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IDENTIFYING CENTERS AND SUBCENTERS IN THE METROPOLITAN REGION OF BELO HORIZONTE THROUGH GOOGLE PLACES OF INTEREST

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Eugênia Dória Viana Cerqueira [a*] - Alexandre Magno Alves Diniz [b]

(a) PhD in Urban Planning and Geography. Professor at the Federal University of Minas Gerais, Pampulha (MG), Brazil.
ORCID: https://orcid.org/0000-0003-0306-4766. **LATTES:** http://lattes.cnpq.br/1124794672450060.
(b) PhD in Geography. Professor at the Pontifical Catholic University of Minas Gerais, Belo Horizonte (MG), Brazil.
ORCID: https://orcid.org/0000-0002-5649-7736. **LATTES:** http://lattes.cnpq.br/7838089940725642.

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(*) CORRESPONDING AUTHOR
Address: UFMA. Av. Antônio Carlos, 6.627, CEP: 31270-901, Pampulha (MG), Brazil.
Phone: (+55 31) 99634-0275.
E-mail: eugeniadoria@gmail.com

Abstract

This research provides novel exploration of the distribution of urban facilities in the Metropolitan Region of Belo Horizonte, to identify primary and secondary centralities. The main findings are based on a Kernel Density, using Google Places of Interest data. Primary and secondary metropolitan centers are detected in the largest municipalities in the Metropolitan Area, as well as smaller suburban subcenters in peripheral municipalities. Moreover, the analysis of five categories of facilities illustrates different centralities structures and inequalities in the distribution of different types of activities.

Keywords: Urban Sprawl, Post-Suburbia, Centralities, POI Data.

Resumo / Résumé

IDENTIFICANDO CENTRALIDADES E SUBCENTRALIDADES NA REGIÃO METROPOLITANA DE BELO HORIZONTE ATRAVÉS DO GOOGLE PLACES OF INTEREST

A presente pesquisa propõe uma nova exploração da distribuição de oportunidades urbanas na Região Metropolitana de Belo Horizonte (RMBH), identificando centralidades urbanas primárias e secundárias. Os principais resultados baseiam-se em uma análise de densidade de Kernel a partir do uso do Google Places of Interest. Os resultados permitem identificar centralidades primárias e secundárias na RMBH, destacando o surgimento de centralidades em áreas periféricas que experimentaram uma importante evolução nas últimas décadas. Além disso, a análise de cinco categorias de equipamentos ilustra as diferentes estruturas de centralidades e desigualdades na distribuição de diferentes tipos de atividades.

Palavras-chave: Espraiamento Urbano, Post-Suburbia, Centralidades, Dados POI.

L'IDENTIFICATION DES CENTRALITES ET SOUS-CENTRALITES DANS LA REGION METROPOLITAINE DE BELO HORIZONTE A PARTIR DU GOOGLE PLACES OF INTEREST

Cette recherche propose une nouvelle exploration de la distribution des ressources urbaines dans la Région Métropolitaine de Belo Horizonte (RMBH), afin d'y identifier des centralités primaires et secondaires. Les principaux résultats sont basés sur une analyse de la densité de Kernel, à partir des données Google Places of Interest. Les résultats permettent d'identifier les centralités primaires et secondaires dans la RMBH et soulignent l'émergence de centralités secondaires dans des zones périphériques qui ont connues d'importantes évolutions ces dernières décennies. En outre, l'analyse de cinq catégories de ressources illustre différentes structures de centralités et des inégalités dans la répartition des différents types d'activités.

Mots-clés: Étalement Urbain, Post-Suburbia, Centralités, Données POI.

INTRODUCTION

Although urban research has long advocated for a dense and monocentric urban form, much of what counts as urbanization today is a matter of generalized suburbanization. The recent literature on post-suburbia (PHELPS; WU, 2011 ; PHELPS, 2018) emphasizes that over the past two decades, long-established peripheral models, such as the classical single-family subdivision, have been giving way to more complex, functionally differentiated, polycentric, socioeconomically mixed and multifunctional metropolitan structures (KEIL, 2013). Low-density areas all over the world have experienced a shift of the traditional suburban model, through the emergence of polycentric and multifunctional structures, new mobility trends, increased autonomy and social diversification. Post-suburbanisation includes a maturation process of classical suburbia, giving way to more complex and fragmented urban structures. Therefore, researchers presently advocate that the notion of suburban areas as mere appendices dependent on city centers has to be discarded, as the post suburbanization era entails the upsurge of multiple centralities (KEIL, 2018).

Although the development of post-suburbia has primarily been depicted in the Global North, an emerging body of research has also illustrated the development of post-suburban structures in the Global South (HEINRICHS et al., 2011; LUKAS; LÓPEZ-MORALES, 2018). Metropolises in developing countries have mimicked some of these broad processes, borrowing from their Global North counterparts the auto-centric model and the emphasis on privacy and exclusivity, under the form of vertical, gated enclaves, and mega-projects that combine residential complexes with shopping malls.

Using the Metropolitan Region of Belo Horizonte (MRBH) - Brazil as a case of study, we aim at assessing the existing centralities, outlining the identification of suburban subcenters. Belo Horizonte is notable as a typical Brazilian metropolis, presenting a socio-occupational structure that matches the overall national metropolitan system (ANDRADE; MENDONÇA; DINIZ, 2015). Mirroring processes taking place at the national scale, recent studies have illustrated some of the key transformations underway in the peripheral areas of the Metropolitan Region of Belo Horizonte, outlining the simultaneous process of consolidation of traditional low-income sectors, alongside the suburbanization of the upper classes. The expansion of the formal real estate market towards low-density areas has produced new diversified suburban structures, marked by the mushrooming of gated communities and the sprawl of commercial and leisure facilities. Sensitive to the various implications of such spatial rearrangement, the latest Metropolitan Masterplan (PDDI), published in 2011, highlights the development of new centralities within this ever-diverse periphery, where the upsurging subcenters can play a potentially key role counterbalancing the highly monocentric metropolitan structure.

