UNIVERSIDADE CATÓLICA PORTUGUESA

Is Spatial Accessibility a factor influencing the number of consultations in Porto Municipality?

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Final Assignment in the dissertation modality presented to Universidade Católica Portuguesa to obtain the master's degree in Business Analytics

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Resumo

A visualização da informação, nomeadamente através dos *dashboards*, é comumente usada de forma a auxiliar o público-alvo, neste caso, Agrupamentos de Centros de Saúde (ACES) e investigadores do setor da saúde, no seu processo de tomada de decisão. Tendo isto como base, este estudo tem como objetivo a elaboração de um *dashboard* com uma interface amiga do utilizador, que colmate as lacunas presentes nos *dashboards* disponibilizados pelo SNS, assim como verificar se a Acessibilidade Espacial tem um impacto estatisticamente relevante no número de consultas nos Cuidados de Saúde Primários, numa primeira fase recorrendo ao teste de correlação de Perason's, seguido pela aplicação dos testes ANOVA e Kruskall-Wallis e, por último, procedendo à análise dos Principais componentes.

Dois métodos matemáticos foram usados de forma a calcular a Acessibilidade Espacial, nomeadamente, o método Two-Step-Floating catchment area e o rácio *supply-to-demand*.

Através deste estudo foi possível perceber que a Acessibilidade Espacial difere entre freguesias do mesmo concelho, sendo que à medida que as freguesias se afastam do centro do concelho a Acessibilidade Espacial decresce. Esta, quando calculada através do rácio *supply-to-demand*, em que a unidade são os centros de saúde, tem um efeito estatisticamente relevante no número de consultas. Na Análise dos Componentes Principais, alguns fatores sugerem que certos tipos de consulta são mais utilizados por determinadas faixas etárias, assim como certas faixas etárias são mais influenciadas pela Acessibilidade Espacial do que outras.

Keywords: Business Intelligence; Spatial Accessibility; Two-Step-Floating Catchment Area Method; Cuidados Primários; Acesso aos Cuidados de Saúde

Abstract

Data visualization, namely dashboards are widely used in helping target audiences such as the ACES and health investigators in the decision-making process. Taking this into consideration, the goal of this study is to elaborate a user-friendly dashboard that reduces the gaps of dashboards provided by the SNS, as well as understand if Spatial Accessibility has a statistical significant effect on the number of consultations in Primary Health Care. This analysis will be performed initially by applying the Pearson's correlation test, then using the ANOVA and Kruskall-Wallis Test, finally by analyzing the Principal Components.

Two mathematical methods were applied to calculate Spatial Accessibility, Two-Step-Floating catchment area method, and supply-to-demand ratio.

Based on this study, it comes to light that the spatial accessibility differs between perishes within each county. The farther away the parishes are from the center, the lower the spatial accessibility. This result emerges when the calculation is made considering the supply-to-demand ratio, where the unit is the primary care center, having a statistically significant impact on the number of consultations. The Principal Component Analysis has demonstrated that certain types of consultations are more popular for specific age groups and that some of those age groups are influenced by Spatial Accessibility.

Keywords: Business Intelligence; Spatial Accessibility; Two-Step-Floating Catchment Area Method; Primary Care; Access to Health Care

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Abbreviations Index

2SFCA - Two Step Floating Catchment Area Method

3SFCA - Three Steps Floating Catchment Area Method

ACES – Agrupamento de Centros de Saúde

ACSCs - Ambulatory Care Sensitive Conditions

ANOVA – Analysis of variance

BI-CSP – Bilhete de identidade dos Cuidados de Saúde Primários

CHD - Coronary Heart Disease

CHF - Chronic Heart Failure

COPD - Chronic Obstructive Pulmonary Diseases

CRRNEU - Comissão Nacional de Reavaliação da Rede Nacional de Emergência/ Urgência

CVD – Cardiovascular Disease

DA - Dissemination Area

ED – Emergency Department

GIS - Geographic Information System

HRQoL - Health-Related-Quality of Life

IOM – Institute of Medicine

NCDs - Non-communicable chronic diseases

OGE -General State Budget

PCA- Principal Component Analysis

PHC- Primary Health Care

SA – Spatial Accessibility

SNS - National Health System

UCSP - Primary Health Care Units

USFs - Family Health Units

WHO- World Health Organization

Introduction

Nowadays people are living longer than before, due to many factors such as better living and working conditions, as well as improvements in the health care systems, which consequently result in a decrease of premature mortality and thereby aged societies (Ministry, 2008).

An aging society may supposedly mean a higher prevalence of chronic diseases and increased health care demand (National Research Council (US) Panel on a Research Agenda and New Data for an Aging World, 2001), composed of more individuals, seniors and with less mobility, which in turn will impact their accessibility to health care units.

Accessibility can be spatial which refers to the capability that an individual possesses to physically access a certain location (McGrail and Humphreys, 2014). Accessibility is a spatial attribute to access dimensions (Khan, 1992).

Based on the Portuguese law nº11/93, dated January 15th, 1993 (SNS,2020), the State ensures that the community has access to health care through the National Health System (SNS), which includes all the institutions and services that are governed by the Health Ministry. Such health care institutions include Primary Health Care Centers, Hospitals, which provide secondary care, and Local Health Units.

One of the main goals of the Portuguese National Health Plan is to guarantee access to a high quality of care, besides ensuring values of universality, equity, and solidarity. However, in the vast majority of regions, some means of transportation are required to reach health care facilities and resources, especially in rural areas (Guagliardo, 2004). In Portugal, the Health Service Planning has undervalued the physical accessibility, which is incoherent with the National Health Care Systems goals, which should, ideally, promote the equal access of the population to health care (Simões, 2004).

The barriers to the use of health care units worsen the bigger the distances are to these services, which many times is aggravated due to the poor public transportation network (Yao, 2013). Having this in consideration and in an attempt of decentralizing the Health System, five Regional Health Administrations were created (Norte, Centro, Lisboa e Vale do Tejo, Alentejo e Algarve). These administrations are the intermediaries between local providers and the Health Ministry. Besides being intermediaries, these entities are also responsible for the local management of health care resources, coordinating activities, as well as providing technical and administrative support. All of this is possible due to the autonomy that was granted to these entities.

The (lack of) accessibility can also be understood from an economic perspective, as a consequence of the costs incurred in order to access the health units, affecting the poorest the most (Gulliford and Morgan, 2013).

Several methods aimed to assess spatial accessibility have been explored in the literature namely, Provider-to-population ratio, also called supply-to-demand ratio, Distance to the nearest provider, Gravitational model, Two-step floating catchment area model (2SFCA), Enhanced Two-Step Floating Catchment Area (E2SFCA), and Three-step floating catchment area model (3SFCA).

The methods applied to evaluate the spatial accessibility in this study were the two-step-floating catchment area model (2SFCA) due to its continuous improvement over time, the fact that it does not differentiate distance impedance within the catchment area (i.e., all population locations within the catchment area are assumed to have equal access to physicians) and it is a dichotomous measure (i.e., all locations outside of the catchment area have no access at all). Besides the 2SFCA it was also applied a simpler method called supply-to-demand ratio that does not require GIS knowledge and where the data required is commonly easily available.

In order to understand the impact of Spatial Accessibility in the number of Primary Health Care consultation in the Porto Municipality, three research questions were defined:

- ◊ What factors influence effective access to Primary Health Care?
- ◊ Are there significant differences regarding spatial accessibility to Primary Health Care Services at parish level in Porto?
- ◊ Does Spatial Accessibility have a statistically significant effect on the number of consultations?

To summarize, this paper aims to elaborate a dashboard that will allow the audience to have a deeper understanding of what seems to be an accessibility gap in the Public Health System which needs to be addressed, to provide equitable access to health care. Furthermore, this dashboard will allow the user to characterize patients that use Primary Health Care in the Porto Municipality, as well as other socioeconomic factors that may influence the number of consultations.

1.Literature Review

1.1.Primary Health Care

Primary health care (PHC) is defined by the World Health Organization (WHO) as an essential health care system based on acceptable scientific, social and technological methods. Its goal is to provide accessible health care to underprivileged individuals and communities. Funds may be assigned by each government or social institutions based on the community's projects. (World Health Organization. Declaration of Alma-Ata, 1978).

The basic principles of primary health care include equality for all, community participation, social and economic development, health campaign interventions, disease prevention, continuous care, and the availability of skilled resources (Declaration of Alma Ata, 1978 and World Health Organization, 2008).

Evidence has shown that primary health care is an important aspect in improving the community's overall health. After all, it addresses the broader determinants of health and focuses on the complete and interrelated aspects of physical, mental, and social health, as well as the individual's overall well-being (who.int, 2020) Furthermore, it reduces social differences, illness, and mortality rates. It is also associated with a balanced distribution of health care across the population. This is something that does not happen with specialized care, as it tends to be concentrated in central hospitals (Stardfield B, Shi L, 2005).

The concept of Primary Health Care has suffered several alterations over time. In some cases, it meant providing primary or ambulatory health care services (Crooks V.A, 2006). However, in other circumstances, this is seen as a set of interventions that provide health care support to low-income families, which is known as Selective Primary Health Care. It is an essential component of human development focused on monetary, social, and political aspects (who.int, 2020).

The availability and accessibility to PHC has a direct impact on an individual's wellbeing. Research has shown that long commutes result in the underutilization of the system which consequently leads to inequality among regions (Hiscock, 2008; Haynes, 2003).

According to some authors, accessibility is the relationship between health service locations and the patient's location. This consists of geographical factors such as transportation, travel time, distance, and cost (Boda, 2013). Availability is the number of service points from which a patient can choose (Guagliardo M. , 2004). These two concepts should be considered together consequently, the fusion of these has resulted in Spatial Accessibility (SA) (Guagliardo M. , 2004).

Research suggests that health care systems that apply strong PHC systems present better financial and clinical results. Furthermore, they are able to sustain the health care system more efficiently than the ones with weak PHC (Ramalho et al, 2019).

The success of PHC systems depends on the quality of the services. However, quality is a very subjective word. The Institute of Medicine (IOM) has defined the concept of quality as a health service that increases the probability of achieving an outcome consistent with current professional knowledge through evidence-based medicine (Institute of Medicine, 1999).

Assessing the quality of health care services is performed through key indicators. These will highlight the opportunities for improvement and allow rapport with the best clinical practices by resorting to planning, organizational and clinical quantitative parameters to achieve better results (Ramalho et al, 2019).

1.2. Portuguese National Health System (SNS)

Since the 1970s, when Portugal started working on the concept of Primary Health Care, there were political challenges associated with creating a National Health System (SNS) which had to be addressed. Over the decades, the Portuguese SNS has continued to undergo several alterations.

In this context, the most significant change was related to the funding of hospitals within the health system. This amendment precedes the SNS creation in 1979 and was an outcome of the Portuguese economy and society's modernization. It was initially implemented at the Misericórdia Hospitals. These hospitals were nationalized after April 25th,1974 and in the 80's they returned to the religious orders. These hospitals worked in close collaboration with the Family Health Units (USFs). When Portugal entered the European Economic Community the SNS Hospitals were given both administrative and financial autonomy (portaldasaude, 2010).

The SNS started out as a free health service, however, nowadays it is tendentially free. The State created a user charge (taxa moderadora) that is paid by patients when using health care services, in order to moderate demand. However, there are exceptions, families with low income are exempt, as well as students and pensioners (Barros, P. P.,2012)

In order to determine how many ACES's, UF's and Hospitals are integrated into the Porto Municipality, it is important to first explain how the Portuguese Health Care Units are structured. The Portuguese PHC is organized into five mainland regions denominated as Health Regional Administration (ARS) – Centro, Norte, Lisboa e Vale do Tejo, Alentejo, and Algarve. These are responsible for addressing the population's health needs within their respective geographical area of intervention, which includes the management of resources, ensuring quality and access to health services, and complying with the National Health Plan. Each ARS is further divided into several local health center

groupings (ACES), which consist of a set of PHC units that encompass a population within a specific and more restrict geographical area of intervention, usually at the municipality or parish level.

1.2.1.Primary and Specialized care services

The Portuguese law (no. 56/79 dated September 15th, 1979) explains the services provided by the SNS in detail and distinguishes these as being primary or specialty care.

A SNS patient has access to a variety of services, which include general health care, disease prevention, specialty medical care; nursing care; hospitalization; patient transportation when medically indicated; specialized diagnosis and treatments; dietary food supplements; medicines, medication products; prostheses, orthoses, complementary therapeutic devices and social support in cooperation with social security services. All these services include both PHC and differentiated care (Eletrónico, 1979).

According to this law, PHC includes disease prevention, ambulatory care, primary care, maternal, pediatric, family, and geriatric planning including homecare. Furthermore, it includes specialized care namely ophthalmology, stomatology, otolaryngology, mental health; hospitalizations when differentiated care is not required; complementary elements of diagnosis and therapy including rehabilitation and nursing care which may include home visits (Eletrónico, 1979).

It should be noted that Primary Health Care does not include specialty care. Specialty care consists of hospitalization and specialized ambulatory procedures for diagnosis, therapy, and rehabilitation, as well as external consultations with specialist doctors. Both types of care include urgent care for illnesses and accidents (Eletrónico, 1979).

Usually, the impact that a family doctor has on a patient's quality of life is related to morbidity and mortality prevention. It is rare to associate this

interaction with medical emergencies. Such a scenario is usually reserved for hospital health care. However, the approach to medical emergencies, despite being rare, is part of the family doctor's functions and has an important role in reducing morbidity and mortality. Many patients, especially in rural areas, continue to seek medical attention from their family doctor in potentially emergency medical situations. (Marquês, Fragoeiro, & Sousa, 2010).

That being said, the emergency and urgent cases are usually the Hospital's responsibility, seeing as they are equipped with the required resources to diagnose and solve these cases more efficiently (Nogueira, 2014).

