Journal of Urban and Environmental Engineering, v.17, n.1, p.3-12

ISSN 1982-3932
doi: 10.4090/juee.2023.v17n1.003012

Journal of Urban and Environmental Engineering

www.journal-uee.org

IMPACT OF SPECIFIC URBAN PARAMETERS TO IMPROVE PUBLIC POLICIES FOR SUSTAINABLE AND SMART CITIES - CASE STUDY IN BRAZIL

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Received 22 November 2022; received in revised form 10 September 2023; accepted 15 September 2022

Abstract: Public administrators, responsible for urban planning, face great challenges to organize and understand the large volume of data generated by cities. These are essential information for public policies. In this context, the present work aimed to analyze georeferenced data and urban parameters, focusing on improving processes related to the planning of sustainable and smart cities. Therefore, a case study was developed in Belo Horizonte. The data were analyzed based on guidelines prescribed by ISO 37.122/2019 and ISO 37.123/2019. The methodology adopted consist of identifying gaps, prioritizing urban parameters, as well as consolidating georeferenced data in a Web GIS platform to study urban problems. The analyzes led to study problems and parameters related to flooding and geological hazards (erosion and silting, landslides, groundwater contamination, and resulting from excavations) as well as their environmental and social causing and aggravating factors. After consolidating the data, it was possible to identify that the parameters (i) population density, (ii) minimum soil permeability coefficients and (iii) demarcation of preservation areas had a great impact when associated with environmental conditions (vegetation, use and occupation soil and topography). In this sense, this work contribute to improve methodologies for analyzing the urban environment with a focus on preventing and mitigating these problems.

Keywords: Smart cities; Sustainable cities; Web GIS; Urban Planning; Resilience.

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INTRODUCTION

The prominence and importance of cities in the history of humanity have never been greater than in the current moment in which we live. Such settlements, which emerged from the advancement of technologies and rules that enabled the permanence and coexistence of large groups of people, have been constantly evolving. Currently, some authors refer to the 21st century as the century of cities. Such importance can be evidenced by projections foreseen for the coming decades: in 2030, it is expected that 60% of the population will live in large metropolises; by 2050, it is estimated that this percentage will increase to 75%, reaching more than 80% by the end of the century. Today, in some developed countries, these rates of urbanization are already a reality, as in the case of the United Kingdom (Yigitcanlar and Kamruzzaman, 2018).

In this way, cities are at the center of global challenges, playing an important and decisive role in their solutions. By occupying only 3% of the earth's surface, they drive economic growth with 80% of the global GDP (Gross Domestic Product). On the other hand, they are responsible for the emission of 75% of the greenhouse gases (Kankaala *et al.*, 2018). Thus, it is clear that changes at the local level have the potential to solve these major challenges through innovation focused on increasing the efficiency of urban processes. In this sense, the demands for breaking paradigms related to the sustainability of cities were recently included in the main international agreements, among which the Sustainable Development Goals (SDGs) and the New Urban Agenda promoted by the United Nations are highlighted.

Thus, it is important that research seeks to investigate urban parameters with the potential to more relevantly influence the development of cities in their progress towards smart and sustainable cities. In Brazil, more than half of the population lives in 6% of the national territory. Only 17 municipalities, among 5,570, concentrate a population of 46.38 million people, that is, 21.9% of Brazilians, out of a total of 211.8 million inhabitants (Guimar and Szpiz, 2020). In this way, the Brazilian urban environment, as well as its growth dynamics, need to be understood so that public actions and policies are increasingly assertive.

Despite the large volume of data produced by cities, it is estimated that about 80-90% of the information collected, processed and stored are not actually used (Dold and Groopman, 2017). Within this context, the present work has the potential to contribute to the improvement of public policies.

METHODS

This is an exploratory study proposal in order to identify patterns and parameters that may be related to factors such as existing infrastructure, land use and occupation disposition, environmental and social aspects.

Thus, initially, a study was conducted based on the methodology provided for in the ISO 37.122/2019 and ISO 37.123/2019 standards, as well as an applied research using the Design Science Research (DSR) methodology that will contribute to correlating and better understanding the georeferenced urban information available. A literature review study was also made in order to contextualize and guide the research through correlated works.

Scenario selection (city)

The scenario for carrying out the study was selected among the main Brazilian cities. In this sense, Belo Horizonte was chosen, one of the main capitals of Brazil, with an estimated population of 2.5 million inhabitants. According to a survey by the Brazilian Institute of Geography and Statistics - IBGE, it is the sixth most populous municipality in the country, the third in the Southeast region and the most populous in the state of Minas Gerais (Guimar and Szpiz, 2020). In addition, the city has an up-to-date database with structured data collection methodology and has a Multiannual Government Action Plan – MGAP based on goals and indicators from the Sustainable Development Goals listed by the United Nations (UN) .

In 2013, Belo Horizonte had the fourth largest gross domestic product (GDP) among Brazilian municipalities, corresponding to 1.53% of the total wealth produced in the country (IBGE, 2016). On the other hand, Belo Horizonte is the 21st capital of the country, out of a total of 27 states, in territorial extension, with area larger than just 5 cities, which have comparatively lower economic indicators.

