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Visualising vacancy using electricity consumption data:
A study of the centre of Belo Horizonte, Brazil

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Being a dissertation submitted to the faculty of The Built Environment as part of the requirements for the award of the MSc Housing and City Planning at University College London:

I declare that this dissertation is entirely my own work and that ideas, data and images, as well as direct quotations, drawn from elsewhere are identified and referenced.

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List of Abbreviations

ANEEL: National Electric Energy Agency

CEMIG: Electricity Company of Minas Gerais

CMBH: Belo Horizonte City Hall

CSV: Comma-Separated Value

FJP: João Pinheiro Foundation

GIS: Geographic Information Systems

HUD: Department of Housing and Urban Development

IBGE: Brazilian Institute of Geography and Statistics

LAD: Location-Aware Devices

LBS: Location-Based Services

NPGAU: Postgraduate Programme in Architecture and Urbanism

NTL: Nighttime Light

PDDI-RMBH: Integrated Development Plan of Belo Horizonte and Metropolitan Region

PNAD: Annual Household Sample Survey

PRODABEL: Company of Informatics and Information of Belo Horizonte Municipality

RMBH: Belo Horizonte Metropolitan Region

UCL: University College London

UFMG: Federal University of Minas Gerais

USPS: United States Postal Service

Abstract

In Brazil, official data confirms that the residential vacancy is greater than the housing deficit. While the simultaneous existence of a built empty stock and families in need of housing has been widely criticised, very little is known about the vacant stock itself. The lack of information is precisely one of the main obstacles to facing this controversial scenario. This dissertation contributes to the scientific discussion on real estate vacancy by presenting a method to visualise the phenomenon in Belo Horizonte, Brazil, using geographic electricity consumption data, which discloses the location of utility poles, characterised by the number of connections at each pole and their billing status. First, the literature review discusses how the capitalist production of space generates a vacant built stock and then how the scientific community has worked with unconventional data sources to inform real estate vacancy. Next, the gathered data is analysed and, from that, Geographic Information Systems (GIS) support the construction of a geoprocessing model. This results in the visualisation of areas of interest where there is a high absolute density of possibly vacant properties. The method is first applied on the municipal scale, and the broader scenario of the city, as well as the method's limitations, are discussed. Then, the process is applied on a local scale, focusing on the Centre neighbourhood. After that, a preliminary test of its effectiveness is conducted through the direct sampling method; photos of the identified areas of interest are collected and analysed. Finally, conclusions are presented, also revealing how the developed method could serve as a tool for public authorities to monitor real estate vacancy.

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“Nas cidades, desordem é só a ordem que não é transparente.”

“*In cities, disorder is only the order that is not transparent.*”

Carlos Nelson Ferreira dos Santos

The centre of Belo Horizonte

Taken by the author (August 2019)

1. Introduction

The most recent study published by the João Pinheiro Foundation (FJP)[1], "Housing Deficit in Brazil 2015" (FJP, 2018), discloses the contradictory numbers which define the Brazilian housing crisis. According to the report, the housing deficit reached 6,355 million houses, while there are 6,893 million vacant housing units in condition to be occupied and 1,012 million under construction or renovation (FJP, 2018, p. 37 & 48). In a hypothetical situation, if all families in need of proper homes immediately occupied the existing built stock, there would still be a surplus of 583,000 residential units left unoccupied. This incoherent scenario is reproduced in Belo Horizonte and its Metropolitan Region (RMBH) and, in this case, 35,113 housing units would be left unoccupied (FJP, 2018, p. 38 & 48).

Undoubtedly, this conflicting scenario cannot be reduced to a simplistic correlation between indexes. Indeed, these indexes are a symptom of a socioeconomic system which is failing to supply a fundamental human right. In addition to revealing the simultaneity between abundance and poverty, this correlation also highlights the problematic of real estate vacancy. Even though this phenomenon is a protagonist in the construction of the contemporary urban space, it continues to be neglected by both government and national research institutions. The only official national data currently available quantifies the total number of vacant houses per census tract[2], and it is collected in vast field surveys conducted by the Brazilian Institute of Geography and Statistics (IBGE). From these results, the FJP's researchers classify vacant houses in one of three categories: "under construction or renovation, in condition to be occupied and in ruins" (FJP, 2018, p. 37). This means that variables which could further characterise vacant houses are not included in the IBGE's survey questionnaire. Thus, from official national data, it is currently impossible to know their address, physical condition, tenure or socioeconomic profile (FJP, 2018, p. 37). In addition, there is no official national data regarding the non-residential empty built stock. That is, there are not enough statistics to support the formulation of public policies which could contemplate the whole built vacant stock as an input to public policies on housing provision.

Therefore, this study embraces the challenge of scientifically analysing real estate vacancy. In summary, one major question guided this endeavour: how to locate real estate vacancy? This study utilises spatial data on electricity consumption in Belo Horizonte provided by the Electricity Company of Minas Gerais[3] (CEMIG). This data discloses the location of utility poles, characterized by the number of connections at each pole and their respective billing status in a specific month. From that, first, CEMIG's data is interpreted and, second, assisted by Geographic Information Systems (GIS), data is processed so real estate vacancy can be visualised in the territory. In short, the geoprocessing of electricity consumption data identifies areas of interest, i.e., spots in territory containing high absolute densities of possibly vacant properties. The process is first applied on the municipal scale, and results, as well as the method's limitations, are discussed.

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[1] The annual reports entitled "Housing Shortage in Brazil" are produced by the FJP based on data raised by the Brazilian Institute of Geography and Statistics (IBGE) through an extensive decennial household survey, the Demographic Census, and through a minor sample household survey, the Annual Household Sample Survey (PNAD). The most recently published housing shortage report (2018) refers to the estimate for 2015. Afterwards, key variables were taken out of the IBGE's research form, and the methodology developed by the FJP cannot be applied anymore. The discontinuity of this vital information made it impossible to evaluate trends since 2015. The 2020 Demographic Census presented a possibility to resume this analysis until, in June 2019, the IBGE disclosed the questionnaire form to be used in 2020. Among others, the question about the cost of urban rent was removed (Rossi, 2019). It is precisely the one that informs the component of the housing deficit which has gathered most attention for its growth: the excessive burden with urban rent (Viana, et al., 2019). As Aragão (2019) points out, "without data, there is no phenomenon".

[2] Urban census tracts typically contain around 300 houses (IBGE, s.d., p. 27).

[3] Belo Horizonte is the capital of Minas Gerais state.

Moreover, from municipal results, the Centre neighbourhood can be identified as the most vacant region of the city in absolute numbers; a fact that justifies its choice as the focus of the following local scale analysis. Then the process is applied to analyse the centre of Belo Horizonte. Finally, Google Earth supports the development of a direct sampling of images of highlighted areas of interest in this neighbourhood, which will assist in the evaluation of the effectiveness of the method.

In summary, this dissertation has two main contributions. The first is the development of a method to visualise real estate vacancy using electricity consumption data. The second is the development of a preliminary test of its effectiveness through an application of the method on a local scale, in the centre of Belo Horizonte, and a direct sampling of photos of the identified areas of interest. Nonetheless, let us first go through the Literature Review to cite the ones who came first and effectively contributed to this research process.

2. Literature Review

2.1. The mismatch between the housing deficit and the vacant built stock

The contemporary context of Brazilian cities is a direct consequence — or a product — of the country's social-economic capitalist formation. In this context, it is vital to clarify that the coexistence of contradictions is not a sign of dysfunction in this system; dualities are, in fact, inherent to the essence of capitalist production relations. As explained by Marx (1930) in "Capital", capitalism operates by generating a crisis mechanism, also maintaining its productive forces subjected to conflicting relations in which the distribution of profit from the labour force is uneven. Indeed, the author demonstrated that recession and unemployment are a result of how the system works, not an indication of failure. For those reasons, Marx believed that the logic in which the system functions would lead to its collapse.

Nevertheless, capitalism survived throughout the 20th century and, in conflict with this scenario, Henri Lefebvre (1976) sought to understand how this explorative ideology was able to be perpetuated. The philosopher argues that the system only survives because it is capable of organising elements of social practice in space, i.e., spatialise new social relations. That is to say that the multiple contradictions intrinsic to the capitalist production logic are reproduced in space. In this context, as discussed by Kapp et al. (2005, p. 37), it is worth noting that the production of housing is part of the production of ample space; thus, the production of housing is also subjugated to the same logic. This means that the simultaneous existence of a "housing deficit" and a vacant stock is not a coincidence, but clear evidence of the disproportionate distribution of wealth resulting from capitalist relations of production.

There is no "housing shortage" *stricto sensu*. Indeed, there is a socioeconomic mismatch between the empty built stock and families in need of housing. Peixoto (2011) discusses that in the context of capitalist housing production, one of the results of the continued market pursuit of capital accumulation is the production of a surplus of houses for the upper and middle classes, the ones who constitute a solvable demand. Since the construction industry produces durable goods, the residential market works through the artifice of innovation promotion, generating a permanent feeling of consumer dissatisfaction which motivates the purchase of a new — and more attractive — house. In that sense, the house left empty doesn't become available to a lower-income family, firstly, due to inaccessible prices and, secondly, because it may become an asset for the previous owner (Peixoto, 2011, pp. 105-108). Therefore, the author concludes that the existence of such a relevant built stock in Brazil is a consequence of the capitalist housing production.

Furthermore, it is also worth noting that real estate vacancy is a protagonist in another dialectic relation that, in this case, stands out among the most controversial contemporary trends of the structuring of urban space. On the one hand, Brazilian city centres are facing residential emptiness and degradation. On the other, the ongoing peripheralization process promotes low populational densities and pressures green areas (Monte-Mór, 2007, 2014). About this, Lefebvre (2003) explains that in the Fordist-Keynesian period, the city — or the city density — became associated with addictions, diseases and pollution, in addition to being associated with complete social segregation. The author argues that it is precisely the introduction of the industrial logic inside the city that drives its "explosion". Thus, those who can choose their place of residence abandon central areas in search of a new way of living. The so-called "New Urbanism" enters the scene, a concept aligned with the marketing strategy of new developments, which is still recurrent in the gated condominium market. About that, Soja (2000) explains that the phenomenon is an opportunist strategy to sell an urban utopia to a frightened middle class pursuing an idealised post-metropolitan life.

In Belo Horizonte, the emigration of the upper classes from the centre to the new frontiers of exploitation of the real estate market started in the 1970s and, as discussed by Lefebvre (2003), this movement fuelled the "explosion" of the city. Empty houses were left behind, triggering a cyclical process in which populational and, consequently, economic emptiness leads to degradation and vice versa (Pontes, 2006). On top of that, the central areas remain empty, while public housing provision delivers poor quality houses in the isolated peripheries, excluding households from the network of opportunities of the city. These days, the high vacancy rates observed in the Centre neighbourhood are empirical evidence of the underutilisation of the region's demographic densification potential. The city "explodes" (Lefebvre, 2003) and there is a "housing deficit", while empty and idle buildings can be found in the central areas and also throughout the whole territory of Belo Horizonte.

2.2. Identifying urban voids through unconventional data sources

Beltrame (2013, p. 115) explains that “urban voids” are residual spaces destitute of social content. Indeed, these spaces are discontinuities within the urban fabric, resulting from the capitalist process of construction and reconstruction of the city. Thus, inevitably, as previously discussed, they reproduce in space the contradictions inherent to this production system. The author argues that urban voids range from the inexistence of construction to non-occupation, under-utilisation and decay of spaces, whether they are plots of land or buildings.

In this context, it is also necessary to understand the concept of **real estate vacancy**. In short, as defined by Bomfim (2004), real estate vacancy is the relation between all empty built spaces and the total spaces of a specific area. Typically, the phenomenon is verified according to the use of the space. While residential vacancy is verified by units, commercial vacancy is usually verified by area. Nonetheless, the author highlights that the definition depends on the objective of the study and, in that sense, it is also vital to note that the same applies to the definition of a **vacant property**. For instance, for the IBGE, a vacant house is the one in which there was no resident on the date of the field verification (IBGE, 2010, p. 67). Nevertheless, for the Department of Housing and Urban Development (HUD) of the United States, a vacant address is the one that has not collected mail for at least 90 consecutive days (Molloy, 2016, p. 122).

The literature review revealed that research around the globe has appealed to unconventional data sources to give insights into urban voids, mainly to overcome the limitations of data raised in field surveys (Chen et al., 2015; Kumagai et al., 2016). To conduct field surveys, a considerable investment of capital, time and labour is necessary. On top of that, Kumagai et al. (2016, p. 709) call attention to the fact that the accuracy of field surveys depends on the definition of a vacant house, as owners often do not seem to consider a house to be vacant despite the empty status, for instance, when used as depositories or destined for future living. Furthermore, Longley et al. (2018, p. 9) note that there is no longer a guarantee of continuity of data gathered in national official field surveys, as fiscal constraint measures which are taking place in several countries are putting them at risk[4]. Hence, through the employment of available data, researchers also found more dynamic, economic and detailed methods of identifying and analysing urban voids.

Smith & Merrett (1987) were the first to test the hypothesis that rating records could be used to quantify residential vacancy in England, in fact, proving that this data source could seriously underestimate the problem. Nevertheless, they opened the path for Sedghi & Arnett (2014), who have utilised the same database to monitor vacant houses in the country. Besides, Molloy (2016), Newman et al. (2016) and Din (2017), supported by GIS, combined and processed data on the duration of vacancy gathered by the United States Postal Service (USPS) to visualise urban voids within the country. With this data, Molloy (2016) located

[4] See footnote 1.

neighbourhoods with high rates of long-term residential vacancy; Newman et al. (2016) built an inventory of vacant land and structural abandonment within the United States; and Din (2017) developed a tool to visualise residential vacancy by length in the city of Pittsburgh.

