University and aims to support metropolitan planning in our State.

1. Introduction

In 2006, municipalities included in Brazilian metropolitan areas, concluded their master plans. Particularly, in the Metropolitan Region of Porto Alegre - MRPA, clear regional development guidelines should have been provided by the state government to these cities, since decisions taken in one of them may affect the whole conurbation.

But due to the lack of regional guidelines, we had local plans based on particular and limited views of the whole metropolitan territory. Regarding to urban mobility, this problem can be detected in the grid layout, when maps of the parts are joined together. Due to the lack of important street connections and hierarchy, relevant continuities were missed. As a result, we have a large scale grid chosen to allow wide movement that, apparently, did not efficiently provide even accessibility to all parts of conurbation, what will certainly affect metropolitan functionality.

We must remember here that the global understanding of the metropolitan phenomenon was last expressed in Brazilian regional planning, in the 70's, when urbanization was strongly affected by industrial capital and when metropolitan plans were developed under a modernist point-of-view, disregarding complexity and taking this particular regional space as something generic to be structured by an extremely large scale road system and a macro zoning. Nowadays, other territory occupation and movement patterns, deriving from new economical processes present in Brazilian economy, require a deep discussion, so that their effects on metropolitan space configuration can be better evaluated and taken into consideration on planning actions.

In the democratic Brazilian context it is admissible that municipal plans express a common sense about the city development and the fact that a subsystem of the grid, here called "city main street grid" (CMSG), was pointed out by society (community and planners), make us accept this process as a collective comprehension of space, because it is related to a grid through which a large number of people daily move. CMSG is seen by local citizens as the group of streets, avenues or highways, that allow movement between neighborhoods, sectors and metropolitan cities. It contains the idea of urban expansion too, in the sense that they have in mind the necessity of new areas for occupation, although, for the purpose of this work, only existent streets are being considered. CMSG is also seen by community as a group of streets along which high densities should be allowed by building regulations, so that they become object of investment in terms of paving and other utilities.

However, it can be argued that urban and metropolitan mobility must be approached as a complex phenomenon. The street grid is a large group of continuous public spaces that allow pedestrian and vehicle movement. City structure is strongly influenced by a bottom-up process which is the result of spatial configuration: relations between each element with all the others in the system, from which other subsystems emerge. Thus, configuration proprieties make some streets different from others and they emerge as being potentially better to form pathways and routes between parts of the city which are distant. Therefore, the way the whole system is structured also influences the more or the less capacity of being understood. On the other hand, CMSG can be seen as a top-down process, considering the way it is selected, in most cases, with insufficient quantitative data, diagnostics and simulation, important variables not taken into consideration, mostly subjective aspects or particular visions of the whole. Space Syntax provides this discussion with a theory and a methodology that takes account of a significant part of complexity involved in accessibility. The spatial configuration of urban systems is revealed or evidenced by axial maps where properties which influence pedestrian and vehicle movement in built environments can be measured, generate elements for analysis and support decision.

Clearly, the contents that communities had in mind when selected CMSG, are closely related to perception/cognition aspects, which will not be object of this preliminary paper, because we are not dealing directly with the necessary theory and methodologies to precisely investigate all factors that influenced the decision process in each municipality.

Despite all these difficulties, we have in fact, as survey and research material, the results of these decisions, which are the CMSG layouts of MRPA, and the premise that they should denote some degree of coherent comprehension of the system functionality, what suggests a syntactic evaluation. In a first moment, we will verify which syntactic measures better reflect the implicit logic of the layouts, not only for each municipality but also for conurbation, and if these subsystems present some degree of autonomy and own intelligibility. In a second moment, we intend to make a brief reflection about the possibility of modeling, under a syntactic approach, a spatial continuous and intelligible subsystem prioritized for large scale through movement.

Thus, the present paper registers a preliminary approach of the urban mobility debate, regarding to spatial intelligibility in Brazilian metropolitan areas. It is limited, in experimental character, to one sector of the whole conurbation of MRPA and has the following specific aims:

- a) Verify how the accessibility pattern in MRPA influences the selection of spaces to be part of the City Main Street Grid (CMSG) in each municipality of conurbation, testing which syntactic measure better reflects this selection, in the city scale and in the metropolitan scale.
- b) Make considerations towards a definition and a syntactic measurement of the large spatial systems degree of comprehension, in Brazilian context, which allows performance evaluation and comparison between configurations.

2. Configuration intelligibility in large urban systems

In this section, we try to keep in mind some important concepts and ideas, from different authors, that must be present in our first attempt to better understand configuration aspects that influence spatial cognition in large urban systems.

Investigation results (Tlauka and Wilson 1994; Magliano, et al 1995) which indicate less importance of land marks than configurational information for navigation in urban environment, as suggested by Lynch (Lynch 1960), reinforces our option for Space Syntax theory and methodology for the present discussion, since movement routes planning in large systems has a tendency to use paving, color and lightning differentiation as well as landmarks and ornamentation to call pedestrian and conductor's attention for a supposed importance of a certain street. The syntactic concept related to the comprehension of urban space during navigation is intelligibility. The following transcriptions show clearly the nature of the syntactic concept and measure of intelligibility defined by Hillier.