We investigate the expansion of suburban subcenters in the MRBH using Google's Places of Interest (POI) data. The main findings are based on the exploration of contour maps generated from a Kernel Density Estimation analysis. Results highlight the identification of primary and secondary metropolitan centers in Belo Horizonte, Contagem and Betim, the largest municipalities in the Metropolitan Area, but also the upsurge of smaller subcenters in recently developed suburban areas. Moreover, the analysis of five categories of facilities illustrates different centralities structures and inequalities in the distribution of different types of activities.

The article is structured as follows. In Section 2, previous studies on the recent evolution of suburban areas are reviewed, focusing on the rise of post-suburban structures in the Global South. Section 3 presents the data and briefly describes the methods used. Results are presented in Section 4 and Section 5 provides a detailed discussion of the main findings, emphasizing the drawn lessons and the agenda for future studies.

URBAN SPRAWL AND POLYCENTRIC STRUCTURES

Although there is no widely accepted definition of the widely discussed concept of urban centrality (PEREIRA et al., 2014) it is commonly accepted that urban centrality is the characteristic of a place being central to its periphery. Urban centralities' defining characteristics are usually associated with symbolism, accessibility and the concentration of activities. It can also be synonymous with

attractiveness and be part of a continuous spatial-functional urban process (MIRANDA; SILVA; DA COSTA, 2020).

Over the past two decades, suburbanization, as we know, has given way to complex mixed metropolitan structures, which vary in scale, function and socioeconomic composition, counterpointing the well-established idea of the traditional single urban centrality. More recently, a growing research avenue has argued that we are entering a "post-suburban" era (KEIL; YOUNG 2011; PHELPS ; WU, 2011), characterized by the simultaneous processes of densification, complexification and diversification of the suburban model that has dominated over the second half of the 20th century. A particular aspect of post-suburbia is that it counterpoints the notion of urban peripheries as mere appendixes of the city center, as suburbanization now takes shape through manifold centralizations and decentralizations. Keil (2018) argues that much of contemporary peripheral development can no longer be directly associated with the center as the main element, but rather must be understood as a dynamic of its own. While density (or lack thereof) has been traditionally pointed to as a major criterion to identify suburban areas, in the post-suburban era it has become an insufficient indicator to define the urban periphery, as according to Lefebvre, the exploding periphery becomes the generator of multiple centralities (LEFEBVRE, 1970).

Manufactured polycentricity has been promoted as a planning strategy to counterbalance the dependency of the center, spreading from Paris' satellite cities (BERROIR et al., 2004) to the suburbs of Rio de Janeiro (HERZOG, 2015). The upsurging suburban subcenters are outlined as potentially autonomous structures that could reduce the dependency upon the city core, developing a complex system of travel patterns that are both local and metropolitan-ranged (BONNIN-OLIVEIRA 2012). In newly suburbanizing countries, suburban development takes the shape of heterogeneous constellations of urbanization, that counterpoint the traditional monocentric structure, particularly in Latin American countries. Over the past two decades, there have been shifts in urban sprawl and land use trends, with the arrival of upper-class populations in the suburbs and the expansion of the real estate market. Thus, in a post-suburban context, new residential high-income developments coexist with the traditionally disadvantaged peripheries, creating a real mosaic of diverse socio-spatial structures. Infrastructures that include high-rise apartments, single-family homes, gated communities and illegal settlements are now part of the emerging suburban fabric in the Global South, creating a landscape that combines elements of the globalized capitalism, such as airports and commercial centers, and informal forms of production (RUFINO, 2016 ; FEBRES, 2019 ; PÉREZ; PALMA, 2021).

THE IDENTIFICATION OF CENTERS AND SUBCENTERS IN BRAZILIAN CITIES

In the Brazilian context, although the monocentric urban pattern is still largely dominant, the emerging of new suburban structures over the past two decades has entailed the upsurge of local peripheral subcenters. The diffusion of satellite suburban megaprojects, such as Alphaville, in São Paulo, and Barra da Tijuca, in Rio de Janeiro, have yielded the implementation of commercial and leisure complexes that mimic the well-known edge cities model (HERZOG, 2015). While various studies have qualitatively described the emergence of polycentric structures in Brazilian cities (PESCATORI, 2017), fewer investigations have aimed at quantitatively identifying urban centralities and, more particularly, secondary subcenters in Brazilian cities.

Recent studies have identified urban centralities in Brazilian cities by using density estimations to measure the level of concentration of facilities over the urban space. Souza and Maraschin (2021) have evaluated retail centralities in Porto Alegre by combining Kernel Density Estimation and accessibility aspects such as street network. Likewise, Nadalin et al. (2018) used Kernel Density Estimation to compare the evolution of the population spatial distribution and job centralities in twelve Brazilian metropolitan regions, demonstrating the upsurge of secondary centralities outside the traditional Central Business Districts (CBD). On a similar note, Pereira et al. (2014) propose an index to quantify urban centralities by combining Kernel Density Estimation with Local Moran's Clusters, which allows the identification of hotspots of employment concentration and the creation of an urban centrality index.