Remote sensing has been widely used to monitor urbanisation due to its capacity to gather information on land surface with consistent and wide coverage (Pan et al., 2020, p. 2), and researchers have also used this technology to analyse urban voids. Deng et al. (2009) utilised high spatial resolution multispectral aerial photographs and GIS datasets to identify, estimate and evaluate the social, economic and environmental impacts of residential vacancy in shrinking cities[5] of the United States. It is worth mentioning that, for this study, authors have interpreted residential vacancy as unoccupied or inhabited land, with or without an abandoned structure; therefore, not considering the vacancy length.

In recent years, nighttime light (NTL) remote sensing images, which detect artificial light, have been widely used to inform human occupation in space (Fan et al., 2014; Zhou et al., 2015; Xie & Weng, 2016; Zhang & Su, 2016). In this context, supported by GIS, Yao & Li (2011), Chen et al. (2015), Niu (2018) and Du et al. (2018) have combined NTL data to analyse vacancy rates at different working scales. On the one hand, Yao & Li (2011) and Chen et al. (2015) analysed the Chinese territory, i.e., worked with the provincial scale. The first ones utilised official data on the prices of residences, while the second ones combined NTL data with other land surface data. On the other hand, Du et al. (2018) worked at a fine scale: census tracts of Buffalo, in the United States. The authors combined NTL data, data on land use and official statistics on residential vacancy to analyse the influence of social environmental factors in residential vacancy. Other researchers (Ge et al., 2018; Ma et al., 2018; Zheng et al., 2017) extracted the perimeter of urbanised areas from NTL data and proposed a ghost city index to estimate urban voids.

According to Pan et al. (2020, p. 2), together with the emergence of Big Data arises the possibility of analysing the urban space at the microscopic scale. A massive quantity of data on individual trajectories, capable of informing socioeconomic patterns, becomes available as they are collected by location-aware devices (LAD) such as smartphones, and location-based services (LBS) such as social-media and navigation apps. In this context, Chi et al. (2015) utilised positioning data gathered by the app Baidu[6] to identify residential vacancy in China. It is worth mentioning that this study, which started from the provincial scale, also identified local areas of interest, working on a fine scale and presenting results never before seen for the Chinese territory. Apart from that, Jin et al. (2017) combined service data from one of the largest internet providers in China with points of interest and data on urban vitality to evaluate ghost cities. Finally, Konomi et al. (2018) have developed a method to infer the location of vacant homes based on Wi-Fi signals.

However, there are some limitations in the sources utilised in the previously mentioned studies. First, as Pan et al. (2020, p. 2) note, NTL images have coarse spatial resolution and, on top of that, the accuracy of these images in identifying residential areas is affected by the interference of urban lighting systems. Furthermore, as explained by the authors, data gathered by LAD and LBS are highly reliant on how and by whom they are used. In general, to overcome these limitations, as noted above, most researchers established indirect relations among the variables adopted in the investigation, and that could impact the accuracy of the obtained results. Nonetheless, new sources of big data become available on a daily basis and, in this context, Longley et al. (2018, p. 8) highlight that consumer data, which arise out of every-day transactions for goods

[5] According to Deng et al. (2009, p. 1), shrinking cities face populational emptiness due to ageing and migration.

[6] See the report "How Baidu Maps turns location data into 3-D cityscapes—and big profits", from Xiaowei Wang. Available at: https://archpaper.com/2019/05/baidu-maps-tech-print/ [Accessed June 2020].

and services, offer increasing effectiveness in providing a better understanding of society's behaviour patterns. In the spectrum of consumer data, the **municipal service and infrastructure data** — or utility data — informs the consumption of resources, such as electricity, water, telephones and broadband services, through the connection of each address with utility lines. Kumagai et al. (2016, p. 709) note that most connections are now monitored through digital sources. Pan et. al (2020, p. 2) add that this type of data is usually recorded over long periods, and among their main advantages are the excellent spatiotemporal resolution and the broad coverage of human activities.

Three studies which utilised municipal service and infrastructure data to analyse urban voids were identified. Kumagai et al. (2016) evaluated the efficiency of water hydrant data on estimating housing vacancies in the city of Neyagawa, in Japan, through combining it with other spatial data. Li et al. (2019) utilised data on the total annual electricity consumption per residence to estimate vacancy in rural areas in China. Finally, Pan et al. (2020) utilised municipal data on water consumption to identify and analyse residential vacancy in the city of Changshu, China. Apart from those, it is worth mentioning that Haramati & Hananel (2016) also associated the consumption of municipal service and infrastructure with vacancy. In this case, the authors first processed geographic data to identify areas with high residential vacancy rates and second, conducted a field verification to monitor the residential water meters.

In this context, it is necessary to mention that Moura & Magalhães (2011) utilised data from CEMIG on units with an **active billing status** to analyse anthropized areas at regional scale in the RMBH, and obtained results also served to inform residential vacancy in the same region. This study subsided the elaboration of the Integrated Development Plan of RMBH (PDDI-RMBH), which was discussed in depth by Peixoto (2011). However, data gathered for the current research differs from data previously utilised by Moura & Magalhães (2011) because it qualifies the billing status of all connections associated with poles. In other words, this means that, apart from connections with an active billing status, connections with an **inactive billing status** were also informed. At the present moment, other research which made use of utility data to analyse the phenomenon of real estate vacancy in Belo Horizonte or even in Brazil has not been found.

In summary, the prospection of methods to identify urban voids intends to bring to light that both the chosen working scale and the delimitation of the concept of vacant property vary according to the possibilities presented by the utilised data as well as the objective of the research. Thus, the first step is discussing data gathered from CEMIG, and that will be done in the next section.

3. Methodological approach, Study area and Data

3.1. Methodological approach

In the context of urban voids, while vacant plots of land are easily recognised as gaps in the landscape, vacant properties assume a generalised invisibility, hiding behind the facades of buildings. In the centre of Belo Horizonte, in daylight, only a portion of those “internal empty spaces” could have been identified through the “for sale” or “for rent” signs. However, at night, the massive number of “turned off” windows reveal the residential underutilisation of the area. This is the scenario illustrated by Figure 1, which has also triggered the idea of pursuing utility data to inform real estate vacancy. As previously noted, this type of data informs the finest of the urban scales, i.e., the address, and this means that the diagnosed "invisibility" of the built empty stock could be overcome. Thus, this research raises the hypothesis that mapping the “non-consumption” of resources such as water or electricity could assist in the visualisation of real estate vacancy in Belo Horizonte, indicating, with precision, areas of interest which could be further investigated.

Figure 1: The Centre landscape.
Source: Taken by the author (August 2019).

Indeed, this dissertation is the first publication of a broader research master project which started on August 2018 in Belo Horizonte[7] at the Postgraduate Programme in Architecture and Urbanism (NPGAU) of the Federal University of Minas Gerais (UFMG). The idea of linking the occupancy status of a property with its consumption — or inexistence of consumption — of utility services was only made possible when, in June 2019, CEMIG provided a comma-separated value (CSV) file containing anonymised spatial data on electricity consumption in Belo Horizonte. Logically, the accuracy of results relies on the coverage of CEMIG’s electricity distribution network. On that, firstly, it is worth noting that the company owns the monopoly of this service in Minas Gerais. Secondly, Moura & Magalhães (2011, pp. 6-7) affirm that CEMIG supplies practically 100% of the areas where human occupation is found in RMBH.

This research combines quantitative and qualitative approaches, taking into consideration the very nature of the gathered data and the possibilities presented by it. The quantitative approach will be assisted by computational techniques of geoprocessing. First, data from CEMIG is interpreted and, through well-defined frameworks, it is processed to derive new insights on absolute densities in the form of maps. Afterwards, the

[7] The author’s hometown.

qualitative approach serves for the interpretation of maps obtained for the municipal and local scales of work. Finally, the direct sampling method will be applied to test the effectiveness of the method.

In the next subsections, a detailed description will be presented of both the characteristics of the utilised data and the frameworks established for the development of the method to visualise real estate vacancy. Therefore, the reader will be able to critically analyse this research's methodological approach, also contributing to scientific advancement on the matter.

3.2. Study area

Figure 2: The location of the study area.
Source: Elaborated by the author.

Belo Horizonte is the capital of Minas Gerais, a state located in the Southeast region of Brazil. Inaugurated on December 12th of 1897, Brazil's first planned city was conceived as a symbol for the new republican ideals of rationality, technique, order and progress (Vilela, 2006, p. 37). The original plan divided its territory into three concentric areas. A circular avenue, the Do Contorno Avenue, delimited the city's Urban Zone (yellow area in Figure 3), in which the Centre neighbourhood is currently located (red limit in Figure 3). On its outskirts, forming a green belt, were the Suburban and the Rural Zones.

Figure 3: Belo Horizonte's original plan and the Centre limit.
Source: CMBH (s.d.). Modified by the author.

According to Vilela (2006, pp. 47-49), in the 1930s, Belo Horizonte witnessed a fast-developing expansion of its limits at the same time that high-rise buildings started to appear in the Centre. In the following decades, with industrialisation, the city grew beyond its administrative perimeter. Little by little, Belo Horizonte faced the gradual destruction of its main historical-cultural references in the name of the constant pursuit for modernization. New buildings replaced historical ones, and avenues were enlarged to increase the traffic flow. In the face of the broader process of metropolization, new centralities were defined and then redefined (Vilela, 2006, p. 56). According to Pontes (2006, pp. 58-59), in the 1970s, the centre of the city started to suffer a gradual reduction of its population, especially due to the migration of the dominant classes to the emergent centralities. The author, based on data raised by the IBGE, estimated that the Centre lost 44.16% of its residents between 1980 and 2000 (Pontes, 2006, p. 64). Consequently, the region also lost its symbolic value, leading to the degradation which can be observed in the area in contemporaneity.

To conclude, since the 1930s, the production of urban space in Belo Horizonte is characterised by a frenetic and unplanned development. The territory of Belo Horizonte has 331,354 km^2, and its estimated population is 2,512,070 people (IBGE, 2019). It is the sixth most populous capital of Brazil. The RMBH, including Belo Horizonte, has 34 municipalities, and the Metropolitan Outskirt of the RMBH has 16 municipalities. The territory of this region is 14,420.5 km^2 (IBGE, 2010) and its estimated population is 5,961,895 people (IBGE, 2019).

3.3. Data

3.3.1. CEMIG

As previously discussed, this research was triggered by the idea of linking the **occupancy status** of a property with its **electricity consumption**. The interpretation of data provided by CEMIG was vital to establish this link and then develop the analysis presented in Section 4. Therefore, it is necessary to highlight that an interdepartmental collection of information was carried out to understand how the company tabulates data, and the assistance of CEMIG's employers was indispensable in this process.

CEMIG provided a CSV file in table format, containing information on the **billing status** of electricity meters registered within the perimeter of Belo Horizonte in a specific month, in this case, June 2019. More specifically, electricity is delivered in properties through this meter, which is installed by CEMIG, so that the company can measure their monthly consumption. Consumer units are properties characterized by the receipt of electricity at only one delivery point, with individualised measurement of consumption, corresponding to a single consumer and located in the same property or adjacent properties (ANEEL, 2014). Therefore, an electricity meter corresponds to a consumer unit. A consumer unit is, most of the time, individual property, especially in regularised urban areas. For instance, in a high-rise residential building, each apartment is a consumer unit. However, in favelas, for example, it is not uncommon for one meter to supply more than one property, which configures adjacent properties. Finally, this data applies to all types of uses of buildings.[8]

Regarding the billing status, consumer units with an **active** billing status are the ones which paid the electricity bill in this specific month; consequently, consumer units with an **inactive** billing status are the ones that didn't. Concerning consumer units with an **active** billing status, they are classified as being those with consumption greater than zero (consumption zero = no) and those with consumption equal to zero (consumption zero = yes). Therefore, consumer units can be classified into three types:

Type 1 = active billing status and consume greater than zero;

Type 2 = active billing status and consume equal to zero;

Type 3 = inactive billing status.

[8] CEMIG also holds information regarding to "consumption classes". They are five: residential, industrial, commercial, rural and public authority. This valuable information was not made available for this research.

On the one hand, Type 1 units have consumed and paid for electricity, while Type 2 units are the ones that received an electricity bill in the category of the "minimum payment". This means that the electricity meter was on, but the unit's general electricity switch was off. On the other hand, Type 3 units, the ones that did not pay the bill, can be related to two situations:

S_1 = the consumer required the shutdown of the electricity meter;

S_2 = the unit is in default for more than 90 consecutive days and had its electricity cut by CEMIG.[9]

Moreover, CEMIG does not register the geographical location of consumer units at their real address. In fact, as previously discussed, their coordinates correspond to the utility pole that supplies its electricity. The typical distance between the derivation point — or the utility pole — and the delivery point — or the property — is 10 meters, although it may range from 7 to 15 meters. This is a standard distance for urban areas[10].

In total, there are 1,142,309 entries in the table provided. To differ occupied properties from the vacant ones, let us associate the **billing status** of a consumer unit with its **occupation status**:

Type 1 = A positive consumption of electricity indicates that the unit is occupied;

Type 2 = In this case, the lack of consumption of electricity indicates vacancy. However, the fact that the shutdown of the meter was not required indicates a more volatile built stock. For instance, properties which have just became available for rent;

Type 3 = These are the consumer units that fit the profile of a more permanent vacant stock.

