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Proposal of a Multicriteria Method to Implement New Primary Health Care Units - a Case Study in São Carlos - SP

Proposta de um Método Multicritério Para Implantação de Novas Unidades de Atenção Primária à Saúde – Estudo de Caso em São Carlos - SP

Lucas Brandão Monteiro de Assis [1] e Paulo Cesar Lima Segantine [2]

1 University of São Paulo, Department of Transportation Engineering, São Carlos-SP, Brazil. lucasbrandaoma@gmail.com
ORCID: https://orcid.org/0000-0002-8338-8535
2 University of São Paulo, Department of Transportation Engineering, São Carlos-SP, Brazil. pclsegantine@usp.br
ORCID: https://orcid.org/0000-0003-1012-0666

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Abstract: Primary Health Care (PHC) is understood as the user's first contact with the Brazilian health system. The planning of PHC units is usually done based on political decisions, which neglect technical aspects related to the theme. The general objective of this study is to present a multicriteria method to assist in planning the implantation of new PHC units, through technical and objective criteria. Then this method is put into practice in the city of São Carlos - SP. The study used as the main tool the Geographic Information System (GIS), and evaluated the quality of six criteria, which are: (1) service area; (2) spatial constraints; (3) risk of natural events; (4) public transportation supply; (5) population distribution; and (6) average income. Each criterion was based on a series of indicators with clear definitions that allowed for the assignment of values according to the theme of the criterion. Each criterion culminated in a thematic map, which, when combined through a raster calculator, allowed the general classification of the study area and the viability of implanting new PHC units. The proposed method proved to be a technical and objective tool, capable of helping in the planning of new PHC units. This is exemplified in the case study in the city of São Carlos-SP.
Keywords: Primary Health Care. Geographic Information System. Implantation of health facilities. PHC's facilities.

Resumo: A Atenção Primária à Saúde (APS) é compreendida como o primeiro contato do usuário com o sistema de saúde brasileiro. O planejamento das unidades de APS, geralmente, é feito com base em decisões políticas, que negligenciam aspectos técnicos relacionados ao tema. O objetivo geral deste estudo é apresentar um método multicritério para auxiliar no planejamento de implantação de novas unidades de APS, por meio de critérios técnicos e bem definidos. Este estudo também se propõe a aplicar método proposto na cidade de São Carlos - SP. A principal ferramenta deste trabalho foi o Sistema de Informação Geográfica (SIG), por meio do qual avaliou-se a qualidade de seis critérios, (1) área de serviço; (2) restrições espaciais; (3) risco de eventos naturais; (4) oferta de transporte público; (5) distribuição populacional; e (6) renda média. Cada critério se baseou em uma série de indicadores com definições claras que permitiram a atribuição de valores conforme o tema do critério e culminou em um mapa temático. A combinação dos mapas temáticos de todos os critérios, por meio de uma Calculadora *Raster*, possibilitou a classificação geral da área de estudo, quanto a viabilidade para implantação de novas unidades de APS. O método proposto se mostrou como uma ferramenta técnica e objetiva, capaz de auxiliar no planejamento de novas unidades de APS. Isso é exemplificado no estudo de caso na cidade de São Carlos– SP.
Palavras-chave: Atenção Primária à Saúde. Sistema de Informação Geográfica. Implantação de equipamentos de saúde. Unidades de APS.

1 INTRODUCTION

The Unified Health System (SUS), the Brazilian health system, is seen as one of the most complex and comprehensive health systems in the world due to the guarantee of integral, universal, and free access to more than 100 million inhabitants (BRASIL, 2012).

The SUS proposition is to guarantee access to health care, for the totality of the Brazilian population, , offering from the simplest care to the most complex procedures. The SUS is considered one of the citizen's right and one of the State's duty (CARVALHO, 2013; SALDIVA; VERAS, 2018).

The SUS management is part of the responsibilities of all spheres of government: municipal, state, and federal. However, each power has different financial and operational roles in public health. The Ministry of Health corresponds to the federal management of SUS and it is responsible for financing half of the resources spent on public health and formulating national health policies, while the execution of the proposed actions is done by state and municipal governments, as well as NGOs, foundations, companies, etc (BRAZIL, 2009).

The care provided by SUS is classified into three levels of attention that differ according to the degree of technology and complexity that the care requires. These three levels are called: Primary Health Care (PHC), which covers care of lower technological complexity and serves as the first access for patients into the SUS, being offered in Family Health Units (USF) and Basic Health Care Units (UBS); Secondary Health Care (SHA), in which the procedures require medium technological complexity, usually being provided by Emergency Care Units (UPA); and Tertiary Health Care (THA), the level that requires greater technological density and, usually, happens in hospitals and specialized centers (MENDES, 2011).

Often, the expression "primary" in PHC is confused as something ordinary or common, however, in this case, this expression refers to the first contact of the user with the SUS, and also to the basis for the health public system. Even with its low technological complexity, PHC is responsible for solving 90% of the problems that are presented to it, and also for the orientation of the patients into the SUS services (MENDES, 2004, 2011).

Despite being so important, PHC units, as well as the other levels of care, do not have well-defined criteria and rules to guide their implementation. There is a lack of guidance from administrative bodies, which causes the deployment of new units to be the result of decisions of mayors, health secretaries, councilors, and requests from the population, making the decisions without any study and technical evidence. The implementation process of new health units, usually, happens in places and buildings that already belong to the municipalities, even if these locations are not the most feasible for providing the service (DREUX, 2004; MORAES, 2013; NEVES, 2015).

Although, many studies relate the spatial aspects of health units that can contribute to their planning, the lack of conformity concerning the scales of analysis and the parameters that should be followed, hinders the use of these studies (DREUX, 2004).

