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City-wide planning metrics for public urban parks and gardens: A case study of Porto, Portugal

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To urban dwellers everywhere

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Declaration of honor

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Fernanda Costa Cavallaro

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Abstract

Public urban parks and gardens are both public open spaces and urban green spaces, making them important contributors to urban vitality and human well-being. The planning of parks and gardens, however, faces the difficulty of metrics often being directed to one category or the other. Based on literature review of research studies and grey literature on both public open spaces and urban green spaces, this work proposes a city-wide and people-centered framework of planning metrics which cover pedestrian accessibility and qualitative measures, focused on principles of equality and inclusivity. The city of Porto, in Portugal, is chosen as case study due to its recent commitment to expanding and requalifying green spaces and the unique role the city plays as the center of the metropolitan region of Porto. The framework utilizes generally accessible secondary data and GIS technologies, which can be adapted to other contexts. The results show the framework can be a useful tool as a first city-wide diagnosis of inequalities and potentials as it provides complementary analyses aligned with current best practices, while also allowing for more or less nuanced diagnoses depending on data disaggregation and availability.

Key-words: public open spaces, urban green spaces, planning metrics, accessibility, quality assessment

Resumo

Parques e jardins urbanos públicos são espaços públicos abertos e áreas verdes urbanas, contribuindo para a vitalidade urbana e o bem-estar da população. O planejamento de parques e jardins, no entanto, encontra a dificuldade de que as métricas geralmente são relacionadas ou aos espaços públicos ou às áreas verdes. Com base na revisão de literatura de estudos acadêmicos e literatura cinzenta sobre tanto espaços públicos abertos como áreas verdes urbanas, o trabalho propõe um quadro de métricas de planejamento centrado nas pessoas e na escala da cidade que aborda tanto acessibilidade pedonal como métricas qualitativas, baseado nos princípios da igualdade e inclusividade. A cidade do Porto, em Portugal, é escolhida como caso de estudo devido ao seu recente compromisso em expandir e requalificar as áreas verdes e no seu papel central dentro da região metropolitana. As análises selecionadas utilizam dados secundários de fácil obtenção e tecnologias SIG, podendo ser aplicadas a outros contextos. Os resultados demonstram que o quadro de métricas de planejamento proposto pode ser uma ferramenta útil como um primeiro diagnóstico geral de desigualdades e potencialidades, uma vez que fornece análises complementares alinhadas às boas práticas atuais, ao mesmo tempo que permite diagnósticos mais ou menos refinados dependendo da desagregação e da disponibilidade dos dados.

Palavras-chave: espaços públicos abertos, áreas verdes urbanas, métricas de planejamento, acessibilidade, avaliação qualitativa

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Acronyms

PUPGs ..... PUBLIC URBAN PARKS AND GARDENS
AMP ..... METROPOLITAN REGION OF PORTO (ÁREA METROPOLITANA DO PORTO)
SDGs ..... SUSTAINABLE DEVELOPMENT GOALS
UN ..... THE UNITED NATIONS
UN-HABITAT ..... THE UNITED NATIONS HUMAN SETTLEMENTS PROGRAMME
WHO ..... WORLD HEALTH ORGANIZATION
OECD ..... ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT
INE ..... INSTITUTO NACIONAL DE ESTATÍSTICA
VCI ..... VIA DE CINTURA INTERNA
UOPG ..... UNIDADES OPERATIVAS DE PLANEAMENTO E GESTÃO
OSM ..... OPEN STREET MAP

1. Introduction

There is some uncertainty when it comes to planning and designing public urban parks and gardens (PUPGs) from a systemic view, as they are both public open spaces and urban green spaces.

Many studies have shown the positive effects of green spaces to human health, well-being and to the environment (Tzoulas et al., 2007; Lopes & Camanho, 2013; Nutsford et al., 2013; Wolch et al., 2014; Ekkel & de Vries, 2017; Jennings & Bamkole, 2019; Reyes-Riveros et al., 2021; Ha et al., 2022), but, because they deal with green spaces, they take into consideration any vegetation, including spaces that are neither frequented nor public (Wolch et al., 2014; Haaland & van den Bosch, 2015; Jennings & Bamkole, 2019). Studies that evaluate the benefits and/or the accessibility of green spaces don't usually discriminate the type of spaces (Haaland & van den Bosch, 2015; Douglas et al., 2017; Ekkel & de Vries, 2017; Letra et al., 2017; Jennings & Bamkole, 2019). Metrics that come from these studies are, therefore, insufficient when it comes to their application in planning and urban design, as the provision of such spaces inevitably has to consider the nature of the space itself, its purpose.

Public open spaces in its pure conception, on the other hand, don't necessarily contain vegetation – think dry squares and streets – but they play a vital role in city life and human well-being through fostering interaction and community building (Llewelyn-Davies, 2007; Gehl & Svarre, 2013; Lopes & Camanho, 2013; Project for Public Spaces, 2016). It would be unrealistic to expect PUPGs to provide all green spaces benefits or public space vitality a city requires, and yet, without clear metrics, they can fall short of their potential to contribute to society and to the environment.

This leads us to the second motivation for studying this theme: just because a place exists, it doesn't mean it is used or useful in the ways we would want it to be: the ways people perceive places, how accessible they are, what activities they support and other qualitative aspects influence how and if people use them (Jacobs, 1961; Whyte, 1980; Hillsdon et al., 2006; Lopes & Camanho, 2013; Brandão et al., 2018). Therefore, the provision of PUPGs alone does not guarantee their effective use and, consequently,

their benefits may also be misrepresented. How much is enough? Where should they be located? For which purposes? How big or small? Which parameters inform the vitality of these spaces?

Best practices in planning compiled by the Economic Commission for Latin America and the Caribbean (ECLAC) (2021, p. 10) advised that "A situation analysis cannot be based on a single examination, but on multiple ones, thus representing as accurately as possible the situation that is 'happening' from the perspective of the multiple actors concerned". It is with this view that this research proposes to look into the planning of PUPGs from a city-wide perspective. A human-centered approach is proposed, interested in understanding how PUPGs can best provide for the population from their role as public open spaces, thus supporting their benefits as urban green spaces.

1.1. Objectives

This work aims to build the basis for an initial city-wide assessment that contemplates the existing urban fabric and population demands by creating a framework of planning metrics which can be used to identify deficits and potentials, according to the best practices in urban design and scientific research from related fields. The city-wide planning metrics framework will then be applied to a case study considering its specific context and available data in order to test how relevant and useful it can be from a planning perspective and to identify limitations. The research aims to answer the following questions:

a. How can PUPGs best serve the population from a human-centered approach, based on equal opportunity and people's preferences?
b. Which metrics for public urban green spaces and public open spaces address the aforementioned question and can be applied in the planning of PUPGs on a city-wide scale?

A literature review of research studies and grey documentation was performed focused on public open spaces, urban green spaces and metrics that have been studied, discussed and tested on both. In order to ensure addressing both equal opportunity and people's preferences, the selected literature attempts to cover the subjects of accessibility, qualitative and quantitative metrics, demographics and people's preferences.

Accessibility analyses can help characterize sites based on how local or urban their reach is, pinpoint places that are lacking in PUPGs based on both resident's population and potential visitors, determine which sites might need assistance of public transport and which streets are more likely to be used by pedestrians. Qualitative metrics combined with demographics and people's preferences can help ensure PUPGs are inclusive, providing for a diversity of needs. Together, these metrics can help inform changes and investments to improve existing places and design and locate new ones.

1.2. Place

The research proposes to apply its framework of planning metrics to the city of Porto, Portugal. Porto is the center of the second largest agglomeration in Portugal, the Metropolitan Region of Porto (Área Metropolitana do Porto – AMP) but only houses 12% of its population (Direção Municipal de Urbanismo, 2021c), which has been following the national trend of aging (Instituto Nacional de Estatística, 2022a). On the other hand, the concentration of jobs and services, cultural and educational institutions, alongside the growing relevance of tourism, creates a dynamic movement of daily activity which combines residents and non-residents (Direção Municipal de Urbanismo, 2021c).

The city has committed to carbon neutrality by 2030 (Porto Digital, 2022; Departamento Municipal de Comunicação e Promoção da Câmara Municipal do Porto, 2024), and one of its goals is the expansion and requalification of green spaces, not only in the shape of new parks and gardens, but also by planting more native trees in public and private green spaces and a street arborization plan (ClimA daPT.Local, 2016;

Departamento de Planeamento e Gestão Ambiental, 2022), with the ambitious goal of doubling the per-capita green area in the city (Direção Municipal de Urbanismo, 2021a).

Other goals, within the context of promoting changes in lifestyle towards a more sustainable city, are to encourage active mobility and healthy habits, for which Porto recognizes the importance of good quality public spaces and of inclusive and quality parks and gardens (Direção Municipal de Urbanismo, 2021c). These goals are in accordance with the Sustainable Development Goals (SDGs) (UN-Habitat, 2020d). Portugal, however, does not currently monitor targets 11.2 and 11.7[1], the most closely related to the city's proposals (Instituto Nacional de Estatística, 2023b), and the United Nations (UN) recognizes there is no agreed methodology for them (UN-Habitat, 2020d). Porto has indicated the need to create a monitoring system for the SDGs related to its strategic goals (Direção Municipal de Urbanismo, 2021a). These combined conditions make Porto an interesting and appropriate place for assessment.

1.3. Structure

The dissertation is structured in six chapters:

Chapter 1 introduces the theme, the objectives and the case study.

Chapter 2 presents the findings from the literature review, divided into four subchapters: 2.1 – "Public open spaces" gives an overview of public spaces seminal theories and their link to current best practices in planning; 2.2 – "Urban Green spaces" looks into the benefits and challenges of urban green spaces planning; 2.3 – "Metrics" combines metrics from grey literature and scientific papers, divided into the categories

[1] **11.2:** "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" and **11.7:** "By 2030, provide universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, older persons and persons with disabilities" United Nations - Statistical Commission. (2023). *Global indicator framework for the Sustainable Development Goals and targets of the 2030 Agenda for Sustainable Development*. United Nations. https://unstats.un.org/sdgs/indicators/Global%20Indicator%20Framework%20after%202023%20refinement_Eng.pdf.

accessibility and *quality assessment*; 2.4 – "City-wide planning metrics" presents the proposed framework of selected analyses to be applied.

Chapter 3 presents the city of Porto, focusing on its street network development, its center role within the AMP, its age demographic context and the city's plans for active mobility and green spaces.

Chapter 4 presents the methodology by addressing the data, data preparation and the measurements and parameters utilized in the *accessibility* and *quality assessment* analyses.

Chapter 5 presents the results of the analyses and discusses the findings supported on the literature review and the specifics of the case study.

Chapter 6 presents the conclusions and recommendations for future research and development.

2. Theoretical Framework

2.1. Public open spaces

The Charter of Public Space defines that "Public spaces are all places publicly owned and or of public use, accessible and enjoyable by all for free without a profit motive" (UN-Habitat, 2016a, p. 6). The United Nations Human Settlements Programme (UN-Habitat) classifies the following types of public spaces: streets; public open spaces (parks, gardens, playgrounds, beaches, riverbanks, and waterfronts); public urban facilities; the 'space of the public'; the City itself; and cyberspace (UN-Habitat, 2018). This research is interested in both "public open spaces" and "streets", the last as the de-facto movement network that connects the first.

Public open spaces have historically been the stage for public life due to their multifunctionality, be it through their role as movement conductors, effectively responsible for the rhythms of daily life – more or less chaotic depending on its success – or by being the common ground where people meet, socialize, express civically and culturally and practice all sorts of communal activities (Department of Urban Studies and Planning - MIT, 2013; Gehl & Svarre, 2013; Lopes & Camanho, 2013; UN-Habitat, 2018). The rhythm varies from hour to hour, from day to day, with different groups dominating certain spaces based on their own schedules and what a place offers (Jacobs, 1961; Whyte, 1980; Lopes & Camanho, 2013). One can think of commuters up and about going to work or study, kids in playgrounds before or after class, teens congregating at the end of a school day or during breaks, groups of older men playing chess on squares, runners in the early morning and after rush hour, to mention a few.

The UN-Habitat sees lively public spaces as vital for the quality of urban life, considering it essential for cities to prosper (UN-Habitat, 2016a). They envision "Five Principles" for sustainable urban development: efficient street network, high density, mixed-use land, social mix, and limited land-use specialization. These principles are supported by vibrant street life, walkability, and affordability. The UN-Habitat affirms the need that governments ensure provision by developing legislation, policies, norms,

and practices from the planning and design phases to protection and management. Public open spaces should be thought of systemically, with governments working together with the community to ensure they are inclusive, safe, well-connected and reflect different uses from different groups (Brandão et al., 2018; UN-Habitat, 2018).

The literature linking public spaces with urban vitality and quality of life goes back to the 1960s (Department of Urban Studies and Planning - MIT, 2013), with public spaces growing in importance as cities dominate the living landscape (United Nations - Habitat III, 2017). In the 1960's, the modernist style of top-down and car-centered urban planning began to be questioned. Kevin Lynch, an urban planner, published "The Image of the City" (1960), where he theorized humans navigate cities through the perception and mental mapping of five different elements: *paths, edges, nodes, landmarks* and *districts*. Lynch's idea was that though each person created their own map and therefore the same element could possibly be attributed different importance and meaning, the juxtaposition of these seemingly different maps created a group image that was somewhat agreed upon, and that the degree of legibility, of imageability, and the richness of these maps are directly proportional to how lively and successful that city is. Enrich the existing, creating more variety of spaces, forms and uses, by working with the landscape and connecting spaces visually are recognized as key aspects of good urban design (Llewelyn-Davies, 2007).

The following year, Jane Jacobs published "The Death and Life of Great American Cities" (1961), where she explored the attributes and practices that promote urban vitality. One of her findings was the need for diversity of uses, which was in direct opposition to the planning standards of monofunctional zoning of the time. She argues that mixed-use streets attract different types of people throughout the day, which is consequential not only for street-life but also other types of public spaces, for the surrounding of the site directly influences its use. For her, parks and squares should naturally be located where "there is work, cultural, resident and commercial activity" (Jacobs, 1961, p. 101), enabling the place to be used by residents and non-residents alike. This call for diversity concurred with Lynch's theory and later became a key point of William Whyte's observations of successful public spaces.

Willian Whyte embarked on a quest to understand what makes some public spaces more efficient – by being preferred and continuously used – than others. During the “Street life project”, he and his team of researchers spent years observing public life in several different places in New York City and came to what, to him as an afterthought, seemed painfully obvious conclusions (Whyte, 1980): supply creates demand, meaning that plazas near high activity and where people normally circulate were more used, advocating then for a variety of uses on the corners and streets surrounding parks and plazas. This idea has been repeatedly confirmed by other researchers of public life and today constitutes best practice in urban design (Llewelyn-Davies, 2007; Gehl, 2013; United Nations - Habitat III, 2017; Nes & Yamu, 2021).

One of Whyte’s collaborators in the “Street Life Project” was Fred Kent, who founded “Project for Public Spaces” (PPS) in 1975 (Department of Urban Studies and Planning - MIT, 2013), from which the concept of “placemaking” emerged. Placemaking is a practice that originated with the goal of facilitating social interaction in public spaces by involving the community in the design process (Department of Urban Studies and Planning - MIT, 2013), a theme also advocated by Jacobs, who opposed what she called “project planning” (1961). Placemaking has evolved to encompass other contemporary urban needs such as health, economic development, social justice, etc. It focuses on improving public spaces through community building by creating spaces they identify with and serve their particular needs, as well as implementing flexible design solutions which can accommodate changes in time (Llewelyn-Davies, 2007; Project for Public Spaces, 2016). It creates social capital by developing ownership and sense of belonging, for the process has been increasingly collaborative (Department of Urban Studies and Planning - MIT, 2013; Clarke, 2017; Jennings & Bamkole, 2019). It has become a widespread and recognized process, even adopted by the UN-Habitat (2016a), whereas “top-down” planning, a practice that has survived its critics, continues to be addressed for its negative impacts (Department of Urban Studies and Planning - MIT, 2013; Wolch et al., 2014; UN-Habitat, 2016a; United Nations - Habitat III, 2017).

The idea of placemaking goes hand in hand with the concept of “third places”, a term coined in 1989 by Ray Oldenburg to define places for social gathering where

community members meet in an informal way (Oldenburg, 1989). Third places include more than just public open spaces, but they have in common the fact that they foster community building. The concept has made a come-back since the COVID-19 pandemic exacerbated social isolation (Ha et al., 2022; Chen et al., 2024). From Generation Z to health experts, people are advocating for more such inclusive, safe, physical places, especially public ones where people don't have to spend to enjoy its benefits (Demopoulos, 2024; Hebert, 2024; Volpe, 2024).

The discussion on public spaces role in urban vitality would not be complete without the contributions of Jan Gehl, who also began his work in the 60s. He continued Jacobs and Whyte's process of using observation as a key tool for studying public life, as well as the good old questions: how many, who, where, what? In "How to study public life", Gehl and his co-author Svarre point out the necessity of understanding the behavior of different groups, particularly the ones who are commonly overlooked: children, women, people with disabilities, the elderly (Gehl & Svarre, 2013). This attention to minority groups is on the agenda of the UN-Habitat and has been getting more track on studies which assess the quality of urban green spaces (United Nations - General Assembly, 2015; Douglas et al., 2017; United Nations - Habitat III, 2017; Brandão et al., 2018; Talal & Santelmann, 2021; Veitch et al., 2022).

More recently, public spaces as a network has been studied under the concept of social infrastructure (Latham & Layton, 2019), in the sense that they foster and facilitate cultural and social activities. The authors number a few dimensions for the successful provision of social infrastructure: abundance; diversity; maintenance; accessibility; responsiveness (to people's needs); democracy ("citizens as equals in shared space"). For that, they encourage analyzing where things work well and why, as well as different groups of people's needs and wants, which is not a new approach, as seen so far. The benefit of this systemic view of public life is that it creates a framework based on the services provided by spaces as the guiding hand of design, and they all directly relate to well-being through the idea of community building.

While these authors and their studies have set the foundation for general principles and good practices for urban design when it comes to public spaces, increased

urbanization and climate change has put pressure on urban green spaces and the need to better understand their role in urban settlements.

