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Abstract
As a socio/spatial/economic phenomenon conurbations seem to emerge according to, at least, two different logics: on the one hand, a local logic structures the everyday life, the individuality of each community making it possible to understand to which place everybody belongs to. Local centralities ensure this part of the process. On the other hand, the global logic "glues" together every part of the system, structures a large-scale interdependency among the parts in terms of production/housing/consumption, which labels the territory through different kinds, volumes and levels of movement (people, goods, information) and global centralities are able to describe the way the entire system works. In this sense, a conurbation is much more than the sum of the parts but is where complex and dynamic processes take place. The role of every municipality in a conurbation depends on a series of aspects, namely its position within the system and the way it relates to each and every part of the whole. Regarding the Porto Alegre Metropolitan Area – PAMA – conurbation, considered as a spatial phenomenon, a deeper look into the spatial system reveals that there are different degrees of conurbation and interdependency among the constituent parts. Some spatial complexes - parts of the whole - seem to be better understood when seen together while others, in spite of belonging to the same conurbation, seem to keep their individuality regarding other neighboring areas both in terms of the space itself and the socio/economic features. Based on these observations, the main goal of this paper is to describe a methodology applied in the PAMA able to identify a conurbation index among the municipalities. This can represent a potentiality (high or low) in the evolving urban sub-systems or, sometimes, a limit in this process. In this way, aspects related to the role and socio/economic characteristics of the municipalities can arise and explain parts of the conurbation phenomenon. The proposed rate will be structured as a syntactic measure of conurbation through space syntax tools. GIS environment and Census data-base will also be used in order to make it possible to compare spatial data and socio-economic features.

1. Conurbation as a Complex Phenomenon

The conurbation process in Brazil is not a recent phenomenon but, currently presents some peculiarities when compared to preview stages. In the classic version, the region was structured through the expansion of a central city, more important in terms of economic activities, jobs and services and with a few more sub-centers, usually presenting some specific functions and a number of other places, quite dependent from the central city.

In the last few decades (from the 80's on), global changes in the production processes resulted also in deep changes in the spatial patterns which needed to adjust from one economic model to a globalized one.

In this sense, to talk about metropolitan conurbation in a globalized world implies in considering it as a complex phenomenon in time and space.

The notion of complexity is used here as referred in Byrne (1998) as "...the domain between linearly determined order and indeterminate chaos." (p.1). He explains that

"Chaos theory, from which accounts of complexity have developed, deals exactly with non-linear relations, with changes which cannot be fitted into a simple linear law, taking the form of statement of single cause and consequent effect." (Byrne, 1998, p.5)

Another contribution is given by Hayek (1964) who says when talking about social structures: "One of the chief results so far achieved by theoretical work in these fields seems to me to be the demonstration that here individual events regularly depend on so many concrete circumstances that we shall never in fact be in a position to ascertain them all; and that in consequence not only the ideal of prediction and control must largely remain beyond our reach, but also the hope remain illusory that we can discover by observation regular connections between the individual events." (Hayek, 1964, p.61-62)

2. Conurbation In Metropolitan Areas

As a socio/spatial/economic phenomenon, conurbations seem to emerge (Hillier, 1996; Johnson, 2003) according to, at least, two different logics: on the one hand, a local logic structures the everyday life, the individuality of each community making it possible to understand to which place everybody belongs to. Local centralities tend to ensure this part of the process which, even in a large scale system as a metropolitan area, can be clearly understood. On the other hand, the global logic "glues" together every part of the system, structures a large-scale interdependency among the parts in terms of production/housing/consumption, which labels the territory through different kinds, volumes and levels of movement (people, goods, information) and global centralities are able to describe the way the entire system works.

The socio-economic and spatial implications of the current situation of the Porto Alegre Metropolitan Area (simply PAMA, from now on) in the south of Brazil, is the goal of a broader ongoing research. But the focus of the present paper will be the discussion of the physical aspect concerning the PAMA's conurbation seeking for an understanding of the different degrees in which the municipalities are connected to each other. (figure 1)
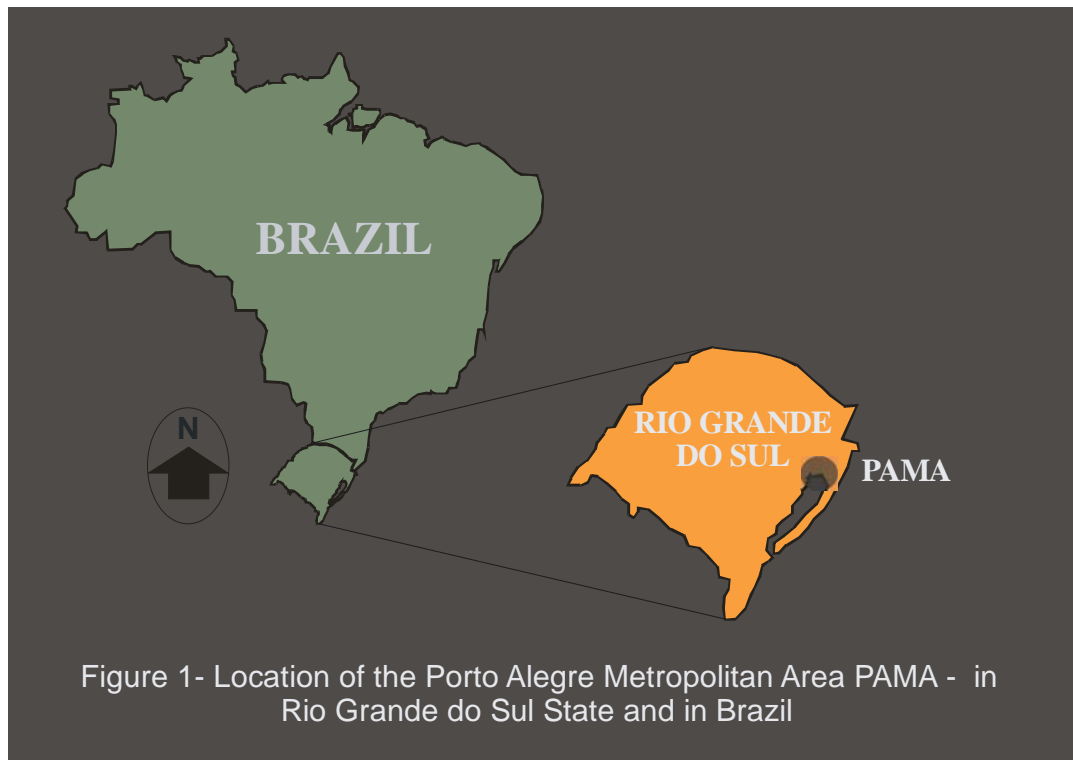