Therefore, considering that there is a lack of methodologies and indications for the planning of PHC units and there are several studies addressing the spatial issue of public health facilities, this study aims to propose a method to identify the most feasible locations for the implementation of PHC units, to assist in the planning of these units, based on six criteria drawn from the studies of Ferrari (1977), Gouvêa (2003), Colaço (2011), Goudard et. al (2015) and Neves (2015).

2 PUBLIC HEALTH UNITS' PLANNING

The planning of the Brazilian health equipment is usually based on the analysis of the radius of coverage of health units, the demographic density of the region, or the epidemiological information of the municipality, measures considered too weak for the definition of the locations to the new health units (NEVES, 2015).

However, the spatial issue of these units has already been the subject of several studies that identified the main aspects that influence and are influenced by the distribution of new public health equipment.

Ferrari (1977) divides the urban planning process into spatial units such as residence, neighborhood, sector, metropolitan center, and others, and relates the planning of public equipment according to the needs of each unit. For the author, the health centers are units that should serve the population with lower income and should be located in its neighborhoods, and the demand to be fulfilled is related to the built area so that posts of 200 m² of the built area should serve a population of 6,000 inhabitants, while posts of 300 m² could serve up to 12,000 inhabitants.

For Santos (1988), the health posts should serve the neighborhoods and be destined to frequent and immediate attendance, following a dimensioning of 1,000 m² of land and 200 m² of building, which can be enlarged depending on the need.

Gouvêa (2003) evaluates the layout of the health posts and centers and considers that both should serve the neighborhoods, due to their basic care feature. For the author, health posts are characterized as equipment for urban areas with low population density (up to 50 inhabitants/ha) or rural areas, sized to serve up to 3,000 inhabitants, with a minimum land area of 360 m² and a radius of influence of 8,000 m maximum. While health centers should be implanted near residential areas with a good supply of public transportation, there should be one unit for every 30,000 inhabitants, with a minimum land area of 2,400 m² and a maximum influence radius of 5,000 m.

In the international scenario, Colaço (2011) shows that countries like France and Portugal have rules for each type of health unit, basing their planning on the population characteristics. Other countries, like the United States and Australia, leave these criteria to the entities responsible for planning the equipment, defining rules only for the size of the buildings according to the level of service offered. For the author, this difference between the countries' regulations is a direct consequence of the differences between the healthcare models, since the United States' healthcare service involves the participation of private entities, that are responsible for the implementation of marketing studies.

Colaço (2011), in her study, still indicates that countries such as Australia, the United States, Finland, France, Portugal, and countries west of the Pacific, have good health indicators and great geographic diversity. In these countries, the health equipment planning, it considers aspects such as (a) age structure of the population; (b) population density; (c) areas of influence; (d) travel time to the equipment; (e) road network access and by public transportation; (f) soil characteristics; (g) surrounding equipment; (h) areas subject to natural events; (i) infrastructure available on site; (j) terrain characteristics.

In Brazil, the implementation of UBS is defined by the Ministry of Health (BRAZIL, 2014) as follows:

> "The choice of the land is the responsibility of the Contracting agency, which must be responsible for meeting the requirements for approval of the land, namely:
> Dominiality on the part of the interested body;
> Appropriate dimensions for the installation of the defined UBS Size (for UBS Size I - minimum of 30mx30m, for UBS Size II - minimum of 35mx30m, for UBS Size III - minimum of 39mx33m and for UBS Size IV - minimum of 49mx33m);
> Maximum slope of 3%;
> Conditions of access to the site;
> Internal accessibility of the site;
> Availability of basic infrastructure (water, power, sewage);
> Urban legislation in effect;
> Population;
> Condition of the surroundings, aiming at visual, acoustic and olfactory hygrothermal comfort
> Availability of labor and construction materials in the region;
> Financial and economic feasibility;
> Physical-environmental constraints of the site.
> Land with a steep topography should be avoided, as this poses risks of flooding, alluviation, and landslides. Also, near high voltage power lines, cemeteries, gas stations, airports, slaughterhouses, garbage dumps, and high traffic roads. According to the RDC n°50 it is forbidden to locate UBS in areas near garbage dumps, noisy and/or polluting industries." (translated from BRAZIL, 2014 p.17)

Goudard et al. (2015) evaluated the spatial distribution of UBS in Joinville-SC through location models of CIPLEX software, considering 10 criteria, which are: (1) average cost for the equipment, (2) population density, (3) average income of the population, (4) employment generation, (5) efficiency of the provided service, (6) unit attractiveness, (7) population satisfaction, (8) biotic impact, (9) facility sustainability, and (10) waste generation. In this study, aspects from the economic, social, and environmental areas are considered.

Neves (2015) evaluated in his study health and education equipment under 7 aspects, (1) the dimensioning of the land and the building; (2) the relationship of the equipment with its surroundings; (3) potential in creating more sustainable urban spaces; (4) the flow of vehicles in the region; (5) the supply of public transportation; (6) the conditions for walking safely and comfortably; and (7) the quality of the construction projects of health units.

The studies mentioned above often address different health units, considering different scales of care.

This may be a reflection of the lack of guidance from legal instruments at the federal and state level, which causes municipal administrations to define in their master plans the conditions to implement new public facilities. However, it is important to note that many times the master plans of small and medium-sized municipalities are mere reproductions of the master plans of larger cities. This practice ends up neglecting the needs and particularities of their regions, and generates documents totally out of context with the local reality, making those master plans not the best option to direct the planning of new facilities (DREUX, 2004; NEVES, 2015).

Some of the works cited throughout this section used a fundamental computational tool for planning public equipment, the Geographic Information System (GIS), which was developed in the 1980s and is a fundamental tool in geoprocessing studies. According to Câmara et al. (2001), the GIS is an application for the computational treatment of data in which the spatial component is fundamental.

Câmara et al. (1996) indicate that the various definitions attributed to GIS reflect one of its main characteristics: the interdisciplinarity offered by the multiplicity of uses. The author also mentions two major attributes of this system, the possibility of integrating data from various sources into a single base, and the provision of means that allow the retrieval, manipulation, and visualization of these data.

