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Urban form and socio-spatial segregation in Santa Catarina Brazilian Cities

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Abstract

Studying socio-spatial segregation is important to analyze internal and external urban processes, particularly in Brazilian and Latin American cities, where socioeconomic inequalities are acute and closely related to aspects of the urban form. Socio-spatial segregation is considered here as a process in which the urban form and more general spatial conditions restrict contacts between high-and low-income groups. We investigate socioeconomic urban segregation in three prominent cities in Santa Catarina State, namely Florianopolis, Joinville and Blumenau, each with distinct population sizes, urban growth stages and differ considerably in urban morphology. Based on geotechnologies and spatial analyses, we calculate local geo-segregation indices, as delineated by Feitosa et al (2007), based on classical measures of local quotient, dissimilarity, exposure and isolation. These spatial indices of urban segregation are able to analyze segregation patterns at urban form by the numeric dimensions of evenness/clustering and exposure/isolation (Reardon and O'Sullivan, 2004) and we discuss then critically from a morphological perspective as a way to contribute to theoretic formulations in Brazilian and other contexts characterized by geo-segregation, highlighting how and to what extent they are able to capture relevant aspects of the urban form, and, conversely, how the latter may be used to improve traditional zone-based indices. This work provides a better understanding of classic segregation indices and their differences and similarities, while discussing relevant contemporary issues on urban form and socio-spatial patterns emergence.

Keyword*: urban segregation; spatial segregation.*

Introduction

Socio-spatial segregation is a process and a result that arises from a symbiosis between specific spatial conditions and the restriction of contact between different social groups, and is a relevant theme in contexts of great socioeconomic inequality, spatial inequalities, and social conflicts (Villaça, 1998). This traditional pattern of socioeconomic center-periphery segregation in Brazilian and Latin American cities is superimposed on another one, in which high- and low-income populations coexist in the peripheric urban space, where spatial strategies for minimizing and restricting contact are maintained at the neighborhood scale (Caldeira, 2011; Sabatini, 2003, among others).

Studies on social-spatial segregation were developed throughout the 20th century, based on two distinct general conceptions in the fields of geography and sociology. Originally, indicators of segregation were developed from non-spatial approaches and global results (Bell, 1954; Duncan and Duncan, 1955), which are currently adapted to involve the spatial dimension and result in local indicators (Reardon and O'Sullivan, 2004; Feitosa et al, 2007).

In this study, we try to approximate the segregation studies to the study of urban form, applying a few traditional measures exploratorily to three cities in the south of Brazil, comparing their spatial behaviors and verifying to what extent they capture similar or distinct aspects of segregation. We also compared these results with the proximity to the center provided by the street network, an aspect that, despite its importance, is not considered by more traditional measures.

Background

Considering the several dimensions and aspects of segregation, a large number of indices was developed to measure it. Recently, Yao et al (2018) listed 37 indices, while Apparicio et al (2008) built the application Geo-Segregation Analyser, which measures 42 indices, 19 of which are measures for one group, 12 are measures to intergroup relations (2 groups), and 8 are measures to multigroup relations.

Massey and Denton (1988) systematized the set of indicators in five dimensions of segregation: (i) uneven distribution in space; (ii) lower exposure or higher isolation; (iii) concentration of a particular social group in smaller area units; (iv) clustering of a determined social group in specific regions or in adjacent areas; (v) position in relation to the urban center.

Reardon and O'Sullivan (2004) proposed a review of these five dimensions and argued that the social-spatial segregation can be best understood using two axes: Evenness / Clustering and Exposure / Isolation.

In this work, we measure the socio-spatial segregation from the two dimensions of Reardon & O'Sullivan (2004), analyzing both in their own right and in relation to a third one, the configurational distance to the main center. In order to measure the segregation in the Evenness/Clustering and Exposure/Isolation dimensions, we used local and global indices. Local indices of segregation are those whose results are specific to each location or zone, usually census tracts, thus allowing to differentiate areas more or less segregated at the intraurban scale. Global indices of segregation, on the other hand, refer to the whole city and, therefore, are useful to comparisons between cities.

The dimension of Evenness/Clustering assumes that the locations where the distribution of social groups in the space deviates from a situation of heterogeneity indicate higher segregation, because proportions of a social group higher than its proportion in the city as a whole would result in the concentration of said social group in one area and, thus, increase the distance between different social groups and approximate people from the same social group.

Social-spatial segregation is also understood by the probability of a particular social group to share, to be co-present, or to find itself in a particular area of interaction, with different groups (Exposure) or among members of the same social group (Isolation). Situations of residential Isolation occur when an area concentrates a considerable portion of a given social group, which is therefore isolated with other individuals of the same social group, while the segregation associated with low Exposure occurs when distinct social groups have the possibility of spatial interaction minimized by being in different parts of the city. The original measures of Exposure and Isolation were developed by Bell (1954), as global indicators that calculate the probability of a particular individual to find individuals of the same group (Isolation) or distinct groups (Exposure), originally considering just the potential for spatial interaction that occurs inside the areas of study, usually restricted to census tracts.