Figure 1- Location of the Porto Alegre Metropolitan Area PAMA - in Rio Grande do Sul State and in Brazil

Figure 1
Location of the Porto Alegro Metropolitan Area PAMA in Rio Grande do Sul State and in Brazil

Another aspect that seems particularly important in large spatial systems like a metropolitan area is that emergent processes are not always able to account for the construction and evolution of the entire structure. We can consider that local rules do matter for the evolving structure over time as a bottom-up process. Nevertheless, there are important changes introduced in top-down processes, mainly through global policies, like a new through-road construction, short cuts, new alternative connections among spaces, for instance, that can introduce deep changes in the local structures which need to readapt itself to the new situation and making it possible that emergent processes can arise again but from a different starting point.

In this sense, a conurbation is much more than the sum of the parts but is where complex and dynamic processes take place. The role of every municipality in a conurbation over time depends on a series of aspects, namely its position within the system and the way it relates to each and every part of the whole. If it is true that this can be achieved through emergent processes, top-down policies can transform the entire accessibility pattern within all metropolitan area in a short time term.

3. The Porto Alegre Metropolitan Area – Pama

These 14 municipalities were born in different times and from different purposes. Porto Alegre, Viamão and Gravataí are the oldest cities and start their evolution from the second half of the 18th century on, in a time when Portuguese and Spanish crowns were fighting for a territory whose limits used to change according to several non-lasting treaties. These are the cases of cities that evolve slowly from small foundation cores. In the beginning of the 19th century the northern part of the region begins to be occupied by Germans and São Leopoldo is the first colony and the main center to the immigrants. Later on Novo Hamburgo, Estância Velha, Campo Bom, Portão and Sapiranga start their development as expansions of São Leopoldo. Porto Alegre was linked with the colonies (firstly with the German ones and, by the end of the 19th century, with the Italian ones) through a railroad built in 1874. Along this railroad new urban settlements were built around some of the rail-stations like Canoas, Esteio and Sapucaia do Sul.

Municipality	Population 1991	Population 2000	Mean annual geometric rate 1991/2000	% of the population of the PAMA in 2000
Alvorada	142,046	183,421	2.88	5.72
Cachoeirinha	88,195	107,472	2.22	3.35
Campo Bom	47,876	54,019	1.35	1.68
Canoas	269,258	305,711	1.42	9.54
Estância Velha	28,190	35,121	2.47	1.09
Esteio	70,547	80,025	1.41	2.50
Gravataí	181,035	232,447	2.82	7.25
Novo Hamburgo	205,668	236,037	1.54	7.36
Portão	19,489	24,616	2,88	0.76
Porto Alegre	1,263,403	1,359,932	0.82	42.42
São Leopoldo	167,907	193,403	1.58	6.03
Sapiranga	56,057	69,181	1.85	2.16
Sapucaia do Sul	104,885	122,677	1.76	3.83
Viamão	169,176	226,669	3.30	7.07
MRPA CONURBATION	2,813,732	3,230,731	1.54	100
RS	9,138,670	10,178,970	1.21	-

Source: adapted from Mello (2001).

Table 1

Population of PAMA Conurbation - 1991-2000

The entire region experiences a remarkable growth during and just after the Second World War as a result of an industrialization process. The growth of the population that follows this process produces cities like Alvorada and Cachoeirinha whose origins are based on consecutive land division developments to low-income dwelling and not in the evolution of a pre-existing urban core.

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The table below shows the surveyed population in 1991 and in 2000, which is the last available census, in the PAMA. These 14 municipalities are responsible for almost one third of the population of the Rio Grande do Sul State which comprises more than 300 municipalities. (table 1)

Following this socio-economic process, important national and state roads were built like the BR-116 which runs from south to north crossing Canoas, Esteio, Sapucaia do Sul, São Leopoldo, Novo Hamburgo and Estância Velha; the RS-030 and the RS-020 cross Cachoeirinha and Gravataí; the RS-118, which connects the BR-116 to the BR-290 passing through the territories of Gravataí, Cachoeirinha, Esteio, Sapucaia do Sul and also of Alvorada and Viamão, though far from their urbanized areas. From the 70's on, the new national and state roads that cross the region and the increase of regional and interregional connections took an important part in the configuration of the metropolitan space. Important roads built at that time are: the BR-290, connecting Porto Alegre to the coast, running east/west from Porto Alegre northern city limits and passing through the municipalities of Cachoeirinha and Gravataí; the RS-239, connecting Estância Velha, Novo Hamburgo, Campo Bom and Sapiranga, almost in the northern limit of the study area; BR-386, connecting the metropolitan area to the northwestern part of the State.

One of the outcomes of this process is that the evolving urban areas begin to carry on roles that are not explained only by a logic internal to them but can only be understood by the way they are inserted in an interdependent and expanding metropolitan system where the conurbation is one of its faces.

This small area concentrates a significant part of the jobs and wealth produced by the State but also a great deal of social problems. The table below shows the rank of the municipalities of the PAMA according some socio-economic features and is produced through the Local Social Extended Index, which takes into account aspects like housing and sanitation, education, health and income of every community. (table2)

Municípios	1991	1992	1993	1994	1995	1996	Mean in the period	Rank in the RS State
Alvorada	0.43	0.42	0.42	0.42	0.41	0.41	0.42	286
Cachoeirinha	0.53	0.52	0.52	0.52	0.52	0.52	0.52	55
Campo Bom	0.54	0.54	0.54	0.55	0.55	0.55	0.55	20
Canoas	0.53	0.53	0.53	0.53	0.53	0.53	0.53	39
Estância Velha	0.54	0.54	0.54	0.54	0.55	0.55	0.54	23
Esteio	0.57	0.56	0.56	0.56	0.56	0.56	0.56	10
Gravataí	0.51	0.50	0.49	0.48	0.47	0.46	0.49	120
Novo Hamburgo	0.54	0.53	0.53	0.53	0.53	0.53	0.53	36
Portão	0.44	0.44	0.44	0.44	0.44	0.45	0.44	222
Porto Alegre	0.65	0.64	0.64	0.63	0.63	0.62	0.63	1
São Leopoldo	0.50	0.50	0.50	0.51	0.51	0.51	0.51	84
Sapiranga	0.50	0.50	0.51	0.51	0.51	0.52	0.51	79
Sapucaia do Sul	0.48	0.48	0.47	0.47	0.47	0.46	0.47	150
Viamão	0.46	0.45	0.45	0.44	0.43	0.42	0.44	223