Contribution of the ISO standards (selection of indicators)

Using the criteria which are listed in the norms of the International Organization for Standardization (ISO) that deal with smart cities and sustainable communities, an analysis was made of the projects, programs and performance indicators adopted by the city.

Such standards establish the main indicators and parameters for smart and sustainable cities. Thus, the assumptions specifically provided for in the ISO 37.122/2019 and ISO 37.123/2021 Standards were used.

To make the diagnosis of the current condition, the standards recommend a matrix correlating objectives with the relevant areas. In this way, it must be verified, at each intersection point, which projects have already been implemented and which need to be implemented. As a result of this analysis, parameters were selected that need to be considered a priority by the administration for the improvement of public policies and analysis of relevant urban problems.

Contribution of the DSR methodology

The term Design Science Research was developed in the sixties. According to Rodrigues (2018), the first authors to use it observed the need to seek a methodical way to design artifacts and thus DSR (Design Science Research) was born. In DSR, a practical problem guides the research and, from it, other practical problems arise, which generates scientific knowledge. For Wieringa (2009), the analysis of these problems and issues generate a regulatory cycle." (Figure 1).

Thus, the DSR methodology was used to do an exploratory analysis that indicates and relates urban problems to parameters and the performance of urban indicators. For that, a model was elaborated with georeferenced information of the city. The model was built on a GIS (Georeferenced Information System) platform by overlaying existing information layers in the mapped databases. The analysis based on the methodology provided for in the ISO standards served as a guideline for the selection of: (a) smaller regions of the city to enable the comparison of indicators; (b) selection of layers and georeferenced data.

Resources used

For data organization, map assembly and analysis, the QGIS software version 3.16 was used. The official databases available for the city of Belo Horizonte were used. Figure 2, below, summarizes the steps and resources needed to carry out the research.

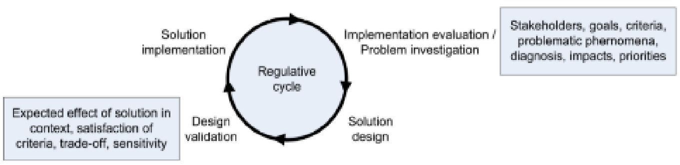

Fig 1. Cycle of the DSR methodology (Wieringa, 2009).

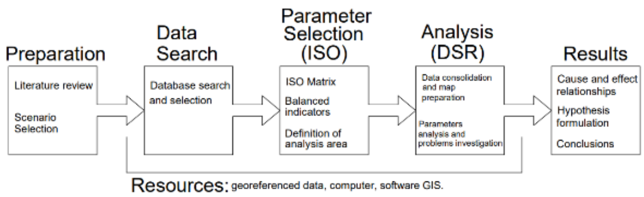

Fig 2. Flowchart of the Proposed Methodology.

Tools for Analysis of Urban Parameters

In the search for a process of continuous improvement of cities, one of the tools that has the potential to contribute is the digital modeling of cities through georeferenced systems (Faltejsek and Kocurova, 2020). The analysis presented in this work was done from the superposition of certain layers of georeferenced data, forming a model to analyze a specific problem.

Correlated Research

Several researchers have dedicated themselves to the study of the impact of urban parameters in the face of the new challenges presented to cities. In this sense, several researches, as well as the present work, made use of technologies and methodologies for georeferenced modeling of cities.

The works prepared by Adachi *et al.* (2014), Kyba *et al.* (2021) and Poslonec-Petri, Vukovi and Frangeš, (2016) had as main objectives to produce knowledge about cities. Analyzes of environmental parameters such as ventilation, street lighting, and noise were carried out with a focus on mitigating urban problems.

The works done by Fernández Moniz *et al.* (2020), Murshed *et al.* (2018), Bhattacharya *et al.* (2020), Casella, Franzini and De Lotto (2016) dealt with solutions based on information georeferencing systems to improve the management of urban infrastructure.

Software used for research

GIS software (georeferenced information systems) can be used to manage smart cities as integrated platforms that allow collecting, storing, managing, analyzing and visualizing spatial information. About 80% of modern city management activities are related to georeferenced data analysis. In this context, a digital city model is an essential support tool for smart cities (Lv *et al.*, 2018).

RESULTS

Analysis based on iso methodology

The databases used in the present work come from surveys carried out by the Municipality of Belo Horizonte and by other interested parties. In addition to the city's georeferenced data, the City of Belo Horizonte makes available, on its internet portal, projects and programs that aim to contribute to the city's evolution in order to pursue the Sustainable Development Goals (SDGs) established by the UN.

To prepare a diagnosis matrix, as provided for in ISO 37.122 and 37.123, the Pluriannual Government Action Plan - MGAP (2018-2021) was analyzed, in addition to other documents (PMBH, 2021e). Among the actions provided for in the aforementioned plan, the city listed 45 strategic development projects. The projects considered strategic include the areas of: safety, health, environmental sustainability, urban mobility, education, culture, social protection, food security, sports, service to citizens and improvement of public management, economic development, tourism, housing, urbanization, regulation and urban environment.