2.2. Urban green spaces

PUPGs, besides being public open spaces, are part of urban green spaces, which have been recognized to play an important role in promoting well-being, physical and mental health (Tzoulas et al., 2007; Lopes & Camanho, 2013; Nutsford et al., 2013; Wolch et al., 2014; Ekkel & de Vries, 2017; Jennings & Bamkole, 2019; Reyes-Riveros et al., 2021; Ha et al., 2022). They encourage positive social interactions through recreational and physical activities, enhancing social support, sense of belonging within a community and identity, all of which are related to both personal well-being and to social cohesion (Tzoulas et al., 2007; Jennings & Bamkole, 2019; Chen et al., 2024).

Green spaces are particularly relevant in the context of cities, where there are fewer opportunities of daily contact with nature compared to rural and suburban areas and where there is a tendency towards increasingly smaller apartments with no outdoor private space (Lopes & Camanho, 2013; Ekkel & de Vries, 2017; Madureira & Monteiro, 2021), which can negatively impact people's physical and mental health (Ayala-Azcárraga et al., 2019; Jennings & Bamkole, 2019). Urbanization is expected to be the "most transformative trend" of the 21st century (United Nations - Habitat III, 2017). A paradigm shift is underway, as cities are heralded for solutions towards sustainable development and being recognized as a possible solution themselves by considering the model of compact cities (United Nations - Habitat III, 2017; OECD Centre for Entrepreneurship, 2019; Madureira & Monteiro, 2021).

However, according to Halland & van den Bosch (2015), literature in planning for compact cities lacks guidelines for spatial planning and provision of green spaces. This is partially explained by the fact that there seems to be a general lack of a conceptual framework to research the matter in the first place (Madureira & Monteiro, 2021). The conundrum is that the process of densification tends to have, as an unfortunate consequence, the loss of green space, due mainly to infill developments and changes in

land use, which is then rarely offset by the provision of public green space (Haaland & van den Bosch, 2015; Madureira & Monteiro, 2021).

Most research on the benefits of green spaces and on the issues affecting them from urban densification don't discuss qualitative aspects, focusing only on green space quantity (Haaland & van den Bosch, 2015; Ekkel & de Vries, 2017; Letra et al., 2017; Jennings & Bamkole, 2019). The danger this then brings is that, aside from different green spaces having different impact and functions (Douglas et al., 2017; Reyes-Riveros et al., 2021; Ha et al., 2022), quantity metrics such as green space per capita risks overestimation because distribution may be uneven, furthering the risk of inequality as another consequence of densification (Haaland & van den Bosch, 2015; Ayala-Azcárraga et al., 2019; Reyes-Riveros et al., 2021). In an urbanized world, green spaces have become an environmental justice issue (Wolch et al., 2014), as the provision of ecosystem services falls on the limited amount of green space available (Haaland & van den Bosch, 2015; Madureira & Monteiro, 2021).

To mitigate possible negative effects of parks and garden's provision, notoriously gentrification of the area, Wolch (2014) recommends working together with the community and local stakeholders both in the planning and design of the site and in developing policies that govern future investments in the area, which meets the SDGs (UN-Habitat, 2020d), the New Urban Agenda (United Nations - Habitat III, 2017) and the OECD Principles on Urban Policy (OECD Centre for Entrepreneurship, 2019), as well as the practice of placemaking (Department of Urban Studies and Planning - MIT, 2013) and best practices in urban design (Llewelyn-Davies, 2007).

The New Urban Agenda (United Nations - Habitat III, 2017) highlights the need to promote green space networks that are inclusive and safe both to enhance resilience to environmental risks and to improve physical and mental health. However, "green space" is used as a broad term without any reference to types or qualitative characteristics. The ecosystem services approach can help to ensure multifunctionality in urban green spaces, as it encompasses both services that contribute directly to the environment – such as pollution reduction, adaptation to climate change, mitigation of heat island effect, improved drainage, increased biodiversity, etc. – and cultural services

– such as promotion of outdoor physical activities, community support and stress (Tzoulas et al., 2007; Haaland & van den Bosch, 2015; Madureira et al., 2018).

The Ecosystem services assessment framework was initially developed by the Millennium Ecosystem Assessment (MA); a program launched by then UN Secretary-General Kofi Annan in 2001 (Millennium Ecosystem Assessment, 2005). The framework synthesizes the direct and indirect interactions between humans and ecosystem services, be on the local, regional or global scales, in the short and long-term. In this framework, ecosystem services are divided into four groups based on their functional lines, as seen in Table 1.

Table 1 – Ecosystem Services

Provisioning Services	**Regulating Services**
food	
fresh water	climate regulation
fuelwood	disease regulation
fiber	water regulations
biochemicals	water purification
generic resources	pollination
Cultural Services	**Supporting Services**
spiritual and religious	
recreation and ecotourism	
aesthetic	soil formation
inspirational	nutrient cycling
educational	primary production
sense of place	
cultural heritage	

Source: Adapted from “Ecosystems and Human Well-being: A framework for Assessment” (Millennium Ecosystem Assessment, 2005)

However, Douglas et al (2017) argues that there is a disconnect between practices and the desired consequences for different services because seeing to one type does not equate to solving another. Ideally, the provision and design of public urban green spaces such as parks and gardens should see to more than one ecosystem

service at a time, but the balancing should be carefully considered based on context, especially when there is risk of contradicting consequences.

As seen, the concept of urban green space is usually broad, meaning any vegetation qualifies – be it public or private, from grass to forest (Direção Municipal de Urbanismo, 2021a; Ha et al., 2022). On the other hand, public open space may not necessarily be a green space. These breadth of meaning makes it hard to derive guidelines for urban planning and urban design, as studies vary in concept and scope and as goals may have opposing effects (Koohsari et al., 2015; Ekkel & de Vries, 2017). Haaland and van den Bosch (2015) further state that the provision of green spaces is not supported by the law in many countries, meaning not only there is a lack of specific guidelines but also of the requirement itself, making it much harder to monitor changes in the existing environment, to make decisions in actual planning and also to monitor the implementation of said plans. As Whyte affirms when it comes to designing public spaces, "lack of guidelines does not give builders and architects more freedom. It reinforces convention" (Whyte, 1980, p. 30). With these issues at hand, which metrics can assist the assessment and planning of PUPGs?

2.3. Metrics

By looking into public space and urban design guidelines developed by organizations such as the UN-Habitat and the World Health Organization (WHO), the research aims to detect how much PUPGs are represented and which metrics are considered for their success. A literature review of scientific papers was also conducted focused on accessibility, site characteristics and people's preferences. The studies are varied in nature and methodology; some are aimed at any type of urban green space whereas others focus on parks and similar public open spaces. The studies which look into characteristics and people's preferences are anchored in different purposes: evaluating associations to physical health, to well-being, to social interactions, or aimed at specific groups. This results from purposefully looking for such diverse studies in an attempt to find similarities and build a city-wide framework for assessing and planning

PUPGs. The metrics are grouped by “accessibility” and “quality assessment”, though some can belong to both.

2.3.1. Accessibility – How much, how close and where?

The term “accessibility” has different meanings in different fields, and sometimes they overlap. One definition of accessibility refers to the ability to reach a place or service, a metric that can be calculated by different methods (El-Geneidy & Levinson, 2006; Ekkel & de Vries, 2017; Liu et al., 2021). This is the concept this study refers to. In urban design and architecture, accessibility also means universal design (World Health Organization - Library Cataloguing-in-Publication Data, 2007), which encompasses micro scale aspects of urban design and architecture and is not the focus of the present study.

Good accessibility is one of several conditions that contribute to the use of public spaces and green spaces, ensuring they are not underutilized or neglected (Llewelyn-Davies, 2007; Tannous et al., 2021). Analyzing PUPGs accessibility contributes to ensure equality amongst the population (United Nations - General Assembly, 2015; World Health Organization - Regional Office for Europe, 2017; Chiang & Li, 2019; Phillips et al., 2023).

The SDGs cover three dimensions: economic, social, and environmental, with a strong emphasis on equality in all levels (UN General United Nations - General Assembly, 2015). Because the UN deals with the complex and varied realities of the world, it is comprehensible that the SDGs are broad and generic, for they aim to provide the basis for further goals. The target that most directly relate to public urban green spaces is Target 11.7: “By 2030, provide universal access to safe, inclusive and accessible green and public spaces, in particular for women and children, older persons and persons with disabilities”, which is then measured by Indicator 11.7.1: “Average share of the built-up area of cities that is open space for public use for all, by sex, age, and persons with disabilities” (UN Statistical United Nations - Statistical Commission, 2023, p. 13). Behind these succinct words is the recognition of lively public spaces as an integral part in

humanizing cities, enhancing social cohesion, identity and quality of life (UN-Habitat, 2020d). The limit is clear though, for the metric of built-up area is only a first step into achieving this goal.

The OECD echoes the sentiment with their principles on urban policy (OECD Centre for Entrepreneurship, 2019, p. 20), of which number 6, "Promote inclusive cities that provide opportunities for all", declares: "Improving access for all urban residents and users – regardless of their gender, age, ethnic background or health status – to drivers of social inclusion, such as local public services, affordable quality housing, transport, education, health, employment and economic opportunities, cultural heritage and amenities, leisure and safe public spaces".

The SDGs also highlight the need for transport accessibility on target 11.2: "By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons", whose indicator 11.2.1 proposed to measure the "Proportion of population that has convenient access to public transport, by sex, age, and persons with disabilities" (UN Statistical United Nations - Statistical Commission, 2023, p. 13). The background of this target highlights the need for compact cities and an emphasis on walkability (UN-Habitat, 2020d).

The aforementioned indicators are global, general ones. The UN encourages that each country further develops metrics it considers relevant for the monitoring of the SDGs but, in the case of Portugal, the document "Objetivos do desenvolvimento sustentável - Agenda 2030 Indicadores para Portugal 2015 – 2022" (Instituto Nacional de Estatística, 2023b), which gathers the data the country has been monitoring in relation to the SDGs, does not contain data for either of these indicators.

It is important to note that the UN recognizes a lack of agreed methodology for many of its indicators, particularly the ones that work at the city level. Indicator 11.2.1 was classified as Tier II – "(…) an established methodology exists, but data is not easily available" and indicator 11.7.1 as Tier III – "there are no established methodology and standards or methodology/standards are being developed/tested" (UN-Habitat, 2020d,

p. 26). This is mirrored in the academia: according to Ekkel & de Vries (2017), there is considerable variation in defining access to green spaces, as will be explored hereafter.

How much and how close?

Some guidelines suggest spatial metrics such as area per inhabitant, but they are usually associated with availability and aimed at defining a minimum of urban green space per capita without discriminating between different types of spaces or their distribution (Haaland & van den Bosch, 2015; Ekkel & de Vries, 2017; Letra et al., 2017; Jennings & Bamkole, 2019). Good mental-health, for example, has been found to better correlate with disaggregated small green and blue spaces, compared to few larger spaces, showcasing the impact of distribution (Ha et al., 2022). The WHO recommends that urban residents have access to at least 0.5-1 hectare within 300 meters linear distance of their homes, and access to an urban green space within a 5 minute-walk of their home (World Health Organization - Regional Office for Europe, 2017). The UN "City-wide public space assessment guide" and the "City-wide public space strategies", both published in 2020 (UN-Habitat, 2020a, 2020b), delineate some dimensions and indicators for public open spaces in general. The first document stablishes a protocol for assessment, as seen in Table 2.

Table 2 – City-wide assessment indicators

City-wide / Quantity dimension	
dimension	**indicator**
spatial distribution	spatial balance of public spaces across the city
network	street connectivity and intersection density length of street per square kilometer connectivity of one public space to another
accessibility	walking distance to open public space (400m and 1km)
quantity	share of land that is open public space share of land that is allocated to streets per capita public space per capita green space

Source: Adapted from UN-Habitat (2020a, p. 35)

The second document brings some general metrics for the indicators. For quantity, UN-Habitat recommends that 45% of total urban area be public space, including streets, of which 15% should be public open space (green or not). When it comes to distribution, it defines residents should live within 400m of the nearest public open space, which it calls “the walkable radius” (UN-Habitat, 2020c). Connectivity is defined by street density. Diversity highlights public spaces that cater to children and older adults, as well as active and passive engagement and commercial markets. Finally, accessibility is defined by the fact that no public open or green space be either physically or financially barred, meaning no walls, fences, gates, or fees.

The UN-Habitat (2018) classifies public open spaces based on size, purpose and catchment, recommending how close they should be to residents, as seen in Table 3.

Table 3 – Public open space classification by the UN-Habitat

Open space type	purpose and needs	area (ha)	distance (m) / reach
Local / pocket	recreation and nature	0.03 to 0.04	400
Neighborhood	recreation, sports, social and nature	0.04 to 0.4	400
District / city	recreation, organized sport, nature	0.4 to 10	800
Regional / Larger	concurrent uses	10 to 50	serves more than one city
National / metropolitan	concurrent uses	50 to 200	serves more than one city

Source: Adapted from UN-Habitat (2018).

In this classification, the UN-Habitat establishes that the 400m distance is equivalent to a 5-minute walk and 800m to a 10-minute walk. These thresholds for walking are the same found in the “Urban Design Compendium” for what it considers “the walkable neighborhood” (Llewelyn-Davies, 2007). It encourages mixed-use within a 5-minute walk (400m) and considers walking distances to be about a 10-minute walk (800m), recommending that local parks should be located a 3-5 minutes’ walk (250-400m) of homes. It has its own classification for parks, as seen in Table 4.

Table 4 – Types of parks by the Urban Design Compendium

Types of parks	public / transport	characteristics	area (ha)	distance (m)
Small	pedestrians, especially children and the elderly	gardens, playgrounds, nature	up to 2	400
Local	pedestrians	court games, children play, nature, fields	2	400
District	all	varied uses, landscape setting	20	1200
Metropolitan	all	varied uses / nature	60	3200
Regional	all	informal recreation / nature	400	3200 to 8000

Source: Adapted from "Urban Design Compendium (Llewelyn-Davies, 2007, p. 56)".

A famous advocate of walking and cycling, Gehl established the idea of the 5km/h city (Gehl, 2013), but recalls that walking speed varies due to age, gender, mobility, purpose, and other factors such as company or even the weather (Gehl & Svarre, 2013). When it comes to threshold distances though, children, people with disabilities and older adults have more difficulties, for which they recommend 500m to be acceptable to most. The UN-Habitat, on the other hand, points to a much lower cut-off distance of 300m for children under 18 (2020c).

A study looking into the relation of green space access and anxiety and mood disorder treatments in Auckland, New Zealand (Nutsford et al., 2013), found that proximity to green space (within a 3km distance), be it usable or just observable, had a positive correlation to decreased anxiety and mood disorder treatment counts, making a case for greener cities in general. The studies looking into walking to green spaces, however, have shown that the optimal threshold falls between 500-600m and that above 1000m there is a significant decrease in visits (Oh & Jeong, 2007; Koohsari et al., 2013; Ekkel & de Vries, 2017; Chiang & Li, 2019). Phillips et all (2023) analyzed accessibility to larger parks (13 to 69ha) and found that the majority of visitors travel by foot if the park is within about 800m, with other modes of transport increasing in proportion to the distance traveled, but with considerable difference in the willingness

to travel to a place based on its size, with larger parks being at an advantage, which they attribute to the fact it can offer more activities.

On studies that account for proximity to home, accessibility measured through network analysis, which is the same as "catchment", gives more accurate results than circular radius using Euclidean distance, as it considers the actual street network that people need to transverse in order to reach the points of interest and therefore exclude inaccessible areas (Oh & Jeong, 2007; Koohsari et al., 2013; Chiang & Li, 2019). Each site's catchment, or influence area, can be calculated by its service area within different walking distances. For this calculation, the entrance points to the site are recommended as sources, instead of the centroid, as size can vary considerably among the studied sites and sometimes their entrance points are located in different streets (Llewelyn-Davies, 2007; Koohsari et al., 2015).

The service areas can then be correlated with socioeconomic or population data to determine possible inequalities, demand and potential patronage (Oh & Jeong, 2007; Koohsari et al., 2015; Bahrini et al., 2017; Letra et al., 2017). One example is to use data pertaining to workers or students in an area in order to determine potential patronage from non-residents (Whyte, 1980; Koohsari et al., 2015; Talal & Santelmann, 2021).

Street network configuration – connectivity

Though it is undoubtedly useful, catchment alone doesn't capture the way people move (Koohsari et al., 2013; Chiang & Li, 2019). Convenience matters in order for people to visit a park or garden (Tannous et al., 2021), and as Chiang & Li (2019) have found, metrics that consider the street configuration and the way people navigate it, such as topological proximity, are better predictors of frequency of visits to parks.

Space Syntax studies the relationship between urban space and social phenomena. It theorizes that the street network is the most decisive factor to determine land use and urban vitality, for movement patterns are directly linked to the street network configuration (Nes & Yamu, 2021; Tannous et al., 2021). One of its measurements for analyzing street networks is connectivity, which assesses the

connections among streets and is positively correlated with the frequency of walking (Chiang & Li, 2019).

Connectivity can be calculated through a few different analyses, of which one is called integration. It calculates how integrated an axial line – a representation of a street based on its directional movement – or a street segment is in relation to all other lines/segments in the system – which is also called "to-movement". Integration can be done for road-center lines by using angular segment analysis. In this case, instead of topological mean depth, angular mean depth is used, and the length of the segment is also considered. Adding a metric radius to the analysis has shown to better correlate to socio-economic data, becoming a standard practice in space syntax since 2012 (Nes & Yamu, 2021).

The idea behind this analysis is that activity correlates with high integration, meaning that better integrated streets have more chance of attracting human movement, functions, and activities, making them livelier, as they can be more easily reached from the other streets (Koohsari et al., 2014; Nes & Yamu, 2021). This means that highly integrated streets can have more chance visits to PUPGs (Koohsari et al., 2014; Chiang & Li, 2019). This analysis can be made globally and locally, varying the radius, resulting in different scales of urban centrality.

Koohsari et al. (2013), however, found a negative association between high street connectivity and leisure walking, as opposed to walking in order to reach a particular place, which they suggest might be explained by the fact that highly connected streets tend to also attract vehicular traffic, which can make them less agreeable and less safe for pedestrians.

In a study assessing the impact that connectivity has on leisure walking compared to utilitarian trips, Pereira et al (2024) analyzed some walkability indicators such as density, diversity, and streetscape features. The idea was to see the relative importance of connectivity compared to other factors, as street configuration itself is harder to alter than the buildings and features on a street The results show that streetscape features were less relevant in utilitarian trips and connectivity indicators were more stable and

slightly better at explaining both types of trips. Together, these two factors were stronger in both cases.