Since by definition urban space at ground level cannot be seen and experienced all at once, but requires the observer to move around the system building up a picture of it piece by piece, we might suspect that intelligibility has something to do with the way in which a picture of the whole urban system can be built up from its parts, and more specifically, from moving around from one part to another. (Hillier 1996, 65)

The essence of urban form is that it is spatially structured and functionally driven. Between structure and function is the notion of intelligibility, defined as the degree to which what can be seen and experienced locally in the system allows the large-scale system to be learnt without conscious effort. Structure, intelligibility and function permit us to see the town as social process, and the fundamental element in all three is the linear spatial element, or axis. (Hillier 1996, 171)

It is known that as the system grows, intelligibility tends to decrease. Grids of real cities naturally get more deformed, interrupted, sometimes irregular regarding to connectivity and less probability of existing lines linking center to the edge.

Hillier (Hillier 2002) analyzed a group of large cities from different cultures, evaluating, among other tests, the presence and position of long lines in their configurations and concluded that only longer lines maintain intelligibility as a system grows.

The incidence of local centralities, not necessarily related to long lines, takes us to the question that they might be representing a system attempt to recover intelligibility at a local level, since, as it is known, it is more difficult globally achieved. If this is so, although the concept of intelligibility is converted into a mathematical correlation, which measures and certifies if the whole configuration is intelligible or not, the sense of movement, brought clearly in the first transcription, should lead us to the idea that a dynamic intelligibility could be discussed and proposed.

Read (Read 1997, 36) observed in a group of cities in Holland, that integration core (axial lines with the highest integration values usually clustered closed to the center of the global configuration), representing spaces with tendency to high occupation rates, didn't correspond to all spaces with high activity level and prioritized for regional scale movement in the rest of the configuration. He defined the concept of "supergrid" and identified the pattern of its spaces as being similar to the "highlighted important streets found in any way-finder map" (pp.36.08). He tested some measures that could capture those spaces, and, among others like connectivity and local integration, found that the measure of choice, once choice map have a tendency to highlight continuities in the axial map, could be a good model. In fact, he succeeded modeling supergrid by calculating new integration values considering the values of the connected spaces at radius 1, 2 or 3. The obtained output - integration gradient map – when selected for 10 and 25 % values - highlighted the supergrid spaces. Read's investigation made us interested in measuring the intelligibility of the integration gradient map, in 10% of the most integrated spaces, reported as having captured supergrid spaces, those better distributed in the whole configuration and containing a great amount of through movement.

This brief reference leads us to the idea that people might be organizing their routes thinking in a higher layer, with the tendency to "forget" short and fragmented spaces, frequently confused and unintelligible in many Brazilian metropolitan areas, highly deformed and interrupted grids, and operating mentally in a higher layer with supergrid spaces. If so, would this subsystem have its own intelligibility, or what definition and model could be used to evaluate the degree of comprehension of a large urban system?

3. Study case and configuration analysis

Conurbation reaches 14 municipalities of the whole Metropolitan Region of Porto Alegre, in Brazil. Its population reaches more than 3 million people. It concentrates 36.40 % and more than 40 % of the Value Added, in only 3.4% of the territory of Rio Grande do Sul, the southernmost state of Brazil. It is located by Lake Guaíba and is cut by Sinos and Gravataí rivers, and other important creeks, which also influence its territorial occupation, as shown in Figure 1.

Based on the criterion of conurbation, minimization of "edge effect" (Penn et al. 1998, 61), and non existence of significant altitude differences, a subsystem of Greater Porto Alegre (MRPA), corresponding to three satellite towns, was selected for the present study: Esteio, Sapucaia do Sul and part of São Leopoldo. The edges of the subsystem are real: Sinos River (north and west), Sapucaia Creek (south) and the limit of occupation, to the east.

In the global configuration, where we can observe which axial lines belong to Esteio (yellow), Sapucaia do Sul (red) and São Leopoldo (green). In dark blue each CMSG is highlighted forming the large scaled grid. We can clearly see the fusion of grids between Esteio and Sapucaia do Sul, while conurbation with São Leopoldo is still being processed (Figure 2).

The long and thick line in the left side of the system is, in fact, a group of axial lines corresponding to the highway BR-116, which plays an important role in the structuring of not only the sectors object of the present study but also the whole MRPA (Ugalde 2002; Ugalde and Rigatti 2007).

Black circles were used to point out some problems which denote how the way space is being structured, and, as a consequence, how its accessibility pattern is affecting the global understanding of the system. The axial map allows some comments about it, as below.