Besides the measure of the concentration of facilities, some set of studies used spatial mobility as

a criterion to assess urban centralities in Brazil, as individual travel patterns could help identifying areas of interest. Lessa et al. (2020) combined data from household travel surveys and the spatial distribution of job opportunities to estimate territorial attractiveness in Belo Horizonte. The results suggest a strong and well-defined spatial pattern in the CBD of the municipality. Similarly, Mello (2019) used data from Rio de Janeiro's household travel survey to evaluate the metropolis' polycentrality.

In this paper, we choose to join the first set of studies, by working mainly with a density centrality measure. In the following section, we use the Metropolitan Region of Belo Horizonte (Brazil) as a case of study, focusing on the identification of primary and suburban centralities.

THE METROPOLITAN REGION OF BELO HORIZONTE AND ITS RECENT TRANSFORMATIONS

In Brazil, the heterogenization of the metropolitan space has produced disjunct urban fragments as the implosion/explosion process mirrors the socio-spatial inequalities that shape contemporary urban land markets (HERZOG, 2015; ALMEIDA et al., 2017). Scholars argued that, over the past two decades, the binary center-periphery model that marked urbanization in Brazil has given way to complex structures with the increasing dispersion of activities and the emergence of secondary subcenters in peripheral areas (LIMONAD; COSTA, 2015).

Belo Horizonte, the capital of the state of Minas Gerais, is notable as a typical Brazilian metropolis, presenting a socio-occupational structure that matches the overall national metropolitan system (ANDRADE; MENDONÇA; DINIZ, 2015). Like most Brazilian metropolises, the MRBH has been characterized by a rapid and uncontrolled process of urban sprawl that resulted in stark socio-spatial inequalities. Belo Horizonte's urban growth has followed a monocentric pattern, with an intense concentration of services and facilities in the central area. Conversely, peripheral areas have been characterized by the lack of urban infrastructure and local amenities, such as shops and health facilities. Over the past two decades, the suburban areas, traditionally depicted as the locus of urban irregularity, have experienced an increasing process of diversification, giving way to variegated land-use patterns, social mix, and complex economic activities. With a simultaneous process of consolidation of traditional low-income sectors, alongside the suburbanization of the upper classes, the expansion of the formal real estate market towards low-density areas has produced new diversified suburban structures, such as newly developed gated communities, commercial and leisure facilities. Thus, previous investigations have argued that the overlapping of suburban process in the MRBH contributes to a gradual reconfiguration of the traditional center-periphery pattern and to the upsurge of new suburban subcenters that compete with the historical dominance of the metropolitan core (COSTA ; MENDONÇA, 2015; ALMEIDA et al., 2015).

Previous investigations have demonstrated that municipalities located in the southern suburban areas of the MRBH, such as Nova Lima and Brumadinho, have experienced a series of socio-spatial transformations over the past two decades with the development of gated communities and the consequent arrival of high-income residents (MENDONÇA et al., 2019). The mushrooming of new residential developments has contributed to the gradual implementation of daily facilities, such as retail, leisure and health services. More recently, some gated developments have included non-residential facilities in their masterplan, contributing to increased but fragmented access to local services.

Likewise, over the past two decades, the northern suburban areas of the MRBH have received a series of investments in infrastructure by the government, which has contributed to significant changes in land-use in the surrounding neighborhoods. The implementation of the Administrative City, the International Airport, the Linha Verde[1] , associated with a series of private investments (especially regarding retail, as well as industrial activities related to the airport-industry project) have considerably altered local dynamics. In a short period, the referred investments have fueled the local real estate market, attracting a series of projects of high-income developments and considerably increasing land values in neighborhoods traditionally marked by low-income settlements. Simultaneously, the northern and eastern peripheral areas of the MRBH have also experienced an increase in the implementation of social housing programs and vertical condos (CAMPOS; DE MENDONÇA, 2013).

To support the plethora of processes happening in the urban peripheries, the development and

consolidation of suburban centralities was one of the main planning guidelines of the most recent Belo Horizonte's Integrated Development Masterplan (PDDI), published in 2011. The Metropolitan plan aimed at promoting a selective decentralization of urban activities and services, in order to counterpoint the monocentric and fragmented pattern that dominated Belo Horizonte's urban development. The proposed planning guidelines suggest the creation of a more compact and cohesive metropolitan fabric, through the development of areas of increased density and greater accessibility to urban amenities (TONNUCI et al, 2019). Thus, it seems capital to identify and comprehend the structure of primary centers and suburban subcenters in the MRBH.

DATA AND METHODS

THE COLLECTION OF POI DATA

The estimation of urban centralities requires detailed and precise cartography of urban services and facilities. The availability of these data varies massively from country to country. Some countries such as France, for example, provide highly updated georeferenced databases that survey all existing facilities in a given territory. In Brazil, the official RAIS data provided by the Ministry of Economy is the most frequently used database for mapping the location of services and the formal job market (PEREIRA et al., 2020 ; PINTO, 2020). Despite providing data disaggregated by economic sectors and occupational types, the RAIS database is exclusively available at the municipal level, failing to readily disclose information at more refined spatial units (NADALIN; FURTADO; RABETTI, 2018). Moreover, as the RAIS database is an administrative record fed by employers, it suffers from underreporting and geographically uneven coverage, as businesses located in peripheral areas tend to be underrepresented (Figure 1).