Insofar in this research, most studies assessing accessibility to green spaces don't make the distinction of whether people consider walking to a green space as leisure walking – as in, the path to the green space is part of their purpose – or if the green space is the destination, affecting their choice on how fast to reach it.

Street network configuration – paths

Kevin Lynch proposes that the way people perceive and mentally map their environment factors in their effective and purposeful use of the space, defending that a city that is "easy to read and navigate" is livelier (Lynch, 1960). Lynch's work is considered the most used method of urban analysis from the place phenomenology tradition (Nes & Yamu, 2021). In his theory, "paths" are the streets preferred by people while going from one place to another, configuring the main channels for movement.

When it comes to walking, several research in cognitive science and other fields, including Space Syntax, show people prefer direct routes, meaning they tend to choose streets and routes that minimize changes in direction and allow for better and broader visibility (Turner, 2007; Filomena et al., 2019; Nes & Yamu, 2021). The interest in bridging Lynch's theory with urban spatial analysis is that it provides a way for systemic computer-based analysis of a measurement associated with people's perceptions and actual navigation preferences. The work of Filomena et al. connects it to a method that has been proven to predict pedestrian movement: angular betweenness, or angular choice, which is also used in Space Syntax to determine main paths.

Betweenness is calculated by counting the number of times a street segment is part of the shortest path between two points, adding up the times each segment is passed through and dividing it by the total sum. The theory is that if a park or garden has entrances in streets with high betweenness values (considered main paths in Space Syntax, also called "through movement"), there is a higher chance of it attracting visitors, as these streets will likely be used more often by pedestrians in their daily

movements. Because betweenness can create bias towards dense systems, Turner (2007) recommends using angular segment analysis, or angular betweenness, as it generates more uniform results for a street whose segments don't vary much in angular measures, as they tend to lead in the same direction. To avoid bias towards longer segments, which can possibly have more connections, the length is adopted as weight. And finally, to diminish edge effect, a metric radius is used. By changing the radius, the analysis can show the main paths in the entire area and the main paths in a smaller, local scale.

Cumulative opportunity and gravity-based models

Other studies that assess the benefits of urban green spaces have shown that a cut-off for distance may be too limiting as areas further away and chance encounters with nature can be just as beneficial and more realistic (Ekkel & de Vries, 2017; Liu et al., 2021; Phillips et al., 2023), determining that cumulative opportunities are better indicators of accessibility (Ekkel & de Vries, 2017; Chiang & Li, 2019; Reyes-Riveros et al., 2021; Ha et al., 2022). Cumulative opportunity considers the number of potential opportunities that can be reached for a travel time or distance (El-Geneidy & Levinson, 2006), increasing the chance of visitation to different urban green areas. There is evidence that disaggregated green and blue spaces offer greater benefit in stress reduction, for example: by looking at the composition and distribution of green spaces in Chicago, cumulative experiences with green spaces were found to be more important to the general well-being than the composition of a single space or the ability to visit a single area (Ha et al., 2022).

Cumulative opportunity, however, does not account for the attractiveness of a site or the cost of travel, which can be addressed by gravity-based measures (El-Geneidy & Levinson, 2006). Several studies have attempted to remedy this by developing variations of the two-step floating catchment area (2SFCA) technique, which considers both supply and demand of a service, by including qualitative characteristics of the parks (such as size or number of amenities), distance decay, different catchment sizes

according to park type, and even different modes of transport (Dony et al., 2015; Bryant & Delamater, 2019; Liu et al., 2021; Phillips et al., 2023).

2.3.2. Quality assessment – For whom and for what?

Jacobs commented on what she called planners' obsession with open spaces and stated that "people do not use city open space just because it is there and because city planners or designers wish they would" (Jacobs, 1961, p. 90). This observation has been continuously validated by studies which found that, to increase the chance of visitation, qualitative metrics – both those that consider aspects of nature composition and those related to activities and programs – contribute to park attractiveness and usage (Tzoulas et al., 2007; Lopes & Camanho, 2013; Wolch et al., 2014; Ekkel & de Vries, 2017; Ayala-Azcárraga et al., 2019; Chiang & Li, 2019; Jennings & Bamkole, 2019; Reyes-Riveros et al., 2021; Talal & Santelmann, 2021). Back in 1960, Lynch already stressed the importance of designing for the people, meaning designing for a diversity of needs, interpretation, and appropriation (Lynch, 1960).

The New Urban Agenda (United Nations - Habitat III, 2017) follows the SDGs core principles. It advocates for a people-centered, age and gender-responsive approach and reinforces the need for "safe, inclusive, accessible, green and quality public spaces", that are well-distributed, well-connected and respond to ecosystem services goals. In the UN-Habitat "Public space site-specific assessment guide" the need for social inclusion is defined by accommodating the values and preferences of different groups, ages, and abilities (UN-Habitat, 2020c), as seen in Table 5. Gehl and Svarre developed a tool known as "the 12 quality criteria" to assess public spaces quality, a list that was born longer and systematically evolved into the 12 core principles seen in Table 6. The "12 quality criteria" has been adopted by the UN-Habitat alongside the "Space Shapers Guide" created by The Commission for Architecture and the Built Environment (CABE), which can be seen in Table 7.

Table 5 – Site-specific assessment indicators by the UN-Habitat

Site-specific / Quality dimension	
dimension	**indicator**
general	typology, scale, ownership, management, adjacent land use
	surface texture of public space
	presence of special elements
comfort	noise level, smell, uncollected garbage
	presence of water body, trees and views
accessibility	presence and condition of vehicular and bike parking
	facilities that restrict vehicular movement
	universal design
	presence of an entrance
	level of accessibility
green environment	presence and quality of biodiversity
	environmental resilience
	presence of energy efficient elements
safety	social and infrastructural problems
	antisocial behavior and harassment to women and girls
	traffic accidents
	perceptions of safety by gender during the day and night
	clear sight lines - see and be seen
	presence of CCTV cameras and street lighting
	presence of security personnel
use and users	users by age, gender and disability
	use of the space
amenities	presence, condition and sufficiency of street lighting, benches, garbage bins, public toilets, fire emergency, signage, water taps, drainage, artificial shading, kiosks, baby care facilities, emergency health facilities

Source: Adapted from UN-Habitat (2020a, p. 35)

Table 6 – Gehl's "12 quality criteria"

The 12 quality criteria			
protection (against)	traffic and accidents	harm by others	unpleasant sensory experiences
comfort (options for)	mobility	stand and linger	sitting
	seeing	talking and listening	play, exercise and activities
enjoyment	human scale	positive aspects of climate and aesthetics	positive sensory experiences

Source: Adapted from "How to study public life" (Gehl & Svarre, 2013).

Table 7 – Space Shapers Guide by CABE

Space Shapers Guide (CABE)	
access	finding your way and getting about
use	activities and opportunities offered
other people	different needs being met
maintenance	cleanliness and care
environment	safety and comfort
design / appearance	look and materials
community	importance to local people
you	how it makes you feel

Source: Adapted from UN-Habitat (2016a, p. 40).

These three frameworks are similar in categories and indicators, mixing subjective and objective criteria, each having its own protocol for application. They will be further explored, together with the results from scientific papers on the subject, in the following sections “for whom? - Demographics” and “for what? – Activities and purposes”.

For whom? – Demographics

The UN-Habitat (2016b) remarks that, overall, data gathered by countries is not disaggregated in a way that allows for monitoring of underprivileged groups access to goods and services, especially when it comes to urban living conditions, which is an important step in the “leave no one behind” effort. They recommend counting for age, sex, disability status, social groups, income levels, migratory status, and locations. Some of the studies recognize this issue and recommend analyzing the socio-demographics characteristics of a place, for experiences and preferences may differ among different age groups, race and gender, and planning uniformly may leave some groups disadvantaged (Douglas et al., 2017; Talal & Santelmann, 2021; Phillips et al., 2023).

Public urban green spaces can increase social cohesion and promote better sense of community through quality social relationships and trust, but, for that to happen, people need to feel safe and integrated (Wolch et al., 2014; Ayala-Azcárraga et al., 2019; Jennings & Bamkole, 2019; Chen et al., 2024). On their literature review assessing the

links between urban green spaces and human well-being, Reyes-Riveros et al (2021) found people avoid frequenting parks associated with unsafety – real or perceived – as some green spaces, if neglected or badly managed, can be associated with crime or feelings of unsafety. In this realm, both Whyte and Gehl have observed that the presence of women is usually a good indicator for how safe a place is (Whyte, 1980; Gehl & Svarre, 2013).

Overcrowding can also impact visitation, and it has been found that park congestion tends to affect low-income neighborhoods more often (Wolch et al., 2014). Other negative characteristics commonly cited are neglect, endemic diseases and noxious fauna, all associated with bad management (Tzoulas et al., 2007; Ayala-Azcárraga et al., 2019; Reyes-Riveros et al., 2021). Working together with the community diminishes the chance of gentrification and wasting resources on designs that don't work, as well as foster community building, ownership, and leadership, enabling management solutions beyond the Estate (Department of Urban Studies and Planning - MIT, 2013; Project for Public Spaces, 2016; Clarke, 2017).

Recognizing that current WHO and UN guidelines for green spaces are lacking when it comes to design attributes, Douglas et al (2017) proposed a life-course approach to designing green spaces to respond to different age-groups needs when it comes to health and well-being. Their work was made from an extensive literature review and attempts to synthesize findings according to different life-phases: prenatal, childhood, adolescence, adulthood, and later life. The summary of interventions for an integrated approach highlights the importance of facilities for physical activities such as sports from childhood to adulthood; activities for social interaction such as sheltered areas, chess tables and allotments for adults and later life; informal green spaces for exploration for kids and teenagers; relaxing and restorative environments, sheltered and seating areas, especially for pregnant people and older adults.

The importance of public restrooms and attention to universal design is often mentioned in relation to pregnant people, parents, older adults and people with disabilities (Project for Public Spaces, 2016; Douglas et al., 2017; World Health Organization - Regional Office for Europe, 2017; Veitch et al., 2022). Other features that

are ranked high for older adults are: a peaceful and relaxing setting, shady trees, seating areas and walking paths. The most common physical activity among older adults was walking, which also places importance in universal design both inside the park and on the way to it to encourage independent use among this age group. The presence of a café appeared as significantly important for social interaction (Douglas et al., 2017; Veitch et al., 2022). When it comes to accessibility, besides the need for universal design, short distance to neighborhood public spaces correlate with life satisfaction (Project for Public Spaces, 2016).

For what? – Activities and purposes

The uses possible in a park or garden can be represented by different criteria such as "amenities", "facilities", "features", "opportunities" or "activities", depending on the study and author. One thing they all have in common is that people should be encouraged to stay, and, for that, the site should enable activities of permanence, such as sitting and people-watching. The Urban Design Compendium encourages routes through the space, in order to create movement, with sitting alongside these routes for people watching and rest (Llewelyn-Davies, 2007). When it comes to sitting, not surprisingly, Whyte (1980). found people preferred plazas with more available sitting space (not necessarily benches, but any suitable seating area), and the variety of where to sit (in different contexts) and how to group (meaning fixed seating worked less than moving seats) was also important. These findings go hand in hand with Jacobs' and with Lynch's advocacy for enriching possibilities (Lynch, 1960; Jacobs, 1961).

Gehl (2013) concurs with Whyte that sitting space doesn't equal only benches but makes the distinction that whereas children and teenagers will often sit anywhere, the older humans get, the more selective they become, therefore, there should be good comfortable benches for that age group. Another aspect that influences permanence is how comfortable people feel, which is influenced by the availability of sun, shade and protection from wind (Jacobs, 1961; Whyte, 1980; Gehl, 2013). Then comes the presence of water (Ha et al., 2022; Veitch et al., 2022), with the particularity that,

according to Whyte's findings (1980), it should be accessible and touchable, not segregated from the public. Cafés and food vendors show up again as a facility that fosters permanence and social interaction (Whyte, 1980; Llewelyn-Davies, 2007; Gehl, 2013; Douglas et al., 2017; Veitch et al., 2022).

Discussing social interaction, Whyte (1980), Gehl and Svarre (2013) point out that people attract people. This is not to say that crowded spaces are healthy, but that people want to be where other people are. Scale, therefore, plays an important role in defining how lively a place is: activities should be encouraged, but in accordance to the scale of the spaces, in order for it to be lively enough that people take interest in taking part (Gehl, 2013). Whyte talks about "triangulation", a term he uses to describe stranger's interacting due to an external common event: it can be anything from a sculpture, children playing, a street performer (Whyte, 1980).

Personal preferences associated with urban green spaces have recently come into focus on several studies as well, pointing to factors that motivate visits to urban green spaces, the types of benefits perceived in association with its use and preferred characteristics and facilities (Madureira et al., 2018). In a recent study investigating the association of park characteristics and social interaction in Utah, United States, the amount of green space, park size and the presence of a playground (in particular) were found to be more relevant than the amount of facilities and amenities (Chen et al., 2024). For subjective criteria, aesthetics seemed to best correlate with social interaction. The study combined data from site characteristics' audits and observation of people's interactions, only examined parks larger than 0.5 acre (about 2000m^2) and which had several facilities for comparison. When it comes to larger parks, Jacobs (1961) warns of the danger of the large monofunctional entity becoming a border, or an "edge", in Lynch's theory (1960), which might be detrimental to the city life surrounding it. To counter such issues, she concurs with Lynch by suggesting locating facilities and amenities that attract use on the edges of large parks, including uses that could be open at night.

Another study looked into the relationship between park's characteristics, the perception people had of the space and how it affected their use and benefits associated

with well-being (Ayala-Azcárraga et al., 2019). Because they analyzed different relationships among patterns of use, well-being and the parks characteristics, some results vary, but there are some consistencies. The results showed that in smaller parks (< 1ha), the majority of users were local (neighbors) whereas in medium (1.1 to 4.5 ha) and larger parks (> 4.6 ha), there was a more balanced mix of visitors and locals. People spent considerably less time in smaller parks but visited them more frequently, which has been associated with sense of belonging and positive mental health benefits (Ha et al., 2022). Though users reported high levels of physical state and life satisfaction regardless of park size, users of smaller parks had more consistent association with positive outcomes.

When it comes to what motivate people to visit parks, accessibility (be it from home, work or school), the naturalness perceived and perception of safety were the variables better related to positive results. The amenities and facilities better ranked were walking trails, playground and exercise equipment (Project for Public Spaces, 2016; Ayala-Azcárraga et al., 2019; Talal & Santelmann, 2021).

In Portugal, Madureira et al (2018) theorized that the varied results and discrepancies they found in their literature review of the theme may arise from local differences, so their study aimed to compare people's perceptions of public green space characteristics in three Portuguese cities, Porto being one of them. Their findings for Porto indicate that cleanliness and maintenance are the most important attribute, followed by richness in plant species, existence of water bodies and tranquility. If we only look at facilities and amenities, then the rank would be water bodies (overall 3rd), sufficient benches (overall 5th) and playground (overall 7th). The results match those of other studies in finding that relatively subjective aspects – maintenance, cleanliness, naturalness, or a diverse green environment – are more important than facilities and amenities. Their results confirmed their supposition of there being some disparities from place to place, which they attributed to the scale of the cities studied.

Addressing people's satisfaction, a survey conducted in 2013 for Porto's metropolitan area (Marques & Queirós, 2017) found that 60% of people surveyed were satisfied with the existing green spaces and 63% with public spaces in general. However,

19% were unsatisfied with the adequacy of public spaces for leisure activities. When it comes to the city of Porto in particular, Madureira et al (2018) found that 15% were dissatisfied and 6% very dissatisfied with public green space quantity whereas 26% were dissatisfied and 4% very dissatisfied with public green space quality. When posed with the question of how investment should be made, 62% preferred they be focused on improving quality (versus quantity), and 78% opted for investments in small public green spaces, instead of in a large public park.

A study in Brisbane, Australia, investigating whether opportunity or nature orientation was more important for park visitation (Lin et al., 2014), brought up another consideration. It found that though proximity to park played a significant role, orientation was found to be even more determining, leading them to conclude that public policies and soft approaches to encourage and increase people's connections with nature are more important than simply increasing park provision. In their literature review, Douglas et al (2017) found a similar relationship from the consistent finding that children who are active in green spaces not only fare better in health as kids and later in life, but also are more likely to visit green spaces as an adult. Programming, then, is key.

Jacobs (1961) defends that if, due to its location, a park can't enjoy a natural influx of people, then it should be designed to draw specific usage and effort made to involve it in cultural activities. An emphasis on the "local" is a possible solution: engaging residents, local businesses, artists and organizations while working with temporary interventions allow for testing designs and prioritize programming and flexibility, which makes maintenance and iterative changes to accommodate new or different demands easier (Department of Urban Studies and Planning - MIT, 2013; Clarke, 2017; Talal & Santelmann, 2021).

In conclusion, there is a considerable variety of metrics that account for accessibility and qualitative aspects which can be applied to PUPGs, and even withing certain metrics it is possible to find variation in methods. The literature review has shown that, when it comes to the design and planning of a specific park or garden, working alongside the community it will serve is best practice. This, however, does not mean planners should only focus on the local scale, as a city-wide assessment is

necessary to ensure a systemic approach to provision and management. In order to attempt a comprehensive people-centered diagnosis of a city such as Porto, a combination of metrics is then proposed.

2.4. City-wide planning metrics

The research aims to determine the metrics that can be applied at the macro city-wide scale and answer to a human-centered approach, interested in equality and people's preferences. As mentioned, data is not often disaggregated in ways that allow for preventing or diagnosing certain inequalities, but some analyses can be made with census data.

In the case of Portugal, population is disaggregated by sex and age-group at the subsection level (Instituto Nacional de Estatística, 2022a). Street networks, on the other hand, are usually available, even if from open sources such as Open Street Map (OSM). More refined analyses can be performed case to case depending on the type of data a city has. Based on the literature review findings, a combination of accessibility metrics and qualitative assessment on a city-wide scale is proposed as a first diagnosis for deficits and potentials, focused on objective parameters that can be performed with commonly available data.

The Public Space's Service System (PSSS) created by an interdisciplinary team that includes members from the universities of Porto and Lisbon (Brandão et al., 2018) developed a method for analyzing public space based on its public services, which is similar to the social infrastructure approach (Latham & Layton, 2019). The PSSS frames public spaces as a relational system and emphasizes the services, actors and values thus obtained by their interaction. Because the values are inherently dependent on the actors' perceptions and use of the space, their participation in the process – be it on its creation or renovation – helps inform decisions that are nuanced and complex, varied and inclusive. This people-centered approach is also similar to the principles of placemaking, though it doesn't advocate for a bottom-up movement. The set of analyses

proposed in this research is loosely based on the PSSS, as it aims to answer its four structural questions (Brandão et al., 2018):

1 – how does this public space (PUPG) relate to its surroundings (system)?