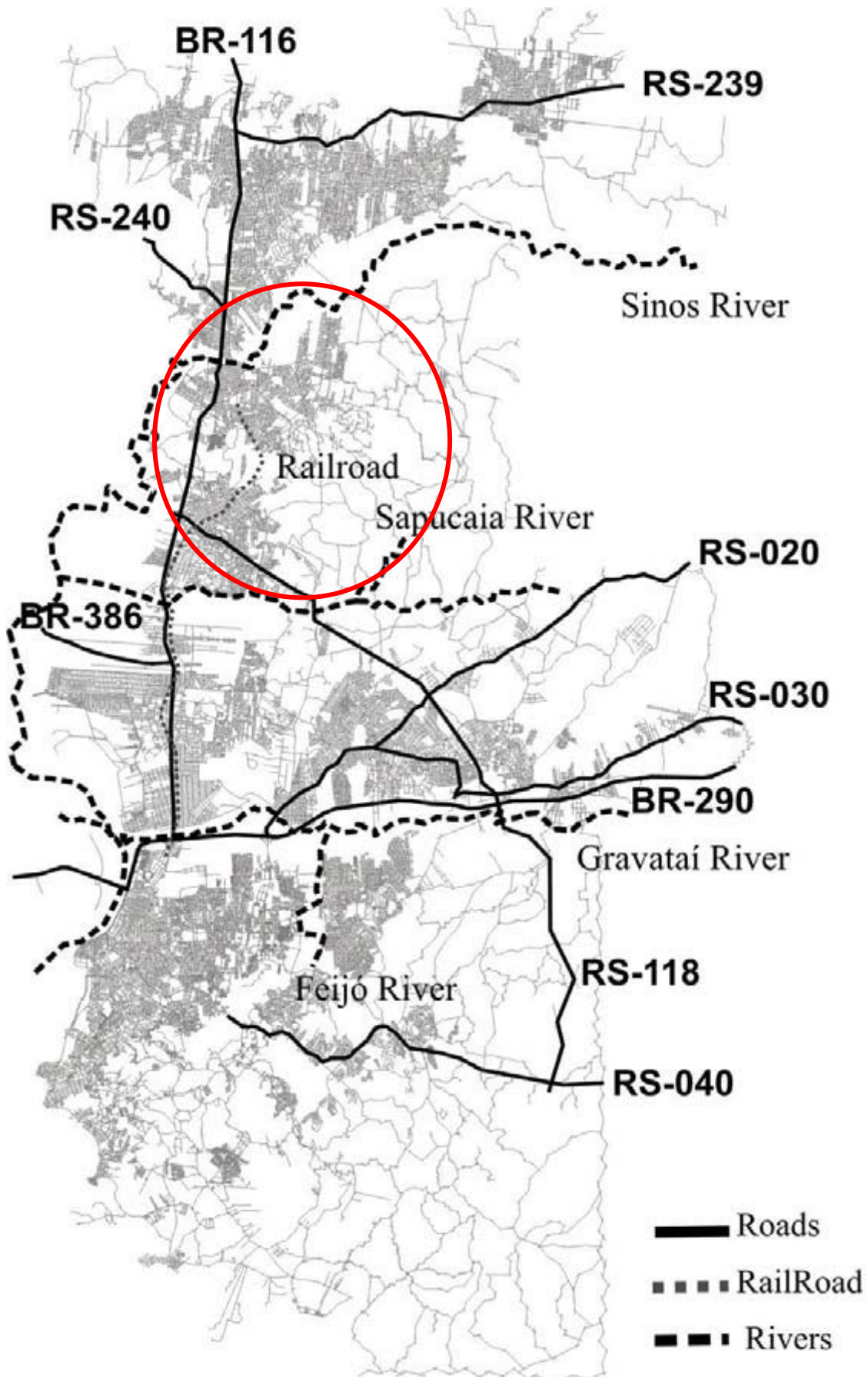


Figure 1
 Metropolitan Region of Porto Alegre – MRPA and study sector.

The linearity, connectivity, length and relative position of BR-116 resulted in high integration values to this group of axial lines and consequently a considerable traffic flow. Nowadays, although well connected, along its parallel lanes, it turned out to be a true obstacle which is also affecting comprehension of the west side of the "wall". This becomes evident when Sapucaia do Sul does not prioritize any space to conduct local traffic flow to the rest of the system, as it was done in the east side of the highway. Although occupation of that part of the city is limited for being close to Sinos River, we observe that Esteio, under the same circumstances, in fact made that selection.