Nevertheless, these measures originally did not consider spatial properties such as adjacencies and distances between zones. Consequently, their results were, for the most part, global, i.e., they represented the situation of segregation of the whole city, neither making internal distinctions between zones nor capturing different internal configurations.

In view of that, by the end of the 20th century, a set of studies proposed adjustments so that the indicators incorporate geometrical and topological properties of the sectors (White 1983; Wong 1993; among others), while other group of studies adopted spatial analyses prior to the calculation of segregation indicators, interpolating the distribution of social groups in the urban space with a spatial proximity function (Reardon and O'Sullivan, 2004).

From this sort of spatial approach to the calculation of segregation (Wong, 2002; Reardon and O'Sullivan, 2004; Feitosa et al, 2007, among others), which seek to overcome the Modifiable Areal Unit Problem (Openshaw, 1983) and the limitations of aggregating data in census tracts, the indices that were originally global (even though there were local indices from the geometrical adaptations), are now mainly calculated at the local level, quantifying how each location is contributing to the composition of the global measurement. Therefore, they can be represented in maps and inform intraurban analyses, assisting in the detection of patterns and in the recognition of different distributions of higher and lower segregation of distinct social groups.

We also analysed the traditional segregation measures within the center and periphery continuum, considering that the urban centers of Brazilian cities as a points of attraction and socio-spatial disputes (Villaça, 1998), while peripheric areas, distant from the urban center, are usually neglected by the state and deprived of transportation and even the most basic infrastructure. However, over the past few decades there has been a tendency of high- and low-income group to coexist in the periphery, where gated communities (or "closed condominiums") have proliferated, with the concurrent use of private security resources, the removal of favelas/slums and the establishment of identity ghettos of minority groups (Caldeira, 2011).

Methodology and General Information

We analyzed socio-spatial segregation by the spatial indicators of Dissimilarity and Location Quotient, quantifying the uneven distribution of social groups, and by the spatial indices of Exposure and Isolation, taking into account the potential to spatial interaction due to the proximity between zones. Based on the mapping of the local indices, we analyzed spatial behaviors of the indicators, making some observations regarding the manifestations of segregation with respect to the urban form.

The analyses involved the cities of Joinville, Blumenau, and the conurbated area of Florianópolis (ACF), three of the highest GDP of the Santa Catarina State, which differ in population sizes, urbanized areas, and morphologies.

For the socioeconomic classification of the population in social groups, we adopted the per capita household income variable from the IBGE Census 2010 (*DomicilioRenda*), based on Brazilian studies on segregation (Zechin, 2014; Lisboa and Feitosa, 2016), IBGE classifications (Statistic Grid1), from IPEA (Social Vulnerability Index2) and from Brazil social programs3. We considered those households with per capita income of up to ½ monthly minimum wage (R$522.50 in 2021)4 as low-income; as high-income, those households with per capita income over 3 MW per month (R$3,135.00 in current figures). This classification resulted in percentages approaching 13%, for both the extracts of high- or low-income in the State of SC.

In this study, we adopted the set of spatial indicators to urban segregation delineated by Feitosa et al (2007), which pre-calculates the local population intensity, applying the kernel model of population data decay aggregated in the centroid. This abstracts the absolute population count in the respective sectors and considers the probabilistic intensity of incidence of a particular social group beyond its census tract and within a given radius (in our case, 600m), and is used as a steppingstone to calculate the spatial indicators of Dissimilarity, Exposure, and Isolation.

Indicators of socio-spatial segregation were calculated using the plugin Segreg/QGIS (Feitosa et al) and the software Geo-Segregation Analyser (Apparicio et al, 2008). Within the dimension of Evenness/Clustering, we calculated the indicators: percentage participation in the respective social groups (global and local); the Location Quotient (LQ) (local) and the Spatial Dissimilarity index (global and local). For the dimension of Exposure/Isolation, we calculated the spatial indices of exposure and isolation (global and local).

[1] https://www.ibge.gov.br/geociencias/atlas/tematicos/24684-atlas-digital-brasil-1-por-1
[2] http://ivs.ipea.gov.br/index.php/pt/
[3] https://www.caixa.gov.br/programas-sociais/bolsa-familia/paginas/default.aspx
[4] In 2010, the Minimum Wage in Brazil was equivalent to R$510.00; in 2020, it was R$1,045.00.

Table 1. Segregation indexes used in this study.