According to the American College of Emergency Medicine, an emergency condition is "(…) any medical condition of recent onset and severity, including but not limited to severe pain, that would lead a prudent layperson, possessing an average knowledge of medicine and health, to believe his or her condition, sickness, or injury is of such a nature that failure to obtain immediate health care could result in placing the patient´s health in serious jeopardy, serious impairment to bodily functions, or serious dysfunction of a bodily organ or part" (physicians, 1999).

The previous definition can be extended with the explanation provided by the Comissão Nacional de Reavaliação da Rede Nacional de Emergência/ Urgência (CRRNEU), which describes it as a process that requires evaluation and/or correction (curative or palliative) in a short period time (CRRNEU, 2012).

1.2.2. The impact of non or less urgent patients attending the Emergency Department

Studies performed in Portugal have shown that between 30 to 35% of patients seen by the Emergency department in Hospitals are classified as being non-urgent or less urgent. If these numbers were to be reduced the emergency services would be able to operate more efficiently, provide better

quality services and reduce costs. This saving could be applied in other areas of the SNS where there is a need for resources or innovation. (Harfouche & Fernandes, 2011) . It is important to highlight that if these non-urgent patients had not attended the Emergency Department (ED) the potential saving in 2011 would have been around 104 million € (Nogueira, 2014).

For these changes to occur it is imperative to inform and reeducate the population as to the difference between hospital emergency services and primary health care. Simultaneously patients tend to use ED in non or less urgent situations since it is the shortest circuit to obtain a specialist appointment.

In a study performed by Gomes related to the unnecessary use of ED and opening hours of both the ED and the UFs were compared. It was evident that there was higher affluence to the ED during the day (71.75%) and on weekdays (79%). This fact demonstrates that the population prefers the ED at the expense of UFs. This is due to many factors that vary from local beliefs to the accessibility of these services (Gomes, 2013). Another factor influencing patient's decision on going to the ED is that this service works twenty-four hours a day, seven days a week. Patients believe that they will be seen by a doctor on the same day (a question of hours depending on the urgency of each patient), perform necessary exams, and consequently, solve their problem faster. Hence the general population believes that the ED is more efficient than other health services provided by the SNS (Nogueira, 2014).

It can be argued that the population prefers using urgent services instead of primary care services. Many authors justify this by stating that there is a lack of integration between the different levels of health care facilities, namely between Hospitals and Primary Health Care Institutions (O & M., 2001).

Another aspect that weights significantly when discussing the excess use of ED is the growing incapacity of the PHC in fulfilling the community's

needs. A clear example is that 953 thousand Portuguese citizens do not have a pre-assigned family doctor. (Harfouche & Fernandes, 2011).

According to Sempere-Selva, frequently the decision of whether to go to the ED or the PHC is based upon its accessibility and convenience (Sempere-Selva et al, 2001).

1.3. Portuguese National Health System (SNS)

Since the early 70s, Portugal has been a front runner when it comes to PHC. At this time the concept of Primary Health Care was implemented as a result of health care reforms performed by Gonçalves Ferreira, Arnaldo Sampaio, and Baltazar Rebelo de Sousa. These reforms were characterized by a network of Primary Health Care initiatives allowing the population to access a set of medical interventions such as health promotion, disease prevention, diagnosis and treatment as well as rehabilitation. This was applied to cases where specialty care was not required (Ferreira, 1975).

The evolution of the Portuguese SNS is internationally recognized both at a European and global level due to its capability of providing universal access to health care services. This can be seen as an important and positive health indicator (Ministério da Saúde, 2020). It is important to underline that the improvements implemented by the SNS have had a positive impact not only on health itself but also on social determinants, such as better living and working conditions, better and safer conditions for the senior population and new-born. (who.int, 2020).

Unfortunately, over the years, problems related to accessibility, quality, and continuity services have been identified. Consequently, health professionals became unsatisfied and unmotivated. This dissatisfaction led to the implementation of a new management model called "Missão para os Cuidados de Saúde" (Health Care Mission). The focus was on creating legal and operational instruments which would enable the SNS to regain its focus on

Primary Health Care, as well as to assure the development of this new methodology (Missão para os Cuidados de Saúde Primários, 2006).

1.4. Health Care Access Barriers

In general, most countries are facing growing health challenges. Not solely related to PHC, but also related to an increasing disparity in life expectancy and mortality; the shifting pattern of diseases within Europe and health service long-term financing due to the increased life expectancy, which consequently raises the levels of chronic diseases. Furthermore, it is important to consider the health illiteracy and inequalities in health services (Saltman, Figueras, & Sakellarides, 1998). When it comes to health service finances, this has become increasingly challenging considering that, on the one hand, low-income families are unable to pay for these services (does not apply to Portugal since SNS is free) and, on the other hand, there has been an increased focus on reducing health expenses. This has led to the development of strategies to deal with the lack of financial resources.

The strategies are to invest additional capital in the health sector, which can be done by shifting funds from other areas or by increasing taxation (Saltman, Figueras, & Sakellarides, 1998).

"Health literacy is linked to literacy and entails people's knowledge, motivation and competencies to access, understand, appraise and apply health information in order to make judgments and take decisions in everyday life concerning health care, disease prevention and health promotion to maintain or improve quality of life during the life course" (Organization, Health Literacy - The solid facts, 2013).

Health literacy has a direct impact when self-assessing one's health. The ability to assess one's health depends on several factors, such as culture, communication skills, knowledge regarding health matters, and their

characteristics. However, the complexity of the health systems and high health costs have an impact on illiteracy and make patients more vulnerable.

A study performed in Canada demonstrated that health illiteracy has cost the health system more than 8 billion dollars (Nogueira, 2014). This represents 3 to 5 % of the country's total health budget. Another study in the United States showed that due to the lack of health literacy, an additional 73 billion dollars were spent on health-related costs. (Organization, Health Literacy - The solid facts, 2013). In 2011, Portugal could have saved around about 100 million euros if the ED was used for its intended purpose, which is to attend emergency cases. As stated earlier, many of the cases attended at the ED were due to the patient's lack of information on how the SNS works (Nogueira, 2014).

Another obstacle to accessing health care, namely PHC, is its accessibility, or lack of. This can be described as a combination between clients and the system. Access to health care consists of five dimensions: availability, accessibility (these two dimensions represent the geographic dimensions of access), accommodation, affordability, and acceptability (Shah T.et al,2016). The accessibility dimension, namely the spatial dimension, will be discussed in detail.

Most countries have as a goal improving health services. To achieve this, it is important to understand and assess the inequalities related to the accessibility of these services.

A study conducted in 2016 in Riyadh Governorate, Saudi Arabia, has demonstrated that there are cluster patterns in public health facility distribution.

According to this research, many regions are underserved by public health facilities, whereas half of Riyadh's population has access to health facilities within 1 kilometer. However, long distances to these services seemed to be a problem for the minority of the population living in 38 districts across the governorate. It was also evident that the central part of the governorate has a higher concentration of health services and the further away from the central region the lower the concentration. This harms the population that lives further

away from the central region seeing as they have less access to public health facilities, they are more likely not to have regular medical care (Mansour, 2016).

In 2019 a study published focused on "constructing a framework for the measurement of accessibility of three levels of public medical facilities from a hierarchical perspective, along with a hierarchical evaluation of medical service facility distribution equity" in Shenzhen City (Jin et al, 2019). From this study, two main conclusions were obtained. The first was that the distribution of medical services is different for each level of medical care. The second is that in order to achieve equity in accessing medical services, it is important to take into consideration both the population distribution and the accessibility distribution. The city where this study was conducted suffers from a severe unbalance in medical service facility distribution, which is inaccessible to 30% of the population (Jin et al, 2019**).**

1.5. GIS and Public Health

The Geographic Information Systems (GIS) is a technology, a discipline, and a problem-solving methodology used to describe, explain and predict patterns as well as processes at geographic scales (Longley et al, 2005). GIS continues to transform the way the earth is described and studied. To put it simply, GIS is a computer-based system that enables the analysis and integration of spatial data (Cromley & McLafferty, 2012).

GIS has been gaining more relevance due to its central coordinating principles, its special techniques developed to handle spatial data, and due to its capability of dealing with management concerns and issues. Additionally, it provides a secure and established foundation for measuring, mapping and, analyzing. It is important to emphasize that the successful usage of the system relies on the appropriate scientific foundations and accepting the uncertainties and imperfections inherent when trying to represent the real world. Accepting

these limitations helps in assessing the conclusions provided by the analysis (Longley et al, 2005).

GIS has been frequently applied when studying a variety of factors that may influence an individual's health. However, the word "health" is frequently perceived incorrectly. Health is seen as the absence of disease when in reality it includes an individual's physical, social and emotional well-being. People are affected by the environment that surrounds them which is connected to social and economic processes operating from small (regional) to large (global) scale. Although an individual's health depends on his/her behavior, it is also influenced by uncontrollable external factors, such as the environment (Cromley & McLafferty, 2012).

When thinking about the environment it is important to consider the community since it reshapes the environment and likewise, the environment impacts an individual's health and well-being which in turn is reflected in his actions. By using GIS, it is possible to have a digital lens to explore the dynamic relationship between people, their health, and well-being (Cromley & McLafferty, 2012).

1.5.1. Geographical dimension - Spatial accessibility

This environment is connected to natural, social and economic processes that operate on local, regional, and global scales. How people behave contributes to their health status, but we cannot divorce behavior from the environmental and social contexts in which it occurs. Not all of the factors that affect our well-being are under the immediate direct control of the individual. The environment of the person is one starting point for public health Geographic Information System (GIS)" (Cromley & McLafferty, 2012).

Other authors like Lin, Allan, and Penning concluded that as costs increase, the ability and willingness to travel decreases. Tanser and colleagues also concluded that travel time is an important accessibility factor (Tanser,

Gijsbertsen, & Herbst, 2006). Additionally, people's knowledge of services declines with distance, and physicians may be less willing to refer patients living far from the health care units (Lin, Allan, & Penning, 2002).

Some researchers have demonstrated that the accessibility and availability of PHC has a direct impact on an individual's health since the distance to the PHC is inversely related to both the utilization of services and area-based equity in health status (Hiscock et al, 2008). Researchers emphasize that the inequality in accessible health care remains a global issue that needs to be solved (Meihan Jin et al, 2019).

Spatial accessibility provides summary measures for two important and related components of accessibility. One of them being the number of available services in relation to the population and the second being the proximity of these services to the population (Meihan Jin et al, 2019).

There are not many studies performed on SA for affordability, acceptability, and accommodation of care, which is mainly due to the high costs of the GIS. However, the costs have been decreasing and improvements are constantly made in GIS which facilitates their use. (Guagliardo M. , 2004).

There are different GIS methods to calculate spatial accessibility each one of them with its advantages and disadvantages. It will be addressed in the following pages.

Research on medical care accessibility in Belgium has demonstrated that different methods should be applied when measuring accessibility (Dewulf et al, 2013). The GIS methods used to measure access to health care have evolved over the last decades, which resulted in a more geographic- sensitive technology.

Several methods of calculating spatial accessibility have been explored in the literature. The most commonly used methods of measuring SA are travel independence to the nearest provider and supply level within bordered areas.

However, these two methods lose validity when applied to congested urban areas (Guagliardo M. , 2004).

The Provider-to-population ratio, also known as the supply ratio, provides a comparison between supply and geographical units and is usually applied to define minimal standards of supply and to identify underserved areas (Jin et al, 2019). The biggest advantages of this model are being very intuitive, the data sources are available, and it does not require GIS tools or knowledge. The strong point of this ratio is the comparison of supply between large geopolitical service areas and the actual supply. These are used to set minimal standards of supply. However, it does not consider if the patient must cross a border, something that is quite common, especially in small municipalities. It does not consider this aspect because this type of ratio was built to analyze variations in accessibility within a municipality. Furthermore, it ignores travel independence and distance (Guagliardo M. , 2004).

Distance to the nearest provider is usually referred to as a travel impedance or travel costs. It is mostly used to measure the distance from a residence or a population center to the medical facilities. Often measured in units of Euclidean distance, in other words, in a straight line (Jin et al, 2019). It is frequently applied in rural areas where health services are limited, and the nearest provider is more likely to be used. Unfortunately, this logic cannot be applied to urban areas because it does not consider multiple health services at a similar distance from a reference point. In order to be precise, all reasonable options for the patient should be considered when measuring the SA. The biggest disadvantage of this method is that it does not consider availability (Guagliardo M. , 2004).

Average travel independence to a provider is the combination of accessibility and availability. It is measured from a patient's point of interest and the travel independence within a country or municipality to a provider, this is then summarized and averaged. This method has certain disadvantages which

should be considered. It overweighs providers located near the periphery; it also inflates the average distance which means decreasing apparent SA for these residents. Furthermore, similar to the provider-to-population ratio, it does not consider border crossing, since many patients do it routinely to seek nearby healthcare services (Guagliardo M. , 2004).

When looking into the Gravitational model, this method combines both indicators of accessibility and availability. Focused on explaining the relationship between the individual's commute and his/her chosen service unit, considering the increasing distance and travel impedance (Connor et al, 1995). This method can be applied to both urban and rural areas since it provides the most valid measures of SA. Additionally, this measure considers alternative service points and is therefore referred to as a cumulative opportunity measure. Nevertheless, this method also has some problems, namely the value of the SA from population to the health service is not intuitive for healthcare workforce policymakers. These stakeholders prefer to use simple distance ratios or provider-to-population ratios despite the difficulties of applying these methods to urban areas (Guagliardo M. , 2004). Another disadvantage is that it only models the supply, there is no adjustment to demand. For instance, if a patient has two services in an equal distance but one serves 1000 people and the other 5000, this means that the providers are not equally accessible and this aspect the model neglects (Guagliardo M. , 2004).