2 – What is this space for (services)?

3 – Who are the actors (or, who does it serve)?

4 – What types of values can we find it in this space (value)?

Questions 1 to 3 are addressed by the selected analyses, as shown in Table 8. Question 4 is related to the subjective values attributed to a space and was partially addressed through the literature review on studies looking into people's preferences, as no site-specific assessment was performed in this research, considering time constraints. For a more complete assessment, question 4 could be included in the present framework via user's surveys and/or site-specific appraisal by trained evaluators (Brandão et al., 2018; UN-Habitat, 2020c).

In accessibility, metrics that deal with distribution have been found to better represent equal opportunities, compared to quantity metrics. In order to address both proximity metrics, which are found to be of relevance to children and older adults, and the importance of the street network spatial configuration in people's movement patterns, accessibility is represented by the analyses *paths* (choice), *connectivity* (integration) and *catchment*. Catchment is performed for a few different groups of potential PUPGs patrons in accordance with available data and census disaggregation.

The accessibility analyses focus on pedestrian usage, for several reasons: it is found to be the most common means of transport to nearby parks and gardens; walking and walkability are in accordance with the SDGs and UN-Habitat guidelines; other means of transport are found to gain importance for larger and/or farther sites, meaning they could be part of a second phase of city-wide assessment analyses, once the PUPGs are thus classified, using gravity based cumulative opportunity metrics. Cycling, though an active mobility mode, was not analyzed because it is not prevalent in Porto's daily

movement trips, corresponding to just 0,36% of trips during the week (Direção Municipal de Urbanismo, 2019), which will be better discussed in chapter 3.

Table 8 – City-wide planning metrics framework

	PSSS	Analyses		Literature Review
ACCESSIBILITY	1	**Paths** (Space Syntax - Choice / Betweenness)	street network	(Lynch, 1960; Turner, 2004, 2007; João Pinelo, 2010; Bahrini et al., 2017; Filomena et al., 2019; UN-Habitat, 2020a; Nes & Yamu, 2021; Tannous et al., 2021)
			correlation coefficient (street network)	
			highest value / site entrance	
	1	**Connectivity** (Space Syntax - Integration)	street network	(Turner, 2004, 2007; João Pinelo, 2010; Koohsari et al., 2013; Koohsari et al., 2014; Bahrini et al., 2017; Chiang & Li, 2019; Huang et al., 2020; UN-Habitat, 2020a; Nes & Yamu, 2021; Tannous et al., 2021; Pereira et al., 2024)
			correlation coefficient (street network)	
			highest value / site entrance	
	1 | 3	**Catchment** (Network Analyst - Service Area)	resident population disaggregated by age group	(Whyte, 1980; El-Geneidy & Levinson, 2006; Llewelyn-Davies, 2007; Oh & Jeong, 2007; Koohsari et al., 2015; Bahrini et al., 2017; Letra et al., 2017; Chiang & Li, 2019; UN-Habitat, 2020a; Talal & Santelmann, 2021)
			potential visitors	
			primary and secondary schools	
QUALITY ASSESSMENT	2	**Size**	classification by size	(Llewelyn-Davies, 2007; UN-Habitat, 2018)
	1	**Type of access**	open or enclosed / gated	(UN-Habitat, 2020a, 2020c)
	2	**Amenities / Facilities**	playground, trail, grassy field, seating, gym, restroom, café, picnic table, sports facility, water feature	(Whyte, 1980; Llewelyn-Davies, 2007; Gehl, 2013; Gehl & Svarre, 2013; Douglas et al., 2017; Madureira et al., 2018; Ayala-Azcárraga et al., 2019; Talal & Santelmann, 2021; Ha et al., 2022; Veitch et al., 2022; Chen et al., 2024)

Source: Author.

Metrics related to quality and people's preferences can be grouped into metrics which deal with objective features, such as amenities and facilities; metrics which deal with nature related features, such as greenness and biodiversity; and metrics which deal with subjective aspects related to people's perception, such as maintenance, safety and cleanliness. Even though they seem to be less relevant compared to nature and

subjective metrics, metrics which deal with objective features utilize data governments usually have or are easy to obtain, being then suggested for this first phase. The quality assessment is thus represented by *size*, *type of access* (whether the space is gated and enclosed or not) and by a set of chosen *amenities and facilities* which have been associated with different age-group preferences, to be used together with census data. Other qualitative aspects could be incorporated in future research, based on scope and availability.

Porto has been chosen due to its role as the center of a metropolitan region and the fact it has recently proposed to increase and requalify its green spaces. The next chapter presents the city by exploring some of the aspects that directly impact the analyses, such as the street network evolution, its aging population and current plans for active mobility and green spaces.

3. Case Study – Porto

Porto is a city located in the northwest of Portugal, the second largest in the country, being the center of the AMP. It is limited to the South by the Douro River and to the West by the Atlantic Ocean. The AMP counts 1.736.228 inhabitants, 231.800 in Porto (Instituto Nacional de Estatística, 2023c).

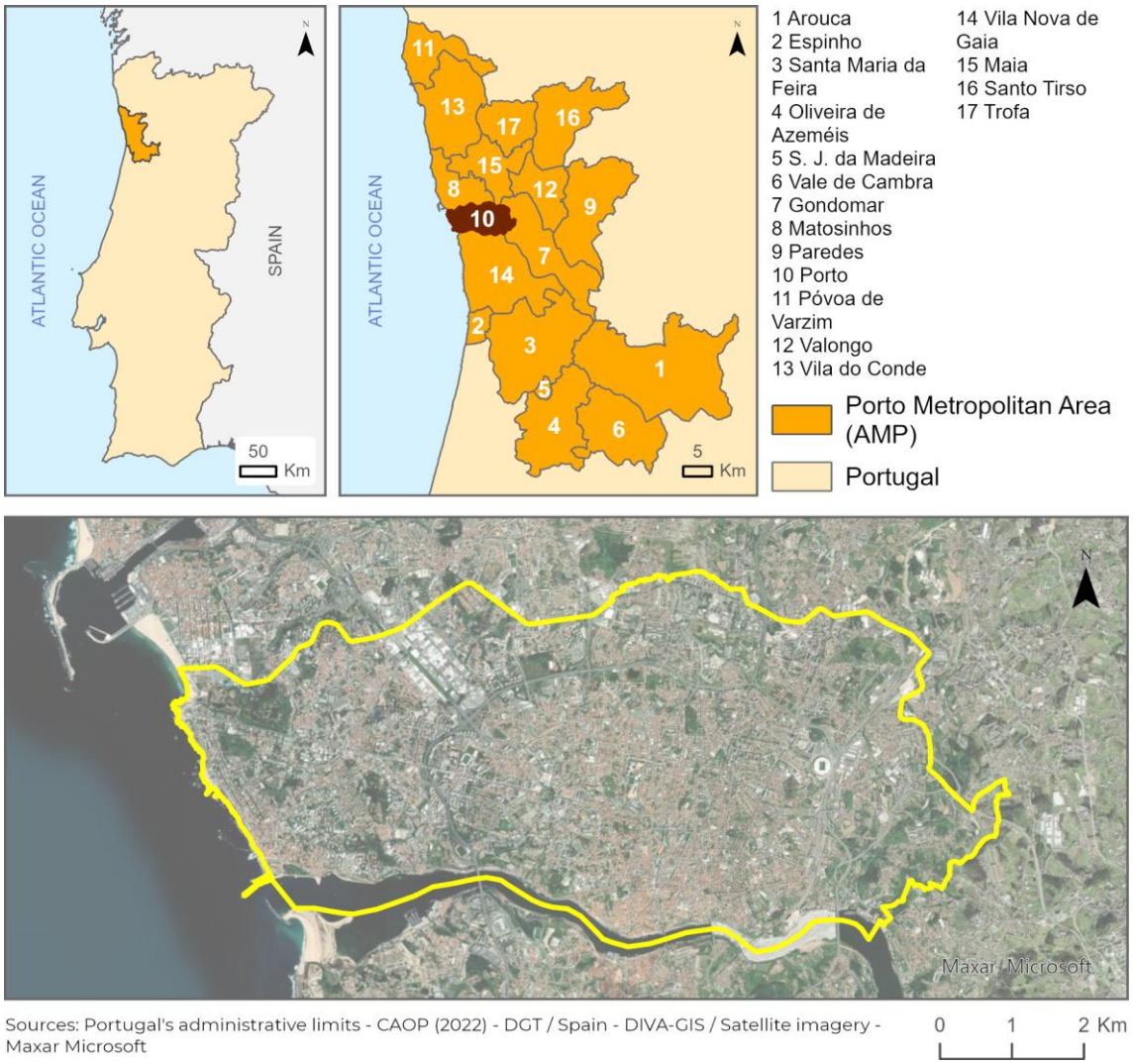


Figure 1 – Porto and Porto Metropolitan Area (AMP).

3.1. Brief historical evolution and context

Porto's official history dates from 1123, as a small village surrounded by Romanesque walls (Oliveira, 2014). A second wall was built in the 14th century, encompassing the river Douro and its port. In the 18th century a public agency for urban planning and management was created – "Junta das Obras Públicas" – opening new streets outside the wall, structured by five existing roads – some from the Roman period – which radiated from it and led to other cities[2]: Matosinhos, Viana do Castelo, Braga, Guimarães and Penafiel (Oliveira, 2014; Carvalho, 2020).

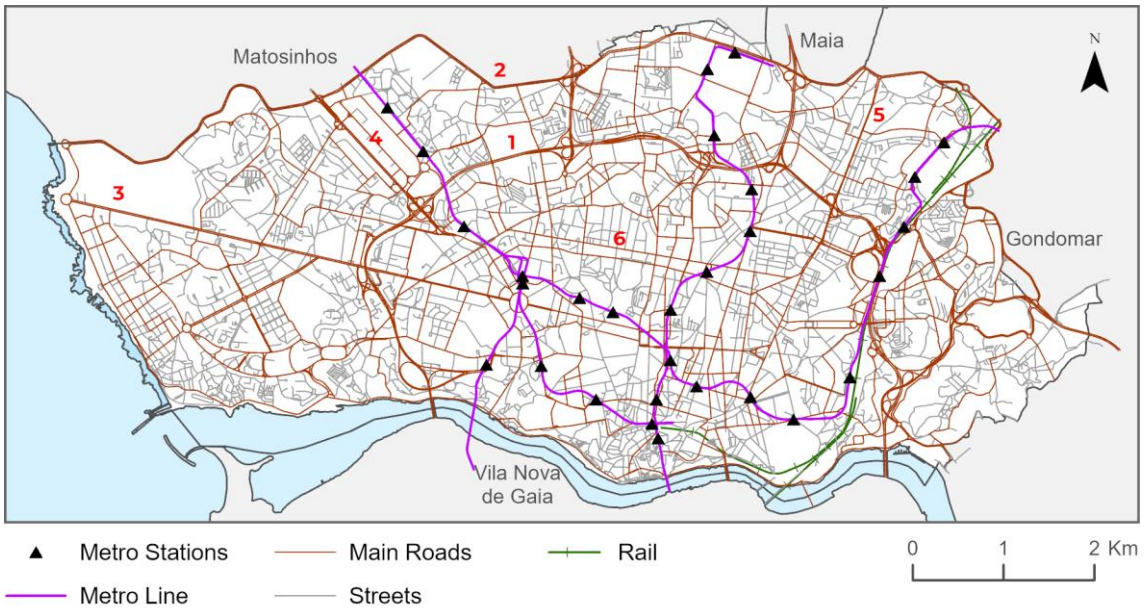
The 19th century saw more population growth due to industrialization and migratory movements (Pinto & Fernandes, 2018), reaching 140 thousand inhabitants (Oliveira, 2014). At this time, the expansion was somewhat guided by the avenues Boavista and Constituição, though it was a slow process and Porto was still very rural overall: small settlements and local commerce concentrated alongside the structural roads, while the proliferation of islands – working-class small dwellings on narrow inner-block streets – happened in the areas close to the new factories (Madureira et al., 2011; Pinto & Fernandes, 2018; Carvalho, 2020). The working class neighborhoods, among other factors such as a new bourgeois way of living and developments in transport, propelled the expansion to the western portions of the territory by high class resident neighborhoods (Pinto & Fernandes, 2018).

In the 20th century the sprawling urbanization and increased population led to the construction of numerous highways and several social housing projects, the first segregating parishes and creating barriers for pedestrians, whereas the second, at times, created poorly integrated neighborhoods due to following modernist principles (Carvalho, 2020). The population peaked at 330 thousand in the 80s, followed by decades of population loss, with some migrating to neighboring cities (Oliveira, 2014;

[2] For a chronological overview of Porto's urban form evolution, see Vitor Oliveira's "Porto maps" at https://vitoroliveira.fe.up.pt/pdf/the-porto-maps.pdf, an excerpt of "A evolução das formas urbanas de Lisboa e do Porto nos séculos XIX e XX", Edições UP, Porto, 2013.

ClimA daPT.Local, 2016), until 2017, when this process saw a slow shift (Sousa & Rodríguez-Barcón, 2021).

The current main traffic roads and structural public transport network can be seen on Figure 2. The main roads are structured by, as signaled in the map, 1, an inner road-ring (Via de Cintura Interna - VCI); 2, Circunvalação Road (which is somewhat parallel to the administrative borders) and connections to highways. Other significant roads are: 3, Boavista Avenue (running Southeast to Norwest towards the ocean); 4, Associação Empresarial de Portugal Avenue (running straight Northwest towards Matosinhos); 5, Fernão de Magalhães Avenue (straight Northeast, to the division between Maia and Gondomar); and 6, Constituição Street (within VCI's perimeter).



Sources: Portugal's administrative limits - CAOP (2022) - DGT | Street network, metro and rail - Plano Diretor Municipal do Porto (2021)

Figure 2 – Porto's main transport networks.

Porto has been fast growing as a touristic destination (Direção Municipal de Urbanismo, 2021c; Sousa & Rodríguez-Barcón, 2021) and 85% of the active population works in the tertiary sector (ClimA daPT.Local, 2016). Porto is the center and concentrator of jobs in the metropolitan region, with almost two thirds of its employees coming from outside the city, considering data from 2011 (Marques & Queirós, 2017).

The hotspots of jobs are located in three areas: on the historical center axis going north towards Asprela Campus of the University of Porto (UP); on the axis from the Campo Alegre Campus (UP) to Casa da Música Concert Hall, located at the eastern stretch of Boavista Avenue; and on the axis in the direction of Matosinhos, around Associação Empresarial de Portugal Avenue, as seen in Figure 3. The attraction generated by educational, cultural, commercial and leisure facilities, which are also concentrated in Porto in regard to the AMP, creates a dense and vast network of daily pendular activity of which the city is the main destination.

FIGURA 49 › Densidade de emprego (hotspots) nos estabelecimentos empresariais com mais de 10 pessoas ao serviço, no Porto e concelhos envolventes (2009).

Fonte: Projeto Policentrismo Urbano, FCT, 2010-2013

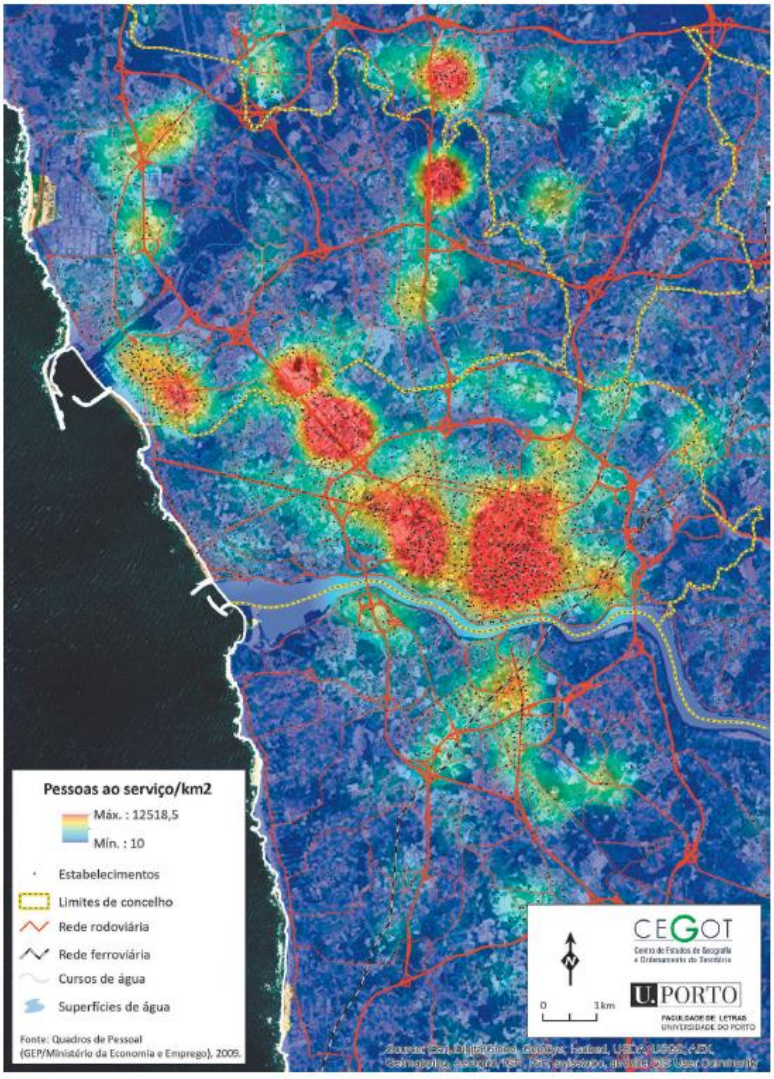


Figure 3 – Job's hot-spots in the AMP.

Source: "AMP 2020, Crescimento sustentável" (Marques & Queirós, 2017, p. 86).

3.2. Aging population

Porto is part of the WHO's Age-friendly Cities network since 2010. In 2013, the city's Urban planning department published a document charting the challenges the city faced (Direção Municipal de Urbanismo, 2013). It addressed the need for cultural, leisure and sport facilities to be equitably accessible for this age group and to host events and programs in line with their interests. When it comes to public spaces in general, it mentions comfortable urban furniture, the availability of benches and public restrooms. Universal design, public transport, safety and aspects of maintenance and cleanliness were recognized as essential for ensuring older adults can move about and take part in city life.