Source: Adapted from Mello (2001)

Table 2
Local Social Extended Index (LSEI) of the Municipalities of the PAMA Conurbation – 1991 to 1996

4. Pama'S Conurbation – Morphological Approach And The Selected Cases

Regarding the PAMA conurbation, considered as a spatial phenomenon, a deeper look into the spatial system reveals that there are different degrees of conurbation and interdependency among the constituent parts. Some spatial complexes - parts of the whole - seem to be better understood

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when seen together while others, in spite of belonging to the same conurbation, seem to keep their individuality regarding other neighboring areas both in terms of the space itself and the socio/economic features they present.

This paper will deal with the differences in terms of physical relations that can be found in the 14 municipalities considered here as the main PAMA's conurbation. It will be proposed a conurbation index using space syntax analysis and measures. Only a few cases from a large number of studies that were made are presented here.

The maps used in this research were upgraded and are part of a larger data-base which will be further explored in the next steps of the research, including configurational and socio-economic data in a GIS environment. These maps were used as a reference to build up all the necessary axial maps of the municipalities and of the entire PAMA.
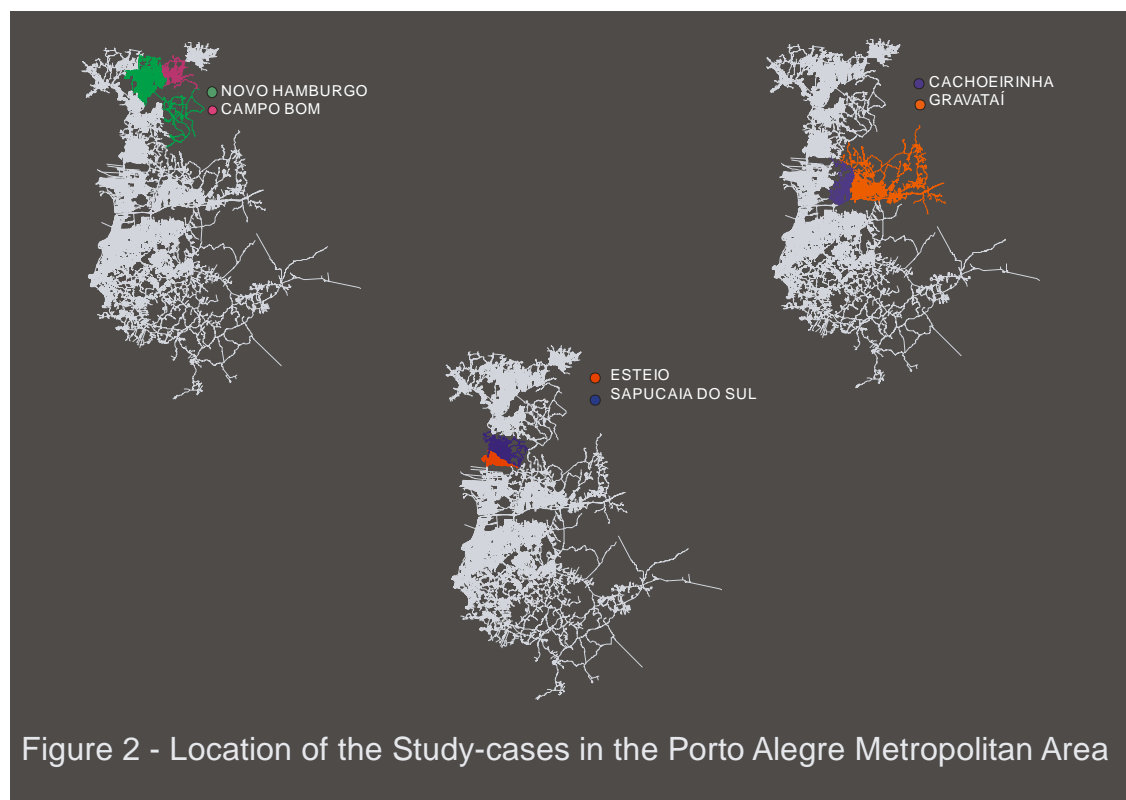

Figure 2 - Location of the Study-cases in the Porto Alegre Metropolitan Area

Figure 2

The syntactic measures were obtained by processing the axial maps though Mindwalk software (Figueiredo, 2002), working with the aggregation of lines with low intersection angles through the concept of continuity lines (Amorim & Figueiredo, 2005) in order to capture aspects of the reality that seem to be lost using the traditional axial maps like the definition of centralities and their relationship with aspects of space occupancy such as land use patterns. The study cases were analyzed through different syntactic measures but the conurbation index suggested in this paper takes into account basically the global integration measure, once it captures key aspects of the urban layout. The conurbation index (CI) is proposed as a comparison between the mean global integration value of the municipalities analyzed separately and the mean global integration value of the grouped municipalities. It is proposed that when there is a strong conurbation between two or more neighboring cities, the syntactic measures of the group tend to be more "robust" than those obtained with the cities analyzed separately, meaning that global integration, intelligibility and synergy tend to be higher while the mean depth tends to be reduced.

CI = Mean global integration value of the isolated municipalities
    Mean global integration value of the grouped municipalities

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This index may represent both a limit in the conurbation process, cases when CI is high or, on the other side, it may represent potential possibilities of conurbation or restrictions to the process according to the possibilities of the urban fabrics to be more or less easily connected. The values obtained were normalized so that they vary from zero to one, making it easier to compare the results.