The Two-Step Floating Catchment area model (2SFCA) takes into consideration both supply and demand. This enables the measurement and modeling of the true health care accessibility without any restrictions on the utilization, which is possible due to the floating catchment areas which overlap each other (McGrail and Humphreys, 2008). The difference between the Two-Step- Floating Catchment area model (2SFCA) and Enhanced Two-Step Floating Catchment Area (2SFCA) is that in the latter the distance decay function is added to the floating catchments (McGrail, 2012). The first step for this method is to

calculate the supply-to-demand ratio within the catchment area of each medical service facility, as defined by a threshold distance that considers the distance attenuation (Meihan Jin et al, 2019). The formula is the following:

$$R_j = S_j / \sum_k P_k f(dkj)$$

Equation 1- First step of 2SFCA method

where S_j is the capacity of supply at location j, the number of doctors in this study; P_k is the demand at location k, the real population of the community in this study; d_{kj} is the distance between k and j; and $f(d)$ is the distance attenuation function (Meihan Jin et al, 2019). In order to calculate the supply-to-demand ratio, it is necessary to calculate the ZIP code centroid and know the coordinates for each health service facility. The second step consists of allocating the supplies j that fall within the catchment of each demand region i and sum up the supply-to-demand ratio R_j previously calculated, which is then converted to the distance attenuation at those locations to obtain accessibility A_i at demand location i. The formula is the following:

$$A_i = \sum_j R_j f(dij) = \sum_j [S_j f(dij) / \sum_k (P_k f(dkj))]$$

Equation 2- Second Step of 2SFCA method

where d_{ij} is the distance between i, j and A_i is the accessibility to health facilities of the demand location i. When A_i presents a high value, this indicates better accessibility to that location (Meihan Jin et al, 2019).

For studies that involve different medical service facility levels, it is advantageous to take into consideration the different radiation levels which differ from health service to health service. To calculate and determine the service level, the following formula should be applied:

$$f(d) = d^{-\alpha}$$

Equation 3- attenuation coefficient 2SFCA method

where α is the attenuation coefficient. This coefficient is used to measure the distance decay speed, which means that when the α is high the faster the distance decay. Different levels of medical service facilities mean different attenuation coefficients and truncation distance (threshold distance that indicates the maximum radius range of the medical service at a certain level). Some researchers have shown that the α is chosen based on the travel distance (Meihan Jin et al, 2019).

One of the positive aspects of this method is that it considers the geopolitical border-crossing dilemma. However, this method also has some limitations since the drive-time catchment borders are artificially sharp (Guagliardo M. , 2004) and it relies only upon one buffer size assuming that access is uniform which can be problematic when units of analysis vary in size and can result in under or overestimation of access across units (Bell, S. &Wilson, 2016). The authors Luo and Wing improved the method by adding an adjustment for variation in transportation options between census areas (Luo & Wang, 2003), however, it was not enough, and to avoid methodological inaccuracies when examining the size of the neighborhoods, the best method to apply is the 3 steps-floating catchment areas (3SFCA) (Bell, S. &Wilson, 2016).

The 3SFCA is based on the 2SFCA method that considers the distance-decay within a catchment area and uses variable catchment sizes. It is important to mention that these modifications in the way that accessibility is calculated are very important for rural and semi-urban areas since in more populated areas these alterations are less functional. The 3SFCA is better applied in intra-urban geographic accessibility to health care since it better explains the relationship between health care access and demand and it assumes that population demand

for health care services is influenced by the availability of other nearby medical sites (Wan, Zou, & Sternberg, 2012). One downside of this method is that it requires the use of GIS. This method requires the location of health care services and the population associated with each geographic area. In order to calculate this method, the first two steps required to calculate the 2SFCA should be applied. The difference in the 3SFCA is the introduction of the population demand in smaller census units called Dissemination Area (DA), instead of using neighborhood centroids. The third step is an index of accessibility score (also called access ratio), at the neighborhood level. This is calculated by averaging the 2SFCA access ratios for all DAs belonging to the neighborhood. It is important to keep in mind that this method does not consider the travel time nor physical distances, resulting in both physical and transportation barriers (Shah et al, 2016). This method requires the use of at least three formulas if the study does not consider different levels of medical service facilities. The first two formulas are the same as the ones used in the 2SFCA, the third formula is:

$$A_i^F = \sum_{r=1,2,3,4} \sum_{j \in D_r} G_{ij} R_j W_r$$
$$= \sum_{j \in D_1} G_{ij} R_j W_1 + \sum_{j \in D_2} G_{ij} R_j W_2 + \sum_{j \in D_3} G_{ij} R_j W_3 + \sum_{j \in D_4} G_{ij} R_j W_4$$

Equation 4- Third Step of the 3SFCA method

Equation 4 is used to compute the spatial access of population where R_j is the supply-to-demand ratio of j within the catchment of G_{ij} (weight selection between location (i) and service (j)) and W_r is the Gaussian weight of the *rth* sub-zone D_r (Wan, Zou, & Sternberg, 2012).

This method adds another layer of consideration which allows one to estimate the facility utilization pattern. However, it has been criticized for causing unnecessary complications in the model, particularly, it increases the technical challenges when implementing the model (Jia & Chen, 2019)

Different articles regarding SA use different methods. Many of them used the 2SFCA and its improvements. This can be seen in the study by (Meihan Jin et al, 2019), where the method overcomes the limitations of other simple methods such as nearest provider and provider-to-population. Nevertheless, there are other studies rely on simple methods, one of these can be found in the paper focusing on Riyadh Governorate, Saudi Arabia. This paper used the nearest neighbor distance to calculate the spatial accessibility (Meihan Jin et al, 2019).

An important aspect to bear in mind is that studies on Spatial Accessibility have limitations related to the study of social inequity when accessing and utilizing health care services (Guagliardo M., 2004).

Certain articles go a step further and state that besides calculating the 2SFCA they also use linear regression to predict the accessibility to health care services.

An article written by Mathon and Lachapelle aimed at understanding if boarder openness had an impact on the spatial accessibility of health care for the population living on the border or close to it. Furthermore, it would compare this with the population that lives near a transportation hub. To support their research, the two-step floating catchment area (E2SFCA) was calculated, and a linear regression was applied. In this particular case, several regression models were conducted in order to predict the accessibility of health care services. Four scenarios of the E2SFCA were used, with each model using two independent variables. Through this analysis, it was possible to understand the impact border openness had on spatial accessibility and it was clear that rural areas have poorer accessibility, regardless of the scenario (Mathon & Lachapelle, 2018).

An additional paper by (Gao et al, 2017) uses the same methods. However, in this particular case, linear regression was used to construct 3 classes in alignment with the results of the Index of Spatial Accessibility. These are “improved”, “unchanged” and “deteriorated”, where both Y and X are the ISA with and without taking into consideration the supply and demand across

borders. Furthermore, statistical association and relevance were also tested through linear regression models where Y was the ISA and X one of the socioeconomic variables. The conclusion obtained from this study was that the edge effect must be analyzed case by case since it relies on the choice of indicator, urban organization, and spatial distribution (Gao et al, 2017).

Linear regression is not always applied, multivariate logistic regression is also an option. The major difference is that when dependent variables are binary as in this case, logistic regression is used, and when the dependent variables are continuous the linear regression is applied. Regression models are frequently referred to in papers as being used to complement spatial accessibility calculation.

A paper elaborated by Gao, et al (2017) uses multivariate logistic regression models to identify determinants for the utilization of gynecologists and it was possible to conclude that the utilization of gynecologists is not associated with a means of transport, be it a car or public transport. Nevertheless, the variables that do influence this utilization are age, social class, and households with members under the age of 18 (Stentzel et al, 2018).

To summarize, SA takes into consideration both the relationship between health service locations and patient's location plus the number of service points from which a patient can choose. It is relevant to study SA since several studies have demonstrated that SA to PHC has a direct impact on an individual's health. Several methods can be applied when calculating SA, some are more complete than others, but all have their advantages. When choosing the method to calculate SA it is important to consider each method's characteristics and the required information.

1.6. Data Visualization

Nowadays a huge amount of information is generated from different sources and stored in different formats. A lot of this information is available for individual access and use. Due to the versatility of this data, problems emerge regarding its visualization, such as how to extract knowledge from all the available data. This being said, the major goal of visualization is that the user can easily understand and interpret information since visualization is a graphical representation that allows the user to efficiently, precisely and, clearly understand the information (Khan & Khan, 2011).

One of the most commonly used definitions found in the literature of visualization is "the use of computer-supported, interactive, visual representations of data to amplify cognition", where cognition can be understood as the acquisition of knowledge (Card et al, 1998).

According to (Khan & Khan, 2011), the way that data is presented should be interpretable, elegant, and descriptive. Dashboards are data visualization tools, which has become very popular over the past few years. It is a valuable tool that can be applied to a variety of fields, from health to business sectors. It is a simple, user- friendly way of displaying key information for monitoring and managing businesses. This makes dashboards a very powerful communication tool. However, close attention to its design is required since it can easily provide bias information. A good dashboard must be objective, simple and user-friendly, which can be achieved through constant technology innovation, design, science and communication (Martinho, 2013).

It is crucial to group data logically and presents only the important metrics,the frequency in which data is refreshed should be defined to ensure the information is updated and relevant for the audience. A good dashboard must

have few colors, important data, smart graphs, a user-friendly design, and time-overview (Martinho, 2013).

The benefit of a good dashboard is the ability to identify and correct negative trends, measure efficiencies and inefficiencies, provide visibility on performance indicators and be time effective seeing as a single report is used (Martinho, 2013). Furthermore, dashboards contain important information which was collected, aggregated, and displayed in a single report, facilitating the understanding and decision-making (Lerouge & Tremblay, 2008).

"Dashboard technology, when well-designed, can help consolidate the data in a meaningful way, so it is clear, consistent and accessible" (Lerouge & Tremblay, 2008).

1.6.1. Target audiences of health care dashboards

Creating a dashboard to target the general public is not a simple task. One of the reasons being that the majority of the population is not familiar with statistical terminology (Bell et al, 2006).

The public, in general, is not interested in the methods used to achieve the information, they trust the practitioner's experience and expertise, hence they consider the information to be reliable (Bell et al, 2006).

Due to the challenges with this type of communication, education targeting Public Health communication differs from regular communication education received by many undergraduates. According to the Department of Health and Human Services, health communication is "the study and use of communication strategies to inform and influence individual and community decisions that enhance health" (Parvanta et al, 2011).

When dashboards are targeted at the general public these are usually to raise awareness of the community's health status and needs (Lerouge & Tremblay, 2008). On the other hand, when addressing the scientific community their expertise, experience and knowledge make them a very demanding

audience when it comes to selecting the correct methodology to use. Considerations such as the methodology's strengths, weaknesses, and how these will influence the results need to be considered. A key factor for this audience is whether the presentation has smoothing tactics, other statistical models or if they are direct observations (Bell et al, 2006).

There is a challenge, however seeing as many people, including well-educated people such as doctors, have low numeracy skills and are therefore unable to understand statistical information. The way to overcome this is by resorting to maps, graphs, and tables (Bell et al, 2006).

1.6.2. Dashboards applied to the Health sector

When looking at health care, dashboards may include key performance indicators such as public health status, benchmarking home health care, and health institutions. Dashboards can indicate their progress, patient status, and information. They are especially useful when it comes to identifying problem areas. (Lerouge & Tremblay, 2008).

In the health sector, dashboards are used to target the general population, health professionals, such as doctors and nurses, research teams, health institutions, and others. Dashboards will however need to be adjusted to fit the target audience and purpose.

To illustrate, a dashboard targeting the general population has been developed in the United States. The intention was to share information related to health, its influencing factors, such as an individual's behavior, social, economic factors, physical environment, health outcomes, and clinical care (Health, 2020).

This dashboard is available online at cityhealthdashboard.com. It consists of a color gradient map, in which the light colors represent lower values (better outcomes), and darker colors represent higher values (worse outcomes). If the users prefer, they can click on the option table and instead of a map, the information will be presented in a table format (Health, 2020).

Dashboards which are targeted towards supporting doctors and nurses in decision- making are different from the one mentioned above. Further details on this type of dashboard can be found in an article by (Gustafson, 2018).

Doctors and nurses are exposed to high -stress levels, they need to be sharp and have the ability to quickly transforming information into actions. Therefore, dashboards are a visual tool that presents patient information in a simple way and aid in processing the information. Furthermore, it is an efficient way to share information (Gustafson, 2018). During the research of this article, the author found that clinicians preferred seeing numerical data, they also favor vital signs being arranged in columns and chronologically presenting the latest measurement on top. Additionally, health professionals have suggested that abnormal values should appear on the dashboard in red since it highlights focus areas and abstracts less crucial information (Gustafson, 2018).

Each audience has its own characteristics, it is very important to have these in mind when selecting the information and design for the dashboard. This is crucial to ensure the message is clearly transmitted to the target audience and bias decisions are not taken (Gustafson, 2018).

Most dashboards targeting the health sector consist of maps, some have the option of transforming the graphical information into a table. Maps include color gradients to help the user identify and retain key information. Examples of these dashboards can be found online on cityhealthdashboard.com and published articles such as "Current practices in spatial analysis of cancer data: mapping health statistics to inform policymakers and the public" (Bell et al, 2006).

Although maps are found in the majority of dashboards targeted for this sector, this presentation also includes statistical graphs. Both maps and graphs adhere to the same color scheme to represent specific regions or features (Bell. et al, 2006).

In Portugal there is a website developed by the SNS, as bicsp.min-saude.pt, targeted for both researchers and health institutions. This site contains several dashboards which include PHC indicators such as, number of consultations, number of people with an assigned family doctor, gender, and age of patients registered at the UF. This type of information is useful for ACES, it supports decision-making and identifies potential gaps in these services (SNS, bicsp.min-saude.pt, 2020). These dashboards contain graphs and tables, they do not contain maps, which researchers consider as being a gap.

1.6.3. Dashboards related to spatial accessibility

GIS and spatial methods are crucial for measuring potential access to health services (Bell et al,2012).