In 2013 Portugal was already an aging country, with fertility rate below the replacement level of 2.1 children per women. Currently, In Portugal, the average age is 45,4 (Instituto Nacional de Estatística, 2022a), people of 65 years-old and above represent 23,4% of the population and children from 0 to 14 years-old 12,4% (Instituto Nacional de Estatística, 2022b).

In Porto, 25,97% of the population are 65 years old or more whereas 11,40% are below 14 years old (Instituto Nacional de Estatística, 2023c). This trend is accompanied by a change in familial structures, with the population of 65 years old and above representing 50,3% of the people living alone in the country (Instituto Nacional de Estatística, 2023a). These data reinforce the risk of isolation and need for public policies and programs directed to older adults, not only aimed at their health and mobility, but also integration in everyday social and leisure activities.

3.3. Porto's plans for active mobility and green spaces

Active Mobility

Porto's masterplan highlights the need for better mobility and services in regards to the aging population and the central role that public spaces and public transport play

in this scenario (Direção Municipal de Urbanismo, 2021c). It also stablishes the need for new approaches when it comes to environmental challenges, mentioning that, beyond the management of resources and risks, there needs to be changes in the population lifestyle when it comes to movement, consumption, leisure, etc. towards a healthy and sustainable city.

To enable these changes, the masterplan proposes to enhance soft modes by creating pedestrian friendly streets, improving the bike lane network and even organizing the educational provision based on resident proximity. At the time of the masterplan's revision, walking represented 31% of the trips during the week (Direção Municipal de Urbanismo, 2019), but it was agreed that this does not equal to good walking conditions, recognizing the need to improve walkability in the city, with special consideration for universal design.

The "Municipal Strategy for the Environment" planned to increase the 15km of bike lanes to 35km by the end of 2020 (Direção Municipal de Urbanismo, 2014). At the time the city's masterplan was revised, the city counted 31,7 km of bike lanes, based on data from 2017 (Direção Municipal de Urbanismo, 2021a). The diagnostic report "Sistema de Mobilidade e Transportes" for the masterplan (Direção Municipal de Urbanismo, 2019) stipulated that the movement by bike corresponded to just 0,36% of trips during the week, with most of bike use associated with tourism or leisure and concentrated on the riverside and ocean front, during the weekends. The document reports the debate towards the existence of the need for dedicated bike lanes, concluding that any change in driver's behavior might necessarily require it, to which the masterplan responds by planning to expand the structural network as a way to promote cycling.

Green Spaces

Madureira et al (2011) conducted a study of the green structure evolution in Porto, which reveals drastic changes in the period between 1892, when the first accurate map of Porto was drafted, and 2000. They calculated that green areas

decreased from 75% of the city to 30%. The decrease came accompanied by fragmentation, with the mean patch size going from 150m² to 26m², as well was homogenization. The only category of green spaces that saw an expansion was public parks and gardens (510%), which has been the result of official plans to offset the effects urbanization had on the rural fabric. It was only in the masterplan of 2000-2006 that the need for a systemic view of ecological and landscape resources was proposed, without, however, addressing connectivity.

Climate change poses a few challenges to the city and its metropolitan region. The majority of Porto's territory is under risk of extreme heat in the summer, whereas the eastern portion and the strips alongside Douro and the Atlantic present increased chance of extreme cold in the winter. The average precipitation is expected to diminish, with more frequent and intense draughts, and more frequent and intense episodes of heavy rainfall (ClimA daPT.Local, 2016; Área Metropolitana do Porto et al., 2017; Direção Municipal de Urbanismo, 2018). When it comes to wind, the historical center is predominantly an area of low air circulation year-round, with the rest of the city presenting a pulverized mix of strong winds and pockets of low circulation (Direção Municipal de Urbanismo, 2018).

Not only these conditions call for the need to better use green spaces as part of a system of green infrastructure, but they also affect the use of these spaces, which should inform the design of PUPGs. The "Plano Metropolitano de Adaptação às Alterações Climáticas" (Área Metropolitana do Porto et al., 2017) recommends care when it comes to "greening" solutions that are oversimplified or generalized, meaning interventions shouldn't add green spaces or trees without careful consideration of which species, how much, where, for what purposes. Though the present dissertation won't go into the landscaping aspects of designing PUPGs, this aspect should not be overlooked.

Porto's "Municipal Strategy for the Environment" gathers measures that aim to tackle challenges in environmental, economic and social sustainability (Câmara Municipal do Porto, 2020). In it, it sees greens spaces' role in minimizing the effects of climate change and proposes green corridors, more green space, the employment of

nature-based solutions, native trees, and tackling the fragmentation of green spaces. It mentions creating local gardens close to where people live and work. At the time, the document stated the goal of adding 106 ha of green spaces to the existing 455, as well as initiatives to improve the existing PUPGs.

Some of these measures were better detailed in Porto's masterplan. The strategic goals emphasize addressing all age-groups, particularly the need of children, people with disabilities, and older adults (Direção Municipal de Urbanismo, 2021c). Porto's masterplan classifies its green areas in five categories, of which one is "Área verde de fruição coletiva" ("Green areas of public fruition"[3]), corresponding to parks and gardens of public access and squares of relevant green expression (more than 50% of the area or potential for rehabilitation), existing and proposed. These places, with few considerations which will be explored in chapter 4, are the green spaces that double as public spaces, in accordance with the objectives of this research. The other categories are of course fundamental for the ecological structure of the city, being integral for the provision of ecosystem services, but fall outside the scope of the current research.

For the "Green areas of public fruition" the masterplan proposes different interventions of ecological nature, such as increased permeability, re-naturalization of watercourses, native species, etc. It aims to increase the availability of such spaces based on a logic of proximity to residents, proposing the new spaces in currently underprivileged areas, and that they should provide for leisure, ludic and sports activities, though it doesn't detail these last aspects.

Porto plans on promoting and rehabilitating its streams and rivers in accordance with its strategies of adaptation to climate change, built on balancing nature based solutions and grey infrastructure (ClimA daPT.Local, 2016; Águas e Energia do Porto, 2024). One of the proposed interventions encompass the re-naturalization of streams associated with retention basins in new urban parks, such as Parque da Asprela, inaugurated in 2022, and others in project, such as Parque da Lapa, besides the promotion of green corridors alongside watercourses (Departamento Municipal de

[3] Translation by the author.

Comunicação e Promoção da Câmara Municipal do Porto, 2022; Águas e Energia do Porto, 2024).

Though Porto's urban fabric is mostly consolidated, the city still shows infill development and its consolidation is part of the masterplan goals (Direção Municipal de Urbanismo, 2021c). In 2023, the number of new construction licenses decreased 8% in relation to 2022, but licenses for new land development grew 20%, (Direção Municipal de Desenvolvimento Urbano, 2024). Porto has several "Unidades Operativas de Planeamento e Gestão" (Planning and Management Operational Unities[4]) (Direção Municipal de Urbanismo, 2021b). These reflect empty or degraded parcels of the territory in need of an integrated approach in order to be successfully connected to the urban fabric. Of these, 14 foresees new projects for public green spaces associated with new developments and/or facilities.

In sum, the provision and requalification of green spaces in Porto are being guided by the need to respond to climate change challenges and social inequalities, with emphasis on the aging population and better mobility. The city masterplan shows consideration to ensuring new developments are well connected and safeguard portions to green areas of public fruition. However, the proposed monitoring indicators found in the masterplan, when it comes to green spaces, relate to metrics of quantity, such as number of hectares and hectare per capita (Direção Municipal de Urbanismo, 2021a, 2021c). Though, as seen, the plans for new PUPGs do consider environmental aspects such as climate change adaptation, protection of water bodies and promotion of biodiversity, demographic and cultural aspects don't seem to have been considered systemically as of yet. From this research perspective based on the literature review findings, this poses the risk of focusing on quantity over quality.

The next chapter explores the methodology utilized for the proposed city-wide planning metrics, explaining the choice of parameters considering the specificities of Porto and available data.

[4] Translation by the author.

4. Methodology

4.1. Data and data preparation

Because the words “urban” and “city” pose a challenge when it comes to defining scale of analysis in a standardized manner, the UN-Habitat (2016b) recommends using the concept of “built-up area of the urban agglomeration”. This comprises the city-center and the suburbs that conform a continuous urban settlement. Due to the nature of the public administration in Portugal, this study restricts the analysis to the administrative boundaries of Porto council – responsible for its PUPGs – plus a kilometer buffer to account for the people who, living in an adjacent city, are still able to make regular use of the PUPGs within this range. The buffer also helps to curb the edge-effect that can skew results in the *paths* and *connectivity* analyses. The study was conducted using secondary data in geographical information systems (GIS), which can be seen in Table 9.

Table 9 – Data type and sources

Data	Period	Type	Source
Administrative limits	2022	geodatabase	CAOP / Direção Geral do Território (DGT)
Street network	2023	shapefile	OpenStreetMap
Porto's green areas of public fruition	2021	geodatabase	Plano Diretor Municipal do Porto / DGT
Demographic data	2021	geodatabase	BGRI / Instituto Nacional de Estatística (INE)
Public and Private schools	2018	table and shapefile	Ministério da Educação; Direção-Geral de Estatísticas da Educação e Ciência (DGEEC) - Rede escolar 2018
Potential visitors	varied	table and shapefile	Informa D&B (2017); Registo Nacional de Turismo (2017); GEP - Gabinete de Estratégia e Planeamento; MTSSS - Carta Social (2018), Ministério da Educação; DGEEC (2020); Ministério da Cultura (2018); CP (2017); C.M.P (2016); Ministério da Saúde e Portal SNS (2020); FLUP-DG/CEGOT.

Source: Author

The diagram on Figure 4 summarizes the data preparation process.

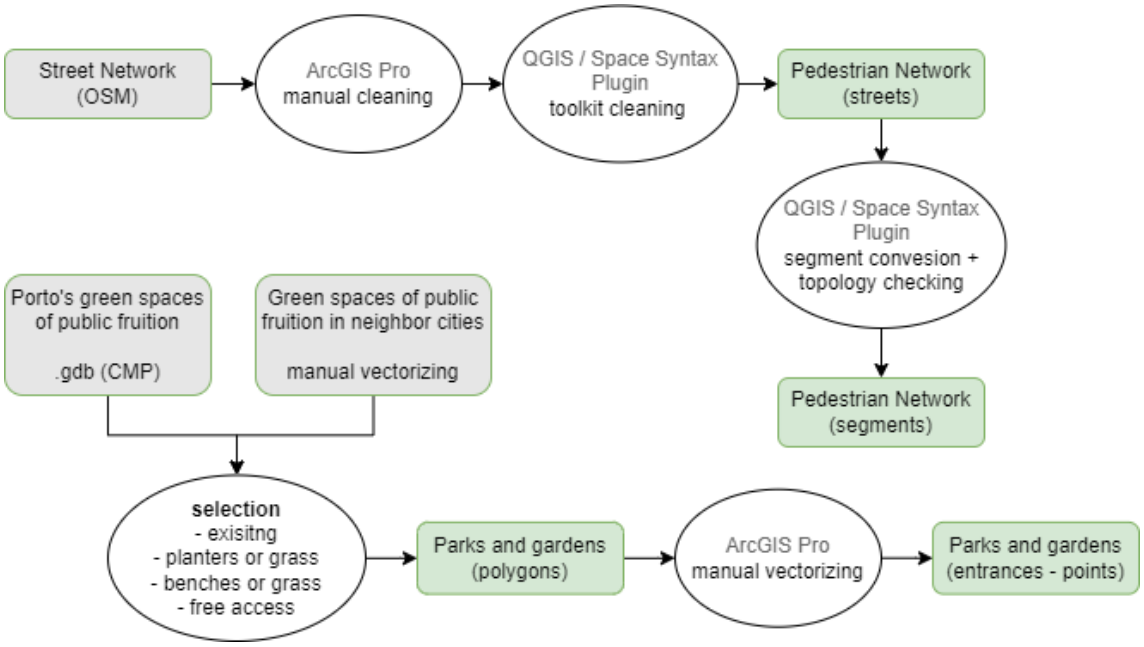


Figure 4 – Data preparation diagram.

Space Syntax, from its beginnings, worked with axial lines as its preferred method of street representation, the axial line representing the visible movement path (Nes & Yamu, 2021). This has limited its use within GIS, as axial maps have to be drawn or automatically derived from block representation of public open spaces in a city, when the most common readily available representation for street networks are road-center lines. Turner (2007) has shown that angular segment analysis can be used with road-center lines and achieve comparable results to axial analysis via angular segment analysis through length-weighted normalization. This development has since been adopted by the space syntax community and included in depthmapX[5], a freely available software initially developed by Alasdair Turner which currently has been integrated to QGIS via its plugin and toolkit (Gil, 2015).

First, the OSM network was manually cleaned and edited. With the help of Google Street View, special care was taken into checking for possible disconnects, simplifying two-way streets and intersections representations with one line and confirming each walkable stretch, removing motorways, garage entrances and

[5] Available at https://www.spacesyntax.online/software-and-manuals/depthmap/, from University College London – Space Syntax.

semipublic streets where people can't freely go through. In this case, the walking paths within enclosed parks and gardens were eliminated as well, for two reasons: one is that their actual existence and location/design is harder to evaluate from satellite imagery or Google Street View; the second is that, because they can't be transversed all day long, they carry less influence on the entire pedestrian network.

Using the Space Syntax QGIS plugin, the shapefile was further cleaned. The toolkit automatically fixes data from OSM, but, after that, the unlinks were checked to ensure all bridges, tunnels and overpasses that remained after the first clean-up were represented. This is the resulting street network used in the *catchment* analysis, but for *connectivity* and *paths*, another step was necessary: the layer – made of polylines – was converted into a segment map and again verified, for the conversion could generate topology errors such as small lines, orphans and islands (Gil, 2015).

The parks and gardens selection followed these criteria: existing parks, squares and gardens that are public and free of charge; which have either seating areas or grass; which have either flowerbeds or grassy fields as vegetation, besides trees. These characteristics were considered the minimum requirements for the site to be both a public open space and a green space. This distinction was necessary because there is some ambiguity in the concept of squares/gardened squares and a careful examination of each site through satellite imagery combined with Google Street View brought the need to eliminate squares whose only vegetation were trees, for the Porto's masterplan had included areas lacking in green coverage in order to rehabilitate them in the future.

Of the 198 polygons from Porto's database, 128 accounted for existing areas. Of these, only 89 entities remained after selecting for the above characteristics and unifying polygons belonging to the same site. Finally, 17 PUPGs belonging to the neighboring cities and located within the 1km buffer were manually added, totaling 106 PUPGs. A new dataset was created for the entrances to the PUPGs, by manually locating each point on either the actual entrance in the case of enclosed PUPGs, or the initial point of every crossing/walking path in the case of open spaces that can be transversed any time of day. This care was taken to ensure more realistic service areas. The resulting pedestrian street network and selected PUPGs can be seen on Figure 5.

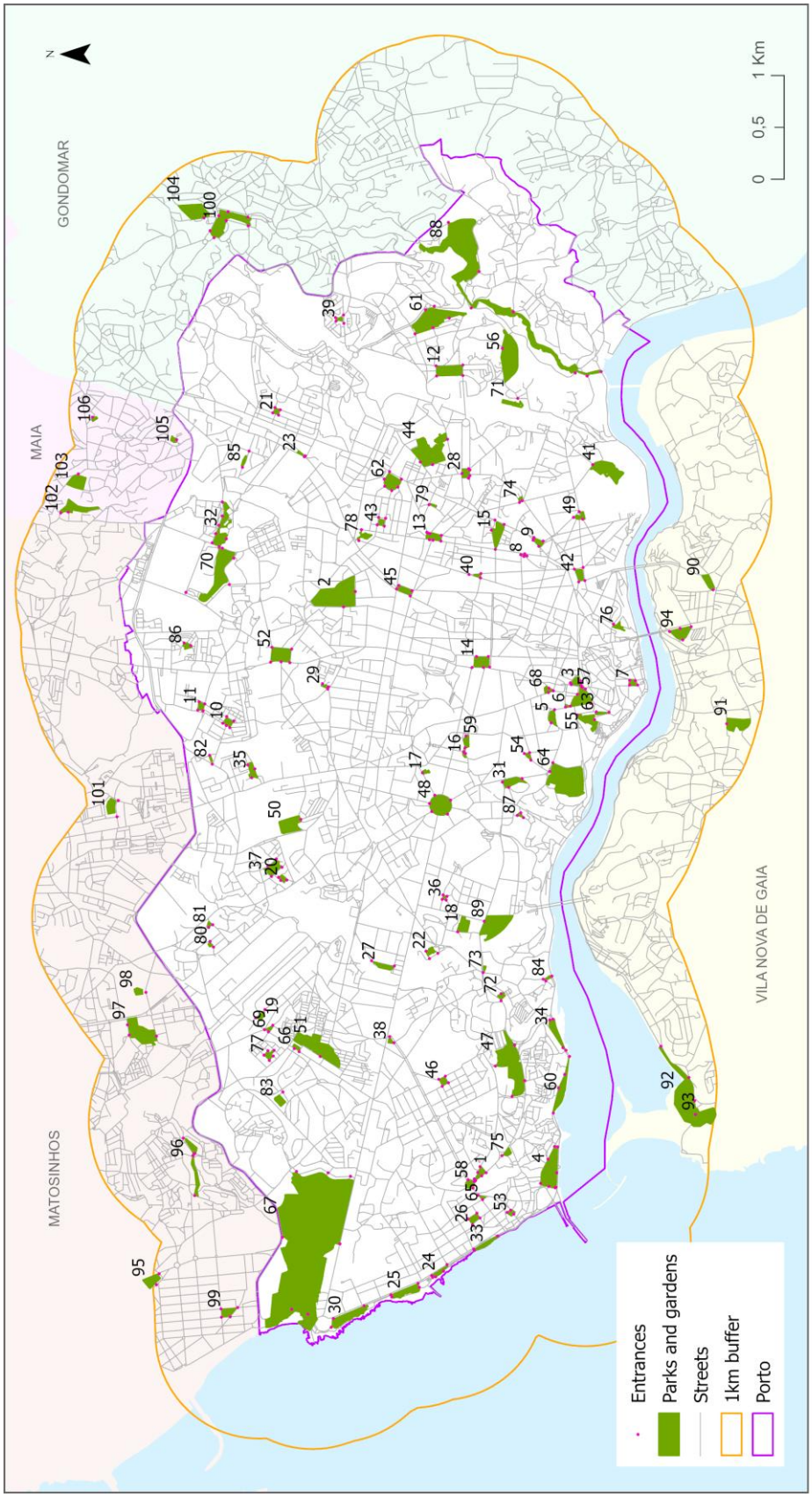


Figure 5 – Pedestrian street network and selected PUPGs.