Therefore:

Table 1: Occupation status of consumer units.
Source: Elaborated by the author.

type	billing status	consumption zero	x	y	occupation status
1	active	no	value	value	occupied
2	active	yes	value	value	volatile stock
3	inactive	-	value	value	vacant

3.3.2. BHGeo

Geographic data were collected from the open-source portal BHGeo, maintained by the Company of Informatics and Information of Belo Horizonte Municipality (PRODABEL). In this portal, there is a geospatial data viewer, called BHMap, on which it is possible to download the following shapefiles:

- Municipal limit;
- Neighbourhood limit;
- Lagoon;
- Park;
- Village and favela[11];
- Land uses.

This data will assist in the construction of the maps in the GIS, also supporting the analysis of results obtained with the processing of CEMIG's data.

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[9] In this case, the consumer has to pay its debts to receive electricity again, which would also classify the consumer unit as active for the next month.

[10] This rule does not apply to rural areas.

[11] These areas correspond to the Special Zones of Social Interest 1 and 2 (ZEIS-1 and ZEIS-2) determined by the Law 11.181/19, which enforced The New Belo Horizonte Plan.

3.3.3. IBGE

Geographic data gathered by the IBGE for the 2010 Demographic Census, the most recent one, were collected from the open-source portal maintained by the organisation. The following variables were utilised:

From the Synopsis results:

- V008 = Permanent private housing units not occupied — vacant.

From the "Basic" file of the Universe results:

- V002 = Residents in permanent private housing units or population residing in permanent private housing units.

From the "Housing" file of the Universe results:

- V002 = Permanent private housing units;
- V044 = Permanent private housing units with electricity from a utility company;
- V047 = Permanent private housing units with electricity from a utility company and with an exclusive meter.[12]

Despite the time difference between CEMIG's data (June 2019) and this source, data from the 2010 Demographic Census will be utilised to assist in the discussion of results obtained through processing CEMIG's data.

3.4. Research ethics

For research purposes, the previously described data was made available by CEMIG as a CSV file. Before it was sent to me by e-mail, the data was anonymised, so no personal data were disclosed. This information is stored solely on my personal computer and cloud accounts, which can only be accessed after a password is encoded.

As discussed in Section 3.3.1, it is impossible to associate, without reasonable doubt, a consumer unit with a specific property. Moreover, in dense urban areas, such as the Centre, is highly likely that consumer units from different buildings are connected to the same utility pole. Nevertheless, the standard distance between the pole and the consumer unit of 10 meters enables an accurate analysis of areas of interest for both of the proposed scales of work.

[12] It is worth mentioning that for the 2020 Demographic Census, questions related to electricity were cut from the IBGE's questionnaire form (Rossi, 2019).

4. Data Analysis

According to Moura (2005, p. 8), the processing of geographic data aims to establish a process which brings progress. The geoprocessing technique not only represents a phenomenon; it also produces a new perspective on urban space through a methodology capable of generating gain to scientific knowledge. Thus, so that it is possible to produce results which can be critically analysed, it is imperative to establish well-defined limits as well as a well-defined protocol when assembling a geoprocessing model. To guide this process, Martin (1996, p. 60) proposes a theoretical diagram and, as shown below, there are four transformation stages:

Table 2: Transformation stages of geoprocessing models.
Source: Martin (1996) & Moura (2005).

T_1	Definition of frameworks and collection of data to inform the spatial analysis.
T_2	Input of raw data in the GIS and normalisation of the information layers.
T_3	Decomposition and recomposition of data using methods for territorial evaluation that describe and illustrate elements based on judgments.
T_4	Preparation of data for output.

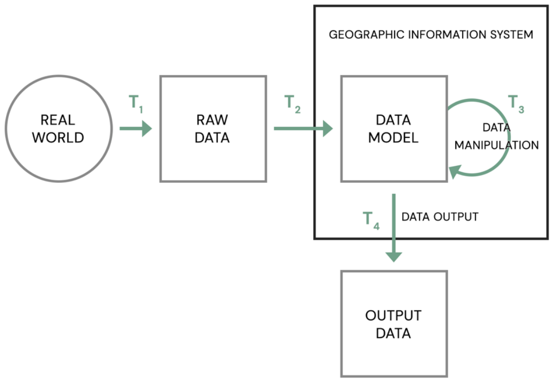


Figure 4: Construction of geoprocessing models.
Source: Martin (1996, p. 60). Elaborated by the author.

Therefore, according to T_1, let us delimitate the frameworks of this geoprocessing model[13]. First, the temporal framework: June 2019. Second, the spatial framework: Belo Horizonte. Utility data provided by CEMIG informed both of those frameworks. The third framework, the conceptual one, is the final objective of the process: to locate — or visualise — areas of interest which stand out for holding high absolute densities of consumer units, total and per type. The last framework, the methodological one, aims to state the criteria adopted in the process, so the method is reproducible and defensible. A diagram was elaborated to illustrate the methodological framework (see **Figure 5**).

Then, let us move on to T_2. With the support of ArcMap, a GIS, raw data was processed and associated with Belo Horizonte's geographic surface as point features. In other words, in the model, poles are represented as points; each point holds information on the classification of consumer units (Type 1 or Type 2 or Type 3) which are connected to this specific point. To assist visualisation, shapefiles downloaded from BHMap were added to the model, providing a basemap. After data was inputted in the model, layers were normalised to the same geographic coordinate system: SIRGAS2000_23S. **Figure 6** illustrates the model in the end of T_2 in Belo Horizonte's Centre near the Municipal Park, and a point feature was selected to exemplify data contained in it. As seen at the bottom of the information window, there are 501 consumer units connected to this utility pole.

[13] I owe this understanding to Dr Ana Clara Moura Mourão.

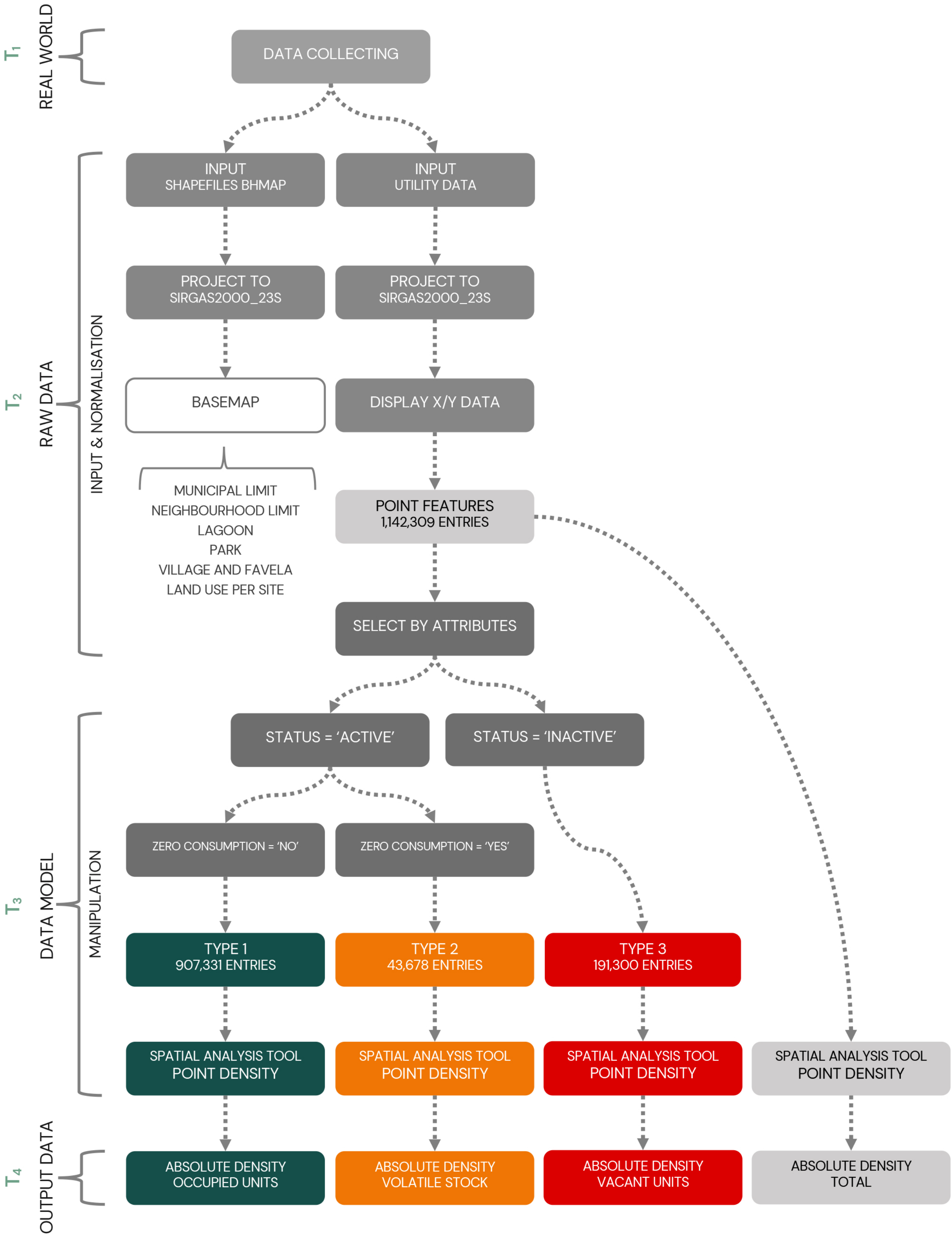


Figure 5: Methodological framework of the geoprocessing model.

Source: Elaborated by the author.

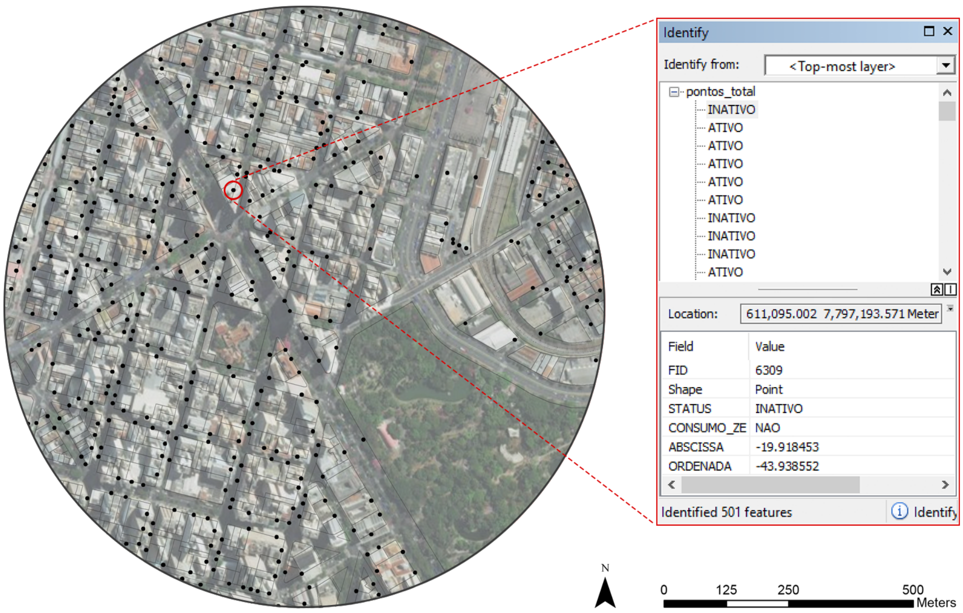


Figure 6: Geoprocessing model in the end of T_2 and information contained in a point feature.
Source: Elaborated by the author.

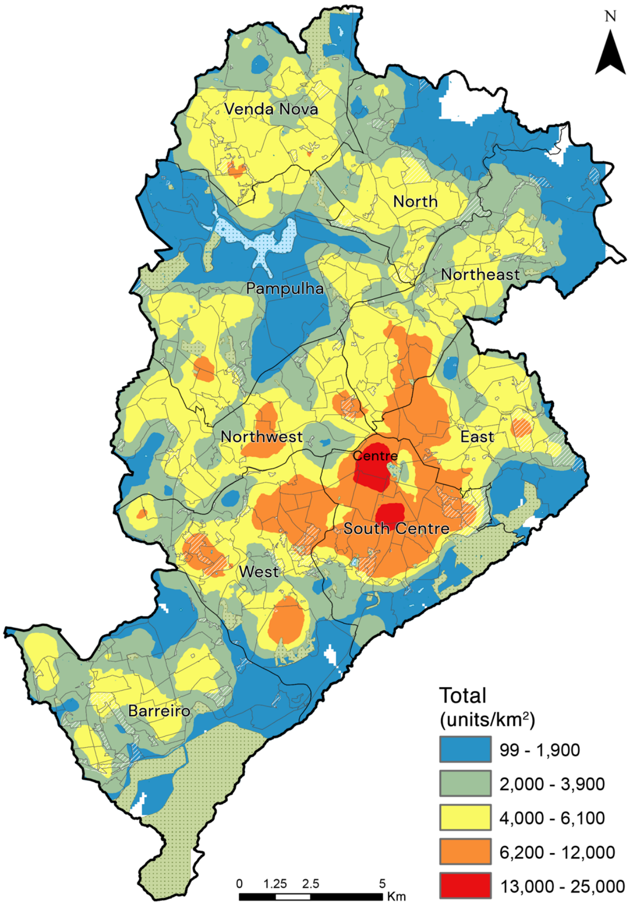
In T_3, normalised data were processed. First, data were decomposed through the Select by Attributes tool. Consumer units were separated by type; each type became a single information layer. Then, data were recomposed using a territorial evaluation model. The Point Density spatial analysis tool was used to calculate the density of consumer units around the centre of each raster cell. This means that, conceptually, the tool sums the total number of consumer units found in the area of influence — or neighbourhood — of each raster cell and divides this number by the neighbourhood area. Therefore, **this is the point where the scale of work must be determined.** To clarify, let us think about the scales which will be analysed in this research. Logically, a radius of 600m, considered appropriate to the municipal scale analysis, is going to determine a broader neighbourhood for each raster cell than a radius of 30m, the one considered appropriate for the local scale analysis. In other words, broader neighbourhoods produce less detailed results and are more appropriate to analyse the municipal scale, while smaller neighbourhoods produce results capable of informing local scales, such as the Centre.