The characteristics of spatial accessibility dashboards are that they all include maps with a color gradient to facilitate the interpretation of the values. Some of those include more than one map, an example is mentioned in an article produced by the authors Shen, Zhou and Lu (2020). This article encompasses several maps showing the level of spatial accessibility seen from the perspective of villages and neighborhoods. It includes commuting time between 15 to 120 minutes to local hospitals. Additionally, it contains a bar chart containing the percentage of villages and neighborhoods per county where the commute time is between 60 and 90 minutes, it also includes a color gradient map with the disparity of spatial accessibility. Finally, there is a line chart that highlights factors influencing the disparity in county hospital's spatial accessibility across counties (Shen et al, 2020).

Another article gave important insights about spatial accessibility considering the travel time and navigation path (Zheng, et al., 2019). To present this data two maps were created where both the distance and the commute time between the origin and the destination were analyzed. Furthermore, boxplots were elaborated where it was possible to see the minimum, maximum, mean,

standard deviation, and the optimal weighted model for commute time. The boxplots to determine the baseline commute time included off-peak periods self-driving transport, peak periods self-driving transport, off-peak periods public transport, and peak periods public transport. Further information related to the Accessibility level frequency distribution was presented as a bar chart. Besides the bars, two lines are presented in this graph where one is related to the distribution frequency and the other to the cumulative frequency. This chart also considers the off-peak periods self-driving transport, peak periods self-driving transport, off-peak period's public transport, and peak periods public transport. The last map allows the user to analyze the internal differences and overall spatial distribution of hospital accessibility in each residential area (Zheng, et al., 2019).

One more article on spatial accessibility follows the same approach as the one previously mentioned: it uses several maps, the first one to identify the location of city in the county, then to show the distribution of public health facilities across the city. Through maps the author presents the percentage of public health facilities in each district, then the spatial accessibility to the closest public health facility, the average distance to the closest public health facility within the districts, population to health facility ratio and distance from population locations to the nearest public health facility. A bar chart with the frequency percentage of unserved areas in each district within 1 km radius of the health facility ratio is also presented (Mansour,2016).

Based on the average nearest neighbor method an additional chart was made to represent Spatial accessibility (Mansour,2016).

There is a lack of papers covering dashboard themes, both in terms of academic papers as well as in the "grey" literature.

A known "grey" literature website is "cityhealthdashboard.com", where the community's health outcomes are visible. Information such as breast cancer deaths, COVID local risk index, obesity, among others, are considered.

Heatmaps are used to represent social- economic factors, health behavior, the physical environment, and clinical care. Furthermore, there is an option to transform the information into a table with two visual presentations. Bar charts with color gradients were also used to facilitate the interpretation of the information (Health, 2020).

Although this website does not mention spatial accessibility, a dashboard was provided and has been used by the public. It contains heat maps which are the most frequently used graphs in spatial accessibility articles. These graphs may be used as a baseline for the final topic of this paper which is to produce a dashboard.

The above- referenced website and the most frequently used graphs referred to scientific papers for spatial accessibility and have been used as the basis for the dashboard analysis provided in this dissertation.

1.7. Research Gaps

The research gaps that currently exist in the literature, meaning the areas that have not yet been covered by literature, can only be identified through an exhaustive literature review.

During the literature review, some research gaps have been identified and will be answered throughout this dissertation. One of the gaps identified was the lack of studies made in Portugal regarding the analysis of Spatial Accessibility to Primary Health Care, as well as verify if the number of consultations in Primary Health Care is related/influenced by Spatial Accessibility. However, during the analysis of this study, it became evident that there were additional factors that were not considered, for instance, the transportation network.

2.Methods and Data

In this section, it will be presented the materials and the methodological steps implemented to elaborate a dashboard providing in-depth information on the accessibility to primary care services in the city of Porto.

2.1. Population and Data Sources

2.1.1. Study Area

Porto municipality was the chosen study area since it is the second -largest city in Portugal. It is located on the coastline in northern Portugal and has a total population of 237.591(pordata, 2019).

Porto municipality has a total area of 16.09 km², divided into 7 parishes, União de Freguesias de Aldoar, Foz do Douro e Nevogilde (7.36 km²); União de Freguesias de Cedofeita, Santo Ildefonso, Sé, Miragaia, São Nicolau e Vitória (5.43 km²); União de Freguesias de Lordelo do Ouro e Massarelos (5.34 km²); Bonfim (3.05 km²); Campanhã (8.13 km²); Paranhos (6.67 km²) and Ramalde (5.68 km²) (pordata, pordata.pt, 2019).

This research will cover the public health care sector, more specifically the USF's and UCSP's, as these facilities are the main PHC providers. It will not cover private health care due to the lack of available information for this sector.

2.1.2.Datasets

The data on public health care facilities used in this study was based on websites managed by the SNS, such as the BI-CSP website.

This website contains information on the number of UF's and UCSP per ARS, number of health care professionals by area (doctors, nurses, and clinical

secretaries) for each UF or UCSP, number of subscribed patients, as well as the age and sex distributions of subscribed patients.

It further provides information related to the utilization rate of medical and nursing consultations for the past 3 years, the consultation proportion for both medical and nursing appointments, unemployment and school dropout rate. This information is solely based on subscribed patients. In order to compare the unemployment rate and school dropouts with the national average rate, information from the INE (INE, ine.pt, 2020) and PORDATA website (PORDATA, 2019) was used.

When it comes to calculating the spatial accessibility, it was necessary to compute the Euclidean distances between the parishes' centroids and the USF or UCSP in that parish and it was also required the determination of the catchment area (area belonging to each UF) in which scientific articles were used as a basis to determine this area. One of the articles was used to analyze the average distance to a PHC in Portugal within a 30 minutes walking distance (ERS, 2009) and another article assessed the walking distance for a healthy middle -aged person to climb a slope of 1 in 20 is 4.8km/h (Morris & Hardman, 2012).

Furthermore, each parish has a dedicated DICOFRE code. The DICOFRE is a 6-digit code that identifies the district, municipality and parish. It can be found on website dgterritótio.gov.pt (dgterritorio, 2020). In addition to calculating the Euclidean Distance, it was also necessary to know the population per parish.

In order to determine the distances in meters between the parish centroids and the USF or UCSP in each parish, it was necessary, to begin with the coordinates of each centroid. This information is projected in the system ETRS89 PTTM06 which is a global reference system recommended by the European Reference Frame, sub-commission of the International Geodsy Association, established through spatial observation techniques (DGT, 2021). This system

calculates the distances and coordinates in WGS84 and provides the latitude and longitude of each parish since the WGS84 is a geodetic reference datum standard for air navigation latitude/longitude coordinates (SkyBrary, 2020).

In terms of the population, this information was taken from the 2011 census. Information can be accessed via the "Instituto Nacional de Estatística" website (INE, censos.ine.pt, 2014).

To elaborate the dashboard extra information was required, namely the gross income both at a parish and national level which was obtained in the INE website (INE, INE.pt, 2018). The number of physicians that the SNS reports in the study area in question was retrieved from the BI-CSP website (SNS, bicsp.min-saude.pt, 2021). Regarding, the number of doctors working in the health private sector, this information was obtained by searching all the private clinics and hospitals in Porto Municipality and counting how many General practitioners there were in each health facility. Furthermore, it was also required the average value per square meter of each parish belonging to Porto Municipality (INE, ine.pt, 2020).

2.2. Variables of interest

SA is the joint analysis of accessibility, which consists of several geographical factors (transportation, travel time and cost) (Boda, 2013), and availability, i.e., the number of service points that a patient can choose (Guagliardo M. , 2004).

In order to understand if SA influenced the number of times that a patient goes to PHC, 3 variables were used as a proxy of this number, which are Proportion of Medical Consultations, Proportion of Nursing Consultation and Utilization Rate for Medical and Nursing Consultation in 3 years. These 3 variables are the independent variables, and the dependent variable is Spatial Accessibility.

The Proportion of Medical Consultations is an indicator that shows the proportion of consultations that each doctor did from his/her list. The numerator is the sum of presential appointments given by the family doctor and as a denominator, it was considered the sum of presential consultations given by any doctor of the facility. The goal of this indicator is to give an account of patients accessing their family doctor, as well as the institution's capacity in substituting the unit's physicians (SNS,2017). The Proportion of Nursing Consultations functions similarly applied to nurses (SNS,2017).

Regarding the Utilization Rate for Medical and Nursing Consultation in three years, the aim is to assess the medical or nurse consultation access by the registered patients. The numerator is the sum of registered patients that had at least one doctor or nurse appointment (presential or not presential) in the last 3 years. The dominator is the sum of registered patients (SNS,2017).

In the dashboard, there are other variables present such as the number of physicians that work in the SNS and the number of doctors that work in the private sector within Porto Municipality. In addition, we also show the number of patients for each group's age.

Furthermore, the dashboard also uses the gross income at both a municipality and national level, the average value per square meter of each parish belonging to Porto Municipality that works as a proxy of income, which is a proxy of the socio-economic stratum (Berzofsky et al, 2014.). With this information, we analyzed if the areas where the population has a higher income continue to use the PHC provided by the SNS and compare it with the areas where the population has a lower income. Besides, it allows us to see if the UF is located near the wealthier areas, the deprived areas, or somewhere in between. Also, as another proxy for income, two other variables were used: the school dropout rate and the unemployment rate.

2.3. Data Analysis and Visualization

2.3.1. Data Analysis

Spatial Accessibility was calculated using both the 2SCFA method and supply-to-demand ratio, which provides a scalar measure that can be readily represented in a map. The impact of spatial accessibility on the utilization of the PHC services was investigated using several statistical methods and graphical representation of the association between these variables affording quantitative metrics that could potentially be incorporated into the dashboard.

2.3.1.1. Accessibility measurement

As mentioned in the previous chapter, spatial accessibility to health facilities has been discussed in several papers however, not all use the same calculation method. The vast majority of these use the 2SFCA. Reiterating, there are advantages and disadvantages in using this method, being the advantages the fact that this method has undergone several improvements over the years and is considered by several authors (Meihan Jin et al, 2019; Luo and Wang, 2003; McGrail and Humphreys, 2008) as being efficient and accurate. One of the limitations of the method is that it does not consider the demand outside the catchment area, as well as the distance attenuation at first. The distance attenuation incorporated in this method is one improvement very appreciated and valued by authors.

The first step consists of identifying all the demand within the catchment area of each UF and then calculate the supply-to-demand ratio. The second step consists in allocating the supply within the catchment area of each demand and sum it to the supply-to-demand ratio, previously calculated (Jin, Liu, Tong, Gong, & Liu, 2019).

Besides the 2SFCA, the supply-to-demand ratio was also used. This is a very simple ratio to use since it does not require GIS analysis. This method can identify underserved or unserved areas and it is commonly applied to help analyze minimal standards of supply calculated (Jin et al, 2019).

The reason why two methods were used to calculate SA is due to the fact that the supply-to-demand ratio does not consider interactions between patients and providers across parish or municipality borders UF (Yang, George and Mullner, 2006). Furthermore, the 2SFCA is calculated for each parish, while the supply-to-demand ratio is calculated by UF.

2.3.1.2. Statistical Analysis

Several parametric and non-parametric tests were considered to assess the association between spatial accessibility and the 3 dependent variables. Analysis of variance with post-hoc testing was implemented to assess if UF with different levels of spatial accessibility differed in their performance. With this aim, UF were categorized into groups based on the tercile values of the distribution of spatial accessibility.

2.3.2.2.1. Correlation Tests

Correlation coefficients are the basis for uncovering potential causal effects. It can also be applied to a set of variables to measure the relationship, if any, between them (Carrol, 1961). In other words, if correlation exists, when the magnitude of one variable changes, the second variable will also suffer an alteration in magnitude. This change can be either in the same direction (positive correlation) or in the opposite direction (negative correlation) (Schober et al, 2018).

The most commonly applied correlation test is the Pearson product-moment correlation. This test is applied when the relationship between two variables is linear and the data is normally distributed (Schober et al, 2018).

The coefficients range from 1 to -1. The closer to the extremes the stronger the relationship between variables. When the coefficient is 0 it indicates that there is no linear association (Schober et al, 2018).

2.3.1.2.2. ANOVA and Kruskall-Wallis Test

One-way Anova and Kruskal-Wallis tests are similar since both indicate if there are or not differences between the mean performance with different groups.

ANOVA identifies the mean difference problems since it uses between and within -group variance differences (Kim, 2017). In other words, compares variance in each group mean from the overall group variance (Bevans, 2020).

After conducting the ANOVA analysis, a test called Post-hoc is frequently used. However, this is only the case if the ANOVA presents statistically significant variables, otherwise, it cannot be performed.

The Kruskal-Wallis test is similar to the ANOVA test seeing as it also analyses the differences among groups, however, it applies to non-normally distributed data and that is the major difference between these two tests and the reason why they were both used. Another distinction between them is that Kruskal-Wallis is a nonparametric distribution whereas ANOVA is a parametric test (Najab, 2010).

The null hypothesis (H0) presupposes that the population mean of the groups are the same and the alternative hypothesis (H1) is that at least one group differs significantly from the overall mean of the dependent variable.

An important aspect to mention is that the effect of spatial accessibility in the outcomes is not adjusted for confounders factors inflation (Kim, 2017).

In order to run these tests, it was necessary to split the dataset obtained through the two methods applied to calculate Spatial Accessibility, 2SFCA and supply-to-demand ratio, in terciles.

2.3.1.2.3. Linear regression

Linear regression models were used to assess the same association adjusted for confounding variables. The small variation is conferred by the fact that spatial accessibility estimated through the 2SFCA method is estimated at the parish level, hence UF located in the same parish will have the same spatial accessibility, limiting the applicability of linear regression. Therefore, linear regression was only implemented with other measures of accessibility (e.g. supply-to-demand ratio as defined by the number of doctors and nurses divided by the number of users register in the UF).

A two-sided significance level of alpha was considered in all statistical tests. The RStudio was used to run all statistical analyses.