1 Jardim[6] José Roquete
2 Parque do Covelo
3 Praça de Lisboa
4 Jardim do Passeio Alegre
5 Jardim de Carrilho Videira (Carregal)
6 Largo do Professor Abel Salazar
7 Jardim da Praça Infante D. Henrique
8 Jardim do Moreda
9 Campo de Vinte e Quatro de Agosto
10 Jardim na Avenida Flor da Rosa
11 Largo Palmira Melheiro
12 Praça da Corujeira
13 Jardim da Praça Rainha D. Amélia
14 Jardim de Teófilo Braga / Praça da República
15 Jardim Paulo Vallada
16 Praça de Pedro Nunes
17 Jardim da Casa - Museu Marta Ortigão Sampaio
18 Jardim da Casa das Artes
19 Jardim na Rua Eng. Ezequiel de Campos
20 Jardim Adelaide Estrada
21 Jardim de Belém
22 Bairro Bessa Leite
23 Largo da Cruz
24 Avenida do Brasil / Praça da Praia do Molhe
25 Jardim Homem do Leme
26 Praça de Liége
27 Jardim Machado de Assis (Foco)
28 Jardim Guedes de Oliveira (Praça das Flores)
29 Largo de S. Dinis
30 Jardim de Montevideu
31 Praça da Galiza
32 Parque da Quinta de Lamas
33 Jardim de Camões
34 Jardim António Cálem
35 Bairro de Santa Lúzia
36 Praça do Conde de Samodães
37 Jardim Sarah Afonso
38 Praça do Monumento ao Empresário
39 Largo de Valverde
40 Jardim José Moreira da Silva
41 Jardins da Quinta do Barão de Nova Sintra
42 Jardim de Marques de Oliveira / Jardim de S. Lázaro
43 Jardim do Conhecimento
44 Parque de S. Roque
45 Jardim da Praça do Marquês de Pombal
46 Largo de D. João III
47 Parque da Pasteleira
48 Praça de Mouzinho de Albuquerque
49 Largo de Soares dos Reis
50 Parque da Prelada
51 Parque Desportivo de Ramalde
52 Jardim da Arca de Água / Praça de Nove de Abril
53 Largo do Capitão Pinheiro Torres de Meireles
54 Largo da Maternidade de Júlio Dinis
55 Parque das Virtudes
56 Quinta de Bonjóia
57 Jardim João Chagas (Cordoaria)
58 Praça do Império
59 Largo do Priorado
60 Jardim das Sobreiras
61 Parque de Cartes
62 Praça de Francisco Sá Carneiro
63 Passeio das Virtudes
64 Jardins do Palácio de Cristal
65 Jardim Antero de Figueiredo (Mercado da Foz)
66 Jardim da Rua do Dr. Joaquim Costa
67 Parque da Cidade
68 Jardim da Praça de Carlos Alberto
69 Jardim da Praça de Afrânio Peixoto
70 Parque Central da Asprela
71 Jardim do Terminal
72 Bairro das Condominhas
73 Jardim do Padrão
74 Alameda de Claudio Carneiro
75 Jardim na Rua Diogo Botelho
76 Jardim Arnaldo Gama (Muralha Fernandina)
77 Jardim na Rua dos Choupos
78 Jardim do Metro dos Combatentes
79 Jardim na Rua do Major David Magno
80 Jardim do Mercado do Viso
81 Rua Cidade de Recife
82 Rua de Santa Lúzia
83 Praceta Cidade da Praia
84 Jardim da Calçada do Ouro
85 Jardim na Rua Professor António Cruz
86 Jardim do Bairro da Azenha
87 Jardim da Pena
88 Parque Oriental
89 Jardim Botânico do Porto
90 Parque da Ponte Maria Pia
91 Parque Quinta das Devesas
92 Reserva Natural Local do Estuário do Douro
93 Parque de São Paio
94 Jardim do Morro
95 Jardim Basílio Teles
96 Parque de Real
97 Parque Urbano do Carriçal
98 Jardim das Sete Bicas
99 Praça Guilherme Pinto
100 Parque Urbano de Rio Tinto
101 Parque do Seixo
102 Parque Urbano dos Amores
103 Jardins da Casa do Alto
104 Parque Quinta das Freiras
105 Jardim das Enxurreiras
106 Jardim do Rosmaninho

[6] Some common words found in the names are: *jardim*, meaning "garden"; *parque*, meaning "park" and *praça,* meaning "square".

4.2. Accessibility

Accessibility is represented by *paths* and *connectivity* as measurements of street network configuration and by *catchment* as a measurement of demand. The analyses are summarized in Figure 6.

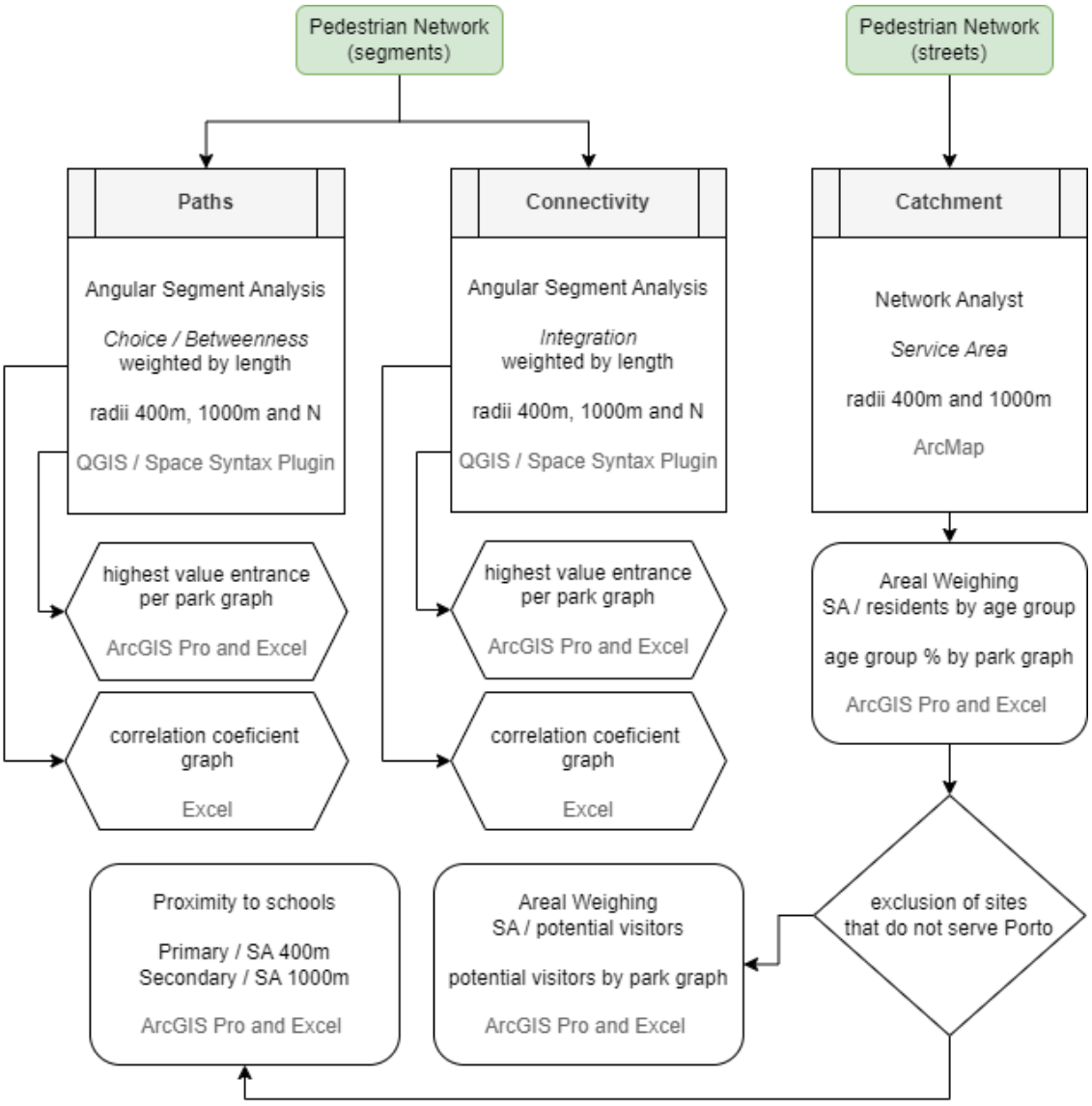


Figure 6 – Accessibility analyses diagram.

Paths and connectivity

Both analyses utilize the same radii: the entire area, or radius = N, was used for the global choice and global integration (Gil, 2015; Nes & Yamu, 2021), and radii of 400m and 1000m used for local choice and local integration. The radius N give a comprehensive picture of the street network configuration, whereas the radius 400m is equivalent to a 5-minute walk and the recommended distance for small, local and neighborhood sites (Llewelyn-Davies, 2007; João Pinelo, 2010; UN-Habitat, 2018; Huang et al., 2020) whereas 1000m is the threshold for walking from which point there is a significant decrease in visits (Oh & Jeong, 2007; Koohsari et al., 2013; Ekkel & de Vries, 2017; Chiang & Li, 2019), besides being the second recommended distance for accessibility analyses by the UN-Habitat, as seen in Table 2. The resulting values are presented in synthetic maps using six color-coded classes distributed by natural breaks according to Nes & Yamu (2021), with classic space syntax color range, where dark blue denotes lower values (low accessibility) and red higher values (high accessibility).

To determine the level of intelligibility of the street network, the correlation coefficient was calculated between the local and global integration levels. The same was done for local and global choice, reflecting the degree to which the main routes are connected to the local streets (Nes & Yamu, 2021).

The PUPGs entrance points were intersected with the resulting choice and integration values as representative of the overall value for each site (Bahrini et al., 2017). On each park and garden, the entrance with the highest value for each analysis was computed as representative of the overall accessibility and for comparison amongst sites, helping determine their vocation as local or urban, which can then be compared to size and to the results of the catchment analyses.

Catchment

The third accessibility metric is catchment, to find out potential demand for each site. The pedestrian street network was modeled in ESRI's software ArcMap, using the aforementioned cleaned street network from OSM. To accurately represent bridges, tunnels and overpasses, endpoint modelling was used, coinciding with the unlinks. The

radii of 400m and 1000m were used in the service area of each park and garden and the entrance points were utilized as sources. The service areas were then used to calculate potential demand represented by residents, school students and visitors' load.

For the resident population, the most recent resident census data was utilized (Instituto Nacional de Estatística, 2022a) disaggregated by age-groups to better represent their needs (World Health Organization - Library Cataloguing-in-Publication Data, 2007; UN-Habitat, 2016b; Douglas et al., 2017; UN-Habitat, 2020d). Areal weighting was processed for the following groups:

- Total population
- Children – 0 to 14 years-old
- Youth and Adult population – 15 to 64 years-old, combining the 15 to 24 and 25 to 64 Census' groups
- Older adults – 65 years-old and above

Kids have less autonomy, walk slower and tend to travel to a more limited range of distance by foot, compared to older teenagers and the adult population in general (Gehl & Svarre, 2013; UN-Habitat, 2020c). Older teenagers have more autonomy and are more likely to study outside of their resident zone. The fact their needs and preferences may differ from adults in general can be represented by the student population, which in this research is represented by schools. Finally, the older adult's population was determined by the census cut-off of 65.

From the results, it was possible to see which parks outside of Porto administration may also serve the city, as well as which neighboring areas may be served by a park or garden belonging to Porto. With this criteria, the following seven PUPGs were eliminated from the analysis, for their service areas (1000m) were entirely outside of the Porto administration borders: Parque da Ponte Maria Pia, Parque Quinta das Devesas, Reserva Natural do Estuário do Rio Douro, Parque de São Paio, Jardim Basílio Teles, Jardim da Casa do Alto e Jardim Rosmaninho.

To account for potential patronage from people who don't necessarily reside near a park or garden, a first approach is to analyze data showcasing the areas of the

city that accumulate more visitors during the day. This goes in hand with the idea that people don't necessarily use just the park nearest to their home, but places near where they work, study or run errands (Jacobs, 1961; Whyte, 1980; Koohsari et al., 2015; Talal & Santelmann, 2021; Phillips et al., 2023), which can give more information on the types of characteristics in demand on each site, besides the risk of overcrowding in some areas. For the city of Porto, it was possible to acquire data from primary and secondary school. The number of students was only available for public schools, so a choice was made to use the schools' locations as representative of each group: primary school was intersected with PUPGs 400m service areas and secondary schools with the 1000m service areas.

Finally, the potential patronage from people who don't necessarily reside in the area, the "potential visitors", was represented by the sum of the following categories: number of jobs, hotel capacity, local accommodation capacity, museum visitors per day, shopping mall visitors per day, social equipment users per day, medical appointments per day, university students. These data can help locate centralities inside of Porto and were provided by the Centre of Studies in Geography and Spatial Planning (Centro de Estudos de Geografia e Ordenamento do Território, CEGOT). Areal weighing was performed for each park and garden for the 400m radii.

4.3. Quality assessment

The research studying park characteristics and people's preferences covered in the literature review has analyzed both objective criteria, such as facilities and amenities, and subjective ones, such as perceptions on maintenance and cleanliness. Because of the limited nature of the present work, though the subjective aspects of park assessment were found to be significantly important and should be included in planning, only objective criteria were selected. Therefore, the quality assessment analyses are focused on objective data that can be acquired systemically without the need for *in situ* visits nor surveys, as a first step into the city-wide assessment. The results can then be

correlated and compared with the accessibility analyses results. They are *type (by size)*, *type of access* and *amenities / facilities*, as summarized in Figure 7.

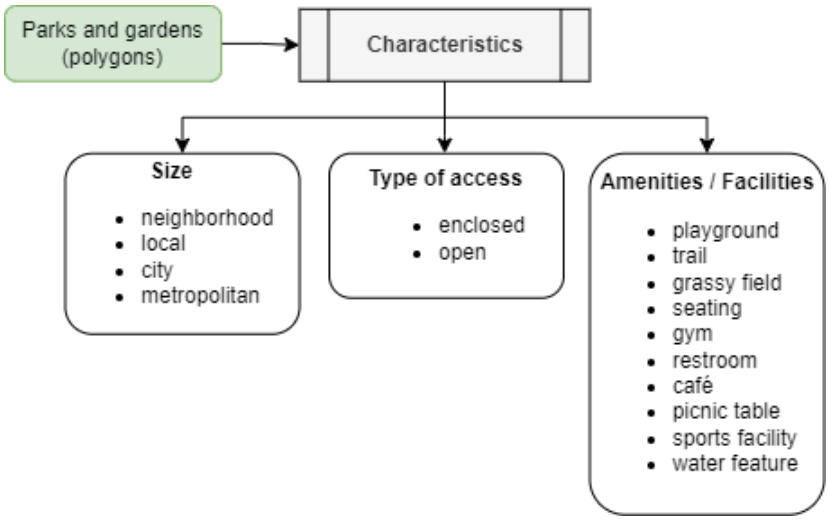


Figure 7 – Quality assessment diagram.

The classification *by size* took into consideration the classifications for open public spaces from the UN-Habitat, found on Table 3, the classifications for parks by the Urban Design Compendium, found on Table 4, and the size range of Porto's PUPGs, as can be seen on Table 10.

Table 10 – Classification of PUPGs by size

Type	area (ha)	distance (m)
Neighborhood	up to 0.4	400
Local	0.4 to 2	400
City	2 to 10	1000
Metropolitan	above 10	-

Source: Author

The *type of access* represents whether the PUPGs are enclosed and gated or not, as defined by the UN-Habitat (UN-Habitat, 2020a, 2020c). The *amenities / facilities* selected for assessment were chosen based on their prevalence in the studies' findings and their association with different age-groups. Their purpose, focus age-group and supporting literature can be found in Table 11.