Of these 45 strategic projects, the public administration prioritized 13 projects that are considered transformative for the city. Transformative projects are focused on the following priority areas: culture, economic development, education, housing, mobility, social protection, health, safety and environmental sustainability (PMBH, 2021e).

Indicator analysis

The projects in progress in the municipality have their performance monitored, according to a specific methodology for calculating each of the 158 indicators detailed in a Monitoring Report of the 17 Sustainable Development Goals of Belo Horizonte. Through this report, a balance analysis of the criteria for monitoring the physical goals of the projects, elaboration and distribution of programs sponsored by the municipality and the budget destined to such actions was make.

To analyze the distribution of indicators, the DSR methodology was used, as well as the benchmarks developed by Ahvenniemi et al. (2017). In this way, an analysis of the indicators and parameters adopted by the main standards and methodologies of evaluation and ordering in rankings of smart cities was done. The parameters were classified into 3 impact categories, which take into account the 3 dimensions of sustainability: social, environmental and economic.

In the work performed by Ahvenniemi et al. (2017) it was noticed that, in the main standards and evaluation methodologies of smart cities and urban sustainability, there are different distributions of monitoring indicators, as can be seen in **Table 1**. In this context, different distributions of indicators are foreseen for so-called smart cities and for cities focused on sustainability.

Table 1. Distribution of indicators for sustainable and smart cities. Adapted from Ahvenniemi *et al. (*2017).

Impact	Percentage of Indicators (Sustainable cities)	Percentage of Indicators (Smart cities)
Environmental	43%	20%
Economic	10%	28%
Social	47%	52%

When analyzing the tables above, it appears that for a sustainable city there is a greater focus on the indicators of the environmental impact category, which represent 43% of the monitored indicators, while for cities of the smart type, on average, the environmental indicators represent only 20% of all indicators used. There is also a relevant difference in the number of indicators related to economic impacts, while in a sustainable city, such indicators are 10% of the total, in a smart city they correspond to 28%. This may suggest some conclusions, which corroborate the studies realized by several authors: the focus of smart cities is more concentrated in the search for better indicators of social and economic impacts (Yigitcanlar and Kamruzzaman, 2018), (Anthopoulos, 2017), (Ahvenniemi et al., 2017), (Zygiaris, 2013), (Yamamura *et al.,* 2017).

To assess the distribution of indicators adopted by Belo Horizonte for monitoring its public policies, the following MGAP monitoring reports (2018-2021) were used: (i) Report on Physical Goals by Program and Action (PMBH, 2021c); (ii) Synthetic Report of Programs by SDGs (PMBH, 2021b); (iii) Indicators per SDG (PMBH, 2021a) and; (iv) Financial Report by Program and Action (PMBH, 2021d). The distribution found for these parameters in Belo Horizonte can be seen in **Table 2**.

In this way, when evaluating, above all, the number of physical goals and the financial resources allocated in these programs, it is noticed that the profile of the city of Belo Horizonte is more similar to that of a sustainable city. Tables 1 and 2 show that both smart cities and sustainable cities prioritize investments in social impact projects. For sustainable cities, investment in environmental initiatives is superior to economic ones. For smart cities, investments in economic projects are slightly higher than those invested in environmental projects. Thus, table 3 indicates that in the city of Belo Horizonte, investments are more focused on projects with social and environmental impacts, which indicates the city's effort to develop towards a city with a sustainable profile.

Table 2. Distribution of parameters (goals, programs and resources) across categories of sustainability impacts (PMBH, 2021a), (PMBH, 2021b) and (PMBH, 2021d).

Impact	Belo Horizonte Physical Goals by Program	Belo Horizonte Programs by SDGs	Belo Horizonte Financial Resources by Program
Environmental	24%	34%	29%
Economic	16%	34%	14%
Social	60%	32%	57%

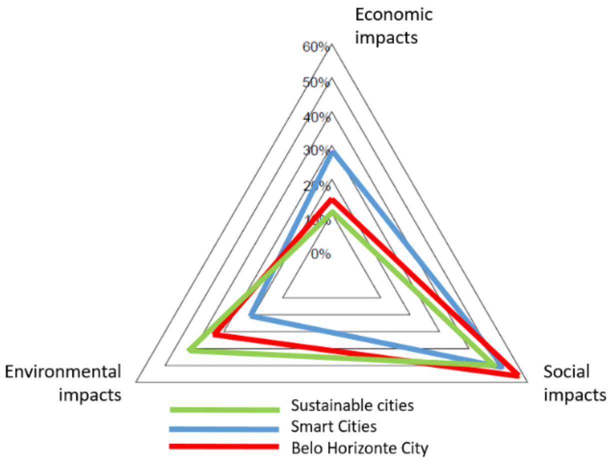

Fig. 3 Comparison between Indicators of Smart Cities / Sustainable Cities / Belo Horizonte (Ahvenniemi et al., 2017), (PMBH, 2021a), (PMBH, 2021b) and (PMBH, 2021d).