This research contains three dependent variables (overall utilization rate for both medical and nurse consultation -3 years, medical consultation proportion and nursing consultation proportion), which means that three multiple linear regressions were required to assess if these variables are influenced by SA. The next section will address model 1 for each regression:

Y (Medical Consultation Proportion) = β0 + β1 (proportion of youth population) + β2 (proportion of working population) + β3 (proportion of elderly population) + β4 (male proportion) + β5 (Spatial Accessibility- 2SFCA) + β6 (School dropout) + β7 (unemployment) + β8 (Spatial Accessibility – Supply-to-demand ratio)

Equation 5 - Multiple Linear Regression- dependent variable Medical Consultation Proportion

Y (Nursing Consultation Proportion) = β0 + β1 (proportion of youth population) + β2 (proportion of working population) + β3 (proportion of elderly population) + β4 (male proportion) + β5 (Spatial Accessibility- 2SFCA)

+ β6 (School dropout) + β7 (unemployment) + β8 (Spatial Accessibility – Supply-to-demand ratio)

Equation 6- Multiple Linear Regression- dependent variable Nursing Consultation Proportion

Y (Overall utilization rate for both Medical and Nursing Consultation – 3 years) = β0 + β1 (proportion of youth population) + β2 (proportion of working population) + β3 (proportion of elderly population) + β4 (male proportion) + β5 (Spatial Accessibility- 2SFCA) + β6 (School dropout) + β7 (unemployment) + β8 (Spatial Accessibility – Supply-to-demand ratio)

Equation 7- Multiple Linear Regression- dependent variable Overall utilization rate for both medical and nursing consultation- 3 years

2.3.2.2.4. Principal Component Analysis

The Principal Component Analysis is a mathematical algorithm that reduces the dimensionality of datasets, increases interpretability, and simultaneously reduces the risk of information being lost. This technique is used to explain the variance structure of a set of variables through linear combinations (Markus Ringnér, 2008). In other words, information is condensed into factors by significantly compiling the volume of information to a reduced number of factors. Factors explaining 70% - 80% of the data variability are selected.

Different criteria can be applied to identify the Principal Components. Different methods may result in different solutions, which means that there is a trade-off and subjective judgment that needs to be used in decision-making. Multiple criteria can be applied. According to Shiken (2009), these are :

- ◊ Kraiser Criteria- recommends keeping as many Principal Components as possible, as long as the variance remains higher than the median variance;
- ◊ Scree Test- refers to the stabilization of the component's variance, also known as the scree plot elbow;

- ◊ Percent of Cumulative Variance- recommends that at least 80% of the total variance is kept;
- ◊ Minimal percentage of variance- Each component explains at least 0.05, 1/p, or 0.7/p.

2.4. Dashboard Development

The development of the dashboard was the outcome of the previous analysis, gathering all the relevant information in a single place. It is a simple way to analyze and collect knowledge from this study.

Additional literature was used to enrich the dashboard provided by the SNS to PHC with information regarding Spatial Accessibility (2SFCA and supply-to-demand ratio), socioeconomic factors (age, municipality average gross income, school dropout, and unemployment rate, as well as the price per square meter – all variables that are a proxy for social classes), there is also detailed information regarding the 3 dependent variables used in this research (Medical Consultation Proportion, Nursing Consultation Proportion, Overall utilization rate for medical and nursing consultations – 3 years).

When constructing this dashboard, the assumption about the target audience is that it would be composed of health investigators and ACES. The KPIs were selected based on the target audience, adding also those that were missing from the dashboards already provided by SNS. The idea was to create a dashboard that can be easily interpreted, simple and that was not saturated with information. In order to achieve this, thinking like the end -user was crucial.

3.Results

3.1.Disparities in Primary Health Care Accessibility

In this research, SA was measured at both the parish and the UF level.

3.1.1. Parish-level analysis

When analyzing the SA results obtained through 2SFCA it was possible to conclude that even though the studied area was small, solely including Porto Municipality with 7 parishes, it is evident that there are differences regarding spatial accessibility to PHC. The parish with the highest accessibility to PHC is Paranhos (0.00115962), followed by Ramalde (0.00118482), União de Freguesias de Lordelo do Ouro e Massarelos (0.00134114), Campanhã (0.00134897), União de freguesias de Aldoar, Foz do Douro e Nevogilde (0.00145233), Bonfim (0.00175368), with the lowest being União de Freguesias de Cedofeita, Santo Ildefonso, Sé, Miragaia, São Nicolau e Vitória (0.00175819).

Figure 1- SA Municipality map - 2SFCA

3.1.2. UF-level analysis

The UF-level analysis was made by applying the SA calculation using the supply-to-demand ratio. In the following table, Spatial Accessibility is being sorted in a descending order.

UF	Spatial Accessibility
UCSP São Roque Lameira	0,00155457
UCSP Foz do Douro	0,00132734
USF-A Lindo Vale	0,00119311
USF-A Prelada	0,00118694
USF-B Aníbal Cunha	0,00118096
USF-A Covelo	0,00117977
USF-A Carvalhido	0,00117388
USF-A Lordelo do Ouro	0,00117356
USF-B Arca d'Água	0,00117214
USF-A Azevedo de Campanhã	0,00116499
USF-A Aldoar	0,00115741
USF-B Garcia da Orta	0,0011456
USF-B Serpa Pinto	0,00114482
USF-B Novo Sentido	0,00113968
USF-B Porto Douro	0,00113058
USF-B Bom Porto	0,00112171
USF-B Faria Guimarães	0,00110421
USF-B Ramalde	0,00108814
USF-B Porto Centro	0,0010745
USF-A Cedofeita	0,0010731
USF-B São João do Porto	0,00106838
USF-B Espaço Saúde	0,00104493
USF -A Barão de Nova Sintra	0,00102058
USF-A Rainha D. Amélia	0,0009989
USF-A Santos Pousada	0,00076544

Table 1- Parish SA according to supply-to-demand ratio

Different UF's within the same parish present different accessibility ratio values, therefore it is not possible to find a pattern regarding parishes through this method seeing as it is dependent on the number of physicians and subscribed patients per UF.

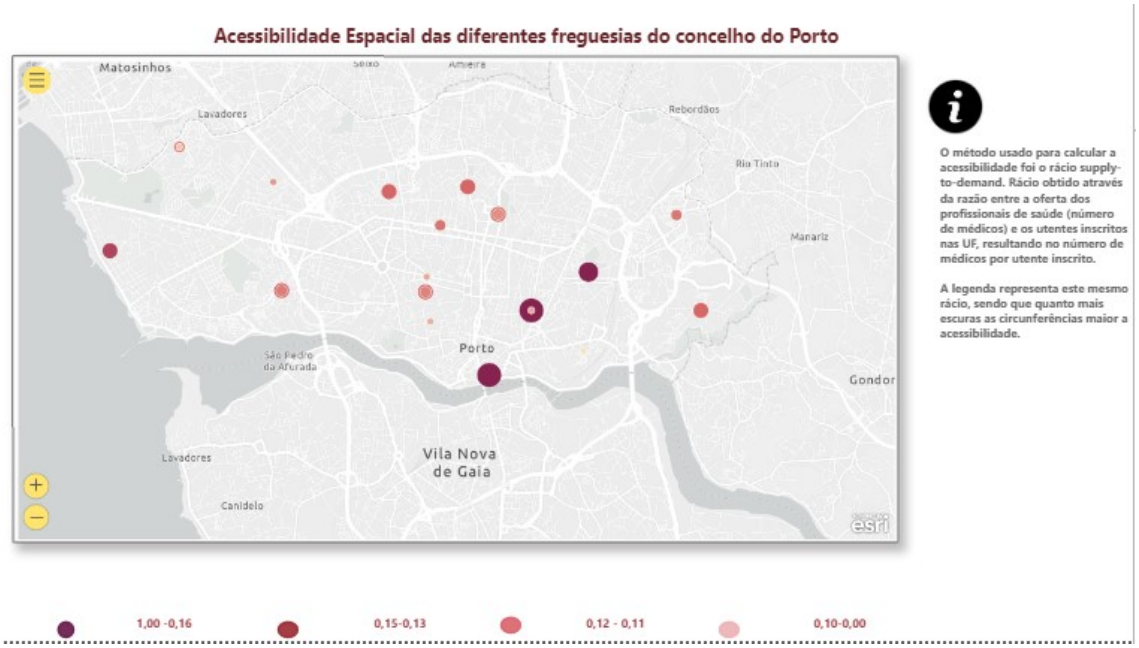

Figure 2- Spatial Accessibility map at a UF level - Supply-to-demand ratio

3.2. The association between accessibility and actual utilization of PHC

In order to verify the association between accessibility and actual utilization of PHC the Pearson's correlation was used.

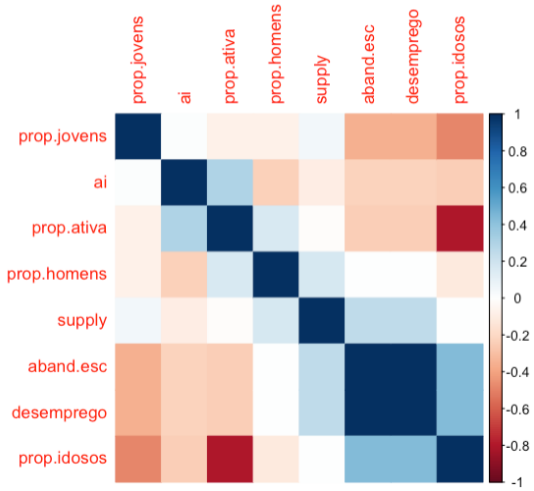

Figure 3- Correlation among variables

Image 3 shows that positively correlated variables are unemployment rate and proportion of elderly people; proportion of elderly people and school dropout; proportion of the working age population and SA calculated through the 2SFCA method; unemployment rate and SA calculated through supply-to-demand ratio and school dropout and unemployment rate. When one of these variables increases the other will also increase, in other words, it will vary in the same direction, and therefore, exhibit a linear association. Variables negatively correlated are the ones that vary in opposite directions. These variables are proportion of elderly people and proportion of the working age population.

Furthermore, the graph highlights some variables that are not correlated at all which means there is no linear relation among the variables such as school dropout and unemployment rates with man proportion; SA calculated through supply-to-demand ratio with proportion of elderly people; SA calculated through the 2SFCA method with proportion of young people; proportion of the working age population with SA calculated through the supply-to-demand ratio.

Both 1-way ANOVA and Kruskal-Wallis tests indicate that the independent variable Spatial Accessibility Terciles, calculated through the 2SFCA method, do not have a statistically significant impact on the three dependent variables (table 2). Supporting that no differences between the mean performance (number of appointments) of UF with different levels of accessibility.

However, when applying the same test to the terciles of the SA calculation using the supply-to-demand ratio, SA does have a statistical significant effect on two variables (Medical Consultation Proportion and Nursing Consultation Proportion) (table 1).

The test results by themselves allow one to conclude that there are significant statistical differences among the terciles relative to consultation numbers when applying the supply-to-demand ratio and not the 2SFCA.