Table 11 – Amenities and facilities selected for assessment

Amenity / Facility	Purpose(s)	Focus groups	Literature Review
playground	social interaction, recreation	children, caregivers	(Douglas et al., 2017; Ayala-Azcárraga et al., 2019; Talal & Santelmann, 2021; Chen et al., 2024)
walking trail	physical activity, social interaction	youth, adults, older adults	(Douglas et al., 2017; Ayala-Azcárraga et al., 2019; Talal & Santelmann, 2021; Veitch et al., 2022)
grassy field	physical activity, social interaction, relaxation	children, youth, adults	(Douglas et al., 2017; Veitch et al., 2022)
benches / seating	relaxation, social interaction	adults, older adults, pregnant people	(Whyte, 1980; Llewelyn-Davies, 2007; Gehl, 2013; Douglas et al., 2017; Madureira et al., 2018)
courts / gym	physical activity, social interaction	children, youth, adults	(Douglas et al., 2017; Madureira et al., 2018; Ayala-Azcárraga et al., 2019)
restroom	comfort	older adults, caregivers, pregnant people	(Douglas et al., 2017; Talal & Santelmann, 2021)
café	social interaction	older adults	(Whyte, 1980; Gehl, 2013; Madureira et al., 2018; Veitch et al., 2022)
picnic table	social interaction	children, caregivers, older adults	(Talal & Santelmann, 2021; Veitch et al., 2022)
water feature	relaxation, recreation	children, youth, older adults	(Whyte, 1980; Madureira et al., 2018; Talal & Santelmann, 2021; Ha et al., 2022; Veitch et al., 2022; Chen et al., 2024)

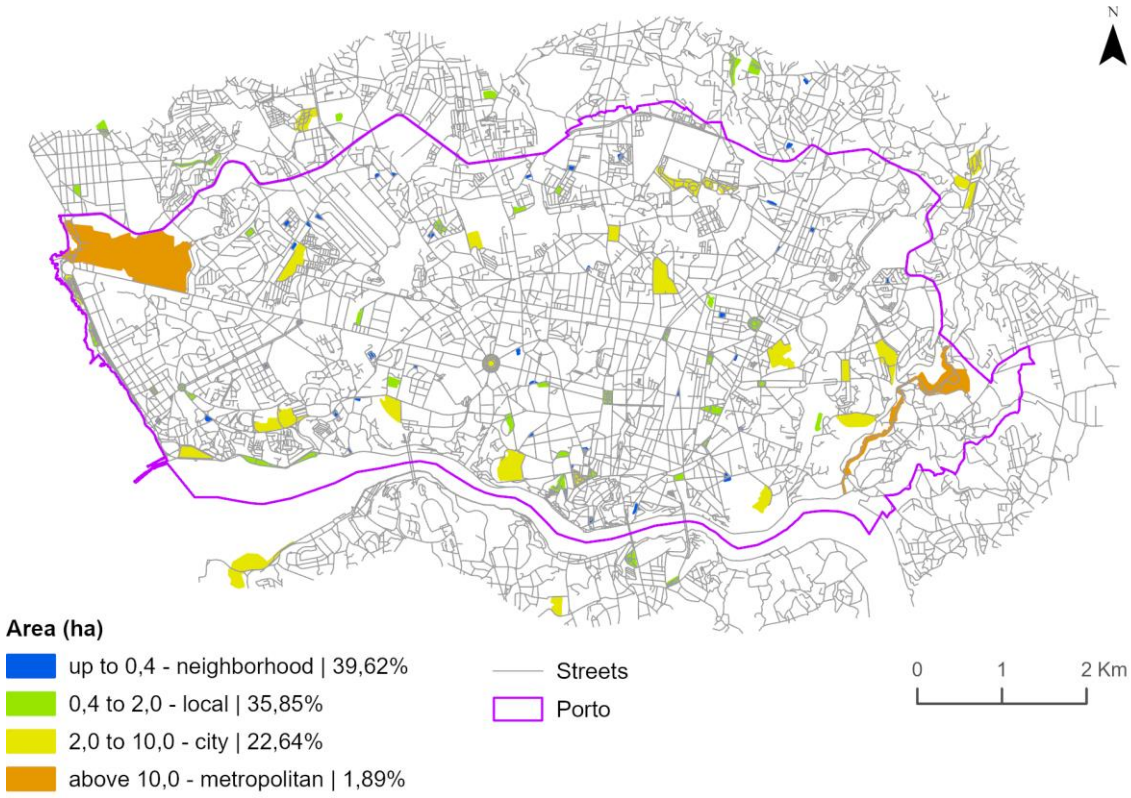
Source: Author.

Information of which facilities and amenities are present on each site was collected from the official websites of Porto[7], the AMP metropolitan sites[8], Matosinhos[9], Vila Nova de Gaia[10], Gondomar[11], Maia[12] and through individually checking through Google Maps, Google Places and Google Street View.

[7] https://ambiente.cm-porto.pt/parques-infantis-desportivos and https://ambiente.cm-porto.pt/estrutura-verde/parques-jardins
[8] "Rede de sítios metropolitanos", at http://maquina1.portodigital.pt/sitios-amp/sitios/
[9] https://www.cm-matosinhos.pt/servicos-municipais/ambiente/parques-e-jardins?WAI-FID=
[10] https://www.cm-gaia.pt/pt/cidade/ambiente/parques-de-gaia/
[11] https://www.cm-gondomar.pt/atividade-municipal/ambiente/espacos-verdes/
[12] https://www.cm-maia.pt/ambiente/ambiente/espacos-verdes

5. Results and Discussion

5.1. Quality assessment - Size



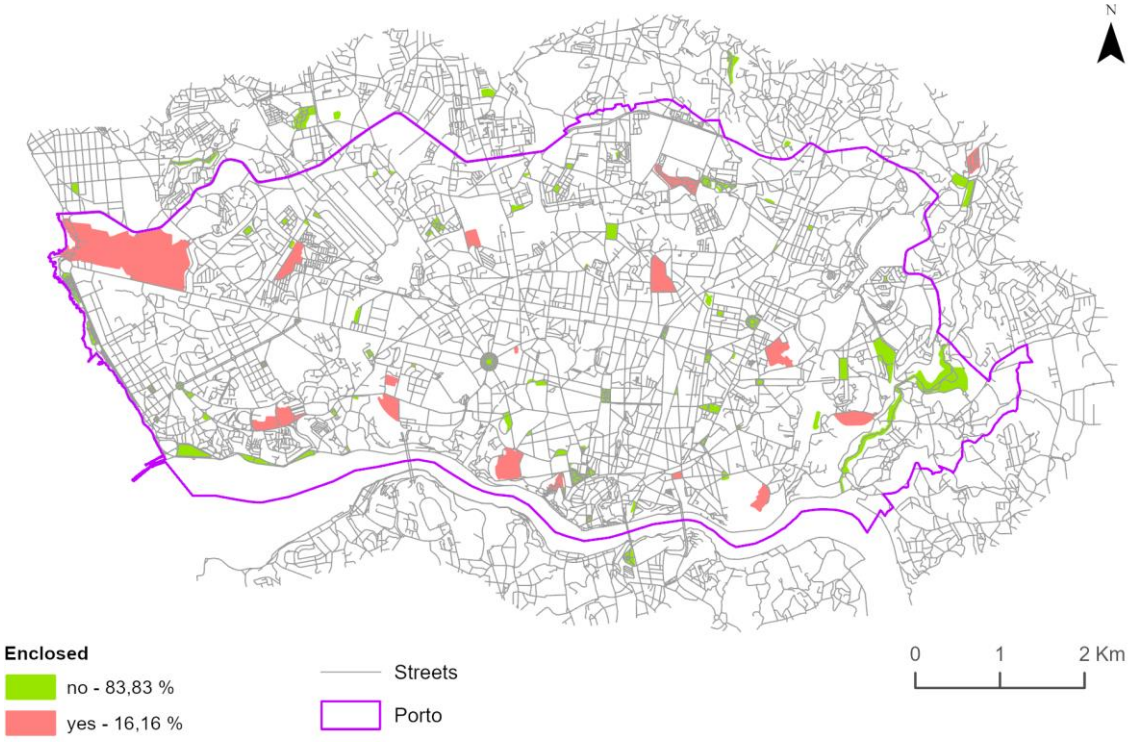
Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited)

Figure 8 – PUPGs classified by size.

The first result is the classification by size, as it will guide the subsequent analyses. The majority of PUPGs in the study area are relatively small considering the classes stablished by the UN-Habitat and the Urban Design Compendium (Tables 3 and 4, respectively), with a mean size of 2,19 ha and median of 0,54 ha. 75,47% are up to 2ha, being thus classified as “neighborhood” or “local”, corresponding to gardened squares and small gardens. The two largest areas are Parque Oriental (19,34 ha) and Parque da Cidade (69,19 ha), both located at the borders of the city, which results from rapid urbanization and the consequent need to provide formal green spaces, as the sites are reminiscent of the green structure plans of the mid-20th century (Madureira et al., 2011). Though the remaining sites, classified as “city” PUPGs (22,64% of the total), are

more evenly distributed, they concentrate around the city center, with the exceptions of Jardim da Cordoaria and Jardins do Palácio de Cristal, and reflect the more fragmented provision of green spaces from the first Porto's masterplan (1960-1962), which, according to Madureira et al, contained several modernist concepts such as single-use zoning and dispersed urban development (2011).

5.2. Quality assessment – Type of access



Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited)

Figure 9 – PUPGs by type of access.

The majority of sites are not enclosed (83,83%). Of the 16 enclosed sites, at least 10 are related to the fact they originated from private properties, with a few still attached to institutions, such as the Jardim Botânico (of University of Porto) and Jardim da Casa (Marta Ortigão Sampaio Museum). The enclosed PUPGs tend to the larger size, with 12 classified as either city or metropolitan.

5.3. Accessibility – Paths and connectivity

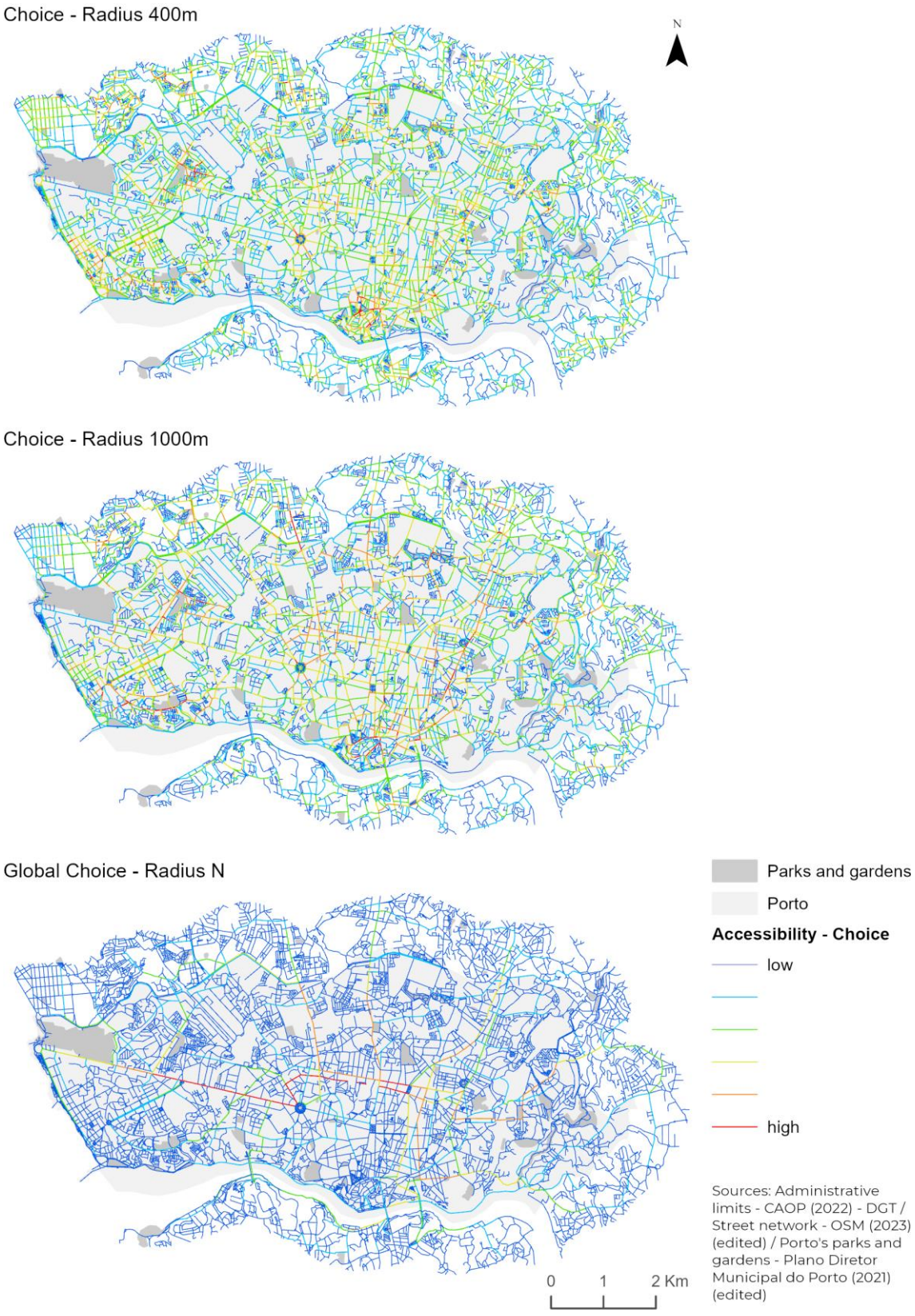


Figure 10 – Accessibility – *paths*. Choice by radius.

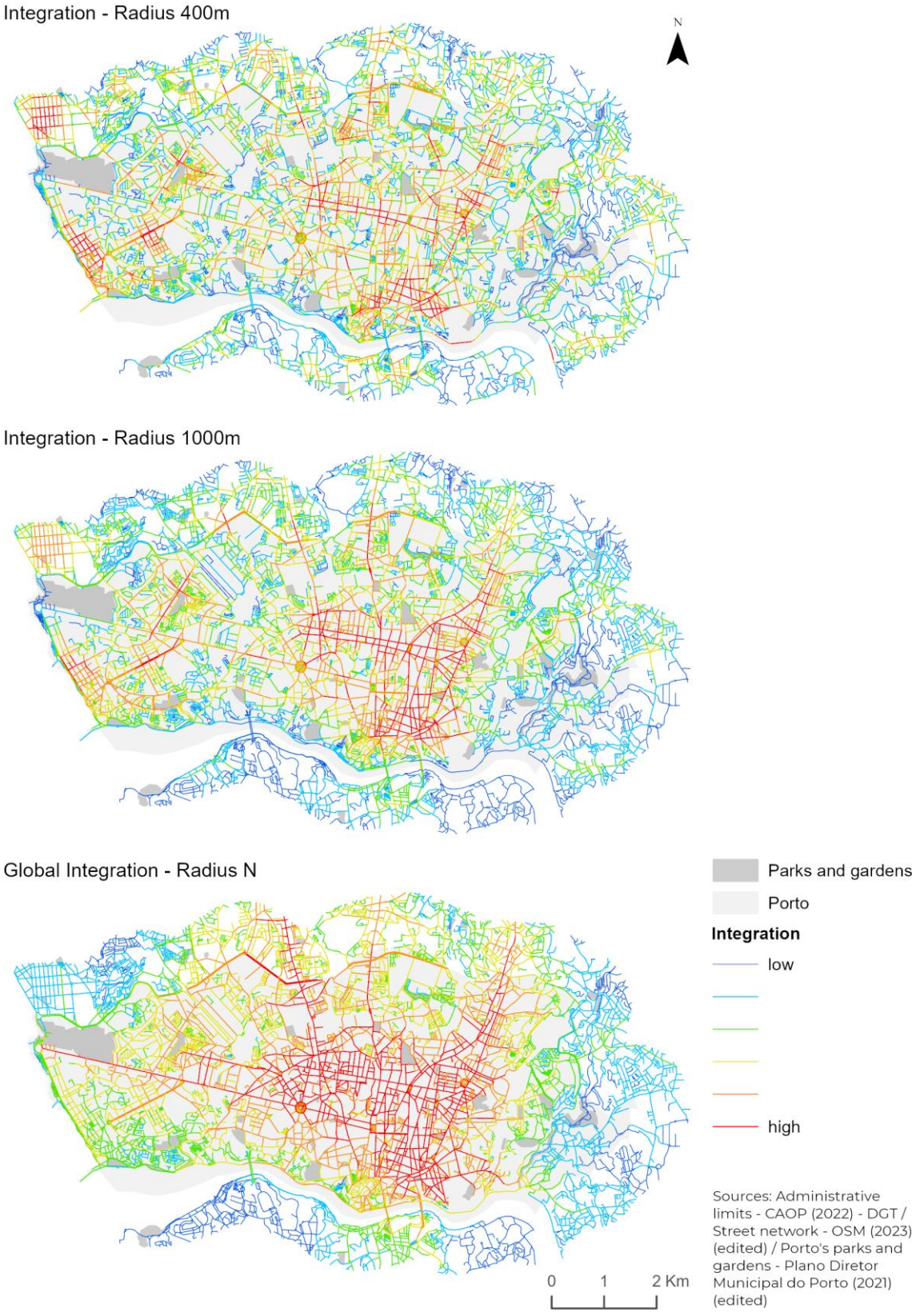


Figure 11 – Accessibility – *connectivity*. Integration by radius.

In the paths set of analyses, shown in Figure 10, global choice is the best radius to illustrate the study area's route hierarchy, showing the longer streets that run through the urban fabric and between neighborhoods, usually consisted of radials and orbitals (Nes & Yamu, 2021). The distinction between main paths and the "background" network (in dark blue) is quite clear, the main paths coinciding with some of the main vehicular roads left in the pedestrian network (see Figure 2) and a few of them representing the old roads that once led to other cities (Oliveira, 2014). The streets from housing projects and resident neighborhoods, which can be recognized in dense clusters, tend to be shorter and end at a right angle, belonging to the background network (Nes & Yamu, 2021). As the radius get smaller, accessibility trends toward median values while sinuous and dead-end streets compose the background network.

In the connectivity set of analyses, shown in Figure 11, most streets inside Porto's borders have medium to high integration values for the global radius (N), the edge effect being more pronounced inside the buffer zone encompassing part of the neighboring cities. The highly connected streets concentrate on the city center and alongside the global main paths, some of which, again, are the main roads of yore which radiated from the city walls (Oliveira, 2014) and which, already in the 19th century, were marked by high commercial activity (Pinto & Fernandes, 2018). For comparison, see Oliveira's Porto maps, linked at footnote 3 (page 48). In the oldest part of the town, the streets which once were inside the city-walls have lower values, as their point of connection to the surrounding system was through the wall doors.

Inside Porto's border, still for the global analysis, lower values concentrate on more isolated neighborhoods – such as the resident projects area near Douro's mouth and Parque da Pasteleira – and on the city's oriental side, which is segregated by the rail (see Figure 2). The Asprela campus, on the northern part of the city, composed of few streets and large plots, and the more affluent neighborhood on the Atlantic front, less densely occupied, both present mid-range values. The smaller radii of 1000m and 400m highlight local and neighborhood centralities, with the noticeable effect that they correspond to the more reticular grids, compared to sinuous and dead-end streets.

Figure 12 illustrates that the local (400m) and global integration show moderate correlation (0,55), meaning the street network has a moderate degree of intelligibility, for many of the streets that are well integrated locally are not so in the global analysis. For choice, the correlation coefficient is very low (0,16), meaning the main paths in the city-wide scale are not well connected to the local streets (Nes & Yamu, 2021).

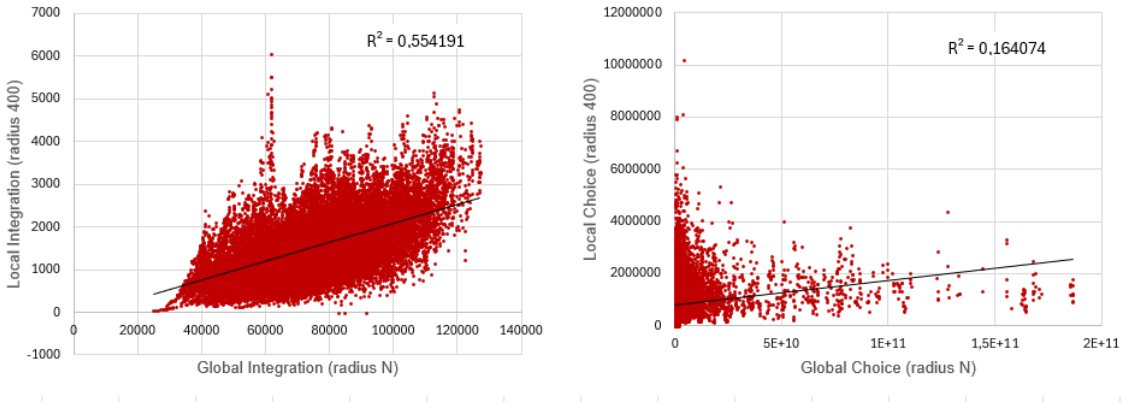


Figure 12 – Correlation coefficient for *connectivity* and *paths*.