To sum up, the Point Density tool was applied, first with a radius of 600m. The process was repeated four times: one to each information layer (total units and per type). Afterwards, the whole procedure was repeated with a smaller radius of 30m. The Natural Breaks (Jenks) classification method was chosen because it maximises differences between classes. Finally, we reached T_4, and results are ready to be exported from the model.

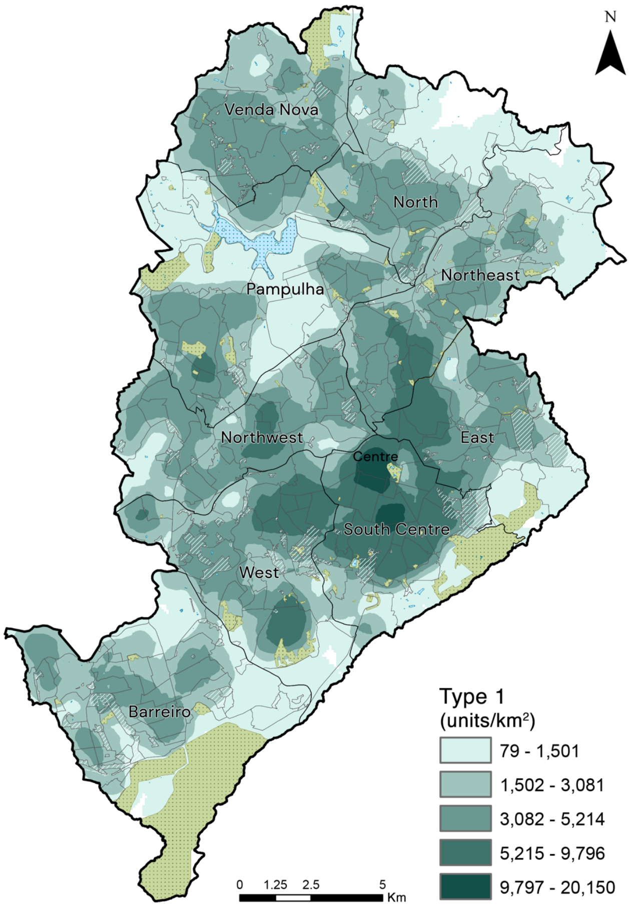
5. Results and Discussion

5.1. Municipal scale

With the geoprocessing of CEMIG's data, areas of interest were identified in Belo Horizonte which highlight high absolute densities of consumer units, total and per type, in June 2019. Considering that establishing limits is inherent and necessary to the research process, it is worth remembering that the focus of this dissertation is real estate vacancy, phenomenon related to Map 3 and Map 4. Nevertheless, Map 1 and Map 2 will be briefly discussed as they also depict information relevant to this analysis.



Map 1: Absolute density of the total of consumer units (Belo Horizonte).



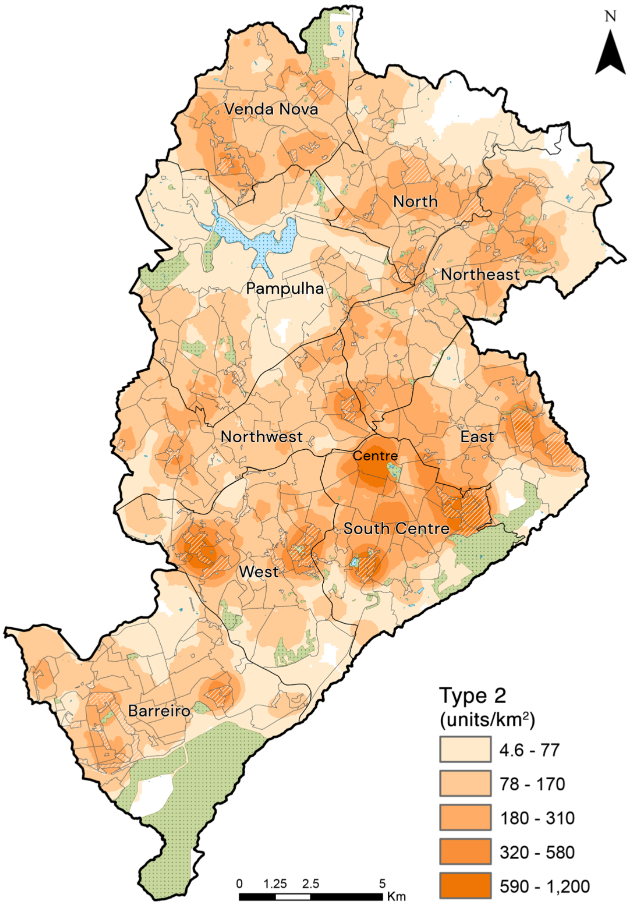
Map 2: Absolute density of consumer units Type 1 (Belo Horizonte).

Source: Elaborated by the author with data from CEMIG & BHGeo.

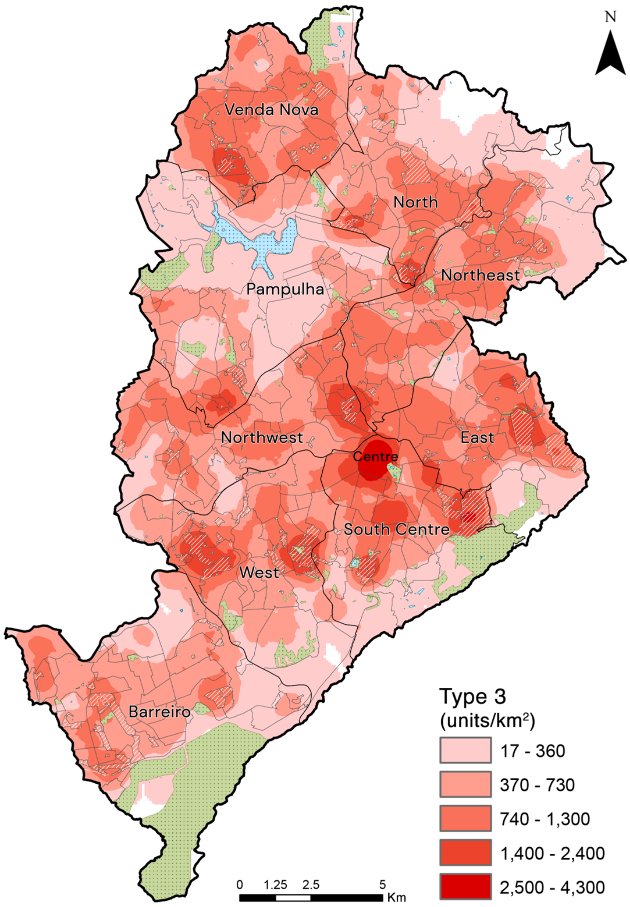
Legend

Municipality | Regional | Neighbourhood | Village & Favela | Lagoon | Park

First of all, it is clear that there is a strong correlation between the highest density spots seen in Map 1 and Map 2. This means that, logically, regions which contain a high density of consumer units (without type distinction), such as the Centre, also contain a high density of occupied consumer units (Type 1). However, there is one exception to this pattern: although there is a high density of consumer units in areas identified as villages and favelas (Map 1), they do not show high densities of occupied consumer units (Map 2). Indeed, these areas show a strong correlation with the highest density spots seen in Map 3 and Map 4. Moreover, it is interesting to note that Map 3 and Map 4 show similar results, suggesting they inform the same phenomenon: real estate vacancy. From them, it is seen that the Centre is the most prominent hotspot within the city; thus, this is the area chosen to be further investigated in the next session.



Map 3: Absolute density of consumer units Type 2 (Belo Horizonte).



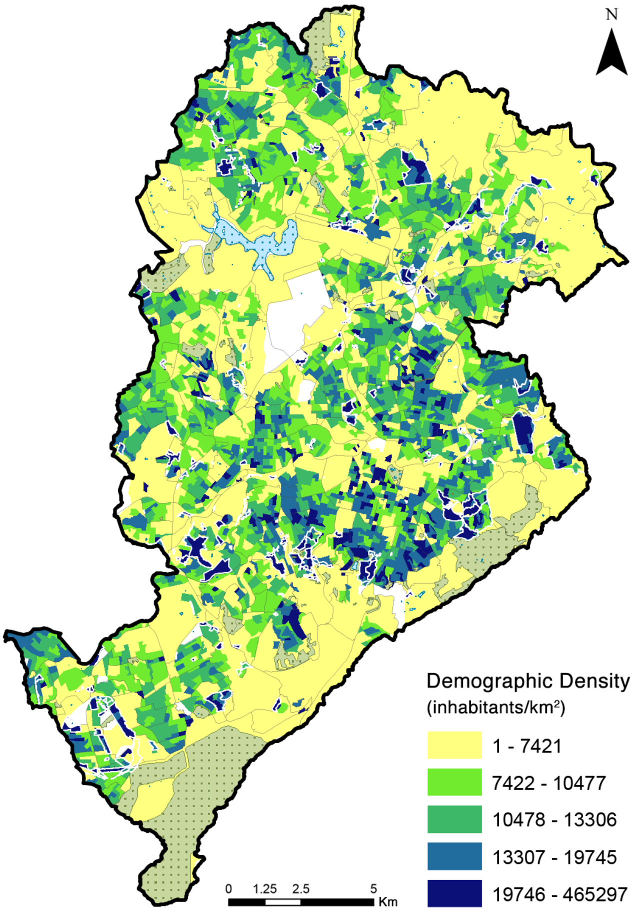
Map 4: Absolute density of consumer units Type 3 (Belo Horizonte).

Source: Elaborated by the author author with data from CEMIG & BHGeo.

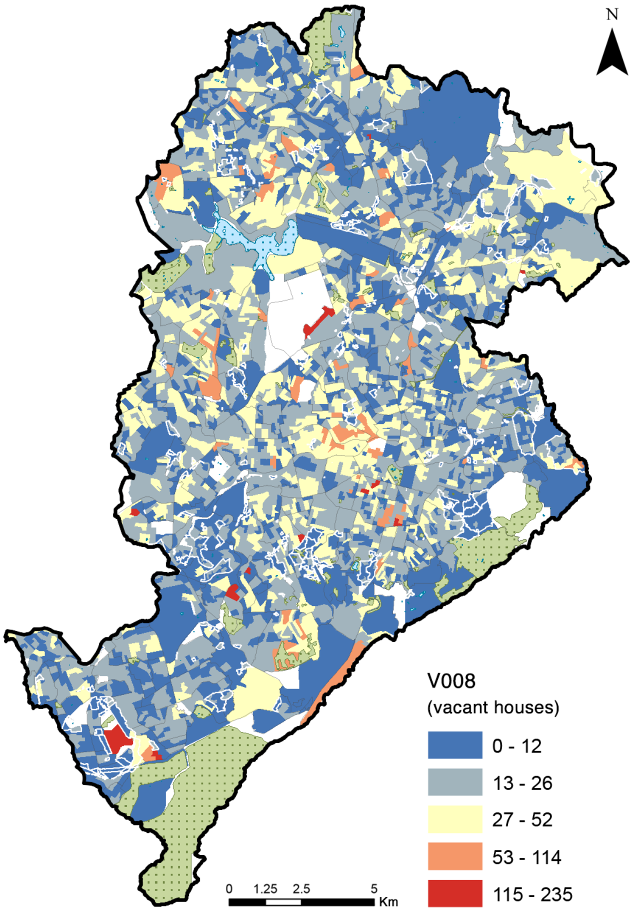
Legend

Municipality | Regional | Neighbourhood | Village & Favela | Lagoon | Park

However, first it is imperative to discuss the strong correlation between villages and favelas and the hotspots seen in Map 3 and Map 4, as it raises some vital questions. As is broadly known, areas of villages and favelas do not present populational emptiness. On the contrary, generally, they face high demographic densities. To scientifically demonstrate this statement, two maps were elaborated with data gathered from the 2010 Demographic Census. As is seen in Map 5, the vast majority of villages and favelas (white limit) are amongst the most populationally dense areas of the city (blue tones). On top of that, from Map 6, which classifies census tracts by intervals of absolute numbers of vacant houses, it is possible to affirm that villages and favelas do not hold a significative number of vacant residences.



Map 5: Demographic density (Belo Horizonte).



Map 6: Vacant houses - V0008 (Belo Horizonte).

Source: Elaborated by the author with data from IBGE.