Index / variable	Description	Spatial unit	Reference
%Social Group	Percentage of each social group in the spatial unit.	Census tract City	
Location Quotient (LQ) - local	Proportion between the percentage of each social group in the census tract and its percentage in the whole city. Values above 1 indicate areas in which it is overrepresented.	Census tract	(Brown e Chung, 2006).
Dissimilarity Index - global	Proportion of people that should change place of residence so that every census tract has the same distribution of social groups as the city.	City	Duncan e Duncan (1955)
Generalized spatial dissimilarity	Measures the degree to which the composition of social groups in a census tract differs from the composition of the city as a whole.	Locality*	Feitosa et al. (2007), from Duncan e Duncan (1955)
Spatial proximity	A function that quantifies the hypothetical influence of the number of people from a social group in the census tract over its neighbors, up to 600m.		Feitosa et al. (2007)
Spatial Exposure index - global	Average proportion of members of a group in the localities (location) of a member of another group.	City	Feitosa et al. (2007), from Bell (1953)
Spatial Exposure index - local	The contribution of each area to the global Spatial Exposure Index.	Locality*	Feitosa et al. (2007)
Spatial Isolation index - global	Average proportion of members of a group in the localities (location) of each member of the same group.	City	Feitosa et al. (2007), from Bell (1953)
Spatial Isolation index - local	The contribution of each area to the global Spatial Isolation Index.	Locality*	Feitosa et al. (2007)

* A locality is the combination of the census tract and its neighbours up to a 600m radius. Local population intensities are the number of people in each locality, as measured by the number of people in the census tract plus the number of people in its neighbours weighted by the inverse of the distance.

Urban form analysis, distance from CBD.

In addition to observing the global indices, which compare situations among cities, we built thematic maps for the local indicators of segregation, applying numerical classifications and color scales.

In order to analyze the patterns and spatial manifestations of local indices of segregation with regard to the relation center versus periphery, a model of spatial differentiation was built, considering the distances to the central business district (CBD) by the street network. From the CBD, over the road network from Open Street Maps, we created irregular and concentric polygons with 3,000m intervals. For illustration and comparison purposes, we also displayed the circles formed by the Euclidean distances of the same radiuses.

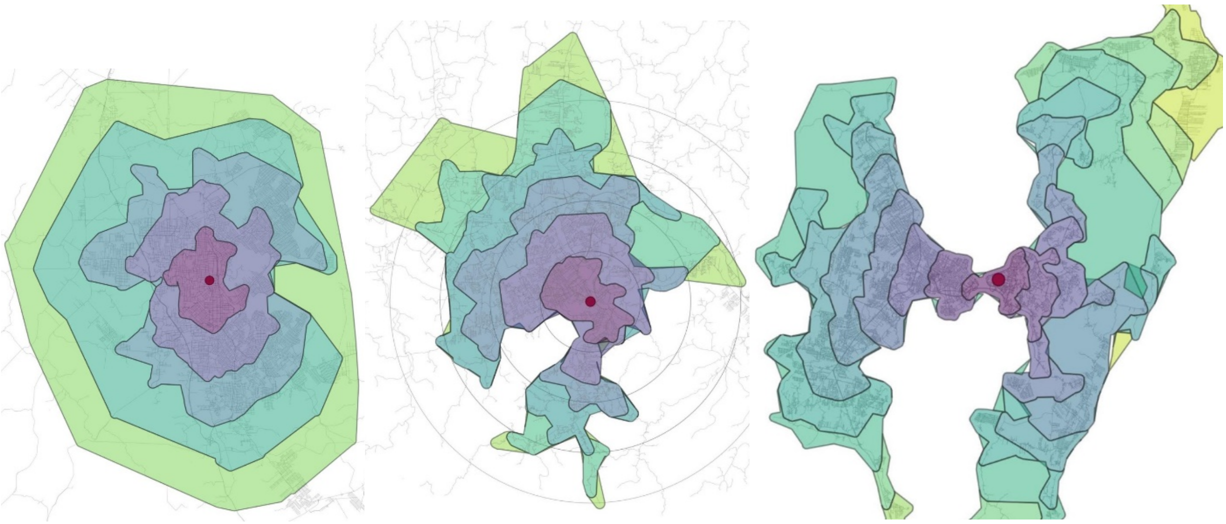

Figure 1. *Spatial differentiation of urban form, distances from CBD each 3,000m: Joinville, Blumenau and Florianopolis.*

For the analyses presented here, a simplified representation of this model of concentric differentiation was adopted, showing the isolines of the distances to the center of up to 3,000m (area 1), 6,000m (area 2), 12,000m (area 3), and up to 24,000m (area 4, which only applies to the AC Florianopolis) over the segregation indices' thematic maps.

Finally, we calculated aggregated indicators of the segregation indices (sum and percentage participation) synthesizing their quantitative incidence in areas 1 to 4.

Results: indexes, locations and form of urban segregation.