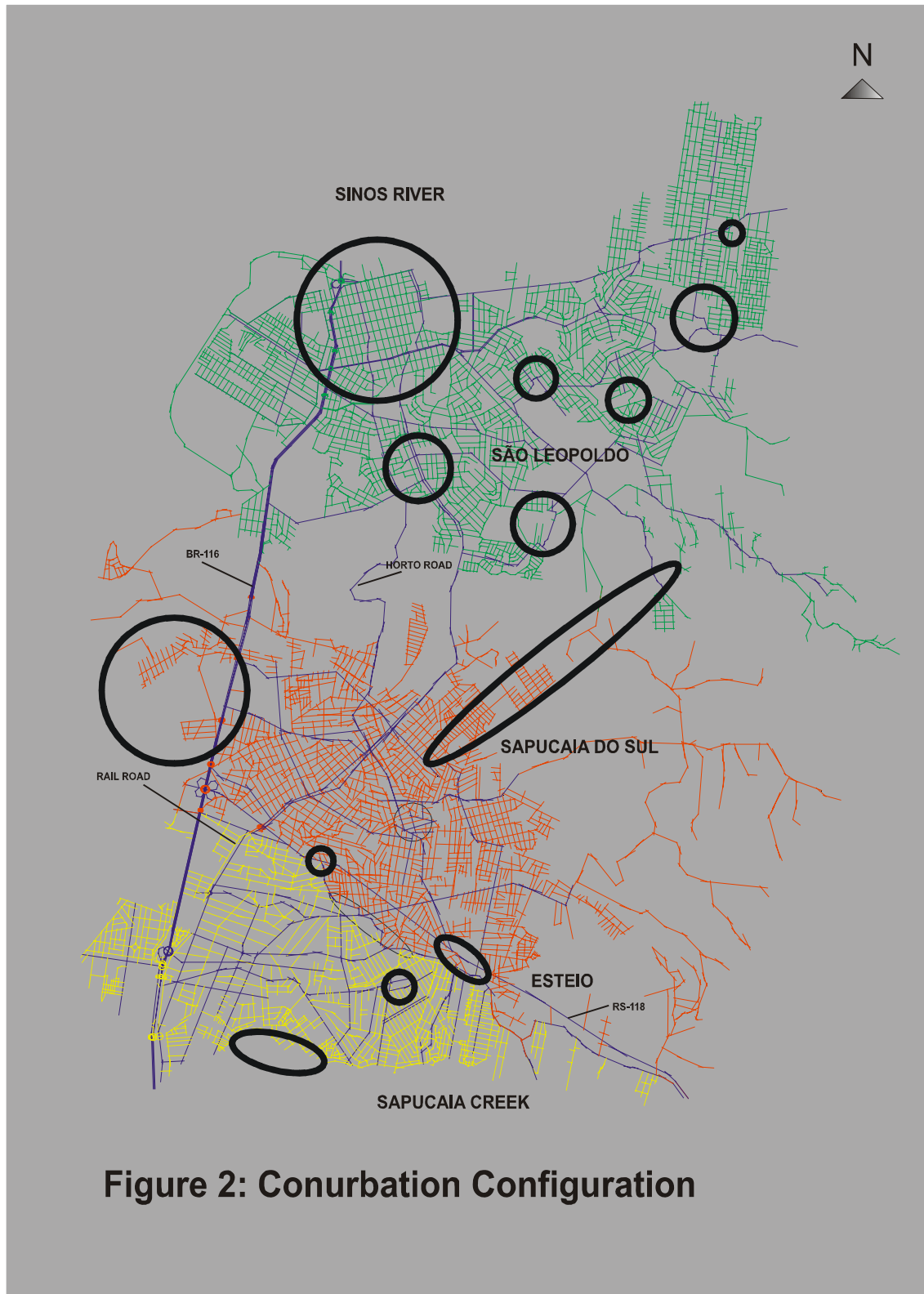


Figure 2

The southern border of Esteio happens to present no conditions to configure a set of axial lines to better integrate this sector to the rest of configuration. On the other hand, it seems that the staff and citizens who participated in Esteio Master Plan didn't have in mind the necessity to solve large scale movement problems in the east part of configuration, not only expressed by the lack of necessary alignments in east-west direction but also for not recognizing two of the few long lines coming from Sapucaia do Sul and interrupted in Esteio territory. By the way, the fact that RS-118, another highway well connected, but not so strongly demanded as BR-116, is relatively closed to the important Luis Pasteur Avenue, the formal city boundary, seems to cause such a confusion in the sense of territoriality of both communities. It can be verified by the lack of connections in a considerable part of the formal limit between the two cities.

The way low-income population informally settled in the north east part of Sapucaia do Sul caused difficulties for the community in selecting spaces to maintain linearity in CMSG. However, what calls our attention is Valdemiro Machado Avenue not being selected. It is, in fact, a long line with high local integration value and also has global importance, besides being close to São Leopoldo expansion areas.

São Leopoldo, originated from a highly integrated orthogonal grid, has difficulties in keeping regularity in the expansion zones. Many subdivisions were not completely built, interrupting potential routes, and in other subdivisions, at east, even regular grids, with long and well connected lines do not match other global integrated lines, sometimes for short distances. The whole settlement gets segregated and it seems that they get excluded from planners and citizens cognition.