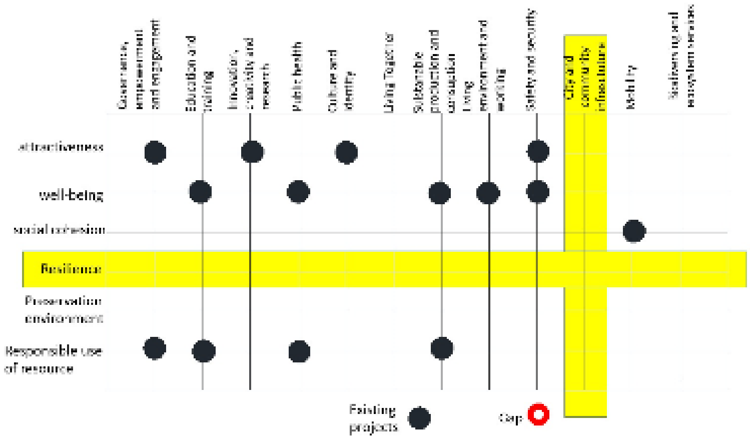

Fig. 4 Matrix for Diagnosis and Project Prioritization/Identification of Gaps among the Transformative Projects of Belo Horizonte. Prepared by the author based on (PMBH, 2021c).

Thus, considering the profile of priority actions and investments promoted by the Municipality of Belo Horizonte, it can be concluded that the main problems tackled have causes related to social and environmental aspects and parameters.

Analysis of the Multiannual Plan of Government Actions (Parameters of ISO standards 37.122 and 37.123)

In view of the previous findings, an analysis of the Multiannual Plan of Governmental Actions was realized based on the methodology adopted by the ISO standards. Thus, the reference matrix for this research was prepared considering two axes: (i) vertical, which includes 6 objectives (Attractiveness, Well-being, Social Cohesion, Resilience, Preservation and Improvement of the Environment and, Responsible Use of Resources) and, (ii) horizontal, covering 12 areas (Governance, Education, Innovation, Public Health, Culture, Coexistence, Economy and Sustainable Consumption, Living and Working Environment, Infrastructure, Mobility, Ecosystem Services, Infrastructure, Mobility, Protection and Security). Thus, the existing transformative projects in the Belo Horizonte's MGAP were launched in the matrix (figure 4) in order to identify priority areas that configure gaps. Within the matrix, areas of action were prioritized that could promote greater balance, within the concept of sustainability, in the selection of projects and urban environmental parameters (region highlighted in yellow).

In this way, it was possible to identify gaps in the transformative projects, especially in relation to:

a) Provide greater resilience, promoted through the implementation of new infrastructure and monitoring technologies;

b) Promote preventive urban planning actions that can guarantee greater safety for the population in the face of public calamity situations;

c) Promote preparedness and civil defense actions that can guarantee greater security for the population in the face of public calamity situations;

d) Promote the expansion and adaptation of urban infrastructure in order to increase the efficiency of city processes (including mobility);

In this sense, it was found that the city's development priorities should be focused on the bases that will allow the evolution of the urban environment, being mainly those related to the development of resilience through adequate infrastructure that provides protection and security to the population, in addition to research focused on the prevention and mitigation of disasters caused by extreme weather events. Thus, according to the evaluation methodology of ISO standards, it is concluded that three main parameters (infrastructure, mobility and resilience) should demand greater attention from the municipal administration.

Elementary Basins and Sanitary Avenues

In Belo Horizonte, one of the most relevant problems and causes associated with these three urban parameters (infrastructure, resilience and urban mobility) is the design and execution of urban works aimed at the implementation or maintenance of sanitary avenues.

This type of solution was widely used in the city of Belo Horizonte. The public opinion of citizens is in favor of this type of solution, which may have facilitated its dissemination. According to research realized by Macedo & Magalhães Junior (2011), the sanitary avenue is an icon appreciated in the urban landscape by approximately 50% of the population that participated in a survey applied through questionnaires in Belo Horizonte. According to the study, the main reason for the preference for sanitary avenues was the more efficient road access and the increase in commercial activities along these new roads. In this regard, the social, environmental and infrastructure area of influence of these avenues coincides with the elementary watershed regions.

Analysis of georeferenced nformation

When analyzing the georeferenced information available in the IDE-BHGeo municipal database, it is observed that Belo Horizonte has approximately30%of streams channeled into closed channels, that is, they were replaced by sanitary routes. Figure 5 presents the covered watercourses channeled (sanitary roads) and the uncovered watercourses (BHGEO, 2021). When analyzing such figures, one can see the coincident route between the canalized structures and the main avenues of the city. The accumulated length of these urban roads that were covered corresponds to approximately 27% of the main roads in the city (avenues and streets with a length of more than 2.0 km).