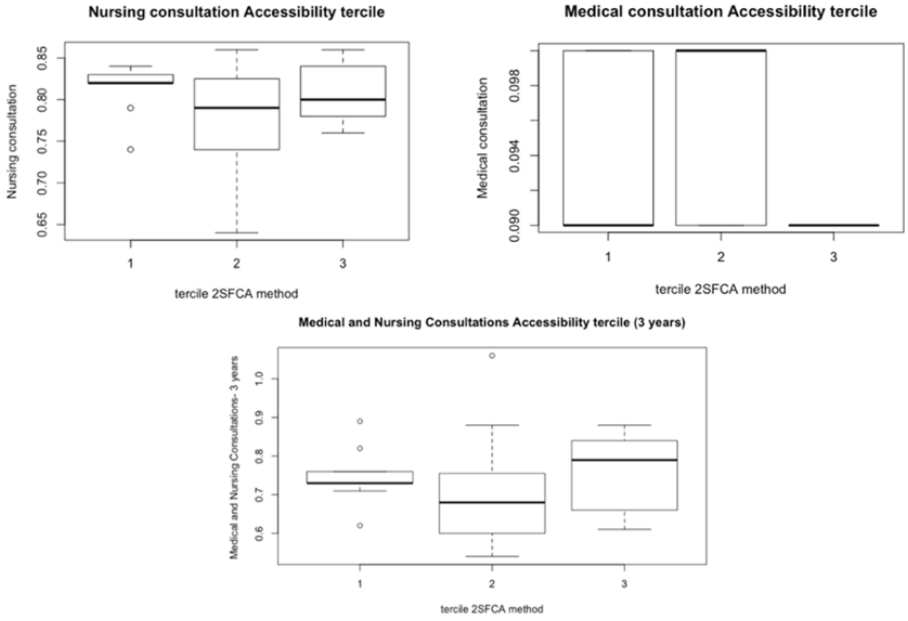

Figure 4 - SA Tercile supply-to-demand ratio

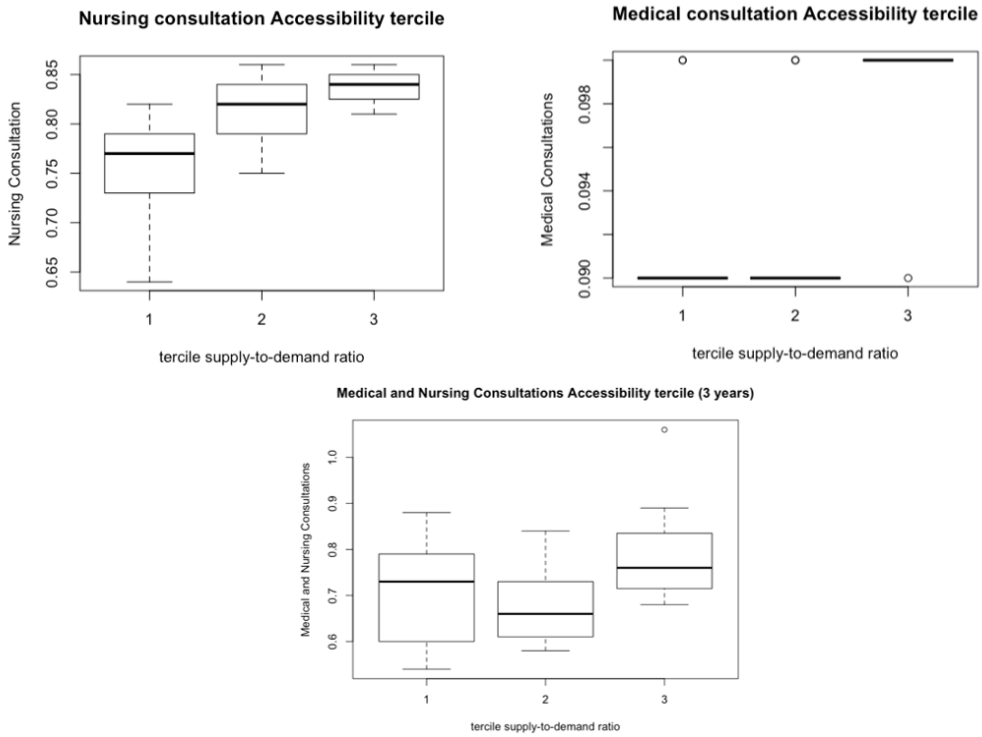

Figure 5- SA Tercile 2SFCA

	2 Step-Floating Catchment area method					Supply-to-demand				
	Accessibility terciles			p-value (ANOVA)	p-value (Kruska-Wallis)	Accessibility terciles			p-value (ANOVA)	p-value (Kruska-Wallis)
	1st (min-P33)	2nd (P33-P66)	3rd (P66-P100)			1st (min-P33)	2nd (P33-P66)	3rd (P66-P100)		
# of UFs	9	11	5	n.a.	n.a.	9	9	7	n.a.	n.a.
Characteristics of UFs (median, IQR)										
# of Doctors and Nurses	114	143	78	n.a.	n.a.	124	109	102	n.a.	n.a.
# of users	99107	126950	70155	n.a.	n.a.	119860	95123	81229	n.a.	n.a.
% female users	0.538	0.537	0.546	n.a.	n.a.	0.539	0.538	0.539	n.a.	n.a.
Outcomes (median, IQR)										
Medical consultation Proportion	0.812	0.0933	0.808	0.638	0.423	0.808	0.789	0.799	0.0124 *	0.0172

Nursing Consultation Proportion	0.739	0.722	0.722	0.936	0.257	0.736	0.724	0.735	0.000433 ***	0.00296 **
Overall utilization rate for medical and nursing consultations – 3 years	0.865	0.836	0.836	0.372	0.621	0.845	0.839	0.840	0.252	0.227

Table 2- The association between SA and actual utilization of PHC according to each method

Linear regression is a mathematical method helpful in determining if the independent variable has any effect on the dependent variable. Furthermore, it adjusts the variables with others that may be misleading. Unfortunately, when trying to perform this method a series of problems emerged that prevented the process from continuing.

When performing linear regressions, small databases and variables with almost no variance are not very useful since there is not enough information to estimate the impact of their variations. This study is only focused on the Porto Municipality, dealing with twenty-five UF's which means the database is pretty small and UFs present very similar or even equal values on some of the variables, such as school dropout and unemployment rate. This highlights the lack of relevance of these variables, which became even more evident due to the small dataset.

When performing multiple linear regression, regardless of the dependent variable used, the problems started with the first model. This model did not present any statistically significant variable, as can be observed in Figure 6, 7 and 8.

```
Call:
lm(formula = consult.med.enf.3 ~ prop.jovens + prop.ativa + prop.idosos +
    prop.homens + ai + aband.esc + desemprego + supply, data = bd)

Residuals:
     Min       1Q   Median       3Q      Max
-0.31497 -0.02259  0.02021  0.05667  0.11406

Coefficients: (1 not defined because of singularities)
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   4.8852     4.7399   1.031    0.317
prop.jovens  -2.6202     4.5158  -0.580    0.569
prop.ativa   -5.9266     4.6774  -1.267    0.222
prop.idosos  -3.8569     4.7598  -0.810    0.429
prop.homens   1.6581     2.4735   0.670    0.512
ai           44.9064   100.3296   0.448    0.660
aband.esc     0.2903     0.4379   0.663    0.516
desemprego        NA         NA      NA       NA
supply       75.0450   103.0671   0.728    0.476

Residual standard error: 0.1066 on 17 degrees of freedom
Multiple R-squared:  0.2723,    Adjusted R-squared:  -0.02727
F-statistic: 0.909 on 7 and 17 DF,  p-value: 0.5226
```

Figure 6- Multiple Linear Regression with the dependent variable Overall utilization rate of medical and nursing consultations- 3 years

```
Call:
lm(formula = consultas.enf ~ prop.jovens + prop.ativa + prop.idosos +
    prop.homens + ai + aband.esc + desemprego + supply, data = bd)

Residuals:
    Min      1Q  Median      3Q     Max
-0.1678 -0.0755 -0.0264  0.1012  0.2388

Coefficients: (1 not defined because of singularities)
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   7.8597     5.4849   1.433    0.170
prop.jovens  -5.0231     5.2256  -0.961    0.350
prop.ativa   -6.7004     5.4127  -1.238    0.233
prop.idosos  -8.7552     5.5079  -1.590    0.130
prop.homens  -1.1820     2.8623  -0.413    0.685
ai          -34.9187   116.1000  -0.301    0.767
aband.esc     0.8754     0.5067   1.728    0.102
desemprego        NA         NA      NA       NA
supply      -73.9890   119.2678  -0.620    0.543

Residual standard error: 0.1234 on 17 degrees of freedom
Multiple R-squared:  0.2636,    Adjusted R-squared:  -0.03956
F-statistic: 0.8695 on 7 and 17 DF,  p-value: 0.5493
```

Figure 7- Multiple Linear Regression with the dependent variable Nursing consultations proportion

```
Call:
lm(formula = consultas.med ~ prop.jovens + prop.ativa + prop.idosos +
    prop.homens + ai + aband.esc + desemprego + supply, data = bd)

Residuals:
     Min       1Q   Median       3Q      Max
-0.10227 -0.02541  0.01212  0.02885  0.06470

Coefficients: (1 not defined because of singularities)
             Estimate Std. Error t value Pr(>|t|)
(Intercept)   1.58376    2.26250   0.700   0.4934
prop.jovens  -1.18909    2.15553  -0.552   0.5884
prop.ativa    0.54340    2.23270   0.243   0.8106
prop.idosos   0.03794    2.27199   0.017   0.9869
prop.homens  -2.18872    1.18070  -1.854   0.0812 .
ai          -21.35603   47.89060  -0.446   0.6613
aband.esc     0.09400    0.20902   0.450   0.6586
desemprego         NA         NA      NA       NA
supply       69.69280   49.19731   1.417   0.1747
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.0509 on 17 degrees of freedom
Multiple R-squared:   0.33,     Adjusted R-squared:  0.05407
F-statistic: 1.196 on 7 and 17 DF,  p-value: 0.3564
```

Figure 8- Multiple Linear Regression with the dependent variable Medical consultations proportion

In order to correctly perform the PCA, a standardization was required seeing as the variables were not on the same scale. After the standardization was performed, it was possible to verify that the scree plot (Figure 9) suggests that only 4 components should be kept since the remaining factors add little information.

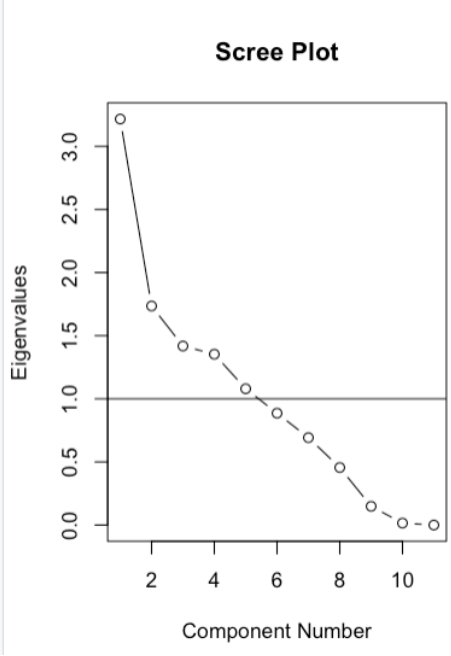

Figure 9-Principal Component Analysis Graph

Based on Kaiser's Criteria, factors with higher values than the average should be considered, which in this case is 1. Based on this method, the recommended number of factors is 5. The criterion for minimal percentage variance considers the components that individually explains at least 5% to be relevant. Based on this criterion, the data variability is explained by 7 factors (Figure 10). The percent cumulative criteria suggest choosing the components that explain at least 80%, which in this case is also 5 (Figure 10).

The number of components chosen must represent the variables well, in other words, it is important to look at the principal components contributing to the variables and that they explain at least 50% of the variable. Regarding the variable youth proportion with only 3 factors, this is well represented since it reaches the 50% mark. Now the working population and proportion of medical

consultations only need 2 factors. The proportion of elderly people, school dropout, and unemployment can be well represented with only 1 factor. This is not the case for male proportion, nursing consultation proportion, and overall utilization rate of both medical and nursing consultations in the last 3 years since it requires 4 factors to be well represented. Regarding the two variables related to SA, a variable that contain the SA values based on the 2SFCA method and supply that comprehends SA values based on the supply-to-demand ratio, both variables require 5 factors to be well represented being this the only two variables requiring these many factors.

```
Call:
PCA(X = bd[, 2:12], scale.unit = TRUE)


Eigenvalues
                       Dim.1   Dim.2   Dim.3   Dim.4   Dim.5   Dim.6   Dim.7   Dim.8   Dim.9  Dim.10  Dim.11
Variance               3.216   1.735   1.418   1.353   1.080   0.886   0.692   0.456   0.148   0.015   0.000
% of var.             29.238  15.774  12.892  12.303   9.815   8.055   6.293   4.142   1.349   0.140   0.000
Cumulative % of var.  29.238  45.011  57.903  70.206  80.021  88.076  94.369  98.511  99.860 100.000 100.000

Variables
                      Dim.1    ctr   cos2    Dim.2    ctr   cos2    Dim.3    ctr   cos2    Dim.4    ctr   cos2    Dim.5    ctr
prop.jovens       | -0.460  6.580  0.212 | -0.107  0.655  0.011 |  0.539 20.456  0.290 |  0.501 18.539  0.251 | -0.195  3.531
prop.ativa        | -0.570 10.099  0.325 |  0.673 26.106  0.453 | -0.079  0.445  0.006 | -0.382 10.780  0.146 |  0.103  0.975
prop.idosos       |  0.761 18.004  0.579 | -0.524 15.849  0.275 | -0.270  5.142  0.073 |  0.027  0.052  0.001 |  0.056  0.287
prop.homens       | -0.035  0.038  0.001 | -0.034  0.065  0.001 |  0.602 25.538  0.362 | -0.626 28.962  0.392 |  0.043  0.171
ai                | -0.382  4.543  0.146 |  0.199  2.287  0.040 | -0.474 15.814  0.224 |  0.134  1.319  0.018 |  0.415 15.971
aband.esc         |  0.852 22.557  0.725 |  0.258  3.850  0.067 | -0.023  0.037  0.001 | -0.211  3.286  0.044 | -0.177  2.903
desemprego        |  0.852 22.557  0.725 |  0.258  3.850  0.067 | -0.023  0.037  0.001 | -0.211  3.286  0.044 | -0.177  2.903
consultas.med     |  0.429  5.721  0.184 |  0.606 21.191  0.368 | -0.154  1.683  0.024 |  0.365  9.836  0.133 |  0.285  7.508
consultas.enf     |  0.106  0.347  0.011 |  0.620 22.188  0.385 |  0.145  1.480  0.021 |  0.345  8.774  0.119 | -0.543 27.271
consult.med.enf.3 |  0.470  6.868  0.221 | -0.068  0.264  0.005 |  0.406 11.630  0.165 |  0.447 14.751  0.200 |  0.349 11.295
supply            |  0.294  2.685  0.086 |  0.253  3.695  0.064 |  0.502 17.738  0.252 | -0.075  0.416  0.006 |  0.542 27.186
                     cos2
prop.jovens         0.038 |
prop.ativa          0.011 |
prop.idosos         0.003 |
prop.homens         0.002 |
ai                  0.172 |
aband.esc           0.031 |
desemprego          0.031 |
consultas.med       0.081 |
consultas.enf       0.294 |
consult.med.enf.3   0.122 |
supply              0.294 |
```

Figure 10- Principal Component Analysis

Plotting the Variables Factor Map (Figure 11) helps in interpreting the variables and analyzing their correlations. Dim 1 mainly entails the proportion of elderly people, school dropout and unemployment rate. Dim 2 presents a higher value for the working population, medical and nursing consultation proportion. Dim 2 suggests that the majority of the patients that attend both medical and nursing consultation are between 10 years to 64 years old. The higher values presented in Dim 3 are male proportion, as well as youth proportion. SA was calculated based on the supply-to-demand ratio and overall

utilization ratio of both medical and nursing consultations in the last 3 years. This may indicate that young males are the ones attending most of the consultations, regardless of the type of consultation (medical or nursing) and that the SA has an impact on this type of patient attending consultations. When looking at Dim 4 for the past 3 years, once again youth's proportion for overall medical and nursing utilization rate stands out. Dim 3 and 4 are very similar. However, Dim 3 is specifically highlighting that young males attend consultations frequently, whereas Dim 4 only highlights youth in general and does not provide further details. Lastly, Dim 5 emphasizes the working age population proportion, as well as SA calculated in two methods. Furthermore, it shows the overall utilization rate of both medical and nursing consultations over the past 3 years and the medical consultations proportions, which suggest that the working age population proportion frequently attends consultations, especially medical consultations and the SA has an effect on this attendance rate.