In general, the GIS can be defined as a tool for collecting, storing, and analyzing objects or phenomena in which the spatial component is a fundamental attribute. The GIS allowed the interaction between very different areas, allowing the integration of data and information from different origins in a single base; the combination of different information, generating different forms of representation; and the possibility for the user to manipulate, consult and visualize the databases. All the attributes and functions inherent to the GIS are shown as great enablers of the GIS as a tool to aid the decision-making process by the public administration (CÂMARA et al., 1996; ROSADO, 2000; SEGANTINE, 2001).

3 METHODS

The objective of this study was to develop a method for the implementation of PHC units, using technical and objective criteria to indicate the locations, within a study area, that have the greatest feasibility for the implementation of new units of this type. As presented in the previous section, many studies investigated the spatial issue of health units presenting several themes and aspects that should be considered in the planning process of these units.

The proposed method, and the six criteria that compose it, were designed considering the studies of Ferrari (1977), Gouvêa (2003), Colaço (2011), Goudard et. al (2015), and Neves (2015).

The analysis of health units can be done considering different aspects, such as social, economic, environmental, transportation, constructive, and several other approaches which can influence the implantation and operation of the health units.

Those analyses can also consider different moments of the health units, such as the planning phase, in which the demand is evaluated and the locations for implementation are considered; or the construction phase, in which the building design, for example, is considered; and/or the operation phase, in which the quality of the service and the relationship of the unit with its surroundings are evaluated.

The proposed method evaluates the aspects of six criteria, which are: (1) Service area of existing units; (2) Spatial constraints; (3) Risk of natural events; (4) Access by public transportation; (5) Population distribution and (6) Average income of the population, which are presented in the next section.

Each criterion has, respectively, a weight related to the impact it has on the planning and operation of PHC units. These weights were defined by the authors of this work, based on Ferrari (1977), Gouvêa (2003), Colaço (2011), Goudard et. al (2015), and Neves (2015). The weight definition process considered how many times the same, or similar, criteria, were treated in these studies, and it was noticed that there was a variation in the impact caused by each criterion. Considering that variation, for the present study, different weights were applied in the evaluation process, intending to prevail in the planning process the demographic and economic aspects of the population, which are the most influential aspects of healthcare issues in Brasil.

The determination of the service areas, the first criterion of the proposed method, aims to identify the presence and absence and the spatial distribution of the health service in the study area, this aspect was also considered in the studies of Colaço (2011), Goudard et al. (2015), and Neves (2015).

The service area's analysis was based on the users' route to the health units, taking into account the distance that must be covered to access the nearest health unit, preferably by foot, which is one of the most important and democratic modes of transportation worldwide (FERRAZ; TORRES, 2004).

To evaluate the criterion, a distance of 1,000 meters was considered as the limit distance for users to walk to the nearest health unit. The same distance was considered in Goudard et. al (2015) study, where those authors considered 1,000 m as a good distance for people to walk from their houses to the health unit. In addition, the criterion also aimed to investigate the overlap of service areas, to reduce the chances of implementing health units in areas that are already served by one or more units of this level of care.

Table 1 – Service area classification.

Criterion	Criterion Weight	Indicator	Indicator Score
Service area	5	Outside existing service area	5
		Within the service area intersection of one unit	-1
		Within the service area intersection of two units	-2
		Within the service area intersection of three units	-3
		Within the service area intersection of four units	-4
		Within the service area intersection of five units or more	-5

Source: The Authors (2021).

The analysis of spatial constraints focuses on identifying areas that in some way negatively affect or even completely preclude the implementation of new PHC units.

Considering the restrictions established by the Construction Guidelines for PHCUs of the Ministry of Health (BRASIL, 2014) and by municipal master plans, the criterion divides the areas that present any restriction into two categories: the prohibited areas, and the areas to be avoided, according to the type of restriction defined by the construction guidelines, as can be seen in Table 2.

Table 2 – Type of spatial constraints.

Areas to be avoided	Prohibited Areas
High flow vehicle lanes, Cemeteries, Gas station, Airports, Slaughterhouses	Landfill, Industrial areas, Areas prohibited by municipal Master Plan.

Source: Adapted from Brasil (2014).

The thematic map classification of spatial constraints is defined according to the information presented in Table 3.

Table 3 – Spatial constraints classifications.

Criterion	Criterion Weight	Indicator	Indicator Score
Spatial Constraints	4	Areas free of restrictions	0
		Within areas that should be avoided	-3
		Within areas where construction is prohibited	-5

Source: The Authors (2021).

The third criterion of the proposed method involves the analysis of the risk of natural events of hydrological and geological nature. These elements are indicated in the guidelines of the Ministry of Health (BRASIL, 2014), which advises that areas with higher chances of flooding or earth movement should be avoided. This aspect was also found in Colaço's (2011) study, which considers several natural events.

The objective of the criterion is to identify the areas with greater susceptibility to natural events such as flooding, inundation, erosion, etc., and may even, according to the reality of the study area, consider seismic activities that cause earthquakes and tsunamis.

This analysis is made considering that many times the occurrence of these events can bring damages to health units, ranging from material losses, such as equipment and supplies, as well as damage to infrastructure and risks to patients and staff of these units.

Carrying out maintenance work to mitigate the consequences of natural events, of a hydrological and geological nature, is a possible action. However, those activities can make the process of implementing health units in places that present this risk much more expensive, and even unnecessary, especially if there are other areas, in the same region, that do not offer this risk.

The thematic map classification of this criterion must correspond to the values indicated in Table 4, and for each natural event considered in the study, there must be a corresponding thematic map.

Table 4 – Risk of natural events classification.