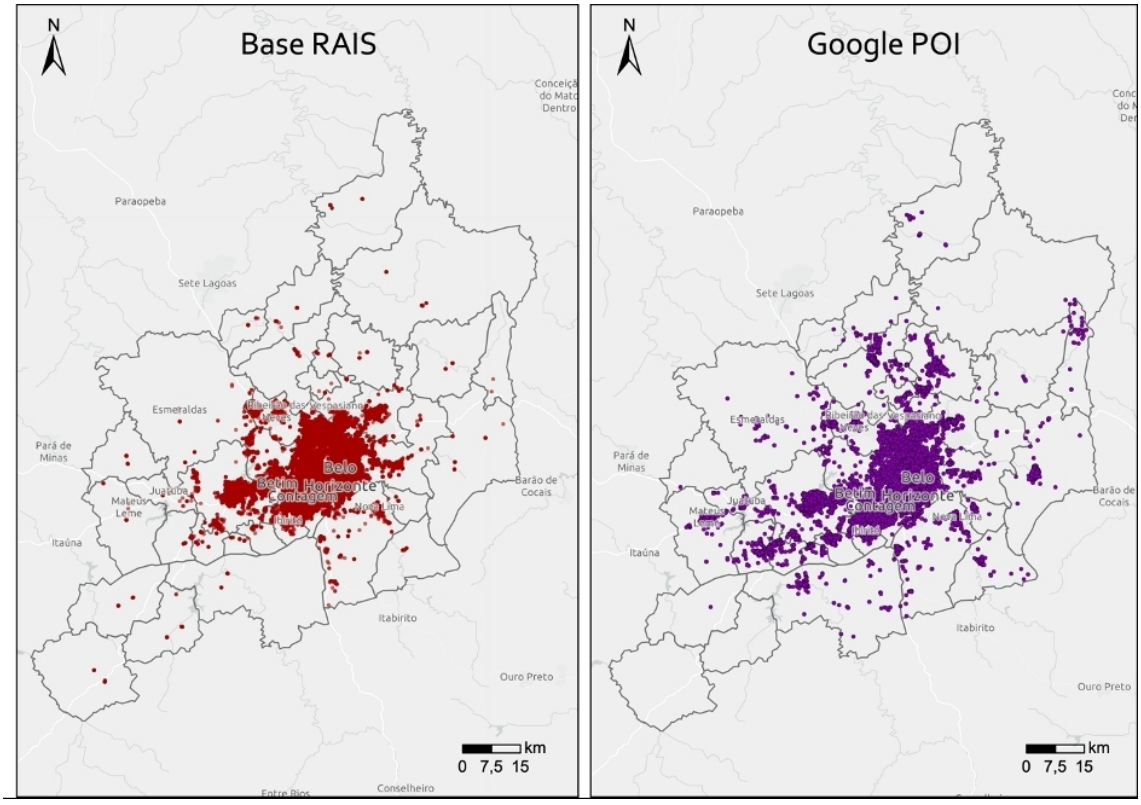

Figure 1- Comparison between the RAIS (2017) and Google POI (2020) databases

Thus, we investigate the upsurge of suburban subcenters in the MRBH using Google's POI (point of interest) data, which provides the georeferenced location of different types of services and facilities

such as bakeries, supermarkets, health facilities etc. With the rapid development of web-based information and the tools for its collection, large amounts of geographic data are becoming promptly available.

POI data are described as "point data on real geographical entities, with spatial and attribute information, high levels of precision, frequent updates, and large data volumes" (DENG et al., 2019, p.2). In recent years, such information has been vastly used in urban research to analyze the distribution of services and facilities, functional areas and urban centralities, as well as identifying spatiotemporal changes (LIN et al., 2018; WANG et al., 2018).

We obtained approximately 30.000 services and activities in the MRBH, with attributes that include POI´s name, type, coordinates, address, opening hours, postal code and description. The collection of data was conducted between October and December of 2020. Although Google's POI data cannot be considered as an open-source base, a significant amount of information can be extracted using Google Cloud Platform's limited trial, which allows its services to be used through a limited number of free credits.

Nonetheless, Google's POI data and its collection present some remarkable limitations. First, Google establishes a limit of 60 results per query, which complexifies the data collection process and may result in a loss of precision regarding the number of POIs detected. The query results' limitations also lead to a loss of automatization in the data collection process.

Compared to the RAIS database, one of the most remarkable disadvantages of Google's POI is that all entities are generally considered equally, while the former takes into account the size and weight of each service through information such as the number of employees, the number of students and patients (for educational and health facilities) and the volume of sales. Thus, investigations using the RAIS database can assign greater weight to larger facilities, such as schools and hospitals. Nonetheless, we argue that POI data can still offer valuable information on the spatial distribution of services while measuring urban centralities.

Although Google organizes POI data into 95 categories based on their business services, reclassified POIs into 35 secondary categories and 5 primary categories. The resulting reclassification process is depicted in Table 1.

Primary classification	**Secondary Classification**		
Commercial/Retail	• Bakery • Supermarket • Beauty salon • Clothing store • Pharmacy	• Butchery • Flower shop • Book store • Home goods store • Electronics store	• Mall • Market
Services	• Restaurant • Bar	• Post office • Bank/ATM • Veterinary care • Other services	• Public library • Gas station
Health	• Health centers • Health (primary attention)	• Laboratory • Health (secondary attention)	• Hospital • Health (tertiary attention)
Leisure	• Gym/ sports club	• Leisure Club • Church	• Stadium • Museum • Theater
Education	• Primary School	• Secondary School	• University

Table 1- Functional Classification of POI

THE IDENTIFICATION OF URBAN CENTERS AND SUBCENTERS

Although a number of different analytical methods can be used to identify urban centralities, the most traditional method is based on measuring the density of commercial activities and services. Thus, we propose a two-step approach for identifying urban centers and subcenters in the MRBH that involves: 1- the estimation of spatial distribution density; 2- the construction of a contour tree. This method has been applied in recent studies to identify urban centralities in different cities (DENG et al. , 2019 ; HAN; SONG, 2020).