The case studies presented here were selected based on common sense, like: "we cannot identify where municipality A ends and municipality B starts", both in terms of the observation of geographic data and also in the way locals describe the city limits. In this group of municipalities the notion of compactness seems to be a very important feature of neighboring urban areas and this are the cases of:

a) Novo Hamburgo + Campo Bom

b) Esteio + Sapucaia do Sul

c) Cachoeirinha + Gravataí. (Figure 2)

5 . The Pama and a Closer Look Into the Cases

The PAMA' structure is highly organized through the long lines responsible of connecting the entire region to the rest of the country namely the national roads BR-116, crossing the PAMA from south to north and the BR-290, crossing the area from west to east which intercept each other in the northern limit of Porto Alegre City (Figure 3). Also important for the whole area are the state roads like the RS-118 that from Viamão runs to the north, crosses the BR-290 and ends at the BR-116 structuring an important ring linking together a number of municipalities; the RS-020 is another important state road that starts in the northeast of Porto Alegre City, crossing the BR-290 and the RS-118.

The distribution of the global integration reinforces the relative importance of these roads as necessary paths to move across the system. The cities that are located along the south-north and the west-east axes – the most integrated lines in the system - concentrate most of the economic activities and the jobs of the region, taking advantage of the accessibility patterns and tend to grow faster than Porto Alegre that has incremented his population in lower rates compared the other municipalities (see table 1). Along these two national roads, 10 out of 14 municipalities are located and will be the base for the selection of the case studies about conurbation within the PAMA.

In the southeast, far from the most integrated spaces of the system is where we find two municipalities that work as dormitory areas for the PAMA.

5.1 Case 1 – Novo Hamburgo and Campo Bom

These neighboring cities are located in the northern part of the PAMA and share the same economic base. Figure 4a shows on the left the distribution of the global integration of each municipality while in the centre is showed the global integration of the two of them considered together. Novo Hamburgo has a rural area in the southeast of the system which is responsible for adding depth to the whole. Campo Bom concentrates global integration basically in one single avenue which connects both cities. Although the city limits are difficult be recognized, it is possible to observe that, even sharing common spaces which tend to draw the limits between them, the urban fabrics do not cross each other ending in the limit lines. Considering the group of cities, Novo Hamburgo concentrates great part of the integration core of this system. The cities when grouped together present a higher mean depth compared to the mean depth of the two cities when analyzed separately and this influence the reduction obtained in the mean global integration value of the grouped cities. Vacant land and interrupted urban fabrics may be producing these results and the integration core of every municipality is almost kept when seen together. The conurbation index obtained is:
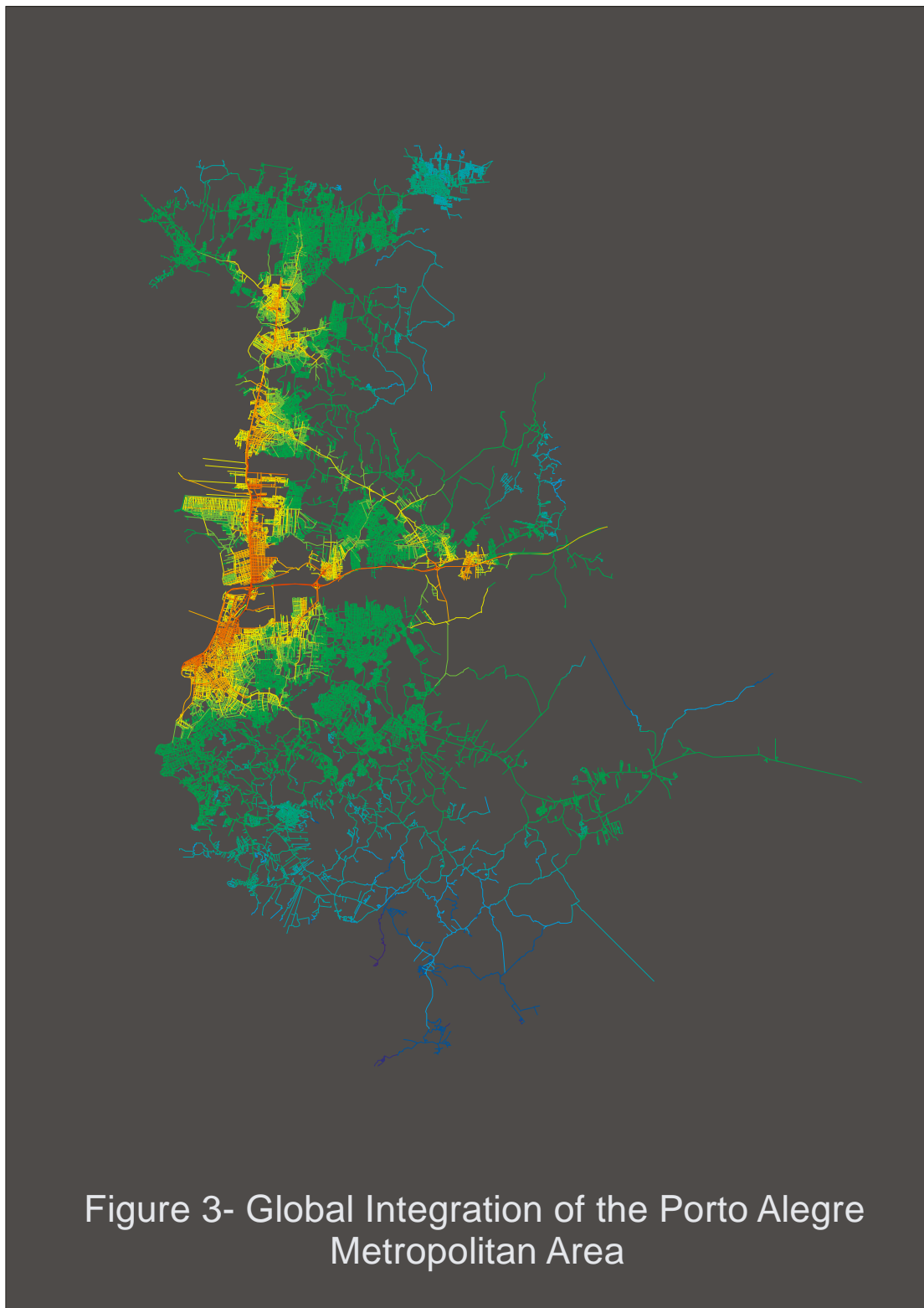
CI = 0.269306396

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Figure 3- Global Integration of the Porto Alegre Metropolitan Area

Figure 3

5.2 Case 2 – Esteio and Sapucaia do Sul

Esteio and Sapucaia do Sul is one example of the creation of high level of conurbation between two cities (figure 4b). The integration core of the grouped cities represents what is actually observed: a continuous city, a join centrality which is the base of the continuity in the distribution of shops and services in both cities. The urban fabrics of both cities are not only "glued" together but cross each other in a systematic way. These features produce a conurbation index CI = 1.0. This is the highest possible conurbation index between two cities where the mean global