Conurbation global integration (a) and global integration of CMSG, extracted from the whole system, (b) are shown in Figure 3. Except for a few axial lines, there are not significant differences, through a visual analysis, in the integration of the axial lines representing CMSG. The reason for part of this low differentiation is integration concentration in BR-116 and axial lines connected to it, at a first step or level, due to an axial fragmentation considering the whole conurbation and a consequent depth increase, with the lack of even integration distribution. Since we are interest to investigate, at a preliminary stage, what is the degree of autonomy of CMSG in relation to whole configuration, we started measuring this way.

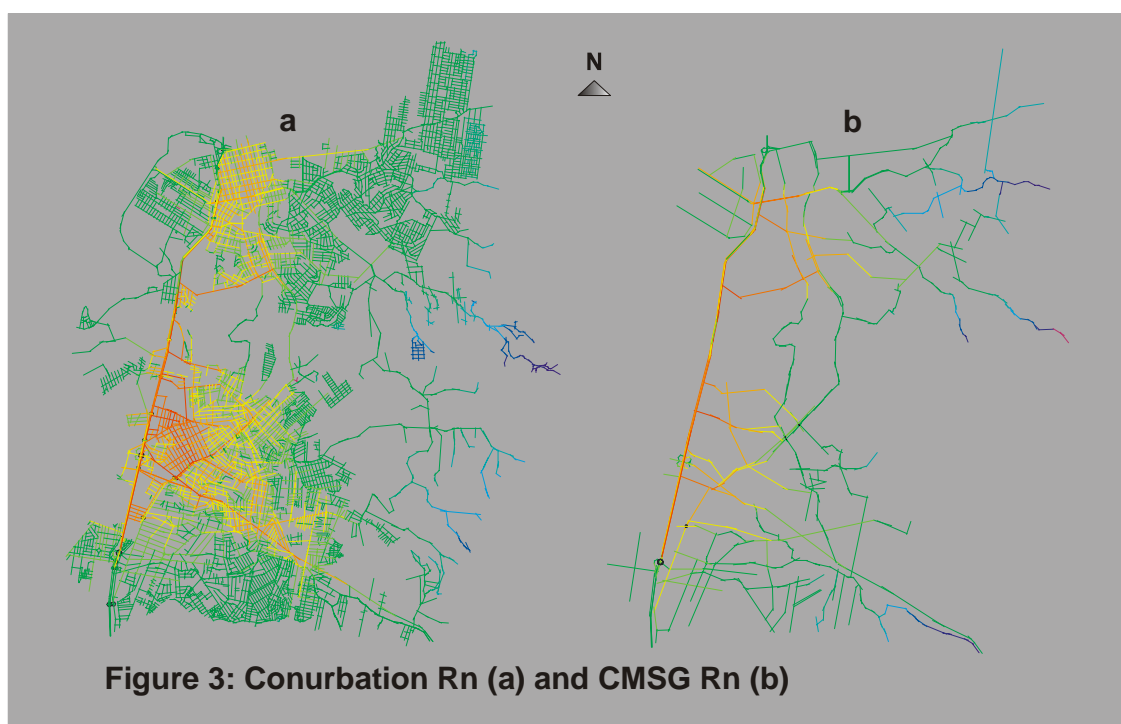


Figure 3

Some results obtained from the municipal configurations and whole system measurements are presented in Table 1. As expected, we found low values for intelligibility, not only in conurbation configuration, but also in each city. But what calls our attention is that Esteio, the smallest system, has the lowest intelligibility value, even lower than the whole configuration. We can observe in Esteio spatial configuration that the most central and integrated axial lines are not the most connected ones, what causes then a low correlation between integration and connectivity. The transition from a wide and well integrated grid to a narrow one, to the east, influenced intelligibility of Esteio, despite being a relative small municipality.

Although Esteio has the highest proportion of CMSG spaces in the whole city configuration, if compared to the other ones, what can be a consequence of the intensive process of discussion among citizens and technical staff during Master Plan elaboration, intelligibility of CMSG is low. It seems that configurational information influenced in the incomplete comprehension of the system, not only in the local but also in a global level.

Table1 : Syntatic Measurements in a sector of RMPA				
MEASURES / TERRITORY	ESTEIO	SAPUCAIA DO SUL	SÃO LEOPOLDO	CONURBATION
AXIAL LINES				
TOTAL SYSTEM	908	1426	1899	4233
CMSG	137	167	276	538
LINE LENGTH LONGER THAN 1000 m				
TOTAL SYSTEM	27	37	51	115
CMSG	20	23	19	62
MEAN CONNECTIVITY (TOTAL SYSTEM)				
	3,88	4,19	3,97	4,0700
GLOBAL INTEGRATION MEAN				
	0,78	0,8723	0,7241	0,5983
SUBSYSTEMS INTELLIGIBILITY (r²)				
GLOBAL INTEGRATION (10%)	0,2116	0,2304	0,2916	0,0200
LOCAL INTEGRATION (10%)	0,5929	0,5869	0,3844	0,4523
INTEGRATION GRADIENT (10%)	****	****	0,0468	****
INTEGRATION GRADIENT (100%)	****	****	0,2921	****
CMSG*	0,2563	0,3337	0,2368	0,3041
CMSG**	****	****	0,2474	****
TOTAL SYSTEM INTELLIGIBILITY. (r²)				
	0,0942	0,2135	0,1329	0,1030
CHOICE INTEL. (r²) ***				
	0,2041(50)	0,2914(40)	0,2051(78)	(-)0,063(30)
*Connectivity limited to subsystem axial lines **R1 Connectivity included ***Connectivity limited to subsystem axial lines (). **** Not measured				