To sum up, villages and favelas do not present high vacancy rates, however, electricity meters installed in these areas were inactive in June 2019. Two hypotheses arise to explain results seen in areas of villages and favelas:

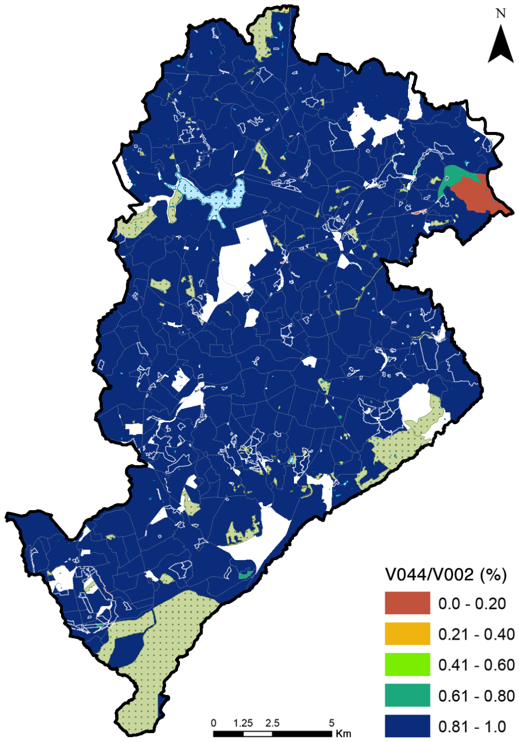
H_1 = A considerable number of occupied properties don't have electricity. This would mean that either residents couldn't afford electricity and requested the shutdown of the meter, or electricity was cut by the company due to a default of more than 90 consecutives days.

H_2 = A high density of occupied properties is illegally connected to the electricity distribution network. This would mean that due to a default of 90 consecutive days, the meter was shut down by the company, but was illegally reconnected to the network by residents themselves. As informed by CEMIG, generally it is not possible for the company to shut down meters in some of these areas because employees are often not well received to carry out this service. In this case, when reaching the default of 90 days, the status of meters becomes inactive, even though they are still receiving electricity.[14]

[14] All units whose meters registered consumption will receive a bill, despite being legally or illegally connected to the network. As informed by the company, the employee responsible for reading the meters will register the consume, and based on that, CEMIG will issue a bill for the consumer unit. The only way to not receive a bill and to have electricity is through a direct illegal connection to the utility pole, or the "hotwiring of electricity supply".

To investigate H_1, data from the 2010 Demographic Census was utilised to elaborate **Map 7**. As can be observed, the vast majority of the municipal territory, including the areas of villages and favelas, is classified in the interval informing that more than 80% of houses are supplied by electricity from CEMIG. Therefore, H_1 can be rejected, as the presence of electricity was verified *in loco* by the IBGE researchers. However, to eliminate any uncertainty, it is necessary to conduct a field verification, especially because this data was gathered in 2010.

Finally, it is possible to conclude that, in areas where there is a high density of illegal connections to the electricity network, the highest density spots don't indicate real estate vacancy. However, they might inform other patterns, such as these areas' social-spatial organisation, i.e., the spatialisation of consumer units which pay — or don't pay — for electricity.

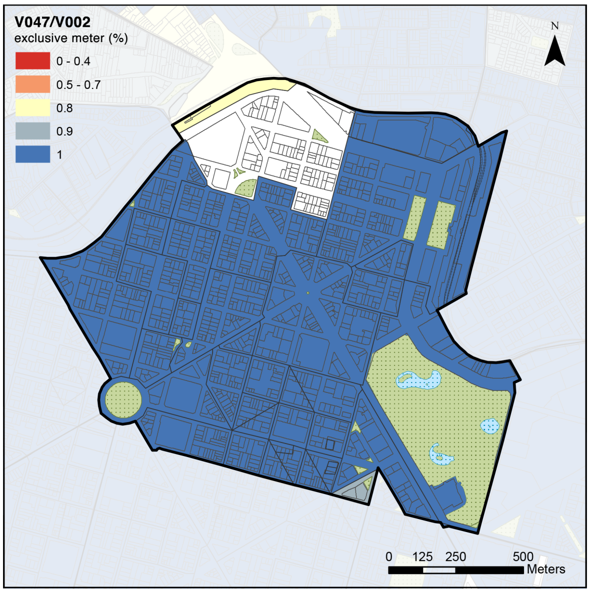


Map 7: Percentage of permanent housing units with electricity from a utility company (Belo Horizonte).

Source: Elaborated by the author with data from IBGE.

5.2. Local scale

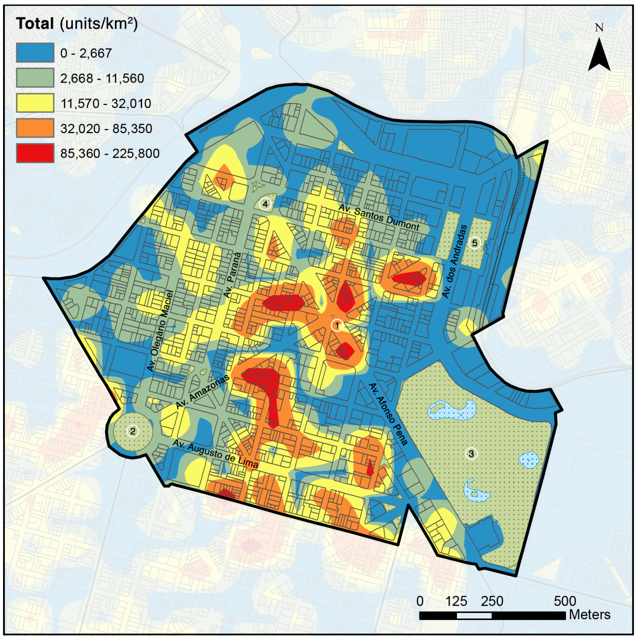
First of all, as seen from **Map 8**[15], in the vast majority of the territory of the Centre, 100% of houses are supplied by utility lines from CEMIG and have an exclusive meter, i.e., meters correspond to individual houses, not adjacent ones. In addition, this is a highly regularised area and, for that reason, CEMIG can monitor connections with far more control than in villages and favelas. Thus, it is highly likely that properties which registered no electricity consumption are either vacant, or its users are living without electricity. This means that, even though a minor number of illegal connections might exist in the Centre, it is very likely that results will not be impacted. Let us move to them.



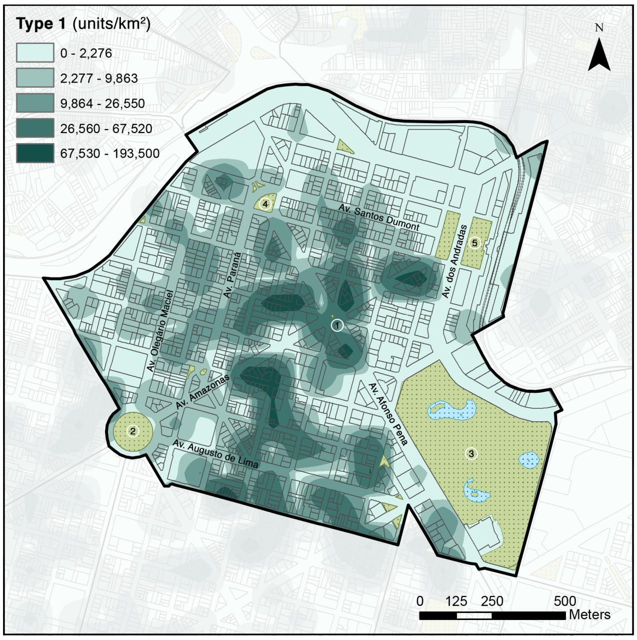
Map 8: Percentage of permanent private housing units with electricity from a utility company and with an exclusive meter (Centre).

Source: Elaborated by the author with data from IBGE.

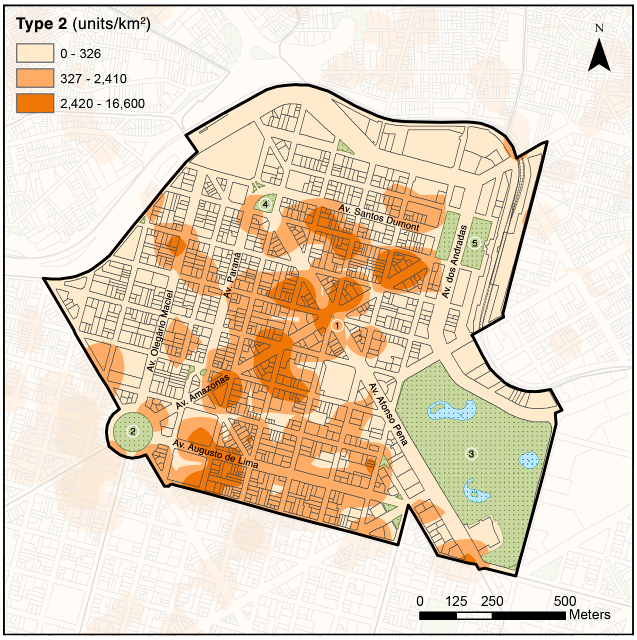
15 The blank part indicates a lack of data in IBGE's database.



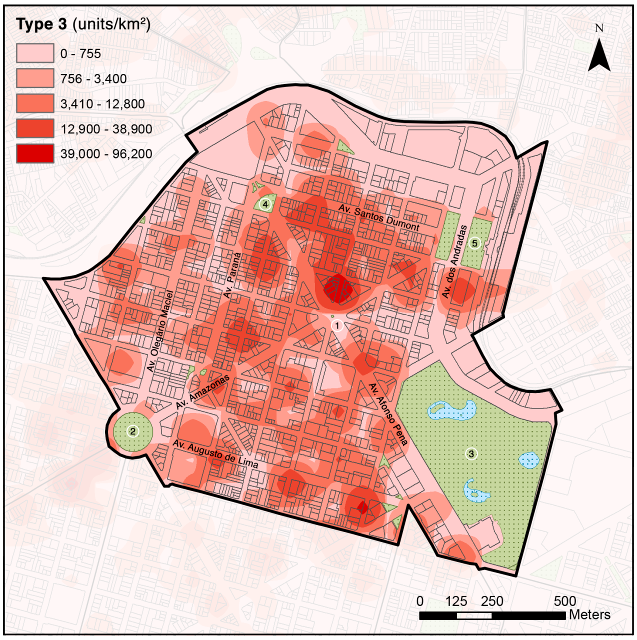
Map 9: Absolute density of the total of consumer units (Centre).



Map 10: Absolute density of consumer units Type 1 (Centre).



Map 11: Absolute density of consumer units Type 2 (Centre).



Map 12: Absolute density of consumer units Type 3 (Centre).

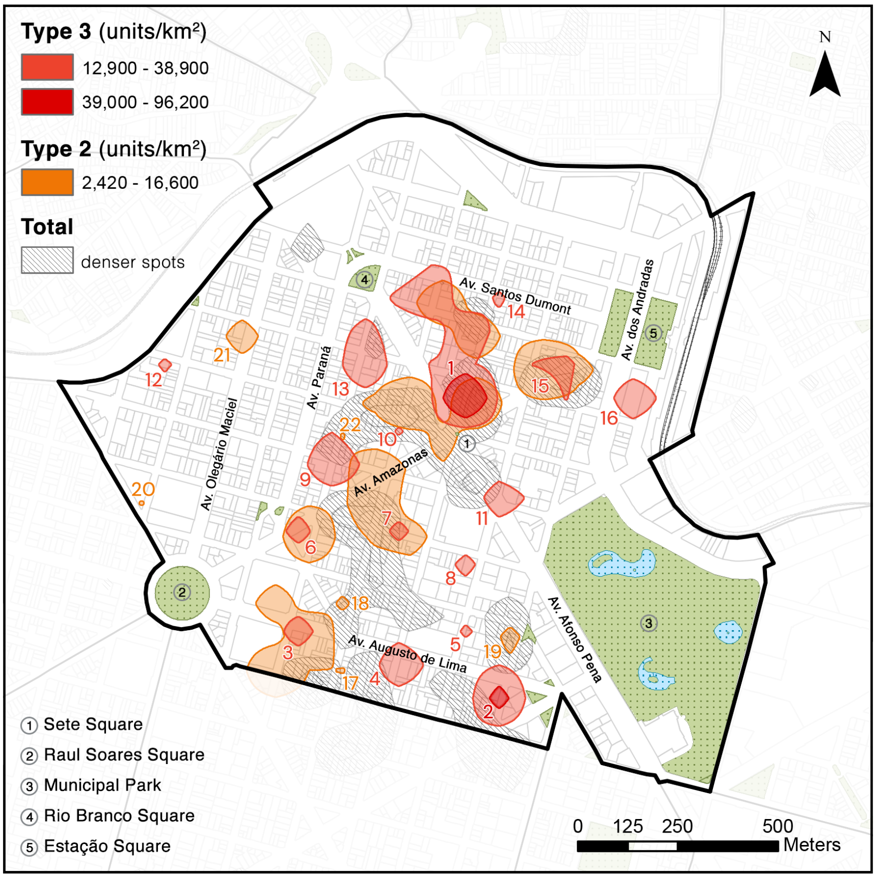
Source: Elaborated by the author with data from CEMIG & BHGeo.