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integration, intelligibility and synergy values of the grouped municipalities are higher than the mean of the parts and while the mean depth is reduced producing an urban layout that is shallower than the parts when seen separately.
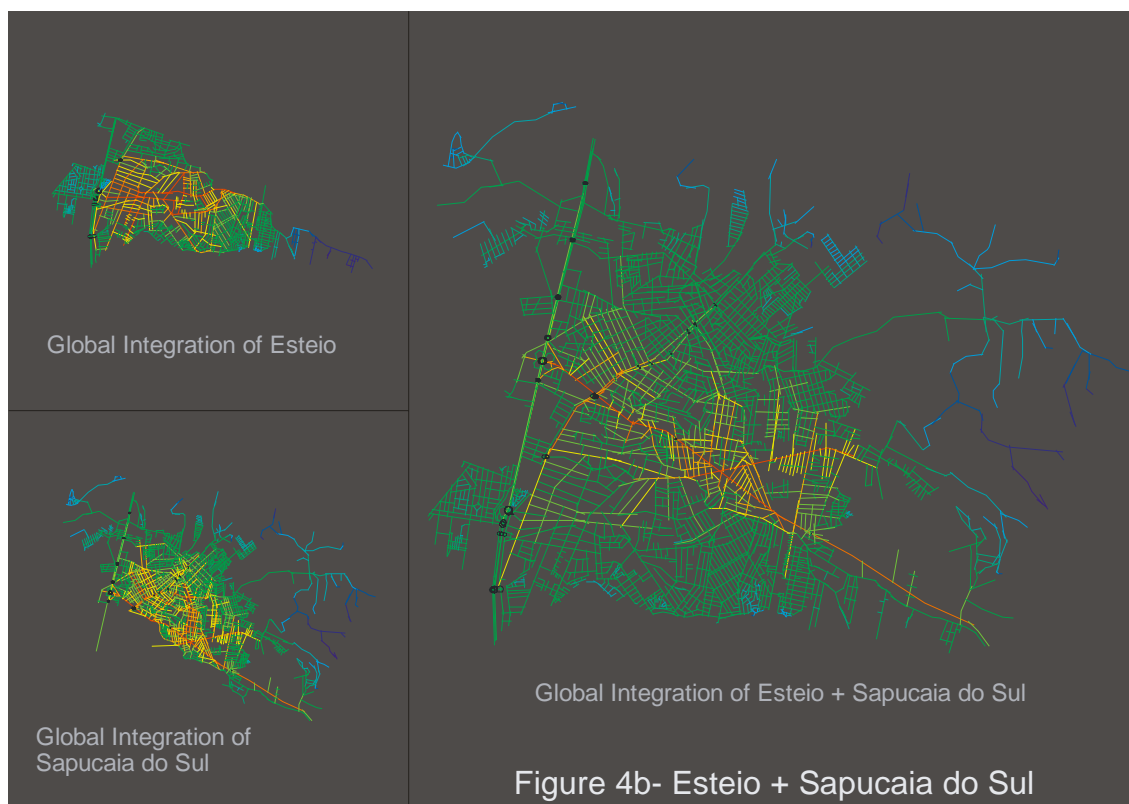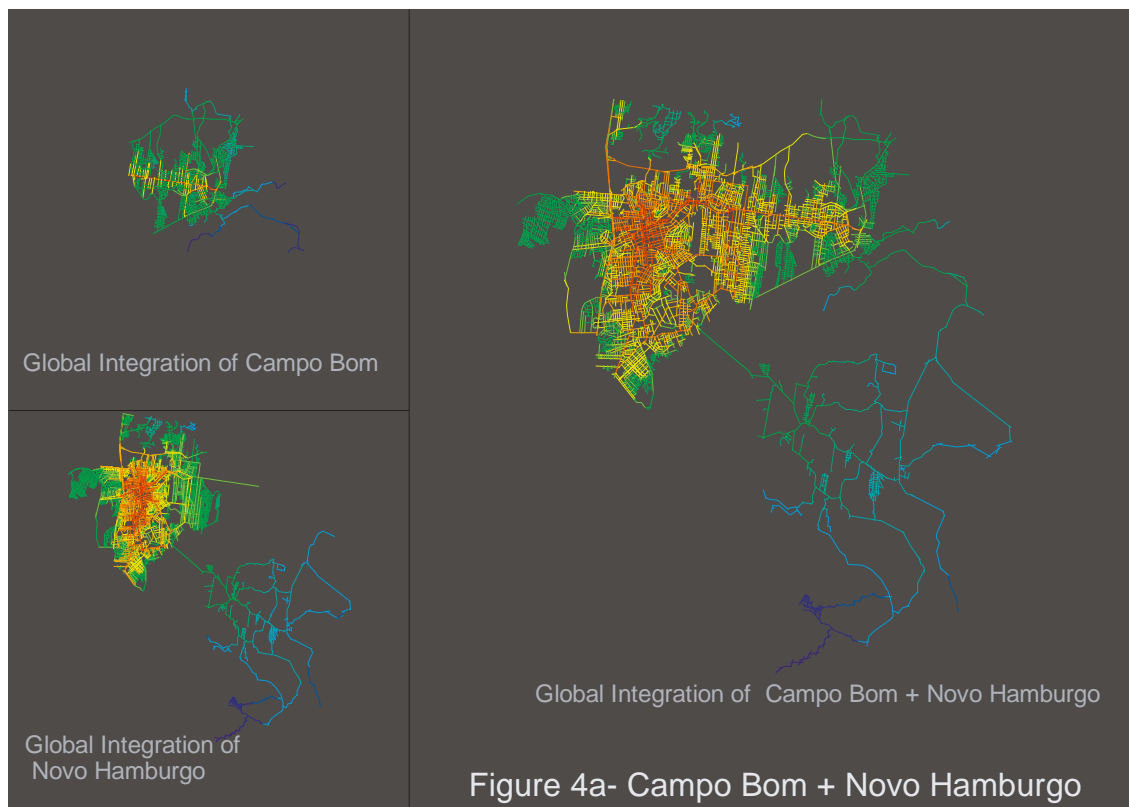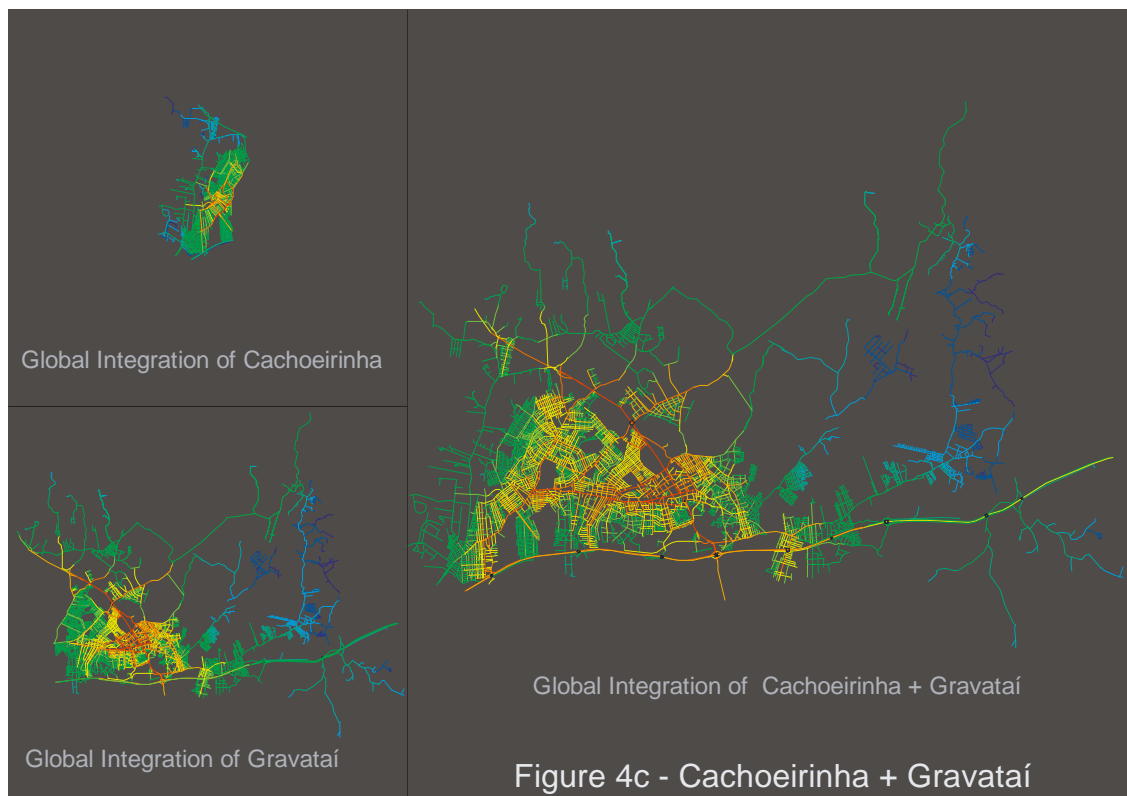