Evenness and Clustering

Figure 2 overlaps the sectors with LQ equal or greater than 1.0, in four classes by natural breaks, with high-income in a blue scale and low-income in a red scale. We can see a spatial pattern of uneven distribution, in the case of Joinville, with a predominant incidence of high-income households in the sectors of area 1 (central), of low-income households in area 3 (peripheric), with area 2 as a transition, in which sectors of high- and low-income dominance coexist. For the cities of Blumenau and Florianopolis, although there is a predominance of centralizing high-income groups and peripheralization of low-income groups, we see that the central area (area 1) is also shared with sectors of low-income dominance and that there are sectors of over-representation of high-income in peripheric areas in the cities (area 3) as well, configuring a situation of greater evenness between social groups, when compared to Joinville.

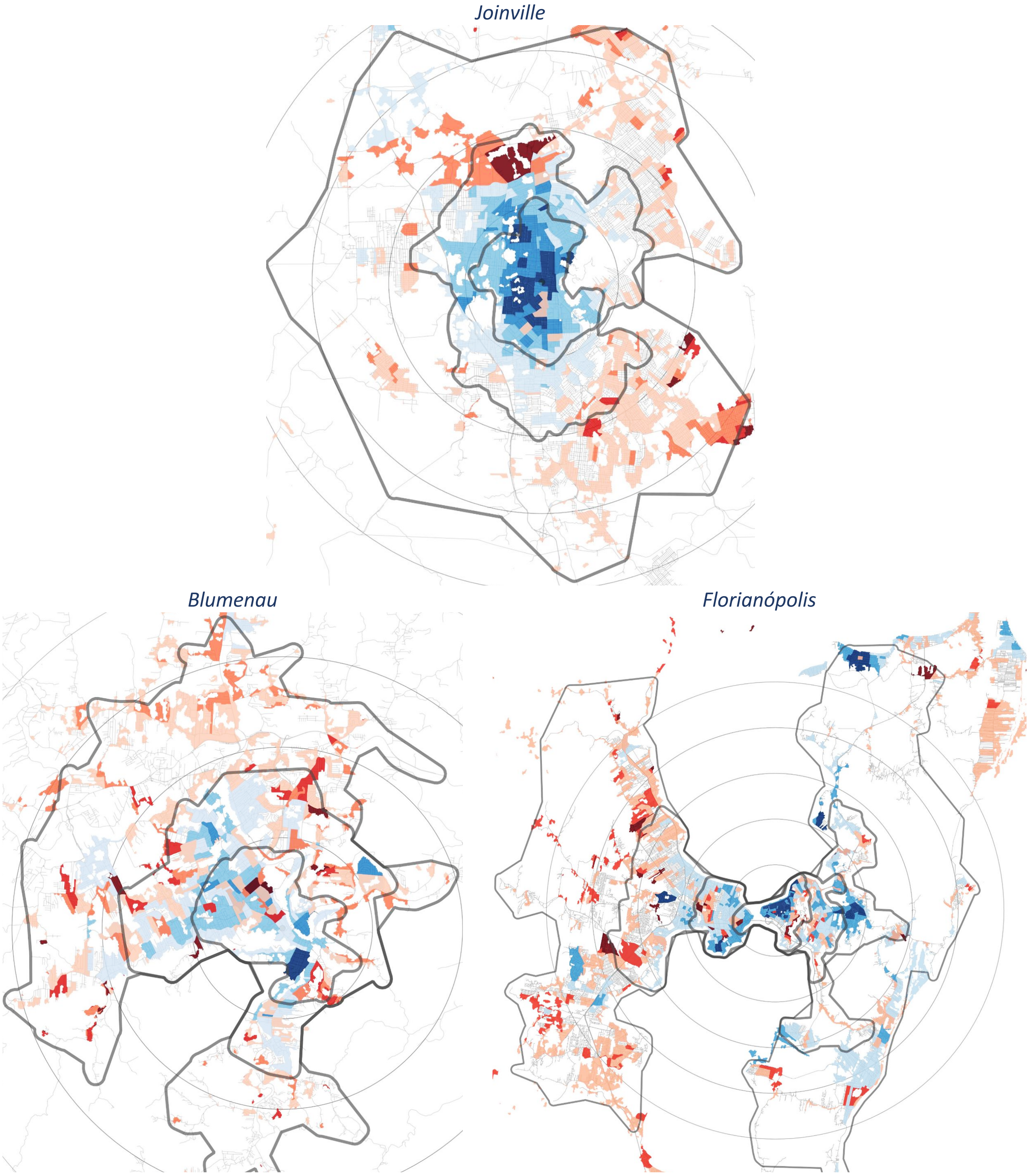

Figure 2. *Tracts with LQ over 1.0, in four classes, high-income (color blue) and low-income (color red).*

Considering only those sectors with LQ over 2.0, where there is an over-representation of the respective socioeconomic class of over two times the global percentage, the graphics presented in figure 3 calculate the quantitative of area with predominance of high- and low-income groups that fall on the respective areas 1, 2, 3 and 4. The color intensity in the bar charts represents the proximity to the center. In all urban areas studied there is an inversion of the predominance of occupation in the direction center-periphery, of the over-represented occupation of high-income in the central areas (dark blue) and the over-represented occupation of low-income in the peripheric areas (light red). In the case of ACF specifically, where the peripheralization of high-income is corroborated, there is the inversion of the sectors with predominance of high-income, which are more uniform between the areas 1 to 4, with higher proportion in the area 4, with distances over 12km in relation to the center.