Criterion	Criterion Weight	Indicator	Indicator Score
Risk of natural events	3	Low concentration	0
		Medium concentration	-3
		High concentration	-5

Source: The Authors (2021).

The offer of public transportation services is the fourth criterion of the proposed method. The analysis of this criterion is justified by the fact that the existence of a public transportation service can contribute to the greater displacement of individuals in the urban environment, allowing greater access to health, education, employment, and leisure opportunities.

The offer of the public transportation system was evaluated based on the location of the access points to the service. For this, it was considered that the accessibility to the public transport service by bus is greater when the walking distances to reach them do not exceed 300 m, it is regular when it is between 300 m and 500 m, and poor when it is greater than 500 m (FERRAZ; TORRES, 2004).

Soltani and Allan (2005) indicated that 400 m is the distance considered convenient to walk to a public transportation station. Furthermore, Alter (1993) presented a Service Level of public transportation based on waiting time, reliability, frequency, and distance to access the service, ranging from level A to level F, in which, the level C, with a maximum distance of 400 m, is the most acceptable level for service users.

Relating Ferraz and Torres' (2004) conception, to Alter's (1993) service level concept, and Soltani and Allan's (2005) study, three evaluation distances were defined: 100 m, 200 m, and 400 m. Those distances consider the distance between the user of the public health system and the access points of the public transportation. The classification of the public transportation supply criteria is presented in Table 5.

Table 5 –Offer of public transportation classification.

Criterion	Criterion Weight	Indicator	Indicator Score
Public Transportation Offer	2	Walking distance to access point up to 100 m	5
		Walking distance to access point up to 200 m	4
		Walking distance to access point up to 400 m	3
		Walking distance to access point higher than 400 m	0

Source: The Authors (2021).

Another criterion considered was the demographic distribution of the study area, a subject that was also found in Colaço (2011) and Goudard et al. (2015) studies. The objective of this criterion is to identify the demand for PHC service and stimulate the implementation of new units in places where there is a larger public. The classification of the criterion is shown in Table 6.

Table 6 – Population distribution classification.

Criterion	Criterion Weight	Indicator	Indicator Score
Population distribution	4	Areas without residences	-5
		Very low concentration of residences	1
		Low concentration of residences	2
		Medium concentration of residences	3
		High concentration of residences	4
		Very high concentration of residences	5

Source: The Authors (2021).

The last criterion considered in the proposed method is the average income of the population in the study area, which was also considered in the study of Goudard et al. (2015). The income analysis, during the planning process, is justified mainly by social and economic disparities, which make the poorer population more dependent on the public health service, unlike the wealthier population, which often chooses the private health service. The classification of this criterion is shown in Table 7.

Table 7 – Average income classification.

Criterion	Criterion Weight	Indicator	Indicator Score
Average income	5	Up to 2 minimum salaries	5
		2 to 4 minimum salaries	4
		4 to 10 minimum salaries	2
		10 to 20 minimum salaries	1
		Above 20 minimum salaries	0

Source: The Authors (2021).

The final classification of the study area considered the combination of the six evaluation criteria through a raster calculator, a tool widely used in feasibility and area classification analyses. Using mathematical operations, and the matrix files as parameters, the pixel values were combined resulting in a new matrix file.

By the raster calculator algorithm, the rasters files, corresponding to the evaluation criteria, were multiplied by the weight of the criteria, respectively. Then, the pixel values were added and a new raster file, resulting from the operations implemented by the user, was generated. Eq. (1), below, exemplifies the process performed by the raster calculator for the final classification of the proposed method.

$$pixel\ value = 5C_1 + 4C_2 + n(3C_3) + 2C_4 + 4C_5 + 5C_6 \quad (1)$$

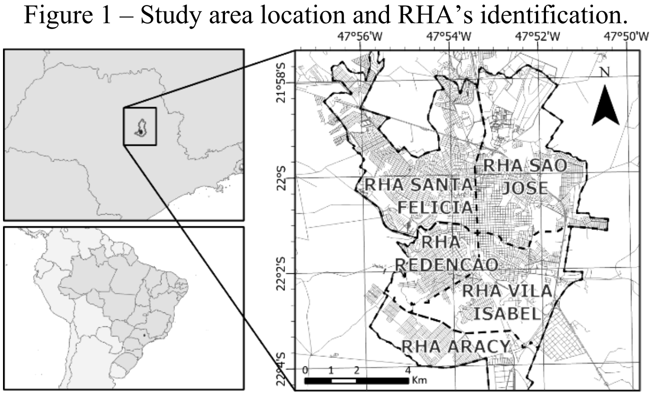
Where: C_1 = Service areas; C_2 = Spatial constraints; n = Number of Natural Events considered; C_3 = Risk of natural event; C_4 = Offer of public transportation; C_5 = Population distribution; and C_6 = Average income

Next, the obtained file undergoes a parameterization process through the reclassification of its values, in which the highest value is defined as 100 and the lowest value is defined as 1, and the intermediate values are divided proportionally within a scale, to identify the regions of the study area that have greater feasibility to deploy new PHC units.

4 CASE STUDY: SÃO CARLOS- SP

São Carlos is a municipality located in the interior of the state of São Paulo. It has about 254,484 inhabitants (IBGE, 2021), with an urban area of 54.30 km² (IBGE, 2010). Figure 1 shows the location of the municipality in the state of São Paulo. This work was developed in the urban area of São Carlos, disregarding the districts of Água Vermelha and Santa Eudóxia, as highlighted in Figure 1, the population of this region is 209,821 inhabitants.

Figure 1 – Study area location and RHA's identification.



Source: The Authors (2021).

São Carlos' PHC units are distributed in five Regional Health Administrations (RHA). Each RHA is responsible for the management of the units in their adhered area and serves as an alternative to Municipal Health Secretariat. 34 primary care units were found, distributed in these five RHA, in which, 22 correspond to the Family Health Unit (USF) program and 12 to the Basic Health Unit (UBS) program. The PHC units and their respective RHA are described in Table 8.