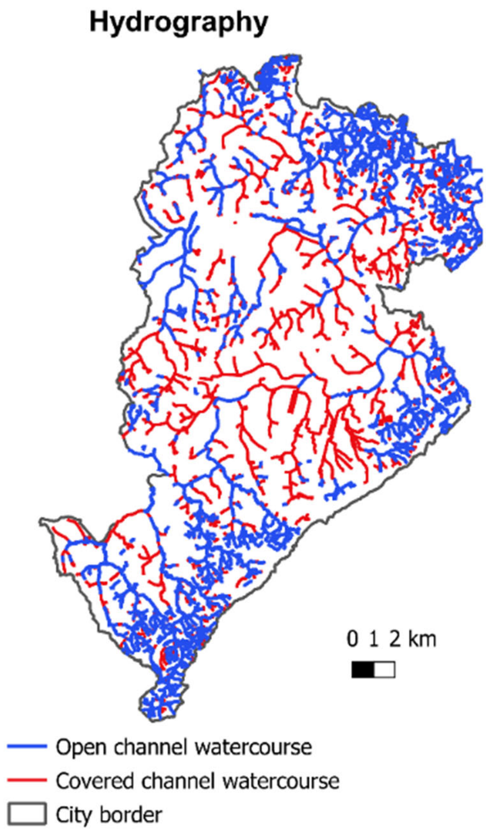

Fig. 5 Map containing the watercourses of Belo Horizonte: covered channeled and uncovered watercourses. Prepared by the author based on BHGEO (2021).

Exploratory analysis of urban problems:

Thus, the object to be analyzed through the Design Science Research methodology were the problems associated with geological and flood risks (erosion and silting, landslides, contamination of groundwater and resulting from excavations), as well as their causing and aggravating factors. environmental and social.

For the elaboration of the study, the urban soil was divided into elementary watersheds. The choice to divide the city into basins, for analysis, was due to the fact that it provided the delimitation of the city in regions with similar size, problems and characteristics. It is expected that it will be a proposal of division compatible with the analysis of the selected problems (geological and flood risks), since the region of influence of the sanitary avenues coincides with the areas of influence of the bodies of water.

When analyzing the IDE BHGeo database, it can be seen that the basins are regions larger than the neighborhoods, and that they coincide with the delimitation of the surroundings of the largest road corridors in the city, thus grouping areas with similar characteristics related to environmental aspects (topography, area permeable, geological and hydrological risk regions), infrastructure (road structure, utilities, size of buildings) and social (economic activities, economic class of residents, land use). Figure 6 presents maps that indicate the elementary basins of the city of Belo Horizonte, with the main existing water courses. **Fig. 7** presents the demographic distribution of the population along these basins.

Fig. 6 Map containing the arrangement of elementary basins (watersheds). Prepared by the author based on BHGEO (2021).

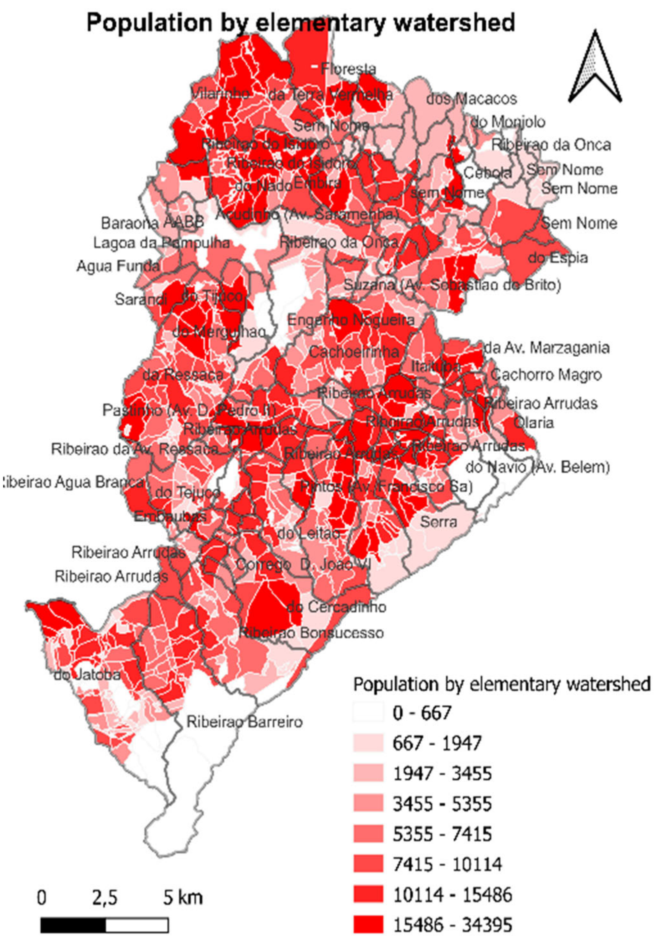

Fig. 7 Map containing the population density. Prepared by the author based on BHGEO (2021).