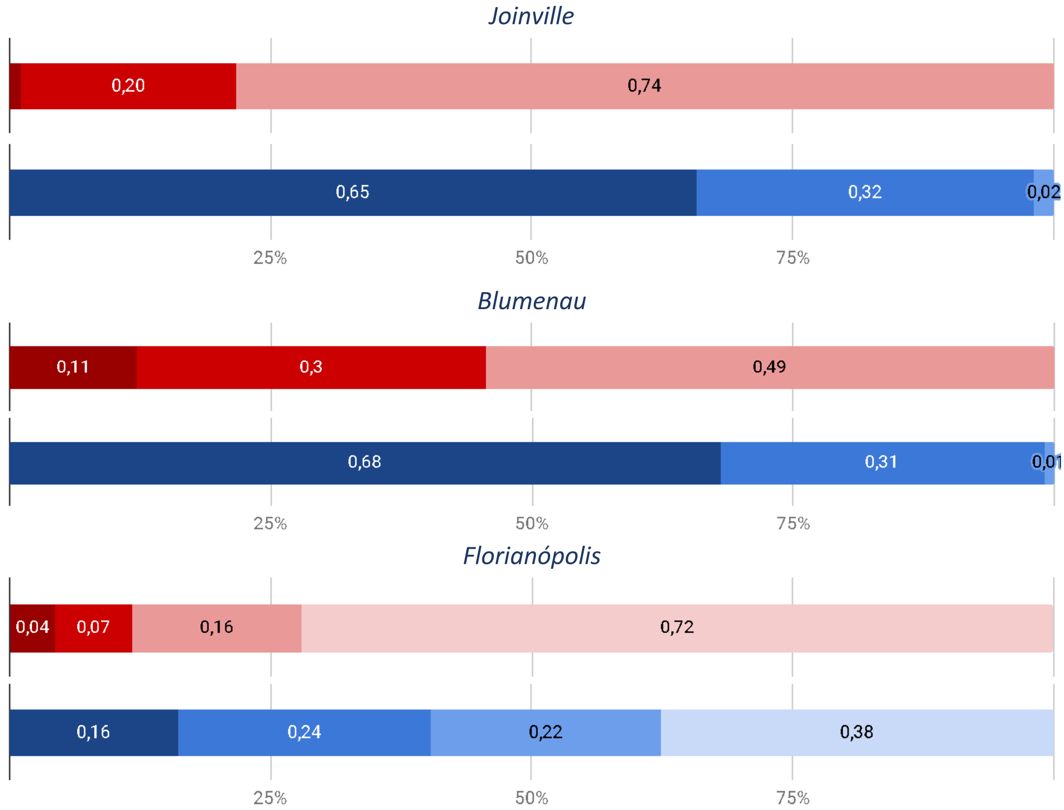

Figure 3. *Percentage incidence of LQ in each concentric area, where intense colors represent the center proximity.*

Regarding the global D index, the three urban areas present indices remarkably close to each other, varying between 0.29 and 0.33. This demonstrates that similar global indices may conceal greatly different intraurban spatial distributions.

In figure 4, in addition to the respective global D indices, we mapped the D indices for each location. In Joinville and Blumenau, there is a central clustering of the sectors with superior local D indices, while in ACF there is a greater dispersion of these sectors, including in area 4, with distances over 12,000 from the center.

Complementarily, the maps presented in the bottom line of figure 4 represent the sum of the local indices of dissimilarity which fall on the respective areas in relation to the proximity to the center. We can see a general pattern of decay from the center to the periphery (more intense purple in the center, area 1, and lighter shades in the periphery) for the three systems. Nevertheless, in the cities of Joinville and Florianopolis, this pattern of decay is interrupted by a semi-peripheric area, with higher incidence of the local indices of Dissimilarity in relation to the area immediately closer to the center, with relative distances to the center between 6,000m and 9,000m in Joinville, and 12,000 to 15,000 in Florianopolis. This analysis reinforces the idea that socio-spatial segregation, contemporarily, conforms to the traditional pattern center-periphery associated with peripheric segregation, in which some sectors distant from the urban center also present a tendency to homogenous distribution, occupied predominantly by a particular social group.