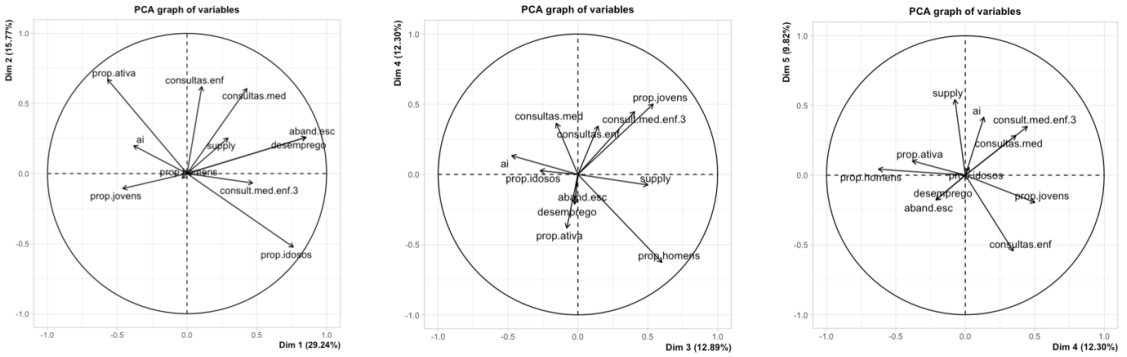

Figure 11- Variables factor map

3.3. Dashboard

As previously mentioned, the purpose of this dashboard is to close the gaps found in the dashboards provided by the SNS. The dashboards provided by the SNS present detailed information regarding the UF. However, the private health sector is not included nor are the socioeconomic characteristics of the

patients from each municipality and the spatial accessibility. All these factors may influence the demand for public PHC.

The dashboard below is a more complete alternative to the dashboards provided by SNS. It is divided into 4 parts, one report exclusively dedicated to the health sector in Porto Municipality (Fig.12), another focused on the socioeconomic characteristics of the population living in the municipality (Fig. 14), other centered on spatial accessibility calculated based on the 2SFCA method (Fig. 13) and the last one based also on SA calculated using the supply-to-demand ratio (Fig.15).

The SNS dashboards provide detailed information per UF, this characteristic is also available in the dashboard below, the user may use page filters to specifically analyze a particular UF.