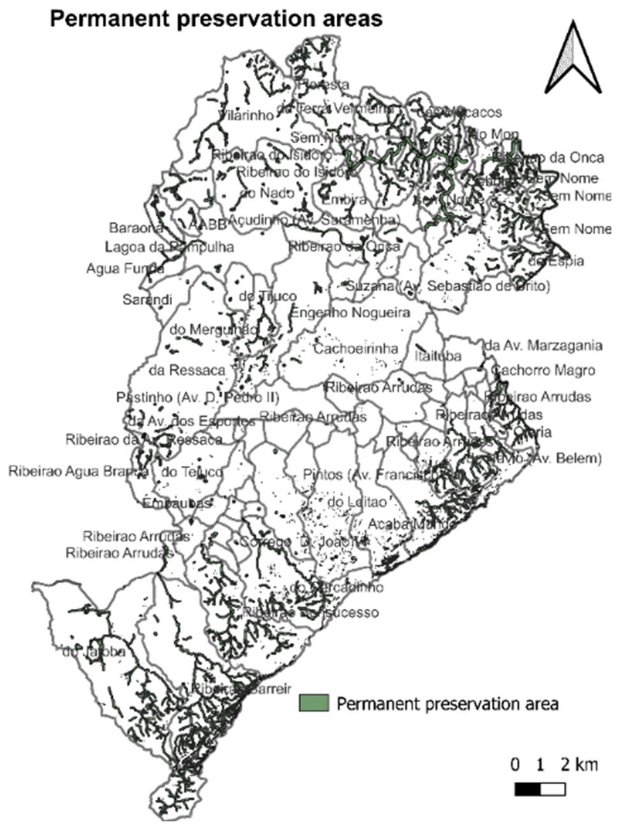

Fig. 8 Map containing the disposition of permanent preservation areas. Prepared by the author based on BHGEO (2021).

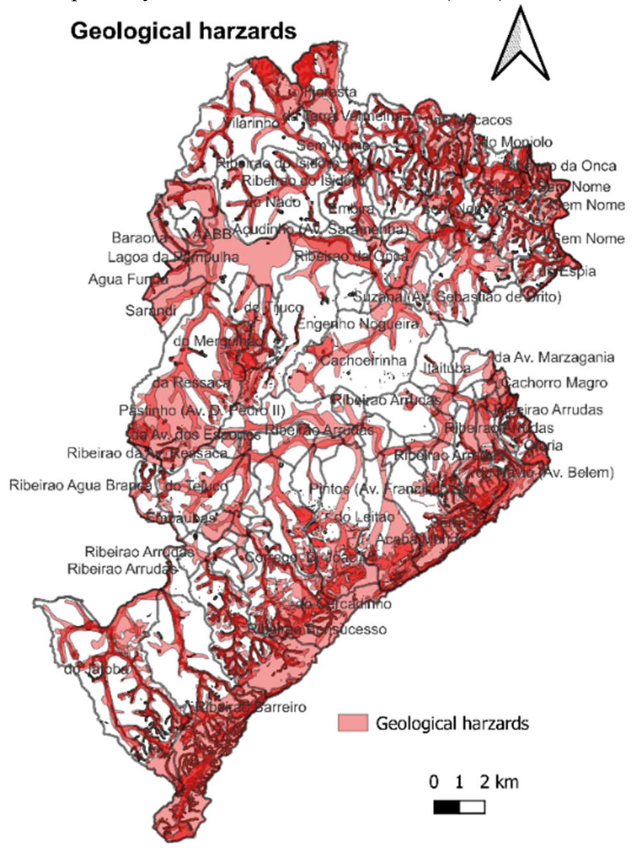

Fig. 9 Map containing the disposition of geological risks. Prepared by the author based on BHGEO (2021).

In this way, it is expected that the analysis of these regions can allow a better understanding of the city's infrastructure and resilience problems, contributing to an improvement in urban planning. When analyzing the maps of geological risks (Figure 9) and permanent preservation areas (Figure 8) it can be seen that the preservation regions are inferior to those that delimit the risk areas. This initial finding may suggest that the conservation areas are insufficient to deal with mitigating geological hazards.

After analyzing the georeferenced data, it was possible to verify that Belo Horizonte has approximately 175 km², that is, 42% of its territory is susceptible to at least one type of geological risk. Thus, it can be said that only 58% of the city's urban land is located in regions not subject to such risks. In some regions more than one type of risk is present and they are overlapped, which can aggravate problems and cause geotechnical accidents. The types of risks existing in the city are distributed as can be seen in **Table 3**.

Table 3. Types of geological hazards existing in the municipality area. Prepared by the author based on BHGEO (2021).

Geological Hazard	Area		
	Susceptible area (km²)	Total risks (%)	Urban territory (%)
Floods	5.73	2%	2%
Groundwater contamination	136.18	49%	41%
Associated with excavations	79.80	29%	24%
Slip	29.47	11%	9%
Erosion and silting	28.54	10%	9%

The **Table 4** presents the 10 elementary watersheds with the largest area vulnerable to geological hazards. Figure 10 shows areas and their minimum permeability coefficient required by the City Hall for approval of projects along the urban territory. The Minimum permeability coefficient is an important parameter to guide public policies with the objective of allowing water infiltration into the soil and preventing flooding. **Fig. 12** also presents the regions occupied by slums in risk areas.

Belo Horizonte's georeferenced data indicate that 95% of the areas occupied by towns and slums, equivalent to approximately 15.6Km², are susceptible to geological hazards, in addition 12% of these occupations are in permanent protection areas, which should be preserved for neutralize geological hazards. **Fig. 11** shows the most vulnerable elementary watershed (basins).

When analyzing the data from the basins with the highest risk area, the most vulnerable areas are also the most populated. Belo Horizonte has 98 areas of elementary watersheds, and, among the 10 that have the highest risk area, 6 are among the most populous in the city, as can be seen in Table 5.

Table 4. Elementary watershed with higher risk areas. Prepared by the author based on BHGEO (2021).