Table 1

Read (Read 1997, 9) mentioned the choice map as being a good indicator of supergrid spaces. We tested it for each city and for the configuration as a whole. The choice maps in Figure 4 highlight important spaces CMSG. However, in São Leopoldo, for example, only 39 out of 276

CMSG were captured by the measure of choice and this proportion falls to a negative value when the whole conurbation is considered.

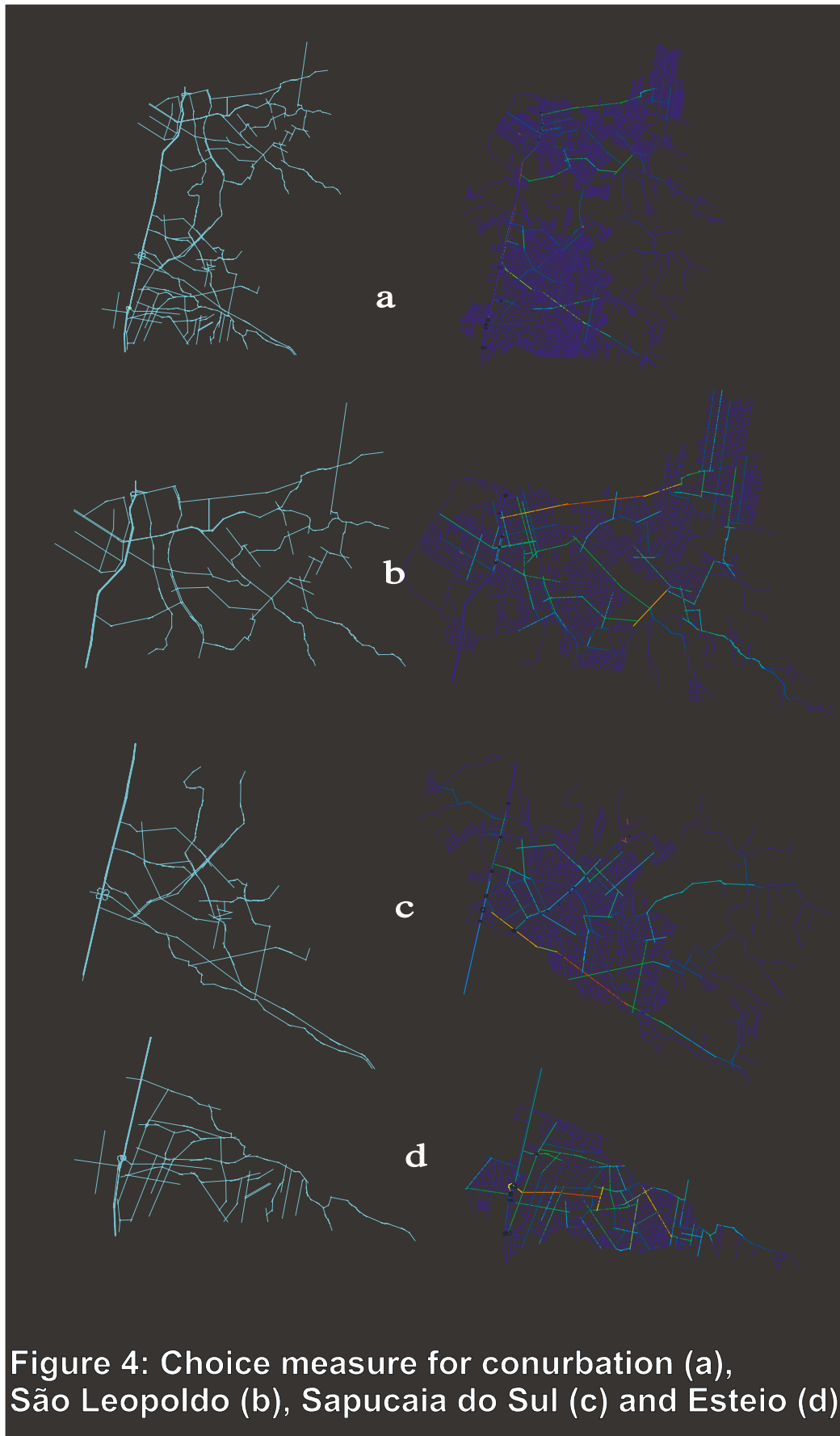


Figure 4

We decided to focus São Leopoldo to test and compare other measures including Read's integration gradient. The results are shown in Table 2 and in Figure 5. Although the number of CMSG spaces captured by global integration core (10%), local integration (10%) and integration gradient (10%) are quite similar, the integration gradient map (10%) seems to have captured more distributed and continuous lines and was not so affected by the integration concentration of the downtown original orthogonal grid, where the algorithm distinguished specific axial lines, including not only the one at the northern boundary (east-west) but also the second line beneath, which is the natural and direct connection of the northern part of the expansion areas with BR-116. It is necessary to say that only 98 spaces out of 276 (total CMSG spaces) were captured by at least one measure. This means that 65,5 % of CMSG spaces in São Leopoldo were selected according to factors related to through movement not considered by syntactic measures.