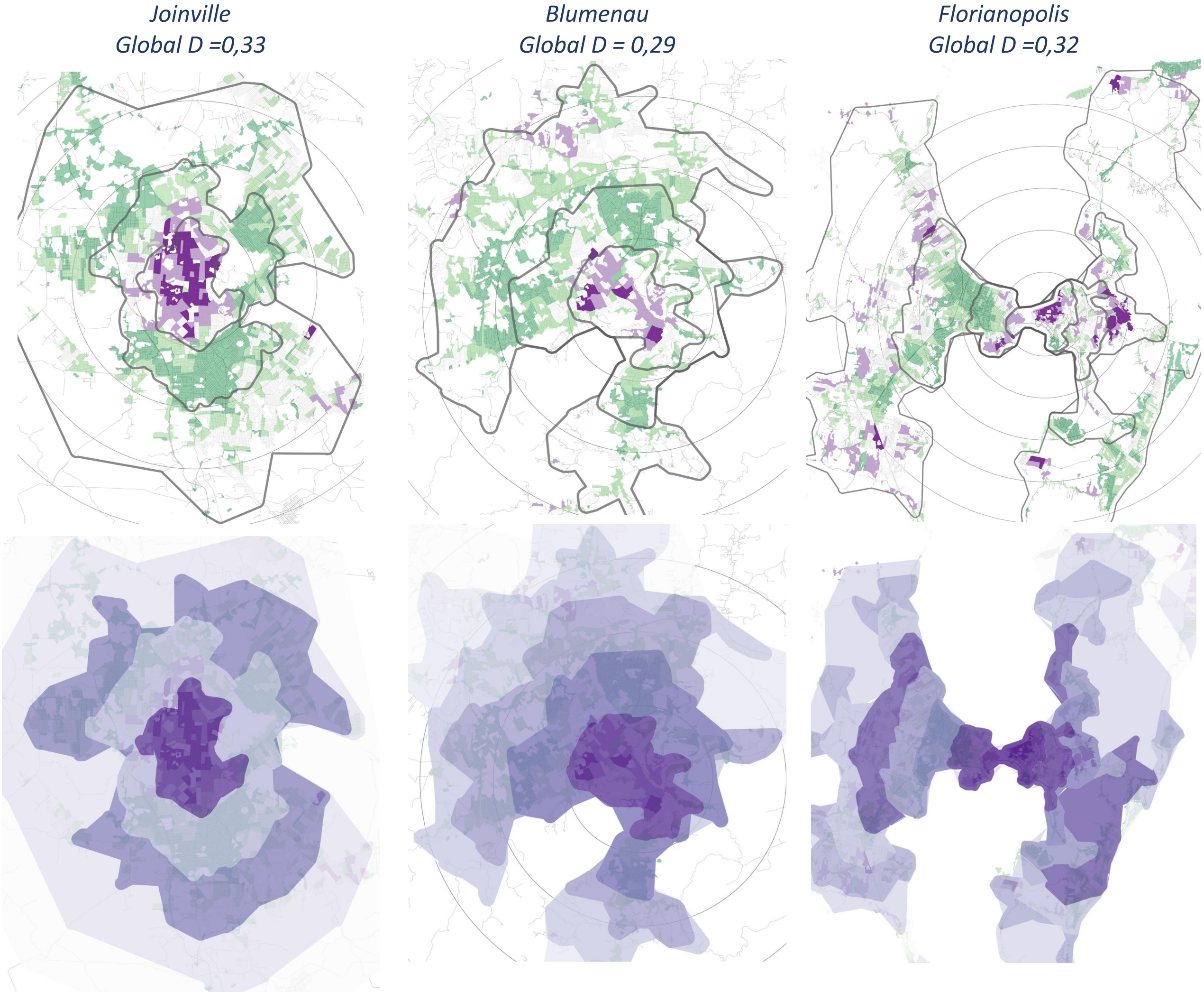

Figure 4. *Dissimilarity index, global, local and index sum in each concentric area.*

It is important to note that the D index, widely used to analyze the dimension of unevenness, has this limitation of not differentiating which social group is over- or under-represented, be it on a global or local scale, which, on the other hand, can be analyzed with the LQ index.

Exposure and isolation

In global indices, the probability of spatial interaction measured by the indicators of Exposure/Isolation, in general, observe a relatively regular pattern among the cities, as shown in figure 5. Lower values are found for spatial interaction with low-income groups (columns on the left, for the respective cities), with indicators varying between 0.13 to 0.05, when compared to indices of spatial interaction to the groups of high income (columns on the right), with a minimum value of 0.16 (Exposure of low-income to the high-income in the city of Blumenau).