CALCULATION OF SPATIAL DISTRIBUTION DENSITY-KERNEL DENSITY ESTIMATION

First, we use a Kernel Density Estimation (KDE) method to estimate the urban centers and subcenters in the MRBH. KDE is a non-parametric probabilistic method that performs a count of all points within a region of influence and considers their decay impact, weighting them by the distance to the location of interest. This method allows the transformation from a simple scatter plot into a smooth density surface output and it has been widely used in spatial analysis to detect the density of retail areas and services, facilities hotspots and urban centralities (YANG et al., 2019). A POI density map was generated from the KDE and POI data using the kernel function with a bandwidth value of 750 meters. In this study, we have tested different search radius ranging from 500 to 1,500 meters, to precisely assess the urban centers in the study area. We have found that setting the search radius to 500 meters or less generated many small POI aggregations areas that could not be identified as urban centers. Conversely, when the bandwidth was set to larger radiuses it overshadowed the smaller suburban subcenters.

GENERATING A CONTOUR TREE – OUTLINE AND STRUCTURE OF POI DISTRIBUTION DENSITY

Second, a contour tree was generated from the POI density map. The construction of the contour tree consists of two main processes: vector contour lines are generation, symbolizing the spatial distribution of POI density and identifying the topological relationship between adjacent contour trees (HAN; SONG, 2020). Within the scope of the spatial distribution of urban functions, a single concentric structure is the most essential constituent unit and can be featured by a local maximum value and a group of closed contour lines containing it. After converting a single concentric structure into a nested contour tree, the region contained in each contour tree represents a relatively concentrated area of POI distribution. However, there may be a polycentric structure in the distribution of various industries, manifested as a compound concentric structure formed by nesting multiple single concentric closed contours once or several times. For example, in Figure 2, the initial contour line is composed of 17 contour lines from a to l (Figure 5a), with two root nodes (b and g) and one composition function center (a), as shown in Figure 5b. In the simplified contour tree, five contour lines are used to represent the centers and subcenters (Figure 5c and 5d).

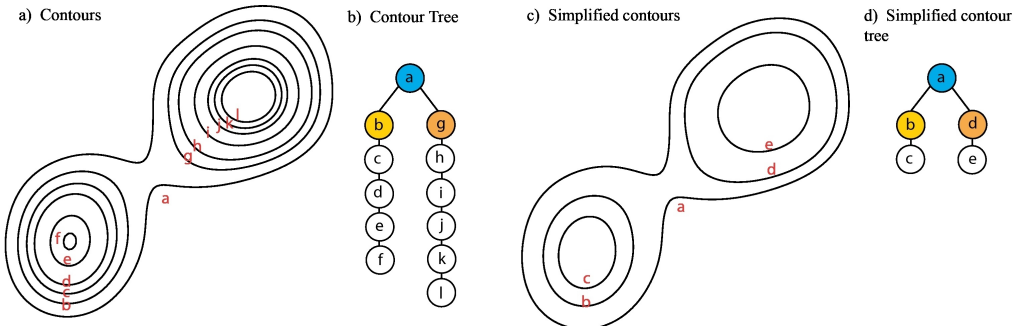

Figure 2- Simplification of the contour tree. Source: adapted from Han and Song (2020)

In this study, the contour levels were determined by a jenks classification method that allowed to create contour tree levels for each type of facility. The jenks method is a natural breaks data classification method, which uses an iterative algorithm that reduces the variance within the groups and maximizes the variance between the Different groups. The largest simplified contour tree had four levels and covered Belo Horizonte's central region. The remaining sub-trees displayed one to two levels on average and were located in the peripheral municipalities of the MRBH

RESULTS

CENTRALITIES IN MRBH

Figure 3 depicts the urban centers and subcenters identified in Belo Horizonte's metropolitan area. The color progression from red to blue represents the variation in POI density levels. Results show that the main center of Belo Horizonte is a composite area with high POI density, consisting of Belo Horizonte and the seats of the municipalities of Contagem and Betim. In the municipality of Belo Horizonte, a major center and three subcenters are detected. The largest metropolitan center is located in Belo Horizonte´s downtown region and contains a significantly higher density of POIs. The subcenters of Barreiro and Venda Nova, respectively in the north and southwest regions of the municipality of Belo Horizonte, are located in low-income peripheral neighborhoods. The third subcenter identified is situated in the Buritis/Belvedere area, which is composed of high-income neighborhoods that have rapidly developed over the past twenty years.