Table 2: Number of São Leopoldo CMSG axial lines captured by syntactic measures				
CMSG	INTEGRATION GRADIENT (10%)	RN (10%)	R3 (10%)	CHOICE
276	51	45	55	39

Table 2

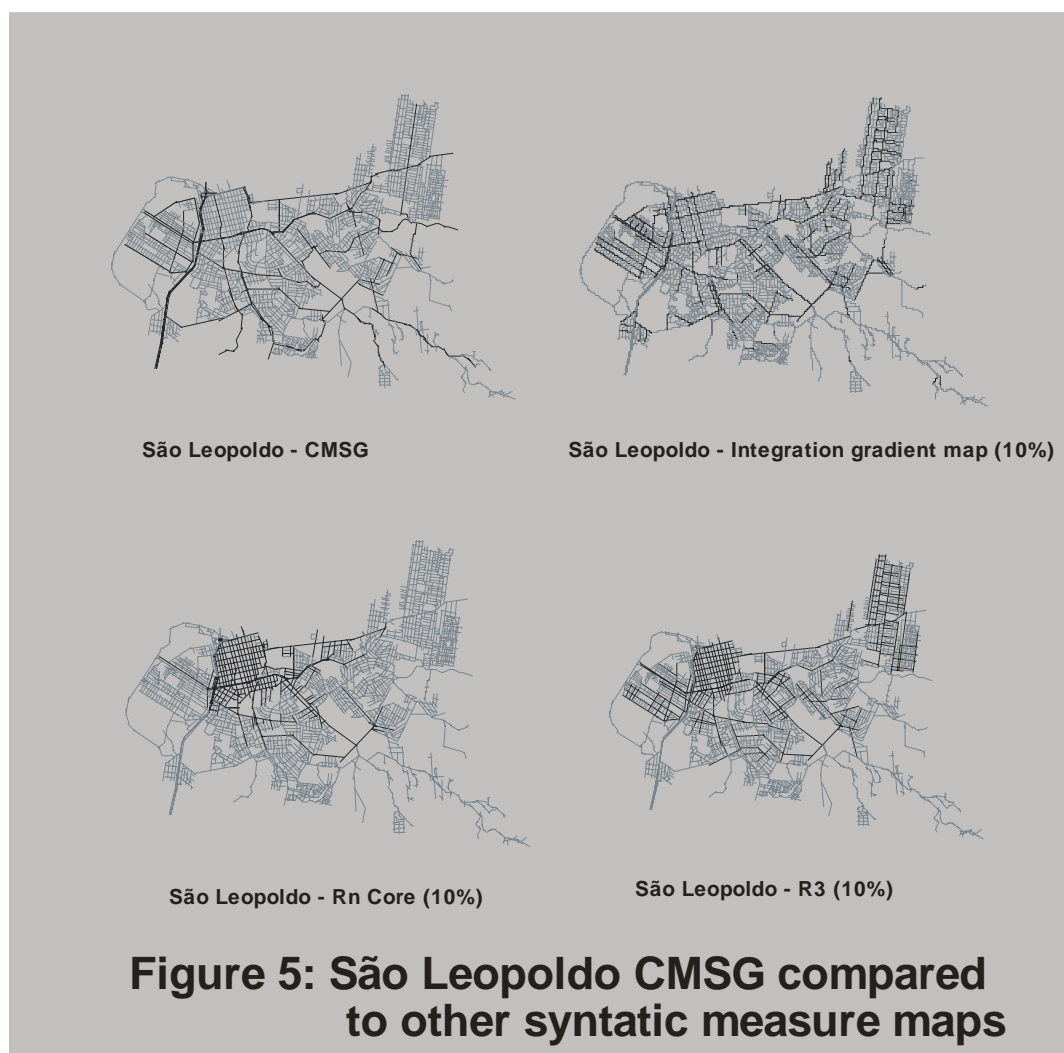


Figure 5

We found some unexpected values for intelligibility, when we tested it for subsystems (10% of the most globally and locally integrated lines, and also for 10% of the most integrated spaces considering Read's methodology, up to the first level of connectivity – R1). For being smaller systems concentrating high integration values and high connectivity there should be a tendency to a higher intelligibility. However, this was not confirmed for the conurbation, whose intelligibility decayed from 0,10 (r^2) to 0,02(r^2) what suggests the hypothesis that very long lines, in the large scale grid of the studied conurbation, are not well connected.