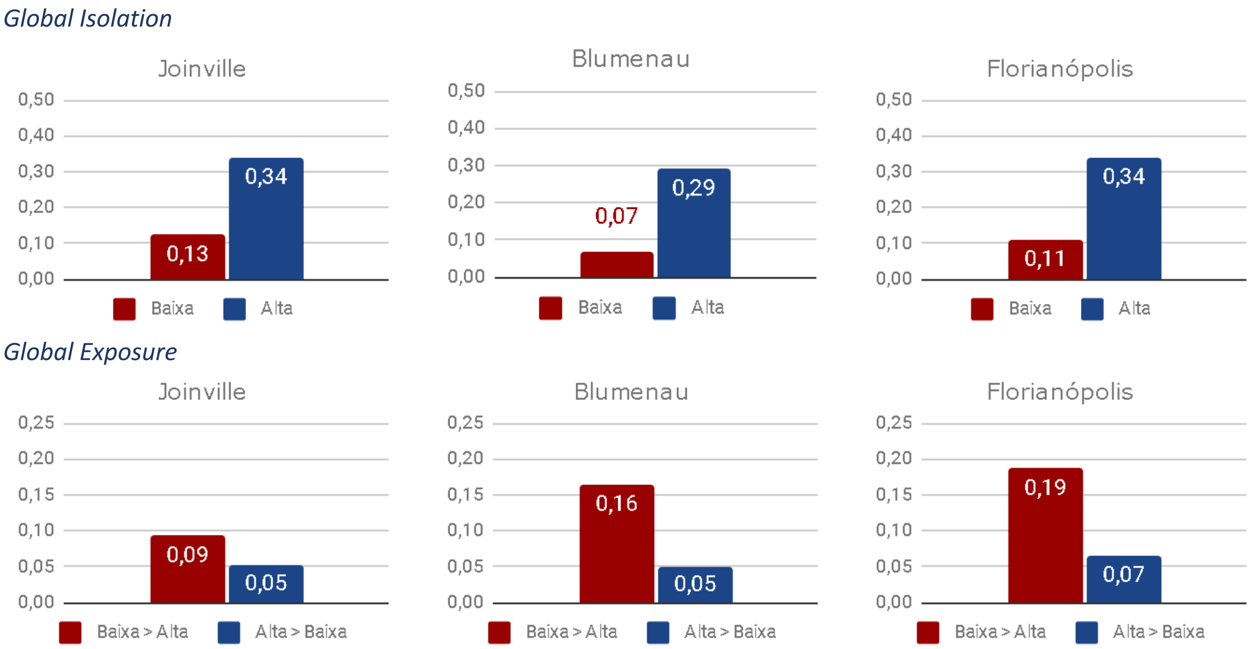

Figure 5. *Isolation and Exposure global indexes.*

Figure 6 shows indices of Isolation with high- and low-income overlapped and only the 80 and 90 percentiles represented, highlighting the sectors in which the respective socioeconomic groups are in a situation of greater Isolation. In the cities of Joinville and Blumenau, the isolation of high-income occurs concentrated in the central area, while the Isolation of low-income groups occurs in a dispersed and fragmented manner, with non-contiguous conformation in peripheric areas.

In the conurbated area of Florianópolis, even if the central pattern of high-income Isolated and peripheric Isolation of low-income groups remains, we also identify sectors of Isolation of high-income in peripheric areas, in the insular portion to the north in the beaches of *Jurerê Internacional* (A), to the south of *Campeche* (B), and in the insular portion, in the *Pedra Branca* allotment (C), as well as Isolated sectors of low-income occur, very close to the center, to the East, in *Morro da Cruz* (D), and to the continental West, in the *Monte Cristo* (E).