Global Integration of Campo Bom

Global Integration of Novo Hamburgo

Global Integration of Campo Bom + Novo Hamburgo

Figure 4a- Campo Bom + Novo Hamburgo

Global Integration of Esteio

Global Integration of Sapucaia do Sul

Global Integration of Esteio + Sapucaia do Sul

Figure 4b- Esteio + Sapucaia do Sul

Figure 4
(a) and *(b)* above; *(c)* on the next page.

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Global Integration of Cachoeirinha

Global Integration of Gravataí

Global Integration of Cachoeirinha + Gravataí

Figure 4c - Cachoeirinha + Gravataí

5.3 Case 3 – Cachoeirinha and Gravatai

Apart from the vacant land that we can observe in the city limits, the urban fabric resulted in grouping together Cachoeirinha and Gravatai seems very compact. The global integration of this system is highly biased by the state roads that run through both municipalities connecting them to the national road BR-290 in the south of this system and to the national road BR-116 in the northwest (figure 4c). The level of accessibility produced by these main roads, which can be observed also in the global integration of the entire PAMA (see figure 3), imprints an important global role to these two cities and is observed also when grouped together and when seen separately.

Even considering some differences between the systems when analyzed together or in parts, we can see that the distribution of the global integration of the grouped cities is very similar to that which is observed in each municipality. The apparently compactness of this system is not consistent with the syntactic measures. In fact, the mean depth of the joined cities is quite higher than de mean depth of the cities analyzed separately. This influences the reduction of the mean global integration value of the grouped cities when compared with the isolated municipalities. The conurbation index obtained for this group of cities is:

CI = 0.436157966

This figure seems mainly be influenced by the presence of a number of large vacant areas along the city limits, which represents at the same time a potential in terms of spatial conurbation in the future, and also by the kind of urban fabric juxtaposition as observed in the case 1 – Novo Hamburgo and Campo Bom, meaning that only a few axial lines of a municipality penetrate the layout of the other producing joined but interrupted urban grids. Both aspects are responsible for the lack of a deeper interaction between the urban layouts of the two cities.

6. Final remarks – what produces conurbation?

Even with a small number of cases presented in this paper, the analysis made of a broader number of cases allows us to make the following preliminary observations about the conurbation

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process in the Porto Alegre Metropolitan Area and, at a more theoretical level, when we can talk about conurbation as a general process concerning the relationship among different spatial systems.

6.1 Compactness

The compactness of the analyzed urban layouts seems to be a necessary condition for the conurbation but is not always sufficient. Two of the presented cases, Novo Hamburgo added to Campo Bom and Cachoeirinha added to Gravatai, present a compact urban fabric in the grouped cities but not a good result in terms of conurbation index took from the spatial structure of the joined municipalities and their syntactic measures as seen above. In both cases, the axial lines that lie along the city limits actually unite two different and unconnected urban fabrics that seldom present lines that cross the city limits and penetrate the neighboring municipalities.