Legend

Centre | Railway | Plots | Lagoon | Park & Square

① Sete Square | ② Raul Soares Square | ③ Municipal Park | ④ Rio Branco Square | ⑤ Estação Square

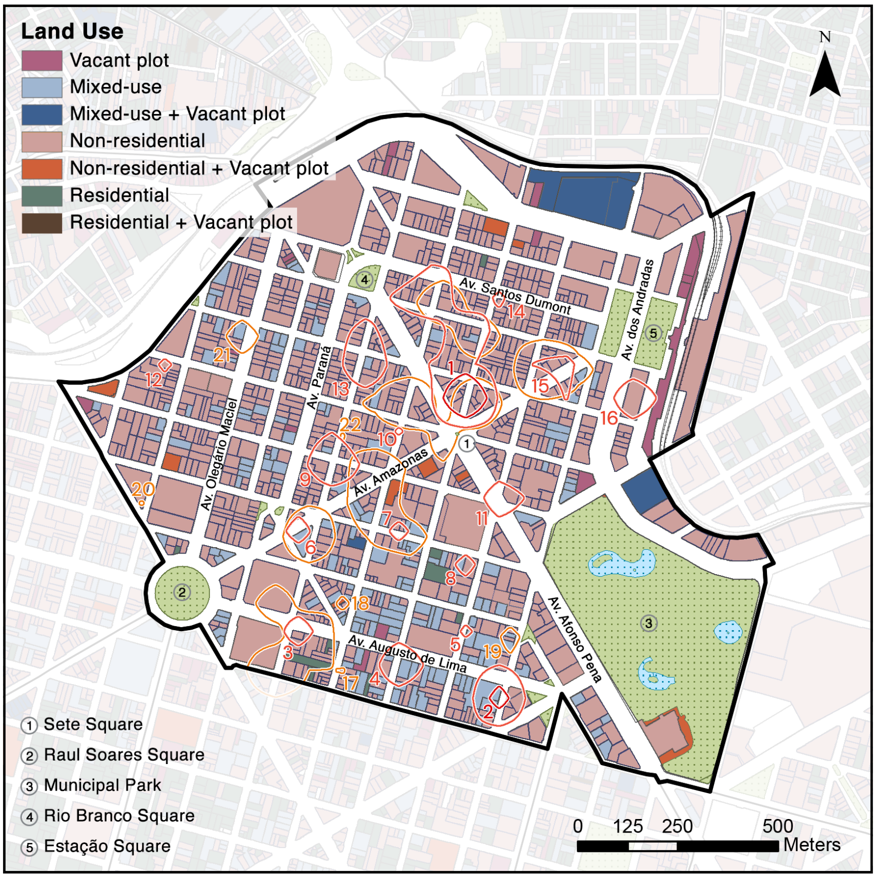
For the Centre, as for the municipal results, a very strong correlation is noted between the highest density spots observed in Map 9 and Map 10. In fact, spots seen in these maps correspond almost entirely. In this context, it is noted that, when comparing Map 9 with Map 11 and Map 12, some correlation between spots can also be observed; however, some isolated high density spots of Type 2 and Type 3 consumer units can also be seen. **Map 13** was elaborated to sum up this information, and numbers were assigned to spots, indicating areas of interest.



Map 13: Correlation between spots of the total of consumer units and Type 2 and Type 3 units (Centre).
Source: Elaborated by the author with data from CEMIG & BHGeo.

Overall, the most prominent area of interest in the Centre irradiates from the Sete Square, space recognised as the heart of Belo Horizonte. As seen from **Map 13**, spots with both Type 2 and Type 3 units surround this square and, together, they spread to North, reaching Santos Dumont Avenue, and West, almost reaching Paraná Avenue. Once spots overlap, it was established that this whole region forms a unique area of interest, indicated as **1** in the map above. The "core" of this area, which shows the highest absolute density of Type 3 units (darker red), overlaps two remarkable commercial high-rise buildings, Helena Passig and Bemge, which are historical symbolic references in Belo Horizonte. Apart from this, only one more spot was classified within this same interval, which is the "core" of the area of interest number **2**. This "core" overlaps Maletta, a high-rise mixed-use building, also a building with historical symbolism. In total, 22 areas of interest were established, and some are formed by overlapping spots of Type 2 *and* Type 3 consumer units, such as **1**, **3**, **6**, **7** and **15**, while others are isolated spots of Type 2 *or* Type 3 consumer units, such as **2**, **4**, **5**, **8**, **9**, **10**, **11**, **12**, **13**, **14**, **16**, **17**, **18**, **19**, **20**, **21** and **22**. It is interesting to note that some of the isolated spots identify a small and focused area of interest. As previously discussed, this means that there is a considerable density of units of the same type in a small area. This is a strong indication that there is a vacant or underutilised building in the immediate surroundings of this spot.

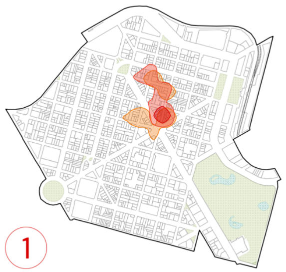
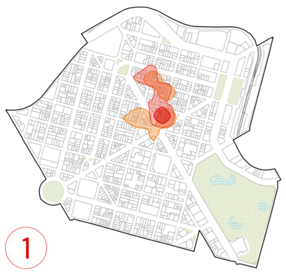
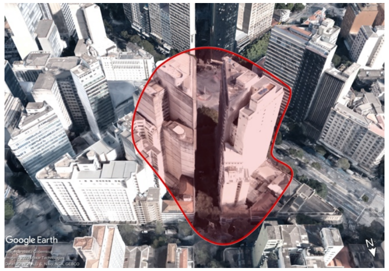
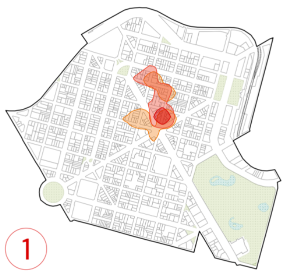
Thus, to trigger a preliminary discussion on the effectiveness of the method, images from Google Earth were collected and analysed to highlight relevant aspects which might give insights about the obtained results. Broader areas of interest were captured through birds-eye 3d views, and Google Street View was utilised to further explore these areas, as well as the small and focused areas of interest. In that sense, images from Google Street View were captured whenever a relevant aspect was noticed. During this process, some viewing limitations were faced due to restrictions inherent to the Google Earth software. In addition, images seen in Google Street View present different reference dates; however, most of those collected for this research were originally captured between April and August 2019, a period relatively close to June 2019 (reference date of CEMIG's data). Moreover, **Map 14** was elaborated to assist in the classification of the land use in areas of interest, also giving insights into the following analysis. Finally, it is vital to highlight that knowing the Centre — as an inhabitant of Belo Horizonte — was vital to this process because vacancy, in some of the areas of interest, cannot be seen from outside the buildings. The information collected through the direct sampling method is in **Table 3**[16].



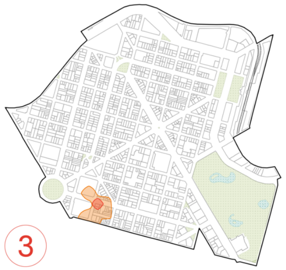
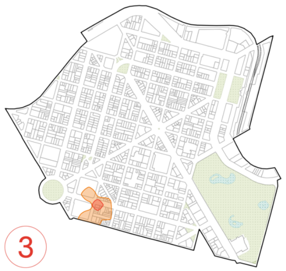
Map 14: Land uses and areas of interest (Centre).
Source: Elaborated by the author with data from CEMIG & BHGeo.

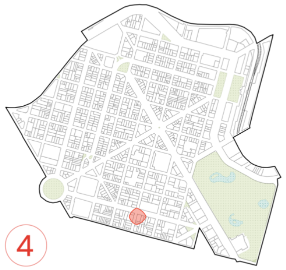
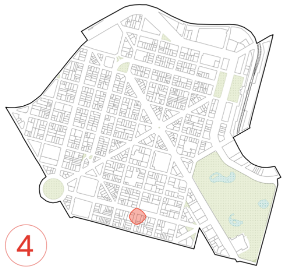
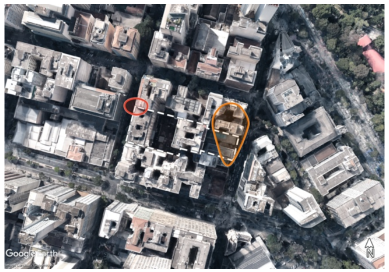
16 Further information about collected images can be found in the Appendix Section.

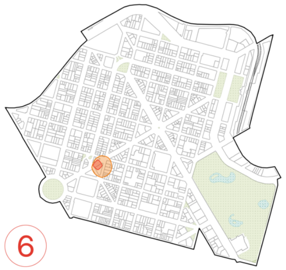
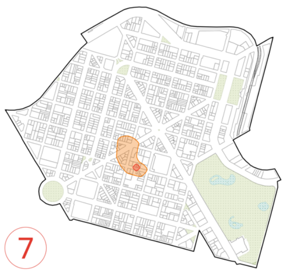
Table 3: Direct sampling of images of areas of interest from Google Earth.[17]
Source: Elaborated by the author.

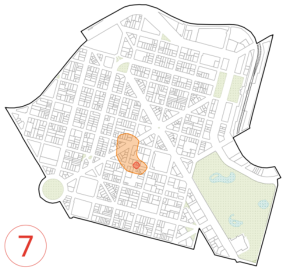
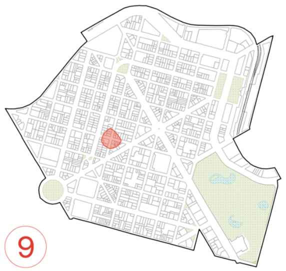
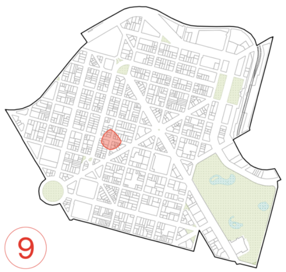
Area of Interest	Image	Location	Land Use	Observations
		Sete Square and adjacent blocks delimited by Santos Dumont and Paraná Avenues	Non-residential Mixed-use	Overall, this area of interest is characterised by a strong presence of occupied ground level commercial spaces, something also observed in other areas of the Centre. The non-residential use is highly predominant. Only 2 mixed-use buildings are located in this area.
		Zoom to "core": Rio de Janeiro Street between the Sete Square and Tupinambás Street	Non-residential	This spot mostly overlaps the high-rise buildings on the sides of Rio de Janeiro Street, such as Helena Passig and Bemge.
		Helena Passig (front) and Bemge (back) Buildings	Non-residential	"For rent" signs in the lowest windows, as well as closed gates on the gallery floor, are seen in Helena Passig. This gallery is quite vacant (Lima, 2019, p. 157). According to real estate agents, several commercial spaces are available for rent in Helena Passig (Viva Real, 2020; Zap Imóveis, 2020). Bemge is completely vacant since May 2018 due to undergoing restauration work (Estado de Minas, 2018).

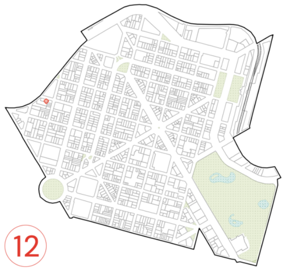
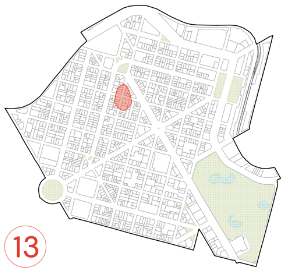
[17] The red and orange spots in the birds-eye images show the approximate corresponding locations of areas of interest.

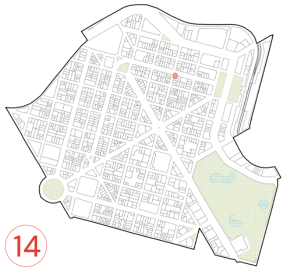
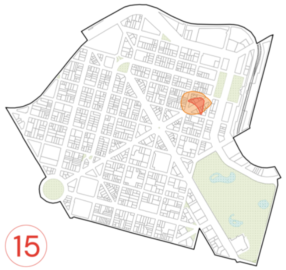
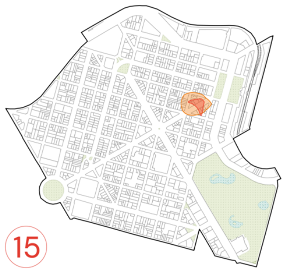
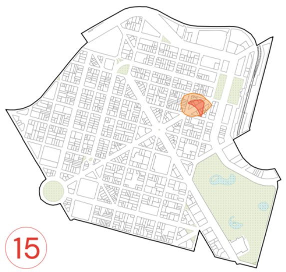
		Da Bahia Street, between Augusto de Lima Avenue and Dos Guajajaras Street	Non-residential Mixed-use	This spot overlaps Malleta Building, its neighbours, and the block where two museums are located, the Inimá de Paula and the Fashion Museum.
		Zoom to "core": 1148 Da Bahia Street	Mixed-use	This spot mostly overlaps Maletta Building. Closed gates are seen on the ground level and on the gallery floor. According to real estate agents, several commercial spaces are available for rent in Maletta (Viva Real, 2020; Zap Imóveis, 2020).
		Augusto de Lima Avenue at Curitiba Street, near the Central Market and Minascentro	Non-residential Residential	The Type 2 spot overlaps both Municipal Market and Minascentro Convention Centre. The non-residential use is predominant; however, four residential buildings are located in this area. This is the only area that registered this land use.
		707 Augusto de Lima Avenue	Non-residential	A "for rent" sign is seen on the upper floor of the building in the corner.

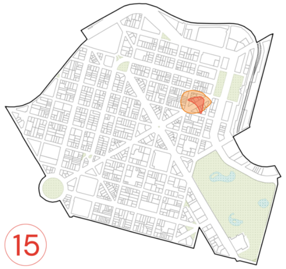
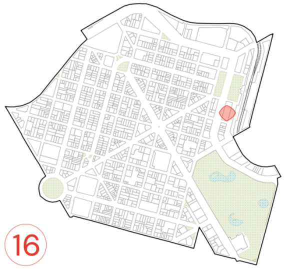
		Augusto de Lima Avenue at Rio de Janeiro Street	Non-residential Mixed-use	Mixed-use buildings are predominant in this spot.
		1131 Rio de Janeiro Street	Mixed-use	Closed gates and “for rent” signs are seen on the ground level.
		1009 Espírito Santo Street	Non-residential Mixed-use	This spot overlaps the former entrance of Bahia Shopping. This building crosses the block and its primary former entrance is on the opposite street. See Area **19**.
		1009 Espírito Santo Street	Non-residential Mixed-use	On the ground level, on the far-right, is the former entrance of Bahia Shopping. Only 500m^2 of its 10,000m^2 are currently being used as a parking lot (Rennó, 2019).