Thus, we measured the axial lines length of Esteio, Sapucaia do Sul and São Leopoldo systems in order to check correlation with their connectivity. Although in real cities generally long lines are well connected, in Brazilian cities, not so compact as the European ones, there could be, in some cases, a weak correlation. Since there is a considerable number of vacant land in the studied conurbation, evidencing long but low connected lines, intelligibility might be largely affected by this situation. The results are in Table 1 and when lines longer than 1,000 m were correlated with their connectivity, the result was a low value ($r^2=0,1681$).

We also expected to find some intelligibility in the integration gradient maps tested in São Leopoldo configuration, set for 10% and 25% of the most integrated lines. However, results indicated low but increasing values for these percentages ($r^2=0,0468$ and $r^2=0,1538$ respectively) reaching 0,2916 for the total gradient.

4. Final considerations

First, we can say that the way the studied sector of Metropolitan Region of Porto Alegre is being structured results in an accessibility pattern which is conditioning not only the identification of a coherent large scale movement grid, but also important interfaces among municipalities. Besides BR-116 and the group of axial lines along the rail road, no other axis was selected to conduct movement among municipalities. The Horto Road, is, in fact, another possibility, but due to its sinuosity, it turned out to be segregated, which is reflected in its low traffic flow.

Urban grids are complex systems where spatial configuration determines differences between all components from which a large number of subsystems can emerge. Conurbation axial map indicates an emerging orthoradial system directed by an angle formed between BR-116 and RS-118 whose bisectrix is represented by axial lines along the rail road. CMSG of Sapucaia do Sul is very representative of this tendency. Maybe that is why the city, despite its low intelligibility value, it is still more intelligible than Esteio and São Leopoldo, according to Table 1 (Total System Intelligibility – r^2). On the other hand, São Leopoldo, has probably some local intelligibilities that can be noticed in the orthogonal grids in east and west side of the city. In the large spatial system of Metropolitan Region of Porto Alegre, we may say, there are parts or zones with different intelligibility intensities. This suggests another study to discuss and define a measure that could capture or evaluate this dynamics. We are not suggesting, though, that orthogonality is imperative to maintain intelligibility. What we must consider, in Brazilian urban reality, is that the high degree of grid deformation and interruption in urban expansion areas generate unintelligible configurations.

We could observe, through this preliminary investigation, that CMSG selected in the municipal masterplans partially accounted for the expected movement influenced by spatial configuration and evaluated by syntactic measures, at least in the case of São Leopoldo, where only 35,5% of the CMSG spaces were captured by the adopted measures. Integration gradient model (supergrid), which is an important contribution for our research purpose, picked 51 out of the 276 CMSG axial lines. These results make us doubt, under a configurational point of view, the efficiency of the solution found by municipal planners and community. Regarding the second goal of this study, procedures were guided by the idea that in Brazilian metropolitan areas, because of the high deformation and interruption of their grids, axial fragmentation and integration concentration, large scale movement has been influenced by a comprehension of space strongly marked by the large scale grids. The question is that, if this is true, large scaled grids might have, we suspect, a degree of autonomy and self-comprehension to be quantified, giving the possibility of different proposed alternatives for a system be compared. We started borrowing Hiller's

measure of intelligibility and tested in the extracted grids (CMSG) to check this "self-comprehension", considering first, its own connectivity and after, in São Leopoldo, considering CMSG axial lines connectivity also brought from the whole grid, what represented a slight value increase (r^2 from 0,2368 to 0,2474). Then we also applied Read's methodology to identify the supergrid in São Leopoldo and compare it with CMSG. Although values were low, differences were detected and its causes were discussed. However this could be better evaluated, simulating different large scale grid alternatives for the same system, what we shall test in the next steps.

This reflection gave us more elements to work on a appropriate configurational measure to evaluate performance of elected or indicated large scale grids. It seems that the new algorithm should consider not only topological but metric information:

- a) Line aggregation Figueiredo and Amorim (Figueiredo and Amorim 2005) developed a model that captures continuity lines according to the angle between them. They verified that wide angles, above 35° , linked axial lines are perceived as one single line. Important differences in measurements occur and must be considered.
- b) Integration Indicates the relative line position in the system and this is obviously necessary to be considered.
- c) Connectivity per length unit This metric information is necessary. Free-ways and highways with very few connections with the rest of configuration must be considered since they have a different condition if compared to other large scale grid spaces.
- d) Total number of axial lines and distributivity (how even are the selected spaces located in the territory) When a CMSG is selected only for a small part of the system with its spaces too much closed one to another, leaving large areas without spaces to be improved in order to allow wide movement, there is certainly a decrease of its efficiency that has to be considered.

The development of the present discussion is relevant for metropolitan planning in Brazil, besides representing an important opportunity to Space Syntax become more visible, diffused and propagated among planners, developers and metropolitan authorities.

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