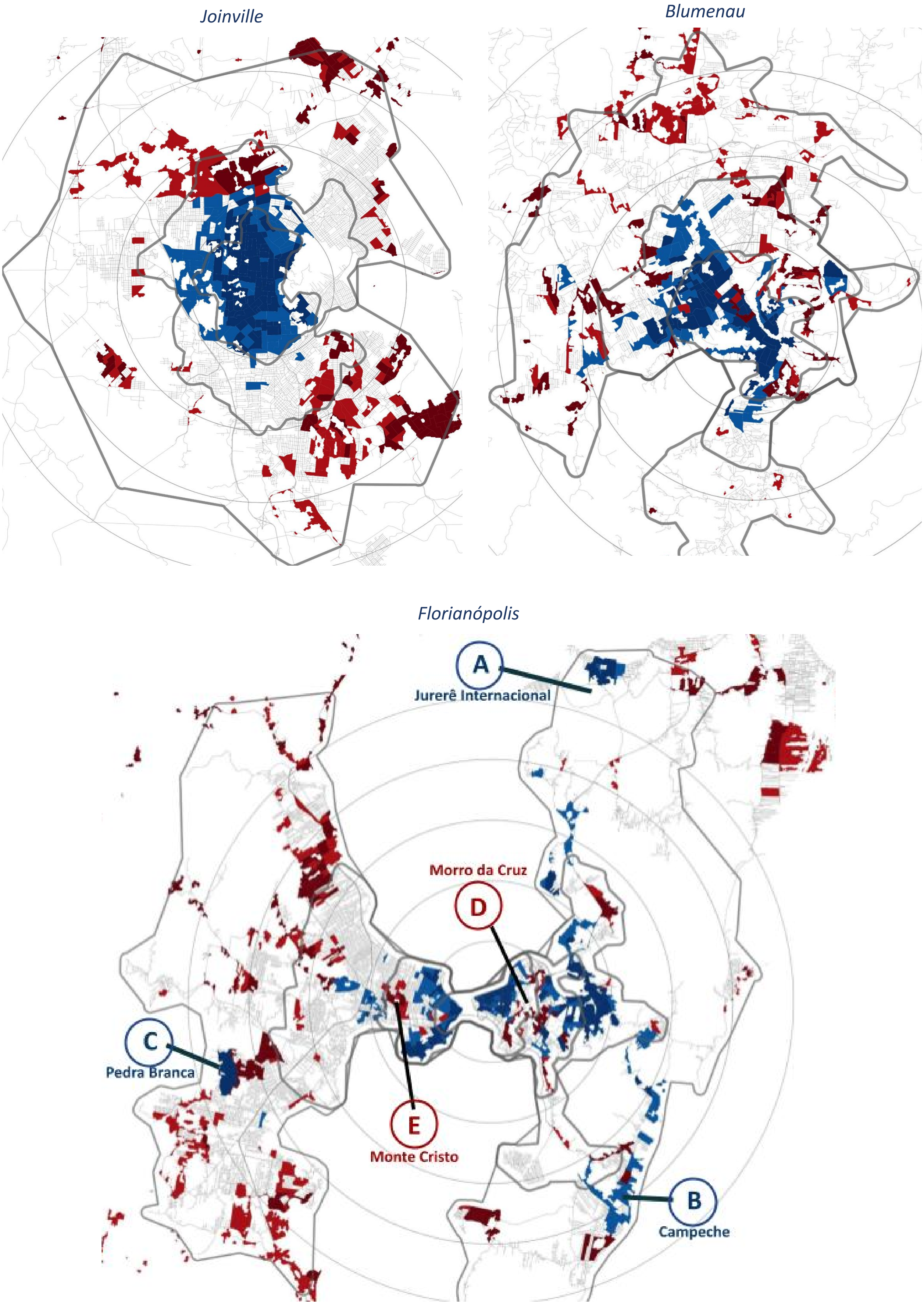

Figure 6. *Local isolation low- and high-income mapping, showing 80 and 90 percentiles.*

Conclusions

Socio-spatial segregation, analyzed from residential location and calculated by traditional indicators, must be comprehended as a process in which distinct social groups create or are subjected to certain spatial conditions that minimize intraurban presential contacts. Traditional studies of socio-spatial segregation, developed from sociologic and geographic emphasis, understand the segregation from the dimensions of Evenness/Clustering and Exposure/Isolation, considering aspects concerning the distribution of social groups in the urban space and to the probability of spatial interaction. The indicators of segregation, originally global, when observed from a local scale, in addition to involving the spatial dimension in the analysis, allow us to analyze the segregation from the intraurban spatial relations, considering relations between the locations and the relative position in the urban structure.

Regarding segregation indexes, it is crucial to use complementary measures to analyze and achieve a wider understanding of the process of segregation, specifically regarding the capacity to differentiate social groups in situations of segregation and the distinct dimensions of segregation itself. For the dimension of Evenness/Clustering, for example, the integrated analysis of the indicators D and LQ is important, allowing to quantify the intensity and qualify the representation of the social groups simultaneously. Regarding the dimension of Exposure/Isolation, developed from the probability of spatial interaction among social groups, we suggest that other models of spatial interaction should be explored, beyond the limits of interaction in the interior of census tracts or defined by the fixed interpolation radius (as applied in this work).

In this study, we observed socio-spatial segregation of high- and low-income groups, regarding the proximity to the urban center from the distances by the road network, allowing a more refined grasp of the dimensions and indicators of segregation, while approaching urban morphology studies. The results support the idea that socioeconomic segregation of Brazilian cities follow an original pattern center-periphery, associated with a contemporary trend of peripheric segregation, where sectors distant from the urban center present uneven distribution of high- and low-income groups.

We consider that such an approximation of segregation studies to the urban form may still be continued, involving different scales of analysis, other morphological features, and spatial units. Especially promising are advances in the relations of proximity and distance, used both for the calculus of spatial indicators of segregation and for the analysis of Euclidean distance in relation to the center of the road network, which may involve other dimensions, configurational and topological, relating the segregation to the dimensions of accessibility, integration or centrality, which distinguish the urban space, as well as related to the relative positions to the facilities, uses and activities which are essential for day to day use of the city but are unevenly distributed in the urban space.

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