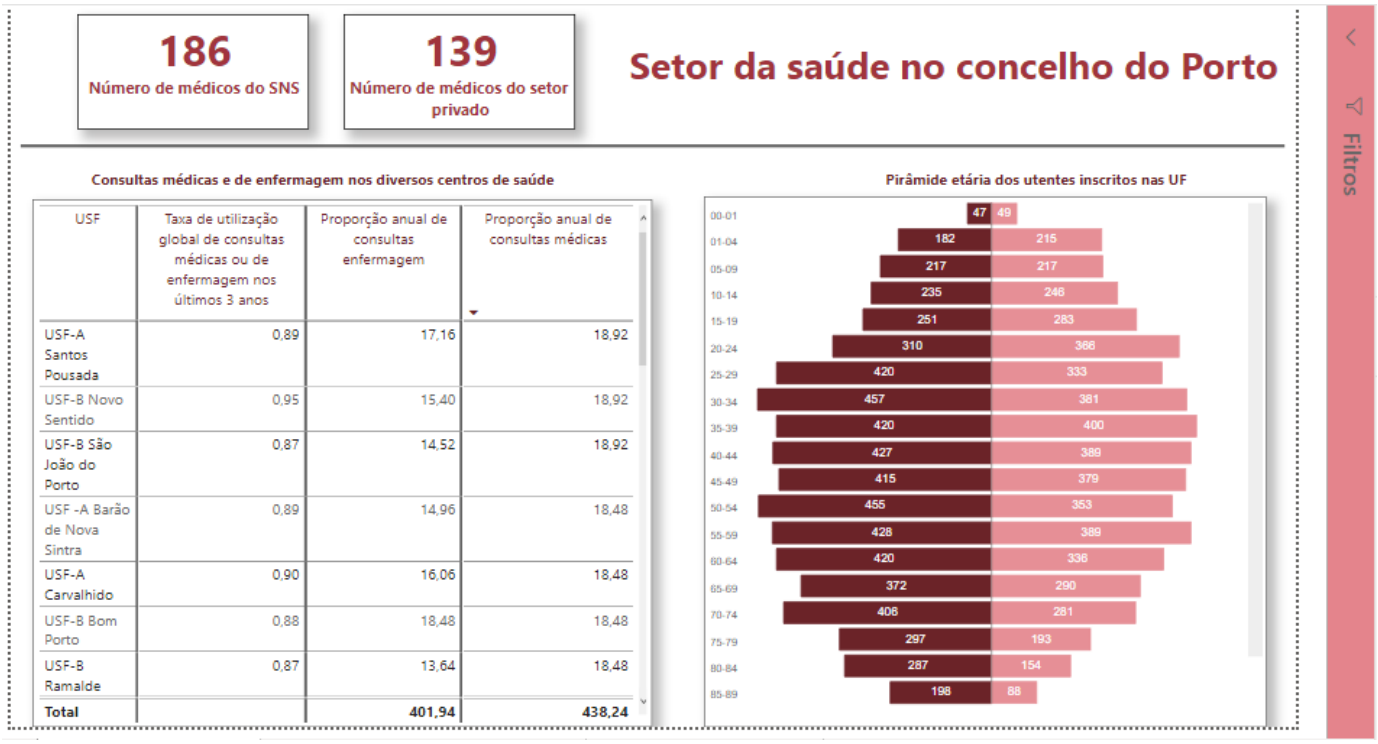

Figure 12- Dashboard Health Sector in Porto Municipality

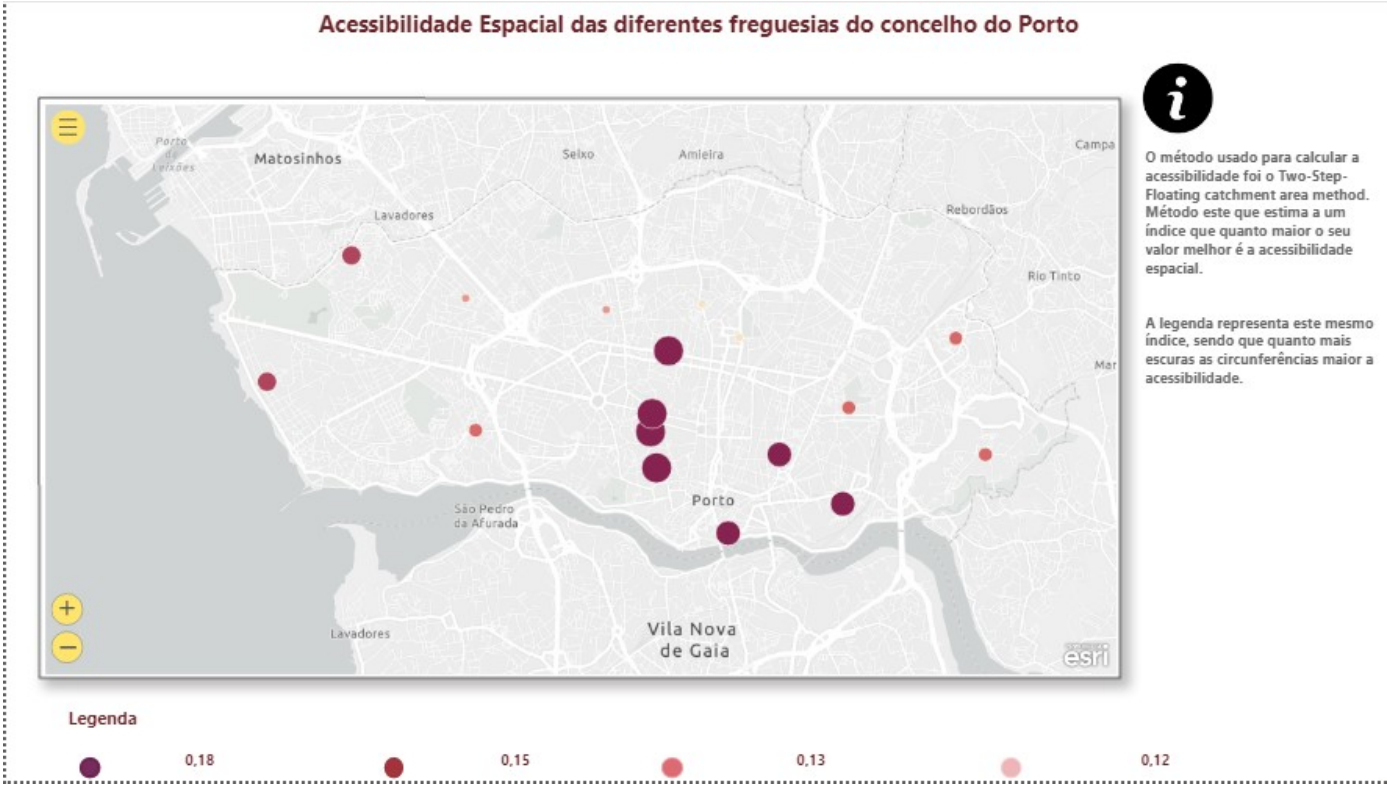

Figure 14- SA map based on the 2SFCA method

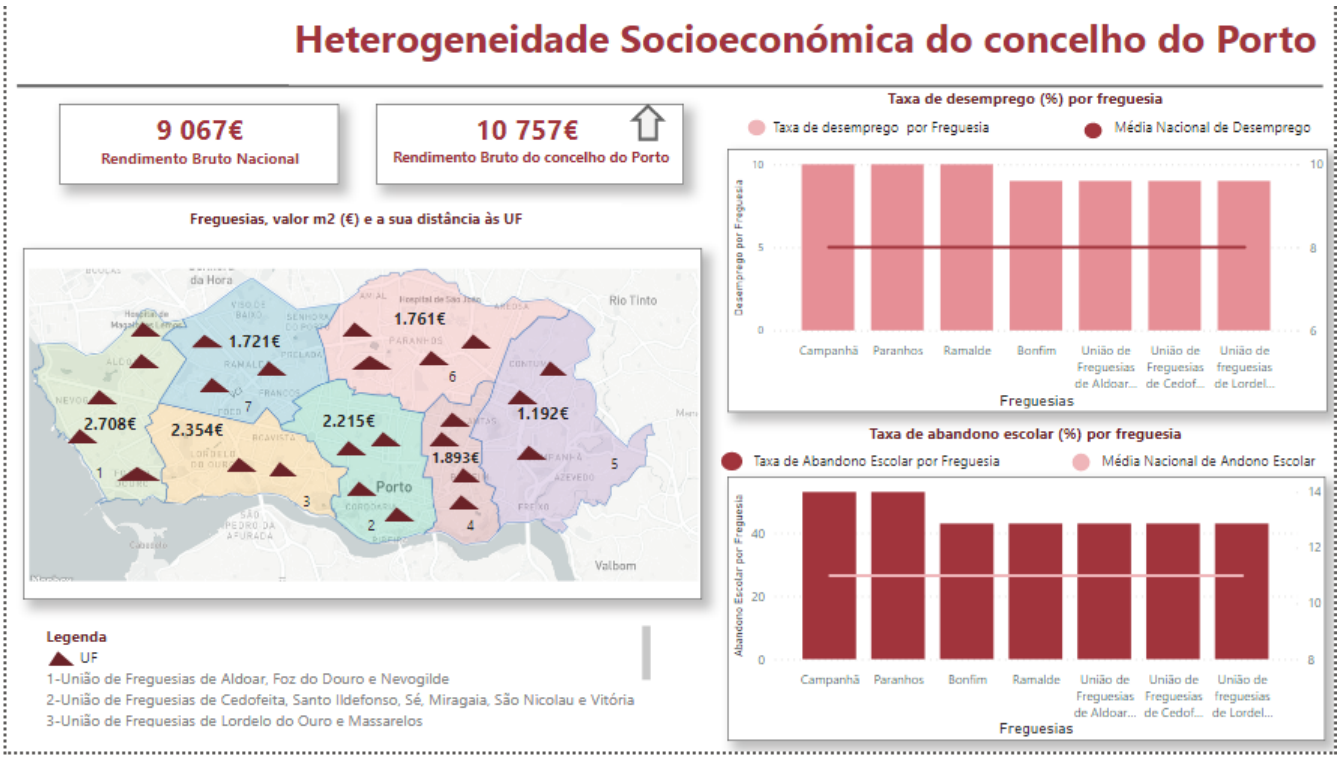

Figure 13- Dashboard Socioeconomic Heterogeneity in Porto Municipality

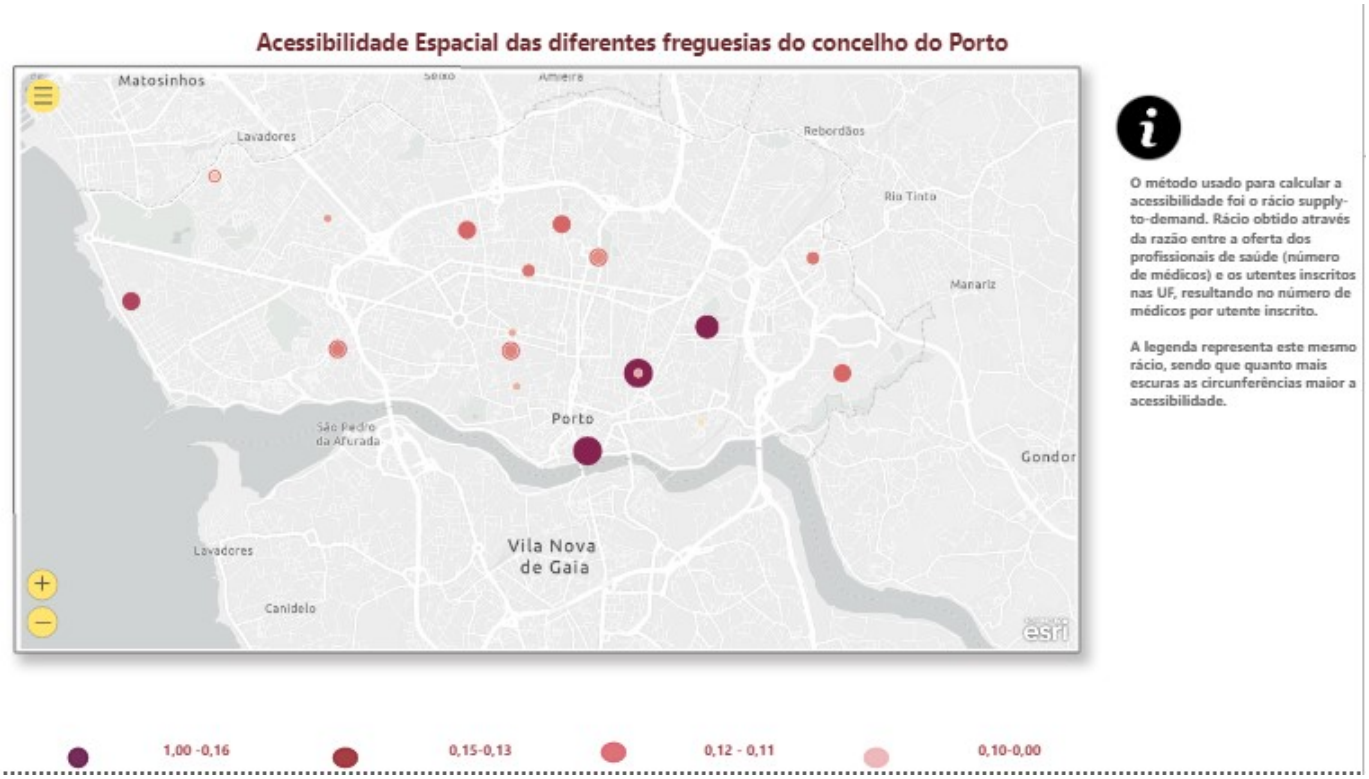

Figure 15- SA map based on supply-to-demand ratio

4. Discussion

The methods use in this study to calculate the SA are 2SFCA and supply-to-demand ratio. The 2SFCA is considered as being a very complete approach providing easy-to-interpret information, which is one of the biggest advantages. The ratio attributed to a location is interpreted as the number of facilities available to each patient in each location, which in this study refers to a parish within Porto Municipality. Nevertheless, some improvements are still required. One of the major drawbacks of the 2SFCA method is that it attributes the same ratio to all locations when that is not always the case, seeing as one location may be closer to a health facility than another. That being said, if one identifies potentially underserved areas as those with ratios smaller than the entire area ratio, ratios based on this method are dubious (Yang et al, 2005). Regarding the supply-to-demand ratio, this is very intuitive, the data required for the calculation is available and it does not require GIS tools or specific know-how, this being the biggest advantage. However, it does not consider border crossing nor accessibility variations within bordered areas, and it also ignores travel independence (Guagliardo, 2004).

The 2SFCA calculation showed that even though the study area is small, different parishes within Porto municipality present different levels of accessibility to PHC. This may be explained by the higher proportion of elderly people in this municipality. According to the 2011 Census, the evolution of the age structure of Porto resulted in an increase in the senior (65 years old or more) proportion and a decrease in the juvenile (0 to 14 years old) proportion (Departamento Municipal de Planeamento Urbano, 2018). Besides, this municipality suffers from heterogeneity in socioeconomic terms, with very expensive areas and social neighborhoods are really close to each other.

In the report of Diagnóstico Social do Porto – Porto Solidário, 13,3% of the population lives in social neighborhoods. Of this share, the majority lives in

neighborhoods located in Campanhã, than Paranhos, Lordelo do Ouro and Ramalde (Centro de Respostas Integradas do Porto Central, 2012). Since 2015 the house prices have increased and the most expensive areas of Porto are downtown, Foz and Boavista (Notícias, 2018).

We found out that Spatial Accessibility does not have a significant effect in medical or nursing consultations when calculated with 2SFCA, since the p-values obtained from two different test, ANOVA Test and Kruskall-Wallis test, were always much higher than 0.05 (table 1). However, it is important to highlight that these results may be biased due to the small dataset used in this study, which only compromised the 25 PHC units located in Porto Municipality.

When calculating SA through the supply-to-demand ratio the dependent variables, Medical Consultation Proportion and Nursing Consultation Proportion present p-values values smaller than 0.05, which means that SA does influence the dependent variables. The difference between the results obtained when applying each method may be a consequence of the particular aspects of each method, since both measure SA. As previously mentioned, the 2SFCA is a more robust method, since it considers the possibility of patients overflow across the parish frontiers to obtain medical assistance, while the supply-to-demand ratio does not consider this possibility, therefore limiting its usefulness.

The supply-to-demand ratio variance is higher among groups when compared to the 2SFCA method. In other words, the data dispersion is higher with the supply-to-demand ratio than it is with the 2SFCA method.

Regarding the dependent variable Medical consultation proportion, all UF present higher proportions than the national average, except for UCSP Foz do Douro and the UCSP São Roque da Lameira, which have a value equal to the national average.

Another interesting aspect is that the unemployment rate, as well as the school dropout rate, are very high in comparison with the national average. The

parishes that have higher values in these two indicators are Bonfim, Paranhos and Campanhã. It is interesting to observe that these 3 parishes and their respective UFs present a higher medical consultation proportion. According to some authors, the economic growth of a country increases the average family budget that consequently raises the purchasing power, which results in a higher demand for private health services (Tountas, Karnaki, Pavi, & Souliotis, 2005). Ribeiro (2009) explains that in Portugal, the demand for private health services is related to seeking a higher level of comfort in hospitalization activities, coverage of certain specialties mostly available in the private sector, such as dentists, growing demand for aesthetic care, and the long waiting list for an appointment both in the PHC and specialties consultation. The conclusions that the authors reached explain why the parish with higher values of school dropout and unemployment rate are the ones with higher medical consultation index since these populations do not have the financial means to pay for health insurance that would allow them to use the institutions and its benefits of the private health sector. Even though at the end of march of 2020, more than 3.15 million Portuguese citizens had health insurance, 80% more than in 2015 (Seguros, 2020). The data regarding a number of citizens with health insurance by municipality is not publicly available.

Regarding the Nursing Consultation proportion, the majority of the UF present lower values than the national average. In the parish of Campanhã there are 2 UF's, USF-A Azevedo Campanhã and UCSP São Roque da Lameira, that present values that are considered outliers, since USF-A Azevedo Campanhã has a value of 1,06 and UCSP São Roque da Lameira 0,54 and the national average is 0,81. According to an article published in the New Zealand Medical Journal, the overall average of medical consultations is always higher than nursing consultations. According to this paper, the average medical consultation per patient per year is 3 and 0 for nursing appointments. Another aspect that contributes to this low number of nursing consultations is that it is rare in the

country that applies the procedure that before an appointment with a doctor a nursing consultation is required (Baldwin, et al., 2016). In Portugal, in the USF the procedure for medical consultations is that it was preceded by a nursing consultation (CINTESIS, 2017).

Considering the utilization rate of medical and nursing consultations – 3 years, the values presented are in line with the values obtained in the other two variables, nursing and medical consultation. The reason for this unison is that this variable takes into consideration the proportion of patients subscribed and that they had at least one medical or nursing appointment in the last 3 years, regardless of being in person or not. The other two variables are similar (Medical/nursing consultation proportion); however, they are specific for each type of consultation (medical or nursing) and have a shorter period of valuation, one year (ACSS, 2017).

It is important to explain the organizational structure of the UF. This explanation will only focus on the types of units used in this study.

In 2005 Primary Health Care underwent a reform that consisted in new organizational models, being the USF the basis of the PHC. These units are innovative since they have autonomy at an organizational and technical level, mandatory information systems, as well as pay-for-performance incentives. There are 3 types of USFs (A, B and C). USF-A is the first step, and it is in this phase that the teamwork abilities are explored. This model has some goals that, as a team, should be reached. If the unit is able to fulfill these objectives, the institution receives certain incentives that can be medical equipment or infrastructure improvements. Now, USF-B is the next stage, a more demanding one. Here there are 2 types of incentives, individual and collective. Like in the previous phase, these incentives are only available if the goals previously established are accomplished. All of this results in different payment schemes, the salary is paid, as well as some supplements related to the list of users and rewards for the performance. Regarding the UCSP, they have the same mission

as the USF, which is the provision of individual and family health care, ensuring accessibility and continuity of care. The differences consist in the lack of autonomy and incentives that are determined according to objectives that this unit does not have. Besides, the nursing appointments prior to medical consultations are not schedule (ACSS, 2017). The fact that UF's receive incentives according to their performance may result in the UF's presenting higher numbers of appointments when compared to the UCSP that do not work based on pay-for-performance.

In Porto Municipality, the vast majority of PHC units are USF, units that have incentives that may influence the number of consultations given to the population, since each unit and in the case of USF-B, each member of the team, tries to be as efficient as they can, in order to earn the incentives.

Unfortunately, in this study, it was not possible to reject the null hypothesis, since there are no sufficient evidence that the independent variable (Spatial Accessibility), when calculated with the 2SFCA, exhibits a statistically significant relationship with the dependent ones (Medical Consultation Proportion, Nursing Consultation Proportion and Overall utilization rate for medical and nursing consultations – 3 years), which resulted in a slightly different dashboard. However, when SA is calculated using supply-to-demand ratio, the dependent variables medical and nursing consultation proportion appear to be influenced by the SA.

In this sense, the dashboard provided in this work is not strictly based upon empirical evidence, but rather it was designed according to the literature and to provide a more complete picture of primary health care accessibility and its main determinates, thereby addressing the lack of such information on other dashboards provided by the SNS. The developed dashboard will help to easily visualize the information, as well as to allow the monitoring of the data in a long-term period. Even though the sample is reduced and does not show the relation

between the variables, the literature supports that different indicators should be monitored, which will be facilitated by the dashboard.

5. Limitations

Some limitations should be noted. The first limitation is that the Portuguese law does not consider a maximum travel time that a patient should go through until reaching a UF, it only mentions that these services should be reasonably close to the population (DRE, 1983). The only information provided is that each UF has to cover the entire parish where it is located, so in order to know the catchment area, an article was used as a basis since it shows that on average each USF is located at a travel distance of 30 minutes (ERS, 2009).

Another limitation related to Portuguese law is that contrary to what happens in other countries, citizens are not allowed to attend a UF outside their residential area, apart from some exceptions. If the patient wants to change the UF in favor of one outside the residence area, due to its personal convenience the law allows that. However, an adequate justification is required. Nevertheless, it is important to mention that it loses the right to some types of care, such as home care (DGS, 2014).

Also related to the distances, in the 2SFCA method, the Euclidean distance was used. The Euclidean distance is a distance between two points that can be proved through the repeated application of the Pythagorean Theorem. When applying this to distance, the Euclidean space becomes a metric space (Liberti, Lavor, Maculan, & Mucherino, 2012). To summarize, the Euclidean distance is a straight line, when in reality not such a path exists.

When trying to use the linear regression method some problems emerged, such as neither of the variables is statistically significant. This problem prevents the model from accurately estimating the significance level of the independent variables. This may be due to the limited study area and the variation in the

independent variables between UF's are reduced, besides this, the hierarchic nature of the data is also an influencing factor.

Regarding the dashboard, some of the visuals required to elaborate the maps carry a cost, therefore the limitation in the presented map is that it is not possible to filter the information and thereby perform detailed analysis on specific data. Furthermore, the dashboard displays the number of general practitioners in order to provide an idea of how many doctors are in the private compared to the public sector. There is a limitation with this approach, the information only provides the head- count and it is not possible to identify how many of these doctors work 40h a week in the private sector. Most of the doctors in the private sector work in an accumulation regime with the public sector.

6. Conclusion

The main topic of this study is to understand if Spatial Accessibility influences the number of consultations in the Porto Municipality. In order to answer this, three questions need to be answered.

Question 1, "Which factors effectively influence access to Primary Health Care?" the answer was provided based on literature review and complemented by the dashboards. The main factors identified in this research were Spatial Accessibility, socioeconomic, and private health factors.

Question 2, "Does Spatial Accessibility differ among parishes within the same municipality?", was answered based on the calculation of Spatial Accessibility and then shown in a map to facilitate the interpretation. In order to calculate the SA, both traditional and advanced measures were applied. The 2SFCA, an advanced method, is also easy to use, interpret and understand (Shalini Kanuganti, 2016), as well as the supply-to-demand method, a more traditional method that is also very used, however not as complete as the previous method since it does not consider supply and demand outside parishes frontiers.

By looking at the map it can be seen that there are some differences among the parishes. Parishes located in the center of the municipality present higher SA than the ones located in the extremities.

Regarding question 3 that aimed to verify if Spatial Accessibility has a statistically significant effect on the number of medical or nursing consultations, two tests were used both the ANOVA and Kruskall-Wallis tests demonstrate that SA does not seem to have a statistically significant effect on the number of consultations when the 2SFCA method is applied. However, when the supply-to-demand ratio is used both medical and nursing consultations seemed to be affected by SA. The linear regression was inconclusive. This may be a

consequence of the limited dataset used, since this study only focused on one municipality. Besides the methods mention above an association test was implemented which demonstrated that there are some variables very correlated and other variables that do not present any association between them. The last statistical procedure implemented was the PCA that demonstrated that some factors explain the SA.

Future work can improve this research by increasing the study area, which will allow one to confirm if SA does not affect the number of consultations or if it was a consequence of the small dataset.

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