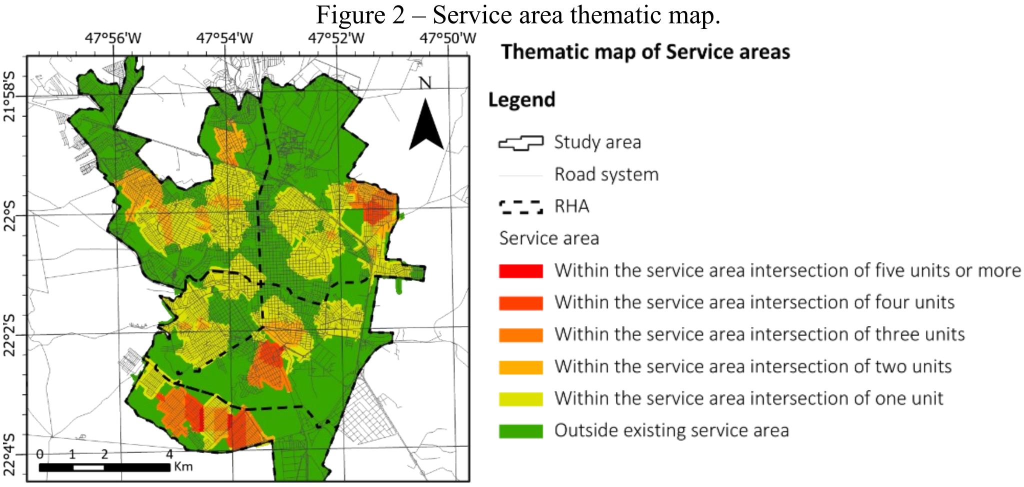
Table 8 – Health units in each RHA.

RHA	Amount of units	Units
Santa Felícia	8	USF Joquei Clube; USF Joquei Clube; USF Romeu Tortorelli; UBS Santa Paula; UBS Delta; UBS Santa Felicia; Equipe 42 USF Arnon De Mello; USF Santa Angelina
São José	7	Equipe 39 USF Sao Carlos VIII; Equipe 38 USF Itamarati; UBS Vila Nery; Equipe 41 USF Jd Sao Rafael; UBS Faga; USF Astolpho Luiz Do Prado; USF Jardim Munique
Redenção	3	UBS Botafogo Valeria De Cassia Ibelli; USF Jardim Sao Carlos; UBS Redencao
Vila Isabel	6	UBS Vila Isabel Rosana Cecato Lahr; UBS Azulville; UBS Cruzeiro Do Sul; USF Jardim Cruzeiro Do Sul; USF Jardim Cruzeiro Do Sul Equipe II; USF Ana Carmen Delamerlini
Cidade Aracy	9	Equipe 1 USF Antenor Garcia; USF Antenor Garcia; USF Antenor Garcia Dr Zigomar Spaziani Filho; USF Zavaglia; USF Cidade Aracy Equipe II; USF Jose Fernando Petrilli Filho; UBS Cidade Aracy Ernesto Pereira Lopes; USF Presidente Collor; USF Cidade Aracy Equipe I

Source: The Authors (2021).

The analysis of the service area considered the location of the existing PHC units and was developed from the definition of the service area of these units, making it possible to analyze the coverage of the service and the overlap between service areas. The map presented in Figure 2 shows the PHC units and their respective service areas in the city of São Carlos- SP.

Figure 2 – Service area thematic map.



Source: The Authors (2021).

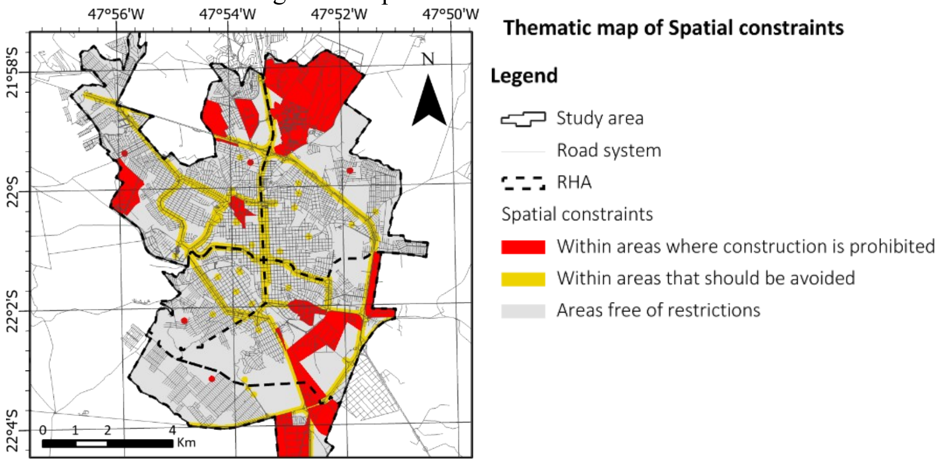
From the thematic map analysis, it was possible to notice that the RHA Cidade Aracy, which was the region with the largest number of units and the highest health service coverage, is the one that presented the lowest classification values. In addition, the places without any health units were ranked with the highest score. This is explained by the objective of the method, which stimulates the implementation of new units in places with lower service offers.

The analysis of the existing health units shows that 15 of them are not in intersection areas with other units. However, 9 units are in intersection areas of two units, another 9 units are also intersecting with three units, and only one unit overlaps with four units.

The spatial constraints considered in the proposed method were divided into two categories: (1) the areas to be avoided in the implementation of new units because they can negatively affect the service, and (2) the prohibited areas, which are exclusionary in the planning process, because they are areas that according to the Ministry of Health (BRASIL, 2014) or the Municipal Master Plan (SÃO CARLOS, 2018) are areas that make the implementation of a new unit unfeasible or that are geared for the development of another type of activities.