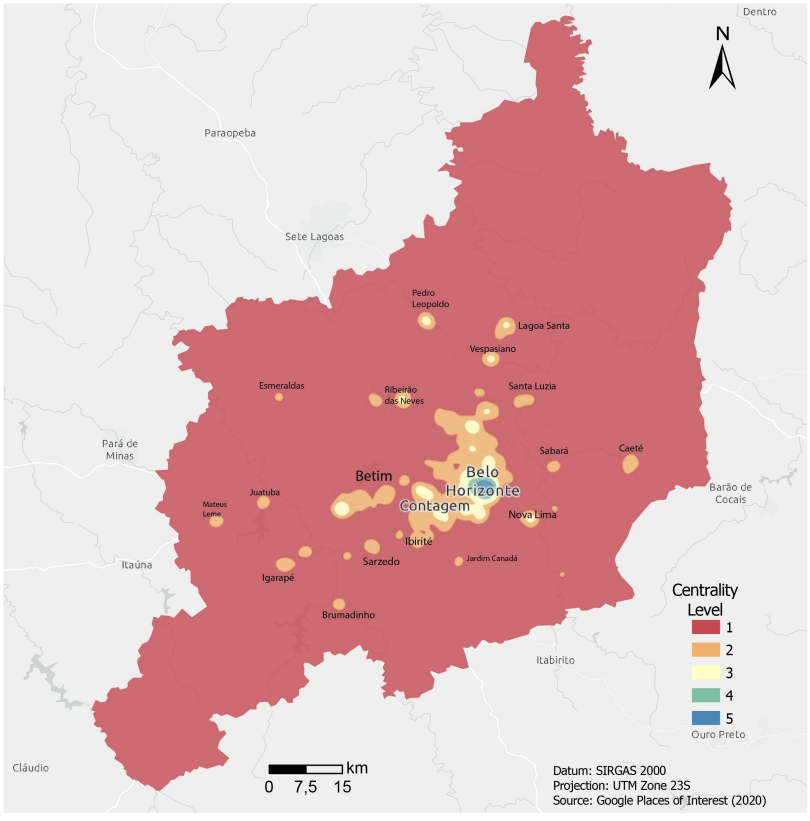

Figure 3-Centers and subcenters in the Metropolitan Region of Belo Horizonte in 2020

Likewise, the central areas of the municipalities of Contagem and Betim display a high POI concentration and appear as the largest centers of the metropolitan area, besides the main center of Belo Horizonte. The referred municipalities are part of the industrial belt, which contributed to the development of the Metropolitan Area in the second half of the 21st century. Thus, the monocentric dominance of the central area of Belo Horizonte is counterpointed by two peripheral centralities that

cover the western area of the metropolis.

Furthermore, we detected a series of subcenters located in the suburban municipalities that integrate the MRBH. These are mainly historical and smaller suburban centers that incorporate only one sub-tree level in the contour map. The centers located in Nova Lima, Ribeirão das Neves, Lagoa Santa and Pedro Leopoldo have higher POI density compared to the other suburban centers and incorporate two sub-tree levels. The centers identified are, nonetheless, very distinct. Nova Lima and Lagoa Santa, located, respectively, in the southern and northern areas of the metropolis, are characterized by the arrival of high-income residents in gated residential developments over the past few decades. Ribeirão das Neves is a consolidated low-income centrality that serves a population of over 340.000 inhabitants.

The contour map also outlines smaller suburban subcenters in the MRBH. It is the case of the Jardim Canada area, a low-income neighborhood situated in the municipality of Nova Lima. This low-income area, which surrounds various high-income gated residential neighborhoods, has experienced rapid development in the last decade, with the implementation of variegated services destined notably to the residents of the mushrooming gated communities (Figure 4). Although the referred changes are still embryonic, these results suggest that POI data allows the detection of very recent urban transformations that would not necessarily be detectable through traditional datasets.

Figure 4- Commercial complex in the Jardim Canadá neighborhood (left) and in Lagoa Santa (right).
Source: taken by the authors (2021)

We've also analyzed the distribution of amenities located in centers and subcenters with contour level 3 and above, which correspond to over half of the services available in the MRBH. The central area of Belo Horizonte holds over 60% of the POIs located in the main centralities identified in the MRBH, showing that the monocentric urban pattern still dominates in terms of spatial distribution of facilities. Nonetheless, denser peripheral centralities, such as the subcenters identified in Contagem, Betim, as well as the Barreiro and Venda Nova neighborhoods concentrate over 25% of the existing facilities in the MRBH. Conversely, results suggest that the composition of facilities tends to be similar in most centralities identified, without clearly specialized centers and subcenters. They are composed by a high proportion of retail and services, which usually correspond to over 60% of POIs identified in each centrality.

To further expand this analysis, we use locational quotient (LQ) measures, which are analytical statistics that measure a region's specialization relative to a larger geographic unit: the closer the LQ is to 1.0, the more means that the region and the larger geographic unit are equally specialized in a particular activity. In this case, the distribution of facilities in each centrality is compared to all centralities combined. The locational quotients measure demonstrate that higher levels of specialization (Table 2) tend to be observed in the municipalities closer to Belo Horizonte. For example, Betim displays a quotient of 1.81 for services, while Barreiro a quotient of 1.57 for retail. Nova Lima and Lagoa Santa have, respectively, locational quotients of 1.48 and 1.97 leisure activities, which can be directly associated with the rise of high-income gated residential developments over the past two decades.

	Barreiro	Betim	Belo Horizonte	Contagem	Lagoa Santa	Nova Lima	Pedro Leopoldo	Ribeirão das Neves	Venda Nova	Vespasiano	TOTAL
Retail	1.57	1.05	0.83	1.28	1.49	1.16	1.30	1.22	1.18	1.41	1.00
Education	1.33	0.84	1.00	0.90	1.37	1.22	1.93	1.03	0.46	0.16	1.00
Leisure	1.76	0.63	0.98	0.19	1.97	1.48	0.95	1.34	1.18	1.44	1.00
Services	0.81	1.81	0.94	0.90	1.04	1.19	1.12	1.16	0.88	1.17	1.00
Health	0.56	0.80	1.13	0.91	0.54	0.78	0.67	0.78	0.95	0.73	1.00
Total	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Table 2 - Locational quotients.