Order	Watershed	Area at risk (Km²)	Watershed area (Km²)	Risk area (%)
1	Ressaca	13.44	20.51	65.53%
2	Barreiro	13.38	21.10	63.40%
3	Jatobá	9.84	23.37	42.11%
4	Cercadinho	9.27	12.12	76.49%
5	Bonsucesso	8.33	11.77	70.76%
6	Arrudas*	8.26	20.49	40.31%
7	Vilarinho	6.68	16.04	41.66%
8	Onça	6.57	10.34	63.56%
9	Pampulha	6.35	8.03	79.11%
10	Leitão	5.61	10.61	52.90%

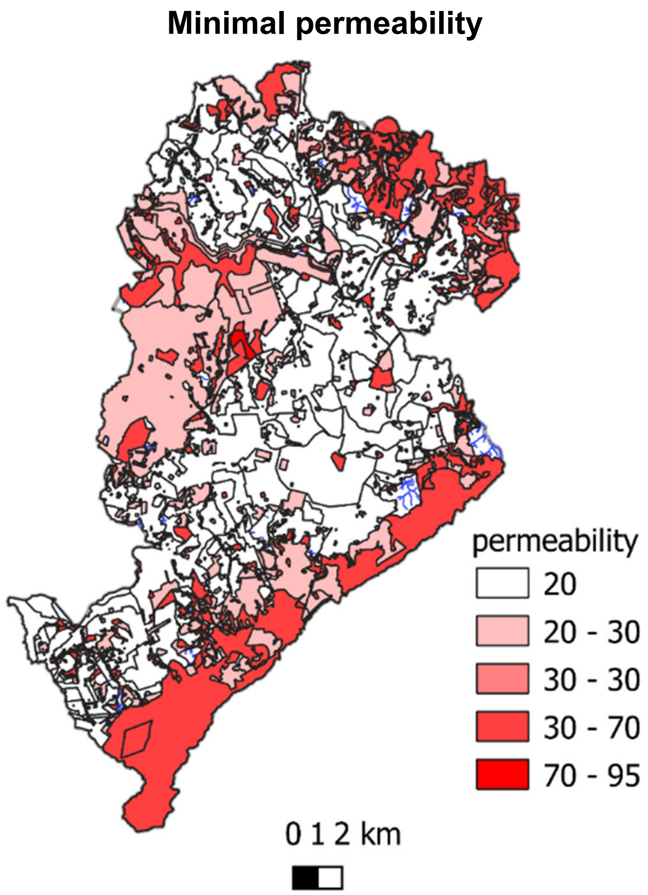

Fig. 10 Map containing the disposition of the minimum permeable areas rate. Prepared by the author based on BHGEO (2021).

Table 5. Most populous elementary watersheds. Prepared by the author based on BHGEO (2021).

Order	Watershed	Population (inhabitant)	Population (%)
1	Ressaca	177,258	7.13%
2	Cachoeirinha	173,986	6.99%
3	Jatobá	158,876	6.39%
4	Vilarinho	158,273	6.36%
5	Nado	152,751	6.14%
6	Leitão	108,729	4.37%
7	Acaba Mundo	74,968	3.01%
8	Barreiro	74,582	3.00%
9	Piteiras	73,929	2.97%
10	Cercadinho	73,732	2.96%

DISCUSSION

The analyzes done based on the methodology provided for in the ISO standards and on the work carried out by Ahvenniemi *et al.* (2017) directed the focus of the study to problems related to resilience and the infrastructure of sanitary avenues in the evaluated city. In this sense, the comparative analysis between regions of elementary watersheds (regions affected by sanitary avenues) was

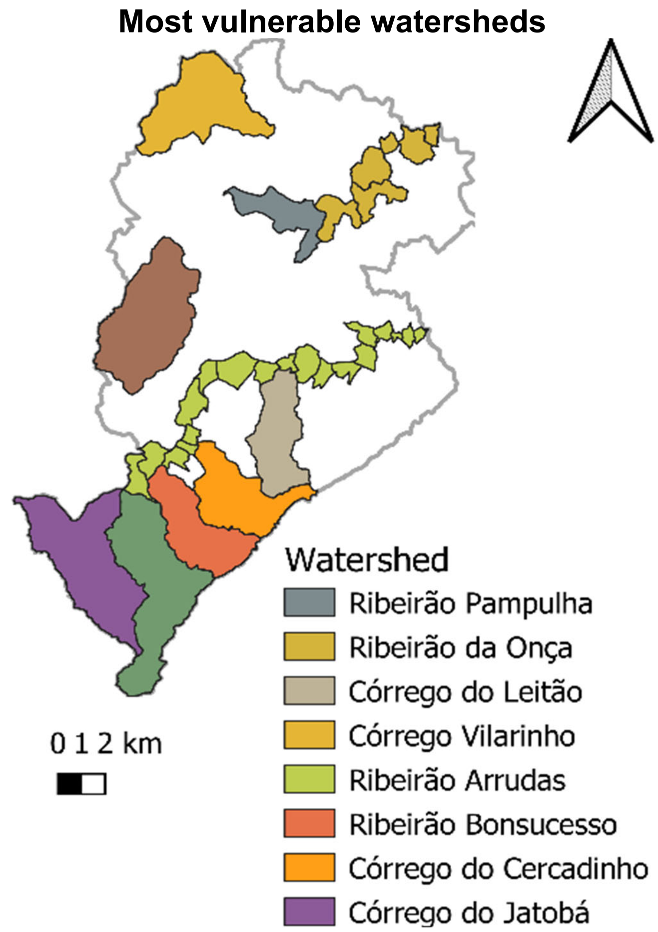

Fig. 11 Map containing the most vulnerable elementary watershed (basins). Prepared by the author based on BHGEO (2021).