The map presented in Figure 3 shows the spatial constraints of São Carlos- SP.

Figure 3 – Spatial constraints classification.



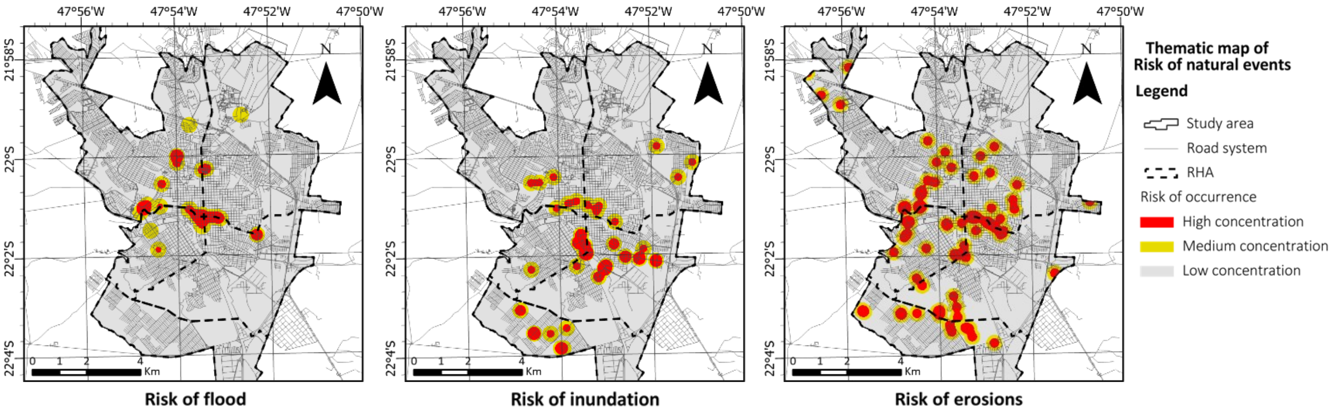
Source: The Authors (2021).

Only two PHC units are in areas that should be avoided and none are within prohibited areas, and although spatial restrictions are present in all RHA, there is still enough space for the implementation of new health units along the study area.

The most recurrent natural events in São Carlos-SP, which were considered in this study, were floods, inundations, and erosion. The location of these events was obtained from the study by Eiras (2017), who surveyed the Civil Defense of the municipality of São Carlos.

The map presented in Figure 4 shows the thematic map of three natural events in São Carlos- SP

Figure 4 – Thematic map of the risk of natural events classification.

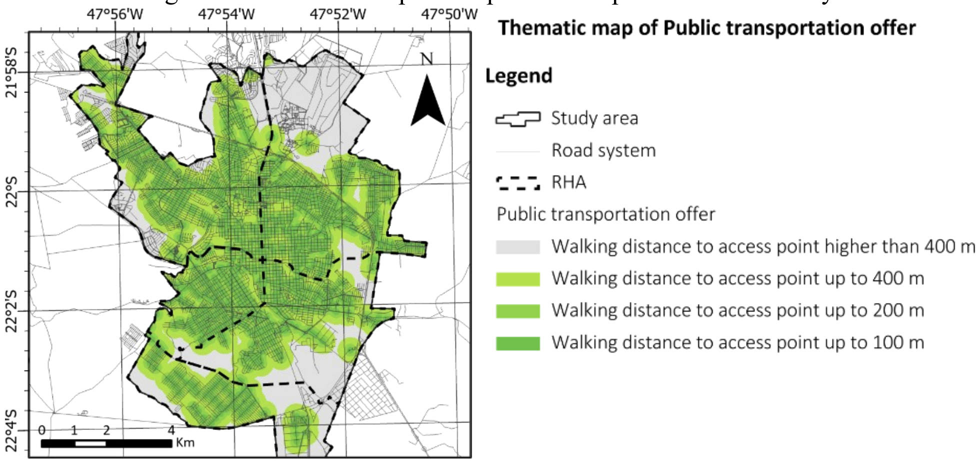


Source: The Authors (2021).

The analysis of the public transportation supply evaluated the bus transportation service, which is the predominant mean of public transportation in the municipality of São Carlos- SP. The analysis was based on the access points to the system and evaluated the location of the bus stops in the municipality and their areas of influence.

The location of bus stops was provided by the municipal transportation department, and the areas of influence were defined from the generation of buffers of 100 m, 200 m, and 400 m, corresponding to levels of service A, B, and C of public transport service, according to Alter (1993). The map presented in Figure 5 is the thematic map of public transportation in São Carlos- SP

Figure 5 – Thematic map of the public transportation availability.



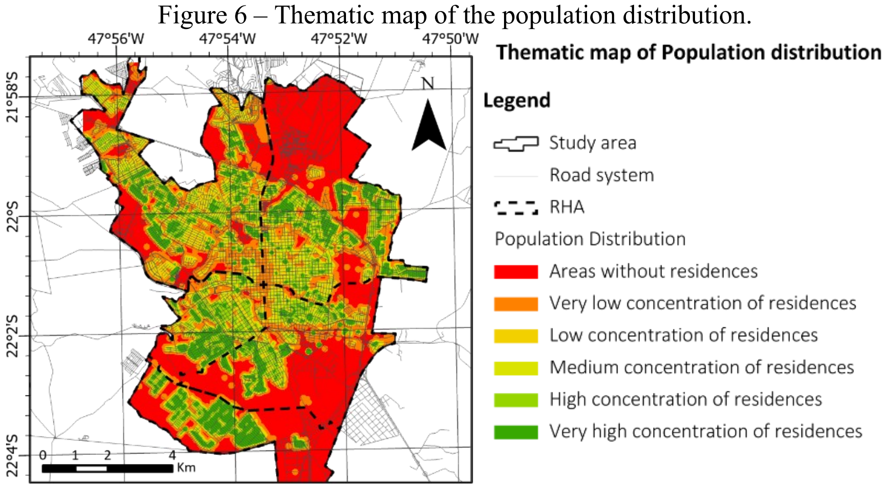
Source: The Authors (2021).