Following this analysis, in the succeeding section we propose to analyze the structure of centralities by type of services in the MRBH, as different type of facilities might follow diverse distribution logics in the metropolitan territory.

CENTRALITIES BY TYPE IN MRBH

The categorization of the POI data by type is used to identify functional centralities in the MRBH. The distribution of facilities in a city follows different patterns based on the type of activity and is determined by a plurality of private and public urban actors. Certain categories of facilities follow clustering patterns, while others are broadly distributed in the territory. These variegated arrangements can entail significant inequalities in accessibility to urban facilities, particularly in suburban areas. The strategies deployed to access a local service, such as a bakery or a post office, are not the same as those for accessing a large-scale facility, such as a hospital. Thus, the case is made for identifying centers and subcenters using the five primary categories proposed in section three.

Results suggest that several shopping/retail centers and subcenters are found in the MRBH (Figure 5). The central area of Belo Horizonte incorporates a large contour area of POI density levels four and five. Moreover, a series of smaller centers are found in Belo Horizonte, in the Barreiro, Venda, Belvedere and Vila da Serra neighborhoods. Findings also demonstrate that the distribution of services facilities follows the same patterns of retail and shops, creating similar areas of centrality.

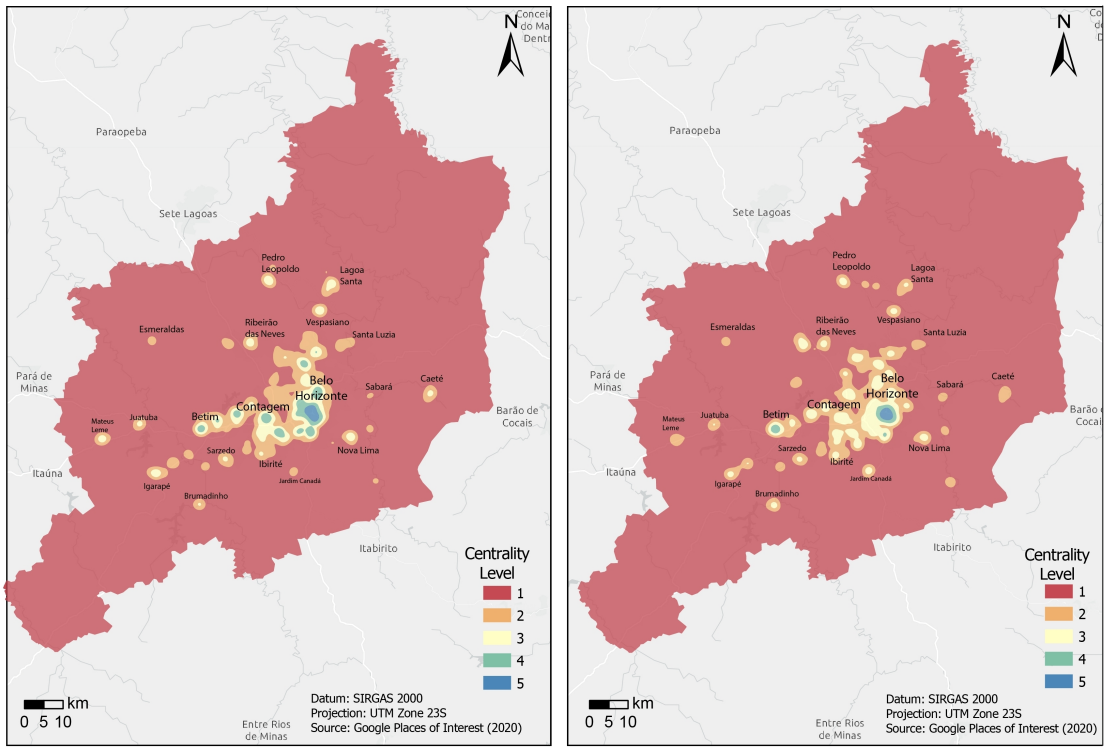

Figure 5- Retail and service centers and subcenters in the Metropolitan Region of Belo Horizonte in 2020

The distribution of health facilities is associated with a different distribution structure than most categories of amenities (Figure 6). Results show that health structures remain vastly concentrated in Belo Horizonte and Contagem and that smaller metropolitan centralities are identified in Betim and the neighborhoods of Venda Nova and Barreiro. The influence of Belo Horizonte spreads over the Vila da Serra neighborhood, in Nova Lima. Moreover, small sub-centers are found in the central areas of most peripheral municipalities, but those only include one sub-tree contour level. It is important to note that the influence area of each center is more limited regarding health facilities than the other categories of services analyzed, which indicates a dependency of the urban core.