 6		Amazonas Avenue at Curitiba and Padre Belchior Streets	Non-residential Mixed-use	Predominance of the non-residential use.
 6		885 Amazonas Avenue	Mixed-use	This spot mostly overlaps a mixed-use building where the Belo Horizonte Gallery is located. Closed gates are seen on its upper floors.
 6		844 Amazonas Avenue	Non-residential	In front of the Belo Horizonte Gallery, closed gates are seen on the upper floor of another gallery.
 7		Amazonas Avenue at São Paulo and Tamôios Streets; Dos Tupis Street, between São Paulo and Rio de Janeiro Streets	Non-residential Mixed-use Non-residential + Vacant plot	This spot overlaps two relevant commercial centres, Cidade Shopping and Feira Shop, also reaching the area near the Ouvidor Gallery.

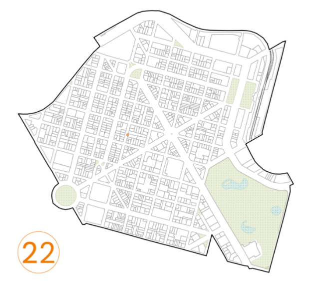
 7		304 Dos Tupis Street	Non-residential Mixed-use	On the left side of the picture is the Cidade Shopping entry. No sign of vacancy could be identified.
 8		149 Dos Tupis Street	Non-residential Mixed-use	Some closed gates are seen in the ground level. On the left-side building (non-residential), siding is seen in front of the second line of windows.
 9		Curitiba Street at Tamôios Street	Non-residential Mixed-use	Non-residential use is predominant.
 9		856 Curitiba Street	Non-residential	Closed gates are seen on the ground floor.

 10		656 São Paulo Street	Non-residential	On the left is Carijós Shopping, inaugurated at the end of June 2019 (Hoje em Dia, 2019). On the right (behind the truck), is one of the entries of Ouvidor Gallery. See Area **22**.
 11		867 Afonso Pena Avenue	Non-residential	This spot mainly overlaps Acaiaca Building. No sign of vacancy could be identified through the image; however, according to real estate agents, several commercial spaces are currently available for rent in Acaiaca (Viva Real, 2020; Zap Imóveis, 2020).
 12		1079 Dos Carijós Street	Non-residential	On the left is Tupinambás Shopping, which occupies the whole block. Especially on Dos Carijós Street, a significant number of closed gates are seen on the ground level on both sides.
 13		Curitiba Street at Tupinambás Street	Non-residential Mixed-use	Non-residential use is predominant. No sign of vacancy could be identified.

 14		195 Rio de Janeiro Street	Non-residential	No sign of vacancy could be identified.
 15		Amazonas Avenue, between Rui Barbosa Square and Espírito Santo Street	Non-residential Mixed-use	Non-residential use is predominant.
 15		100 Amazonas Avenue	Non-residential	A “for rent” sign is seen on the facade.
 15		115 Amazonas Avenue	Non-residential	Closed gates are seen on the ground floor level. On the far-left building is a sign informing that $2,900m^2$ are for sale in it.

 15		69 Amazonas Avenue	Non-residential Mixed-use	Closed gates are seen on the ground floor and upper floor levels.
 16		367 Andradas Avenue	Non-residential	A relevant number of closed gates is seen at Central Building.
 17		1238 São Paulo Street	Non-residential	On the right, a sign informs that the building is entirely available for rent. On the left, a sign informs that an entire floor on the building is available for rent.
 18		1104 São Paulo Street	Non-residential Non-residential + Vacant plot	“For rent” signs are seen in the lowest windows of the high-rise building.

 19		1000 Da Bahia Street	Non-residential Mixed-use	On the far-left side, the darkest facade corresponds to the entry of a former hotel, whose tower is currently completely vacant (Rennó, 2019). The only used space is the parking lot. At the centre, below the horizontal rectangle, is the main entrance of Bahia Shopping. This building is abandoned. See Area **5**. On the far-right building, “for rent” and “for sale” signs are seen.
 20		519 Rio Grande do Sul Street	Non-residential	On the right is the Novo Market. Its area is highly underutilised (Lima, 2019, pp. 190-193).
 20		519 Rio Grande do Sul Street	Non-residential	On the left, are seen closed gates.
 21		274 Olegário Maciel Avenue	Non-residential Mixed-use	On the left, are seen closed gates on the ground floor. On the low-rise building in the middle is seen a “for sale” sign.

		711 Curitiba Street	Non-residential	This spot is right next to one of the entries of Ouvidor Gallery. See Area **10**. No sign of vacancy could be identified.

6. Recommendations and Conclusions

How to locate real estate vacancy? Aiming to answer this question, a method was developed to visualise the phenomenon using electricity consumption spatial data. Through a well-defined research approach and with the support of GIS, this idea culminated in a process capable of highlighting high absolute densities of possibly vacant consumer units, first throughout the territory of Belo Horizonte and, second, in the Centre. To test the effectiveness of this method, Google Earth was utilised to assist in the direct sampling of images of the Centre's areas of interest. In this context, dates of reference for images from Google Street View and CEMIG's data were acceptably correspondent; thus, this tool was utilised in the development of a digital "field survey". As seen in images from Table 3, some aspects which might be an indication of real estate vacancy were identified in areas 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20 and 21. More importantly, it is possible to affirm that this preliminary test has validated the method, especially through the precise identification of Bemge (1) and Bahia Shopping (5 and 19), two buildings which were unquestionably empty on June 2019. Nevertheless, there is no clear evidence of real estate vacancy in areas 7, 13, 14 and 22, neither from collected images nor from other sources consulted until the present moment. Therefore, it is vital to highlight that an *in loco* verification would have been necessary to further investigate not only these areas, but also to verify the other results and reduce the degree of uncertainty.

Furthermore, as previously discussed, this dissertation approached an analysis of the absolute density of the total of consumer units and per type. To exemplify the difference between an absolute and a relative numeric approach, let us think about two regions with exactly the same area and the same relative number of vacant units (Type 2 + Type 3 x 100 / Total). One area is highly verticalized, while the other has only one-story houses. Even though relative numbers might be equal, the verticalized area — the one with the highest concentration of the total of units — will also hold the highest total number of vacant units. This might explain why the Centre, the area with the highest absolute density of the total of consumer units (Map 1), also has the highest absolute densities of units per type (Map 2, Map 3 and Map 4). This pattern is also observed for the Centre results and explains why areas of interest, most of the time, are adjacent or overlap two typologies. The first one is major commercial centres: Bahia Shopping (5 and 19), Ouvidor Gallery (10 and 22), Municipal Market (3), Belo Horizonte Gallery (6), Cidade Shopping (7), Feira Shop (7), Carijós Shopping (10), Tupinambás Shopping (12), Central Building (16) and Novo Market (20). The second typology is high-rise and dense buildings: among others, there are commercial ones, such as Helena Passig (1), Joaquim de Paula (1), Bemge (1) and Acaiaca (11); and mixed-use ones, such as Maletta (2). In other words, this approach neglects utility poles which might present exactly the same relative number of Type 2 and Type 3 connections of, for instance, the pole surrounding Maletta Building. In that sense, the analysis in relative numbers might lead to smaller vacant or underutilised buildings. That is this research's next objective, which will be developed at NPGAU.

Nonetheless, the centre of Belo Horizonte is, as demonstrated by the developed method, the most vacant region of the city in absolute numbers. Even though the identified land use is mainly non-residential (Map 14), this means that the area holds a considerable potential for populational densification. In that sense, a public policy which could mobilize vacant and underutilised commercial buildings, promoting their rehabilitation and reconversion, is vital to face the Brazilian housing shortage, especially considering that the scenario of Belo Horizonte is seen throughout the majority of the country's capitals.

To conclude, it is expected that this study has also brought to light how existing information could be mobilised to inform new spatial analysis. Compared to the currently available national official data gathered in onerous field surveys, which discloses the total number of vacant houses per census tracts, the method to visualise real estate vacancy utilising electricity consumption data contributed to the process of locating the phenomenon. Indeed, the method presents a new perspective which can assist public authorities in monitoring real estate vacancy with a fine-grained spatiotemporal resolution. Similar research could be developed not only within the municipal perimeter, but also in other cities of Minas Gerais state which rely on CEMIG's electricity distribution network. With the appropriate adaptations in the data analysis process, it is very possible that the method could be replicated around Brazil and, as previously done, in other parts of the world.

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Appendix

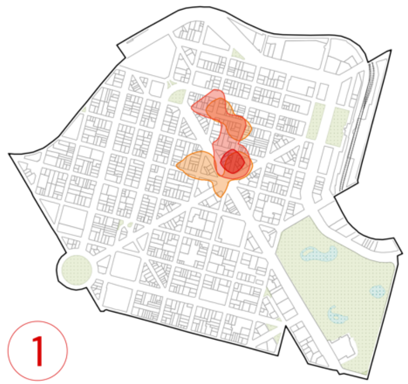
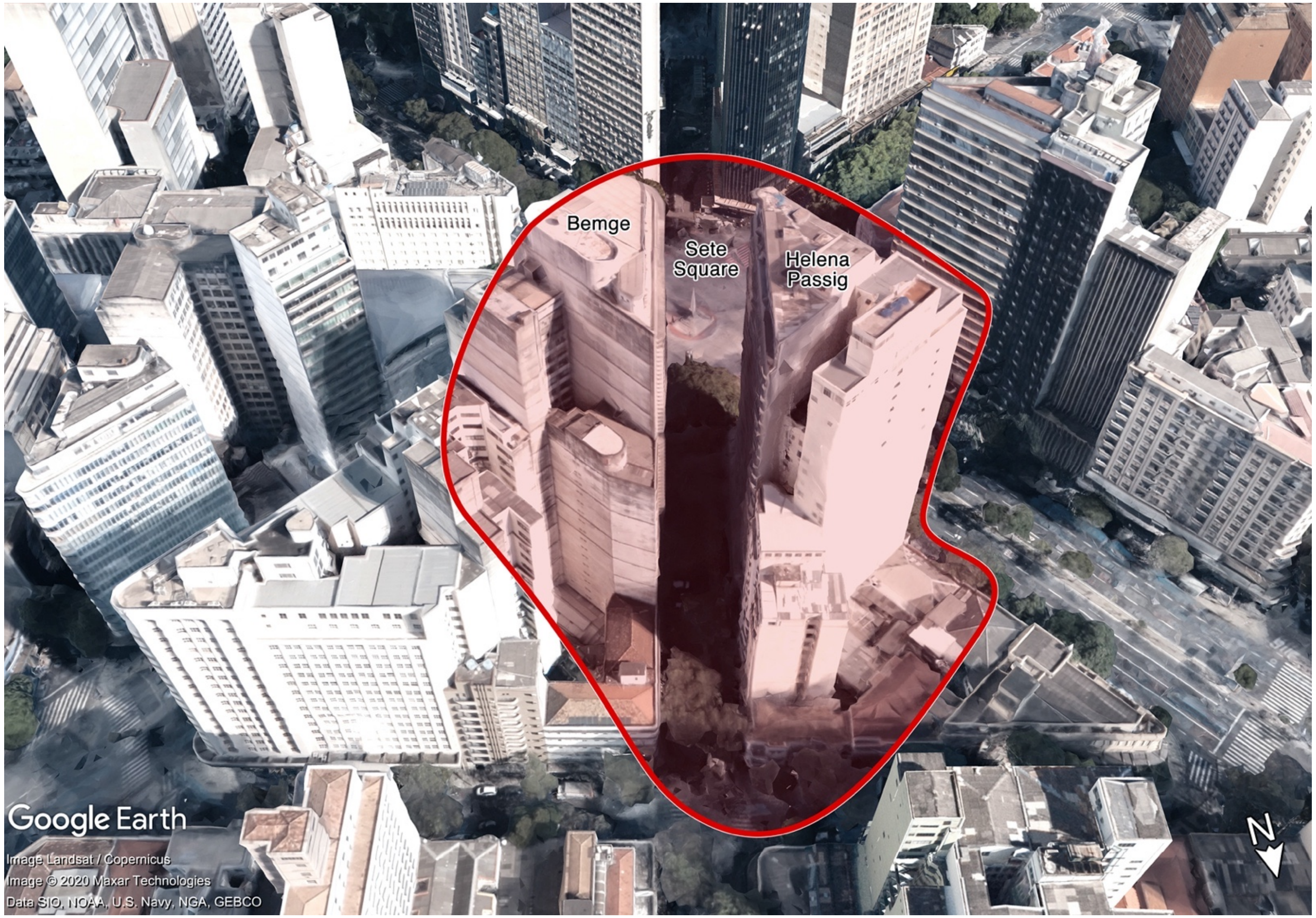


Figure 7: Area of interest 1 – birds-eye image.

Source: Google Earth [Accessed 04 September 2020]. Modified by the author.