From the analysis of the thematic map, it is possible to see that most of the study area is covered by the public transportation service and that few residential areas of the city do not have bus stops at a distance of up to 400 m.

As for the existing health units, 20 are located 100 m away from at least one bus stop, 14 are up to 200 m away from at least one bus stop, and none of the units are more distant than 200 m from the bus stops.

Another criterion evaluated by the method was population distribution. To evaluate this criterion, the data of water connections, provided by the Water and Sewage System of São Carlos - SAAE São Carlos, were used. From the location of the residences, it was possible to define the population distribution in the territory and identify the regions that concentrate the largest number of inhabitants, and thus identify the areas that offer the greatest demand for the service. The map presented in Figure 6 shows the thematic map of population distribution in São Carlos-SP.

Figure 6 – Thematic map of the population distribution.



Source: The Authors (2021).

From the map, it was possible to identify that the biggest concentration of people is in the southern region of the city, mainly in the Cidade Aracy region and south of RHA Redenção. The central region, where the RHA Santa Felícia, São José, Redenção and Vila Isabel meet, is the region that concentrates the lowest number of inhabitants, but it is also the region with the highest commerce activity.

The last criterion, to analyze the average income of the population of the study area, was based on data from the IBGE's 2010 Census, and was based on the classification of the nominal average income of the census sectors into five categories, according to the minimum salary, as shown in Table 9.

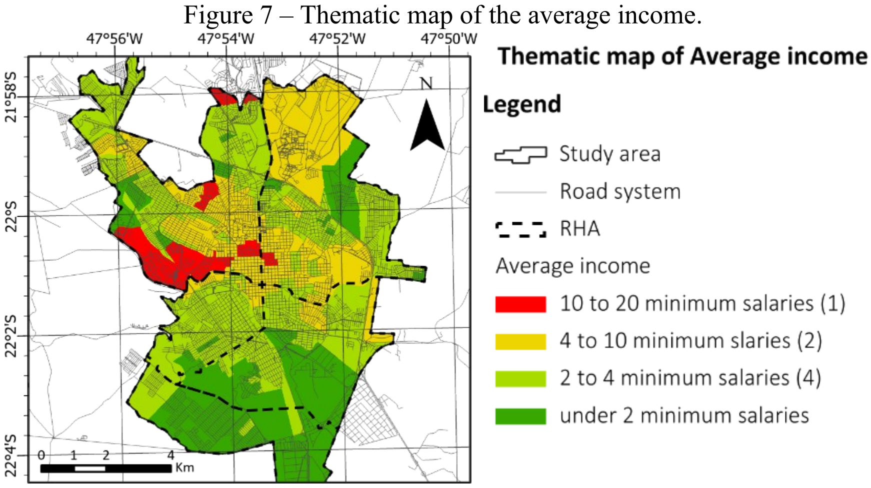
Table 9 – Classification of the average based on the minimum salary.

Minimum salary in 2010	**Salary range**	
R$ 510.00	Up to 2 minimum salaries	R$ 1 020.00
	2 to 4 minimum salaries	R$ 1 020,00 to R$ 2 040,00
	4 to 10 minimum salaries	R$ 2 040,00 to R$ 5 100,00
	10 to 20 minimum salaries	R$ 5 100,00 to R$ 10 200,00
	Above 20 minimum salaries	Above R$ 10 200,00

Source: The Authors (2021).

The map presented in Figure 7 shows the thematic map of average income in São Carlos- SP

Figure 7 – Thematic map of the average income.



Source: The Authors (2021).

From the thematic map of the average income classification, the income distribution in the city of São Carlos- SP shows that in all the RHA there are sectors with an average income of less than two minimum salaries, almost always located on the margins of the study area.

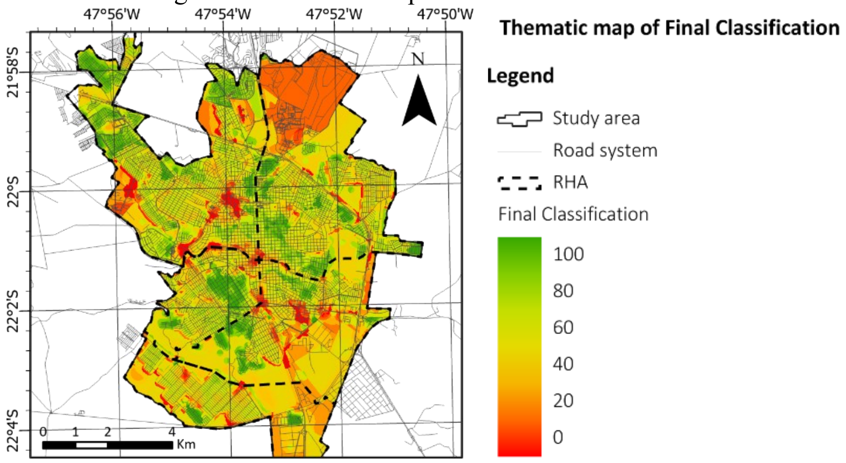
The RHA Cidade Aracy is composed, basically, by the population with nominal income below two minimum salaries, as well as the RHA Vila Isabel. Those same RHA have health units very close to these lower-income sectors. In general, only five units are located in places with average income higher than four minimum salaries, the other 29 units are in regions where the average income is up to 4 minimum salaries.

As for the sectors with income above 4 minimum salaries, most of them are concentrated in the central part of the city, and RHA Santa Felícia has the highest number of sectors with nominal average income above 10 minimum salaries.

These sectors, with much higher income, do not have PHC units within their region, which becomes a positive point for the current situation of the service in the city since the population with higher income usually prefers private health services.