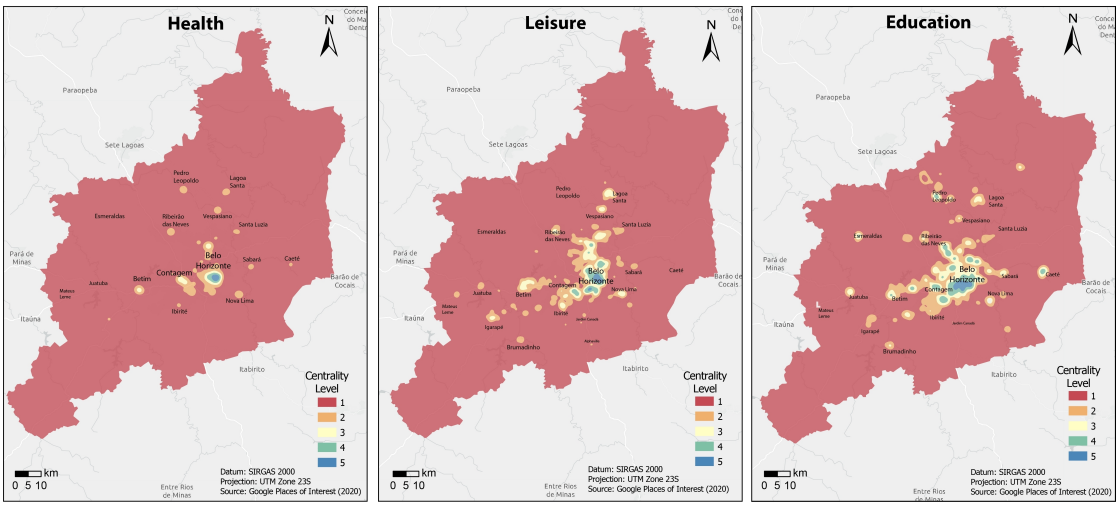

Figure 6- Health, leisure and education centers and subcenters in the Metropolitan Region of Belo Horizonte in 2020

Figure 6 also illustrates that leisure centralities are concentrated mainly in the central area of Belo Horizonte and its peripheral neighborhoods. The second-largest center includes high-income neighborhoods that have widely developed over the last two decades, such as the Buritis/Belvedere area, in Belo Horizonte, and the Vila da Serra and Vale do Sereno neighborhoods, in Nova Lima. It is important to note that smaller subcenters are found in Nova Lima and Brumadinho, surrounding gated neighborhoods, such as Alphaville and Morro do Chapéu and Casa Branca. Over the last decade, these areas have been equipped with leisure clubs and sports facilities, mainly destined to the high-income residents of the gated developments. Finally, the model demonstrates that a series of centers and subcenters of educational facilities are found in the MRBH. A large main center is located in central Belo Horizonte, surrounded by a series of smaller centers with high POI density levels. Moreover, most suburban subcenters exhibit three contour levels, contrasting with the other categories of facilities.

CONCLUSION

This paper brings an original contribution to the study of the ongoing suburban processes in the Global South. Using the Metropolitan Region of Belo Horizonte (Brazil) as an example, this paper presents a novel exploration of the distribution of urban facilities in the Metropolitan Region of Belo Horizonte, with the identification of urban centers and subcenters. Findings demonstrate that, although the monocentric pattern still dominates the spatial distribution of facilities in the Metropolitan Region of Belo Horizonte, the identification of secondary centralities suggest that it might be giving way to more complex and heterogeneous metropolitan structures (LIMONAD; COSTA, 2015). The spatial distribution of resources helps identifying peripheral centralities, particularly in the northwest-southwest axis of the metropolis, in the municipalities of Contagem and Betim. Moreover, smaller concentrations of POIs are also identified in Nova Lima, Brumadinho and Lagoa Santa. Although a temporal investigation would be mandatory to assess the upsurge and consolidation of secondary centers in the

MRBH, the POI analysis infers the existence of suburban subcenters, echoing previous investigations (TONUCCI FILHO; MEDEIROS DE FREITAS, 2019). A future research prospect would be to reevaluate the POI distribution in the MRBH in the next few years.

Moreover, one of the main contributions of this study is that it takes into account a larger range of facilities than most centralities studies, that usually focus on job or retail opportunities. Findings show, for instance, health facilities remain extremely concentrated in the central area of Belo Horizonte, while educational facilities are broadly distributed in the territory, creating a series of smaller centers and sub-centers. These results translate the logics behind how services are provided in Brazil. Public health care is organized hierarchically by SUS (Universal Health System) and divided in primary, secondary and tertiary care. This distribution pattern entails significant inequalities in access to health facilities, especially regarding complex care services, which tend to be concentrated in denser areas. Although previous studies have focused mainly on inequalities in access to health care at a regional level (RUIVO, 2012), the results exposed in this paper highlight inequalities also at a metropolitan scale. Conversely, public educational sector is structured with varying responsibilities: federal (tertiary education), state (secondary education) and municipal (primary education). Thus, primary education is provided by municipalities as a proximity service, which contributes to a more homogenous spatial distribution pattern.

The exploration of georreferenced POI data intends to fills the gaps observed in official databases, particularly in developing countries, where those databases are inexistent or not regularly updated. Moreover, with the use of Google's POI, a data source that covers most countries in the world, the methodology developed in this paper could be straightforwardly reproducible in other developing countries. The interpretation of the findings should, however, consider some key limitations, particularly regarding the database used and the uncertainty and incompleteness of POI data. First, it is important to note that the collection methods available for Google POI data are limited and might entail a loss of precision in the creation of large datasets. Moreover, as Deng et al. (2019) point out, all entities are generally considered equally in POI data analysis, but in reality, larger facilities such as schools and hospitals should be given greater weight.

The findings of this study are noteworthy for policymakers, as the monocentric structure that has shaped urban development of many Latin-American cities has entailed stark inequalities in access to daily facilities. The discussion also sheds light on the urge to investigate the full array of the transformations taking place in suburban areas over the past two decades and expand the research agenda on the emergence of post-suburban structures in the Global South. In view of the results found here, we emphasize that the growing diversification of suburban structures in the Global South needs to be taken into consideration in planning policy-making and in future investigations, which should also evaluate the effect of these emerging suburban centralities in accessibility to daily urban amenities and its inequalities to different groups of metropolitan residents (TONUCCI FILHO; MEDEIROS DE FREITAS, 2019).

NOTE

1- The Linha Verde is a road network project that aimed at improving the connection between the central area of Belo Horizonte and the north area of the MRBH.

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