the procedure used to analyze problems related to hydro-geological risks. Therefore, the Web GIS tool (QGIS) proved to be useful, as it allowed the handling and organization of georeferenced data to enable the necessary analyses. It was also possible to identify that a large part (95%) of the areas occupied by slums, lacking investment in infrastructure, are in risk areas.

It should also be noted that part of these occupations are in areas that, by law, should be preserved. On the other hand, it was possible to perceive that the public administration has implemented strict criteria in the requirements for guaranteeing soil permeability in regions more susceptible to risks. In this way, over the years, there may be a reduction in the implementation of projects that entail the waterproofing of the land in these regions.

The study also highlights the need to reassess solutions widely used in Brazil, such as channeling streams and implementing sanitary avenues. This type of solution is still designed for most Brazilian cities. However, in the last 50 years, investments in urban infrastructure related to sewage collection and treatment were insufficient. These deficit investments compromised the environmental performance of cities, directly affecting water resources (Macedo & Magalhães Junior, 2011). As a consequence, one of the liabilities of Brazilian cities was the deterioration of water courses and the potentializing of hydro-geological risks.

CONCLUSIONS

The study indicated that the analysis of urban problems with the consolidation of information, through the methodologies used (ISO 37.122; 37.123 and DSR), allowed a good preliminary assessment of urban problems of great impact. In this sense, it was possible to identify regions with similar environmental and social problems and characteristics, allowing them to be compared and ordered by intensity. In this context, the population density parameter appears as a relevant parameter when associated with environmental conditions (characterization and delimitation of risks and regions of vulnerability, regions of elementary basins, infrastructure for channeling water courses). Other parameters of great importance were the instrumental ones that guide public policies, such as minimum soil permeability coefficients for new projects and the delimitation of permanent preservation areas.

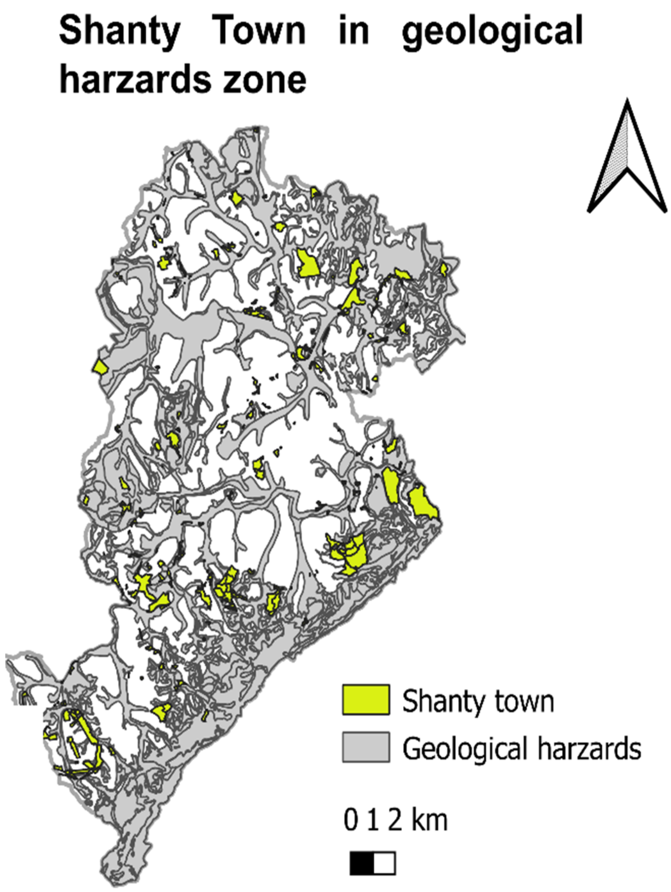

Fig. 12 Map containing the disposition of the minimum permeable areas, the most vulnerable elementary basins and villages and slums in risk areas. Prepared by the author based on BHGEO (2021).

The parameters analyzed converged to the specific analysis of urban resilience and infrastructure problems, however the methodologies used in the work can be used to analyze other types of urban problems. Similar studies will allow better results when associated with data in adequate quantity and quality.

The case study done did not intend to carry out an exhaustive and complete analysis of specific problems, since such problems are highly complex and need to be studied considering more variables, data and indicators. Anyway, it was possible to validate guidelines that can be used to study the relevance of urban parameters focusing smarter and more sustainable cities.

ACKNOWLEDGEMENT The authors are grateful for the support and assistance provided by PPGEC / CEFET-MG to the research group and the scientific initiation program.

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