Then, from the combination of the thematic maps a new map of the general classification of the territory was obtained, this map is shown in Figure 8 and allows us to observe that the marginal areas of the city were classified as unviable, due mainly to the concentration of areas focused on the development of industries and universities, and by the low concentration of residences. This was also observed in some specific areas such as the surroundings of the Rotatory of Christ the Redeemer, Praça Itália, and the Municipal Market due to the occurrence of natural events. The most suitable locations for the implantation of new units are located mainly between the service areas of the existing units, which shows that there is indeed a lack of service in these places.

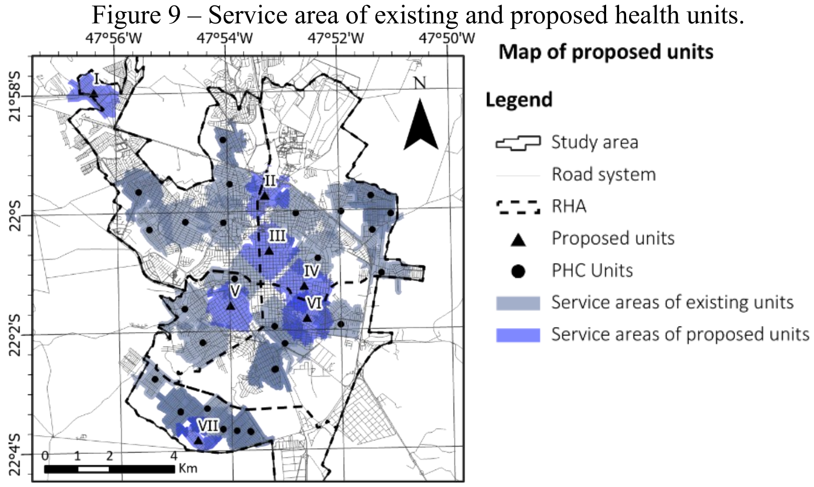
Figure 8 – Thematic map of the final classification.



Source: The Authors (2021).

Considering the classification of the study area, 7 locations were proposed for the implementation of new health units, as shown in Figure 9.

Figure 9 – Service area of existing and proposed health units.



Source: The Authors (2021).

The classification of the units, regarding the criteria evaluated and the proximity to the units that already exist within the study area is shown in Table 10.

Table 10 – Final classification of proposed units.

Rating criteria		Proposed units						
		VII	II	V	I	VI	III	IV
Service area		5	5	5	5	5	5	5
Spatial constratints		0	0	0	0	0	0	0
Risk of natural events	Flood	0	0	0	0	0	0	0
	Inundation	0	0	0	0	0	0	-3
	Erosion	0	0	0	0	0	0	-5
Offer of public transportation		4	4	5	5	5	4	5
Average income		5	4	4	4	2	2	4
Population distribution		5	5	4	4	5	5	5
Final classification		99	97	96	96	96	95	86
Distance, in meters, to the nearest existing PHC unit		1266,217	1462,191	1229,986	4162,441	1240,389	1758,973	1325,058

Source: The Authors (2021).

5 CONCLUSIONS

The present study was developed to propose a method to help defining locations for the implantation of new Primary Health Care units. The proposed method was based on themes related to the Primary Care network and sought to indicate objectively and based on technical criteria, the most suitable places to implant new units of this level of care.

PHC is a fundamental element for the Brazilian public health system, functioning as a way of access for new users, and despite this, those units do not have their planning guided by a clear and objective methodology. As a consequence, for a long time, these units were implemented by public managers through political decisions without the necessary technical support, which caused many of them to be implemented in the least suitable places for the population.

The development of this work occurred from the union between the themes addressed by several authors who investigated the spatial aspect of health units at different scales. The process of developing a method was achieved due to the proposition of six criteria, which together made it possible to indicate the most suitable locations for the deployment of new PHC units.

The criteria considered were: (1) analysis of service areas, (2) spatial constraints, (3) the risk of natural events, (4) the availability of public transportation, (5) population distribution, and (6) the average nominal income of the study area. The determination of each criterion enabled the final classification of the study area.

In general, the method was capable to attend the proposal of this study, which was: being a technical and objective tool based on technical criteria and quantifiable indicators, helping to decrease the level of subjectivity in the process.

The reduction of subjectivity in planning process is justified, mainly, by the fact that this study is based on well-defined spatial information, such as the location of residences, the places where natural events occur, the average income of the population indicated by the demographic census, or the land-use policies. All these data represent phenomena that are materialized in space or documented in public policy instruments.

The presented method proved to be a valid tool for the decision-making process, especially when comparing the current health service coverage in the study area and the coverage after considering the suggested units, which shows a significant increase in the service coverage and, consequently, in the assisted population.

Given all the issues addressed throughout this study, it is important to point out that the implementation of public equipment can, and should, be a political decision, but the decision process must keep the focus on serving the population based on the principle of equity, and for this, the public managers must know that there are technical and objective tools which are capable of assisting them in the urban planning process.

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Authors' Contribution

The first author (Lucas Brandão Monteiro de Assis) was responsible Conceptualization, Research, Visualization, Writing – initial draft and Writing – review and editing. The second author (Paulo Cesar Lima Segantine) was responsible for Conceptualization, Supervision and Writing – revision and editing.

Conflict of interest

The authors declare no conflict of interest.

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Author's biography

Lucas Brandão Monteiro de Assis, Vila Velha - ES, Brazil. He graduated as a Mobility Engineer from the Federal University of Itajubá - Campus Itabira (UNIFEI- Campus Itabira) in 2019. In 2021 he has received a master's degree in sciences in the Graduate Program in Transportation Engineering at the São Carlos School of Engineering, University of São Paulo. His interests are in teaching GIS applications as a volunteer. His research interests are in the area of geoprocessing and geospatial sciences.