6.2 Depth of the spatial system

When the grouping of two different urban layouts is able to reduce the mean depth of the resulted spatial system there is an improvement of the conurbation index once it directly interferes in the results of the global integration values. This aspect was tested for the group of cities of Cachoeirinha and Gravatai in two different ways: firstly, by removing from the spatial system of Gravatai the lines belonging to its rural area and considering only the more compact urban fabric (not necessarily with higher conurbation, like previously observed) (figure 5a). In doing so, part of the eastern part of Gravatai comprising the lines responsible for little ringness and for producing an important impact in the mean depth of the entire system was removed. This new urban layout produced a conurbation index of:
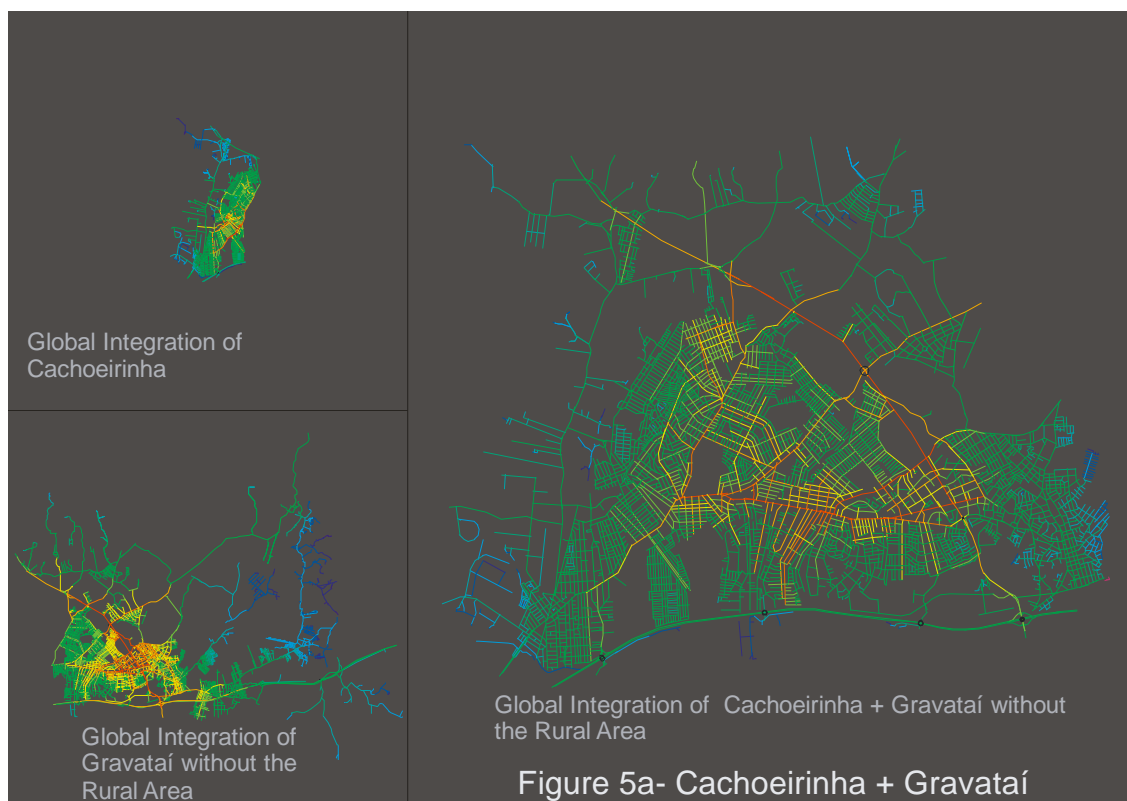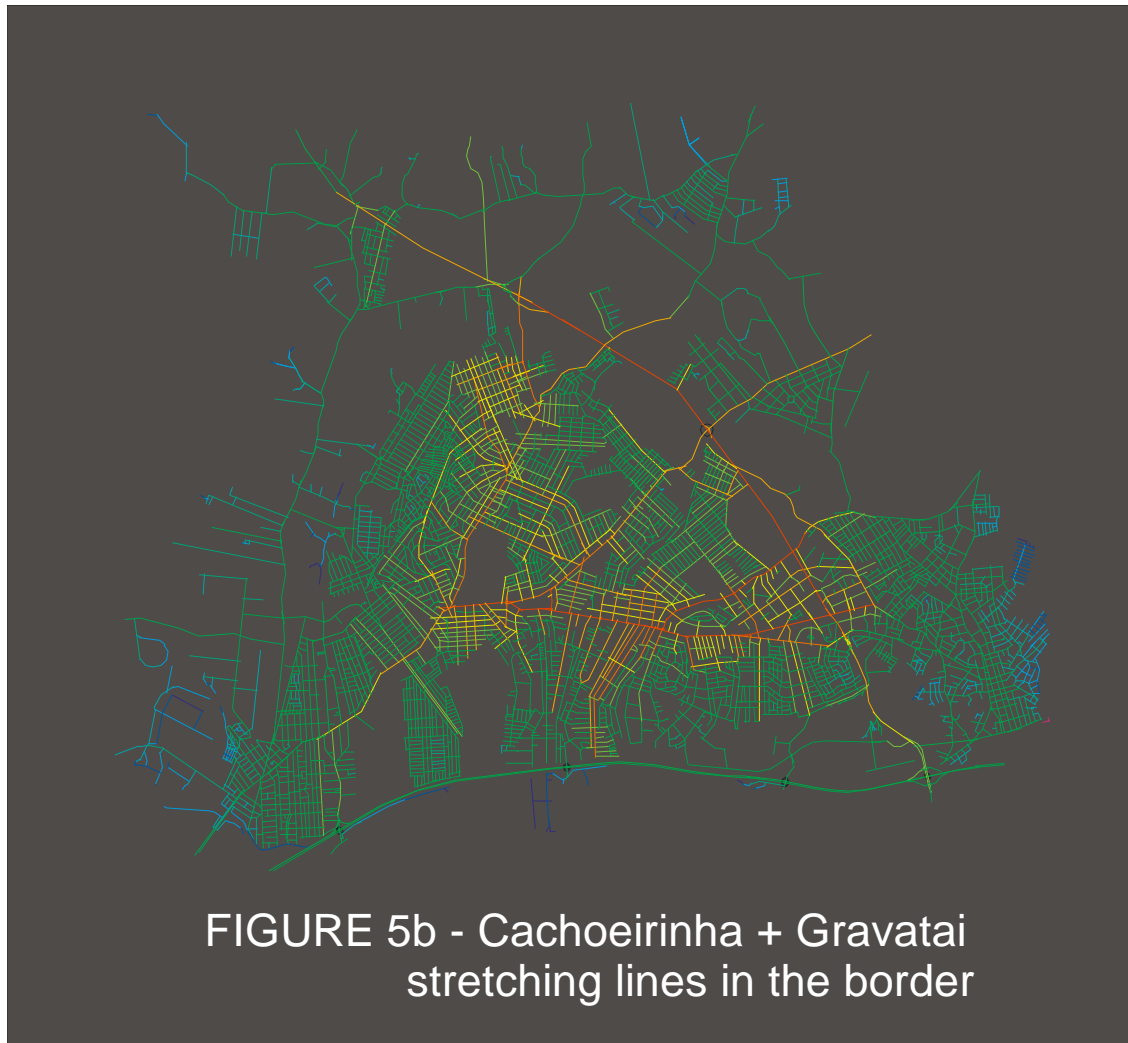
CI = 0.614399606.