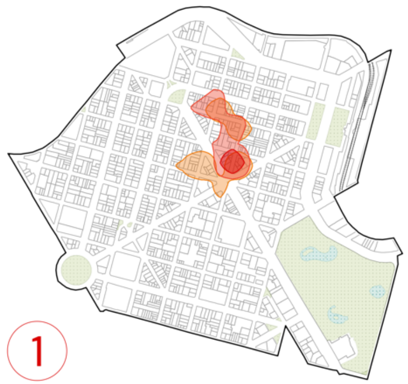


Figure 8: Area of interest 1 – birds-eye image of the “core”.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

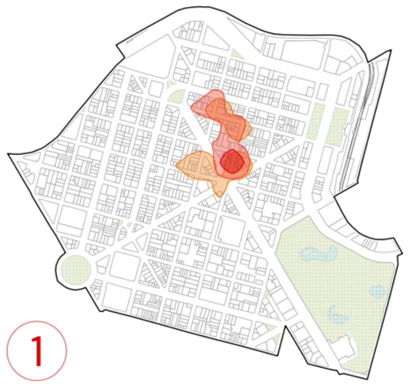


Figure 9: Area of interest 1 – Helena Passig and Bemge Buildings.
Source: Google Street View – March 2020 [Accessed 04 September 2020]. Modified by the author.

Figure 10: Area of interest 2 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 11: Area of interest 2 – Maletta Building.

Source: Google Street View – May 2019 [Accessed 04 September 2020]. Modified by the author.

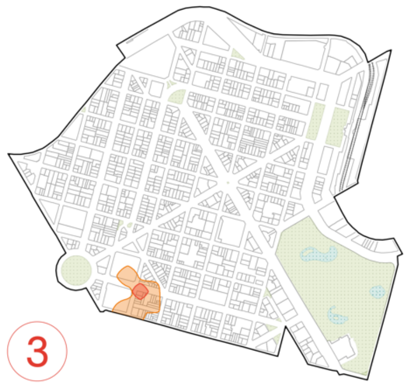


Figure 12: Area of interest 3 – birds-eye image.

Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

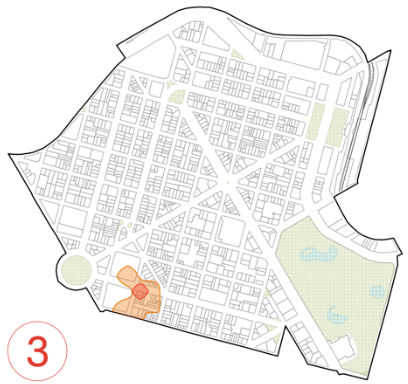


Figure 13: Area of interest 3 – street level.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

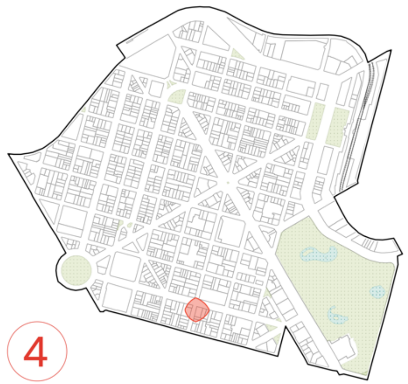


Figure 14: Area of interest 4 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

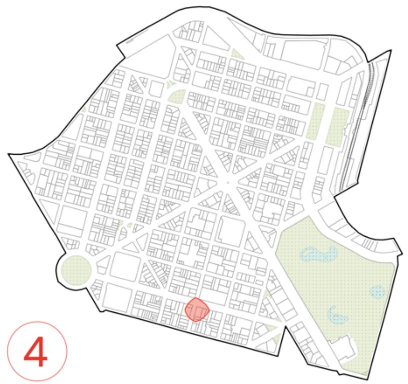


Figure 15: Area of interest 4 – street level.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

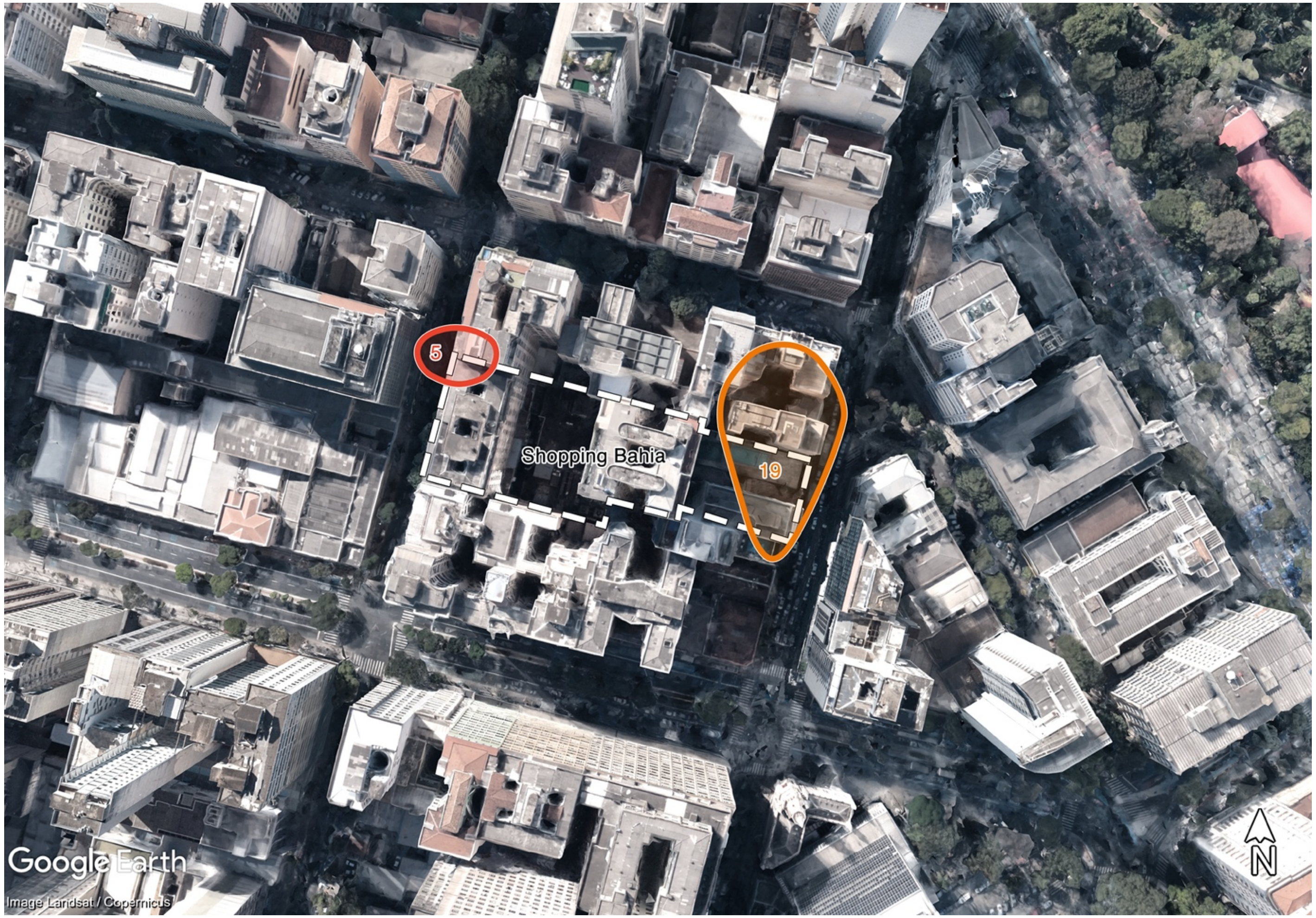


Figure 16: Area of interest 5 – birds-eye image (limit of Bahia Shopping and Area 19).
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 17: Area of interest 5 – former entrance of Bahia Shopping.
Source: Google Street View – May 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 18: Area of interest 6 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 19: Area of interest 6 – Belo Horizonte Gallery.
Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 20: Area of interest 6 – street level.

Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

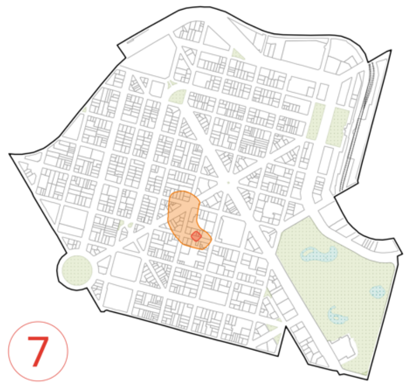


Figure 21: Area of interest 7 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

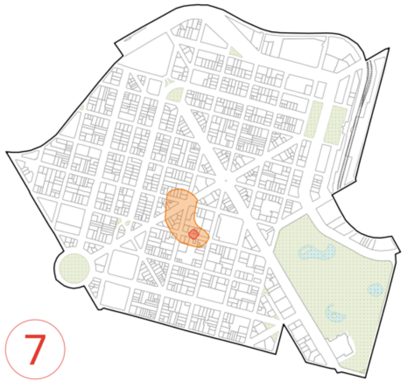


Figure 22: Area of interest 7 – entrance of Cidade Shopping.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 23: Area of interest 8 – street level.
Source: Google Street View – May 2019 [Accessed 04 September 2020]. Modified by the author.

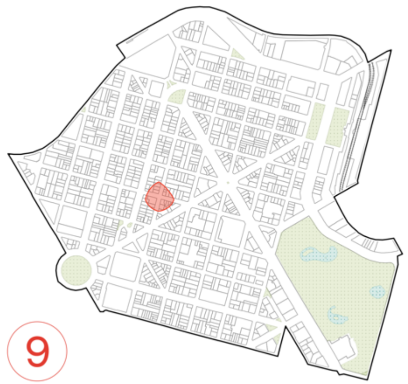


Figure 24: Area of interest 9 – birds-eye image.

Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 25: Area of interest 9 – street level.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 26: Area of interest 10 – Carijós Shopping and Ouvidor Gallery.
Source: Google Street View – June 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 27: Area of interest 11 – Acaiaca Building.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 28: Area of interest 12 – Tupinambás Shopping.
Source: Google Street View – May 2019 [Accessed 04 September 2020]. Modified by the author.

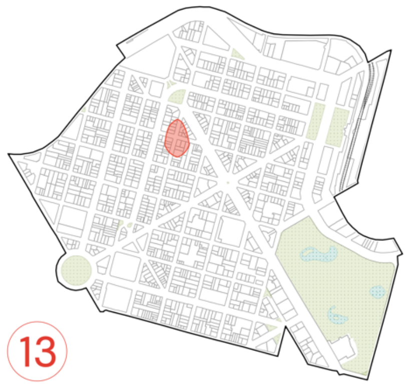


Figure 29: Area of interest 13 – birds-eye image.

Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 30: Area of interest 14 – street level.

Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.

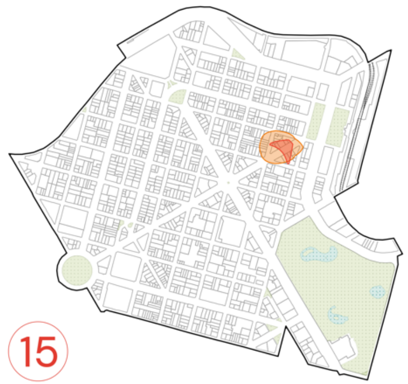


Figure 31: Area of interest 15 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

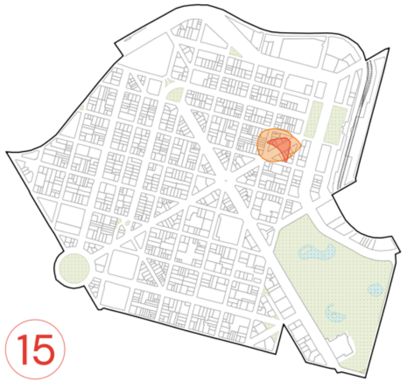


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Figure 32: Area of interest 15 – street level.
Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

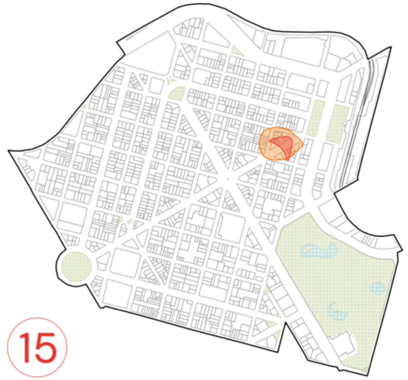

Figure 33: Area of interest 15 – street level.

Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

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Figure 34: Area of interest 15 – street level.

Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

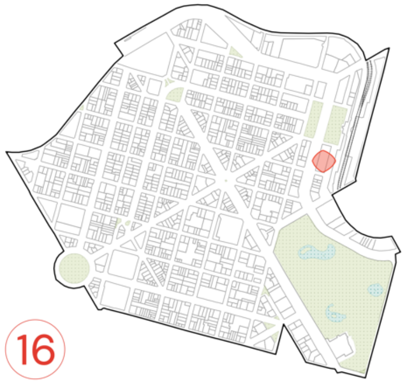

Figure 35: Area of interest 16 – Central Building.
Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 36: Area of interest 17 – street level.

Source: Google Street View – June 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 37: Area of interest 18 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

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Figure 38: Area of interest 19 – former entrance of Bahia Shopping.
Source: Google Street View – May 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 39: Area of interest 20 – birds-eye image.
Source: Google Earth [Accessed 04 September 2020]. Modified by the author.

Figure 40: Area of interest 20 – street level.
Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

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Figure 41: Area of interest 21 – street level.

Source: Google Street View – August 2019 [Accessed 04 September 2020]. Modified by the author.

Figure 42: Area of interest 22 – entrance of Ouvidor Gallery.
Source: Google Street View – April 2019 [Accessed 04 September 2020]. Modified by the author.