Global Integration of Cachoeirinha

Global Integration of Gravataí without the Rural Area

Global Integration of Cachoeirinha + Gravataí without the Rural Area

Figure 5a- Cachoeirinha + Gravataí

Figure 5
(a) above and (b) on next page.

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FIGURE 5b - Cachoeirinha + Gravatai
stretching lines in the border

This figure is almost 50% higher than the conurbation index considered in the case study 3 as showed above.

The second test was made by taking the spatial system resulted from the test made before and, along the city limits, a number of a randomly chosen axial lines of every municipality were slightly extended into the each other neighbouring systems, without producing new urban fabrics. The conurbation index so obtained was:

CI = 0.696360669.

This index is significantly higher than that obtained in the description of the case study 3. Off course, this is only a theoretical exercise dealing with depth in urban systems but, it is strong enough to show the importance of spatial depth in producing conurbation.

6.3 The distribution of the integration

The case study number 2 – Esteio added to Sapucaia do Sul – which presents a conurbation index of 1 allows us to observe other features that seems to contribute to a high conurbation index, namely the spatial distribution of the global integration or, more specifically, the integration core of a group of cities. In case study 2, the integration core of the grouped cities tends to produce a centrality that both covers and contains the centralities of the parts (figure 6). In this case, even if the new centrality does not eliminate the centralities of the parts or the identities of every municipality, we can find proximity and continuity of the city centres within the centrality of the joined cities as an important aspect of the conurbation.

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The findings explained in this paper shall be much more elaborated and tested, including a larger sample of cases, grouping more than two different neighbouring municipalities, for instance, allowing to identifying common or different patterns of conurbation with similar or different outcomes. Nevertheless, what was possible to suggest from the study made in the municipalities of the Porto Alegre Metropolitan Area is a conurbation index, according to the way parts and wholes produce configurational features that can be measured and compared. This conurbation index can easily identify the impacts of actual or future urban expansions of neighbouring urban areas allowing to understanding how this process can lead to public policies that, instead of competing each other, could promote join efforts in order to solve urban problems that tend to be shared between the municipalities, specially taking into account that in Brazil there is no urban planning at the regional scale but only at the local scale.
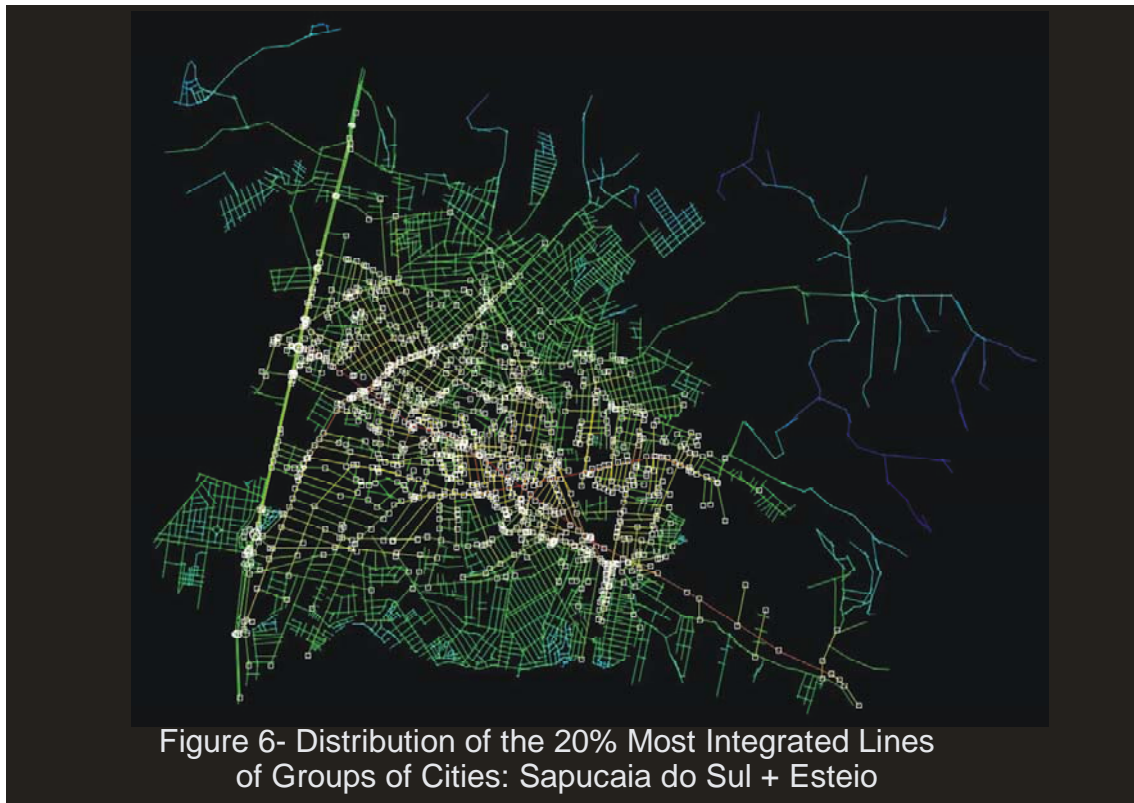

Figure 6- Distribution of the 20% Most Integrated Lines
of Groups of Cities: Sapucaia do Sul + Esteio

Figure 6

Another necessary observation for future studies is that it is necessary to include in the conurbation index the differences that can be observed in the limits of neighbouring cities that, even if we cannot say that some peculiarities cannot produce conurbation, they can make it more difficult to occur. This is particularly the case of municipalities that are separated by rivers, flooding areas, big regional parks or other restrictions to free evolving urban fabrics. The remarks made so far, even in a provisional way, have shown that the key aspects that contribute to a higher level of conurbation among cities are:

a) The compactness of the whole urban fabric;

b) The reduction of depth of the spatial system;

c) The distribution of the integration in the system.

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