When analyzing all PUPGs as represented by their highest value entrance, which can be seen in Figure 13, they tend to be well located when it comes to integration. For all radii, the majority of sites have an entrance on the mid to high half of the scale (yellow to red), totaling 85% on radius 400m, 76% on radius 1000m and 82% on radius N. This means that most PUPGs have at least one entrance on a street with good to-movement potential, giving them higher probability of chance visitors (Koohsari et al., 2014; Chiang & Li, 2019; Nes & Yamu, 2021).

The scenario is different when it comes to main paths. The sites are predominantly located on streets that fall in the middle of the scale (from green to orange) when it comes to the local radii of 400m and 1000m, 77% and 70%, respectively. For global choice though, the majority of the PUPGs (76%) fall on the two lower classes, being located in streets with low through-movement potential, or the background network. Therefore, when it comes to main paths, most parks are reasonably locally accessible but not globally accessible (Nes & Yamu, 2021).

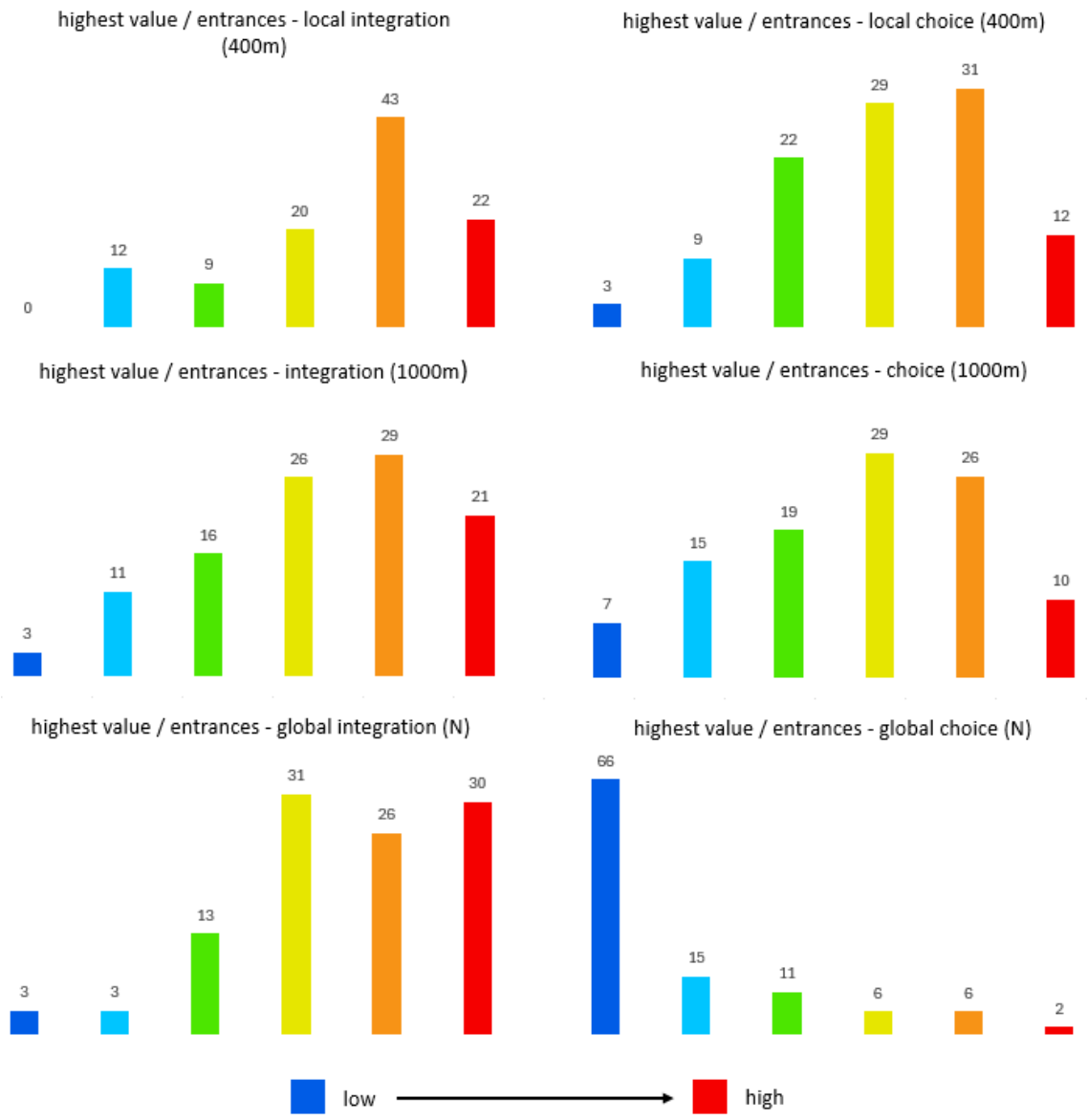


Figure 13 – Highest value per entrance for integration and choice, classified.

When results are grouped by size, as shown in Figure 14, it is possible to see that neighborhood PUPGs are mostly well located within the local radii (400m and 1000m), on both analyses. Very few fall on the lower classes, barely surpassing 10% overall, but then each case should be considered individually as some sites may host activities that should well be more isolated from main paths, such as neighborhood playgrounds, and therefore this would not constitute a problem, especially as streets with high vehicular traffic may be considered less favorably for some age groups such as children and older adults (Koohsari et al., 2013; Chiang & Li, 2019). Local PUPGs follow a similar dynamic.

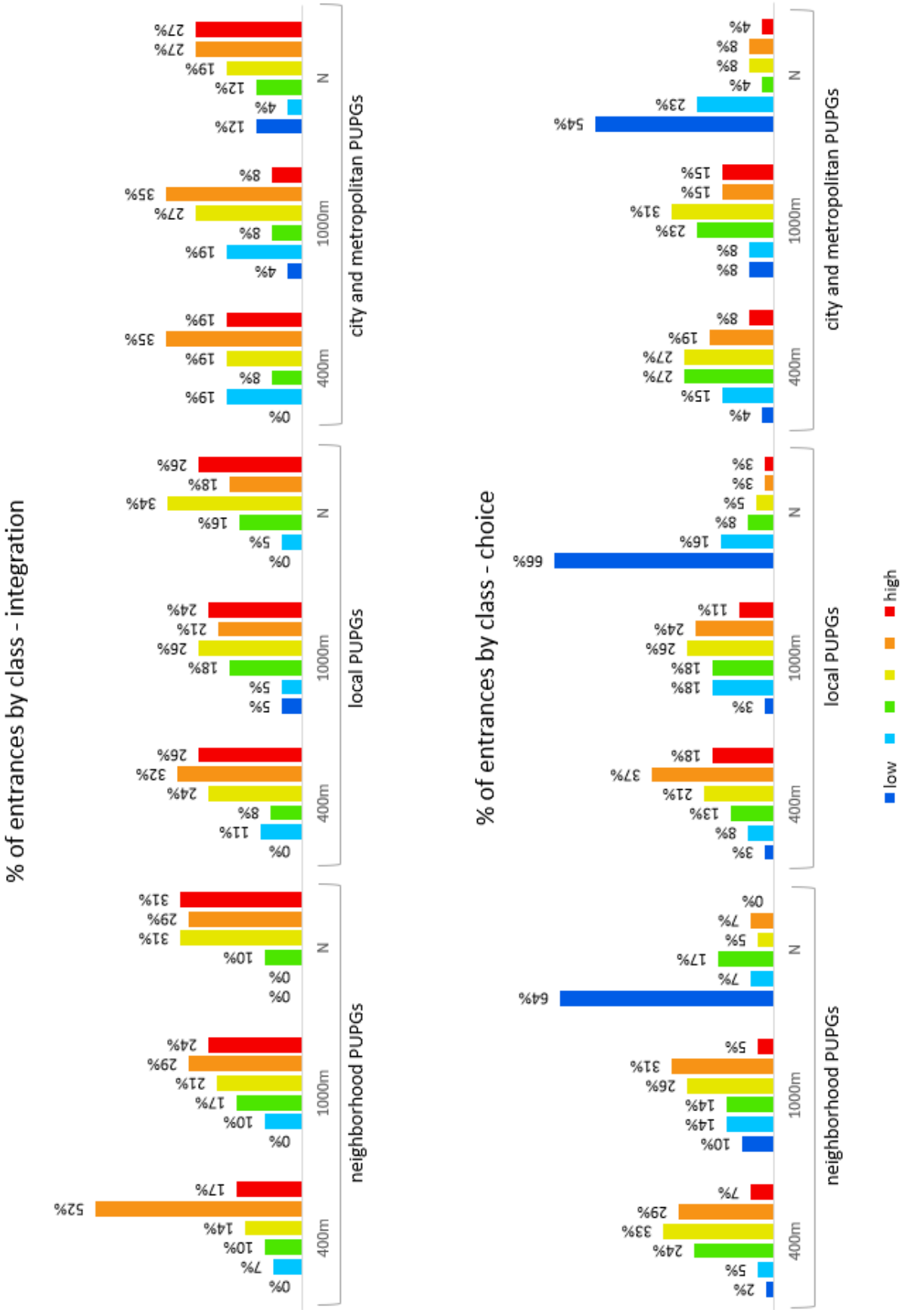


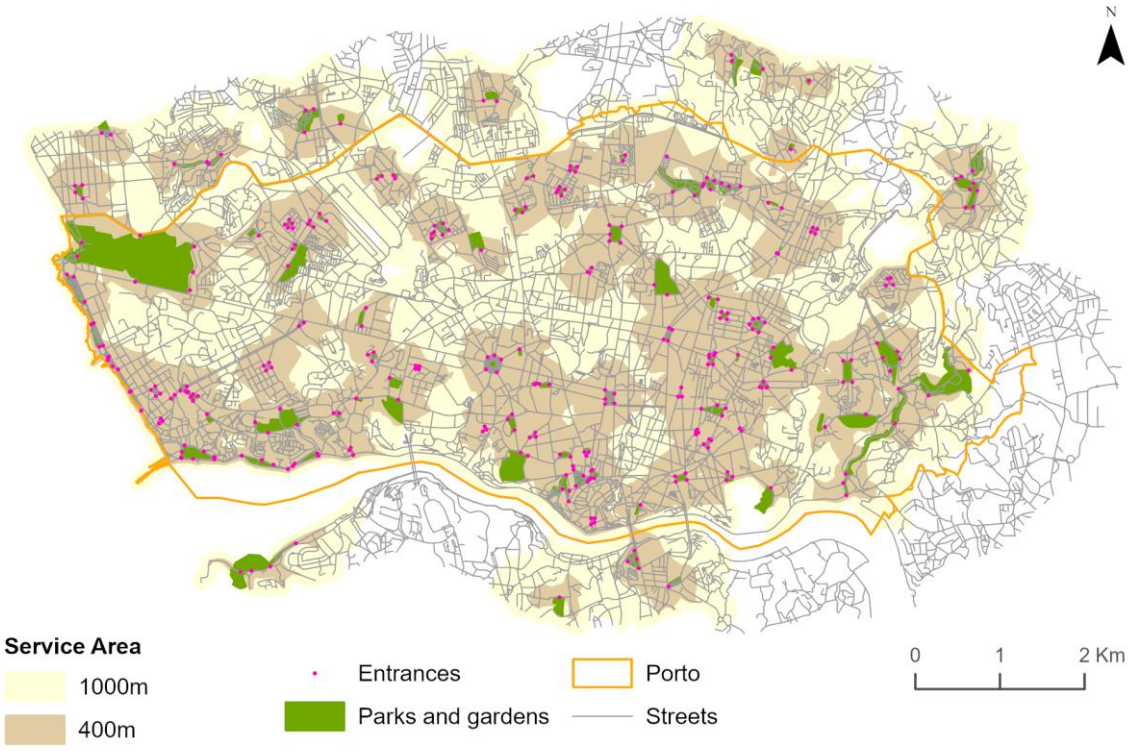
Figure 14 - Percentage of entrances by class and site's size.

On the other hand, the city and metropolitan PUPGs could take advantage of having entrances on streets which boast more movement (high integration) or are main paths (high choice), enhancing their chances of attracting visitors. In this case, given the fact that almost half are enclosed (52,17% of the city and metropolitan Porto's serving PUPGs), some alterations could be further and individually studied, such as adding new entrances or relocating existing ones.

So far, the structural characteristics of *size* and *type of access* have helped to comprehend the different contexts and distribution of PUPGs, considering the city's history and inherited attributes. The size classification has shown to be an important asset to illustrated other results, as it can also help identify commonalities between PUPGs within the same class, which will be further explored in this chapter. The accessibility analyses *paths* and *connectivity* help understand some of the potentials and difficulties that PUPGs can have based on their location, particularly when, as is the case, their location is the result of a mix of different planning standards, residual land and a street network which has been created in part organically and partially planned (Madureira et al., 2011; Oliveira, 2014; Pinto & Fernandes, 2018; Carvalho, 2020).

The location of public transport stops and routes could further help inform movement patterns once these analyses are done, which would be especially relevant for the PUPGs found to either be located in streets with high to-movement and through-movement potential or classified as city and metropolitan. As mentioned in subchapter 2.3, gravity based cumulative opportunities models could be appropriate, together with demographics and/or quality parameters. The actual movement and visitation pattern of PUPGs could be analyzed through mobile data or count surveys, which would help validate results and plan on an individual site basis.

5.4. Accessibility – Catchment

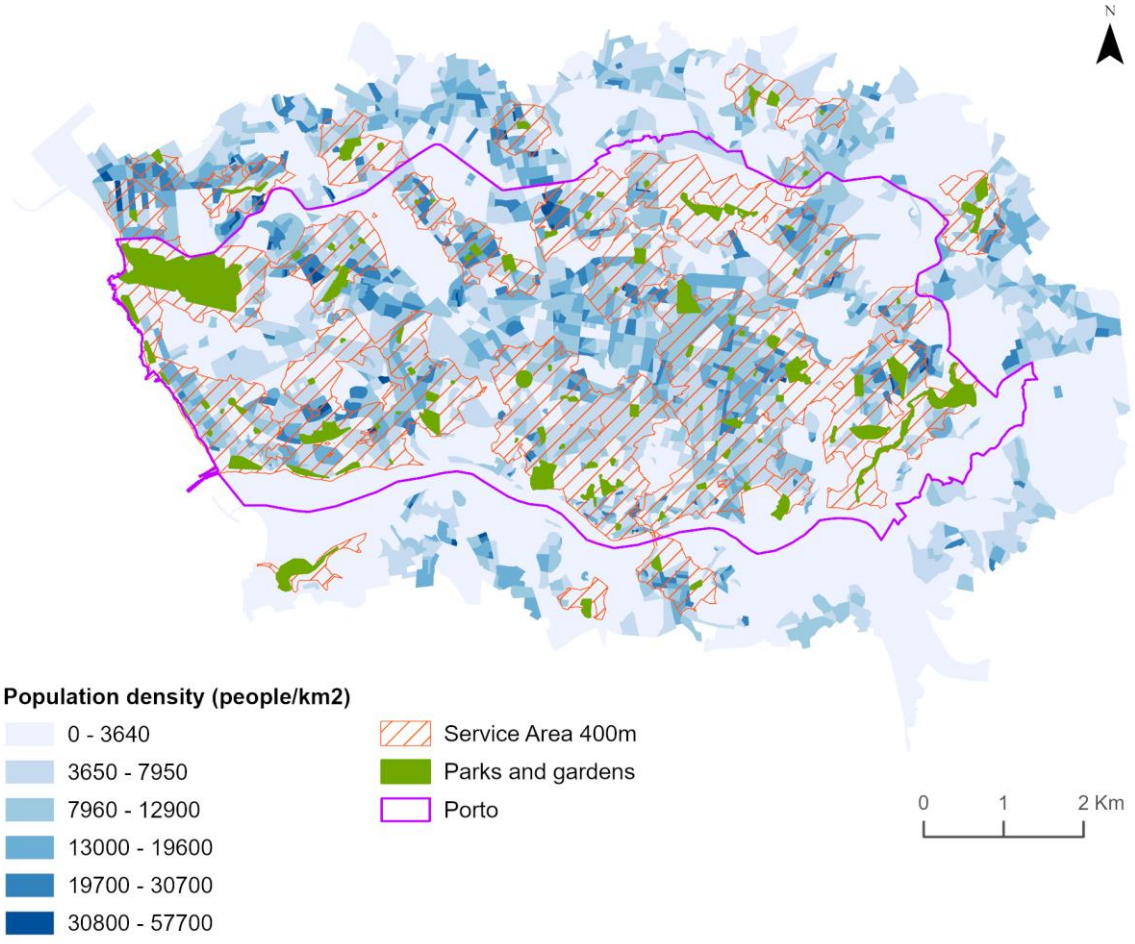


Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited)

Figure 15 – *Catchment* radii 400m and 1000m.

Figure 15 shows that the service area of 1000m covers most of the city of Porto, save for very few streets, showing good accessibility overall (UN-Habitat, 2020a). The 400m radius, however, leaves out several portions of the city, which carry more implication for the neighborhood and local PUPGs (Llewelyn-Davies, 2007; UN-Habitat, 2018) and for children and older adults (Llewelyn-Davies, 2007; Gehl & Svarre, 2013; Project for Public Spaces, 2016; UN-Habitat, 2020c), as will be better explored in the following results. When it comes to the PUPGs outside of Porto's administration, the analysis helped to eliminate the sites which are neither served by a PUPG located in Porto, nor serve Porto's population, as was explained in subchapter 4.2.

Accessibility – Catchment – Resident population



Sources: Administrative limits - CAOP (2022) - DGT / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Residential population - Census (2021), INE

Figure 16 – Resident population density (people/km²).

Figure 16 shows that many of the more densely populated subsections fall outside the reach of a PUPG for the 400m radius, with most such subsections concentrated within the main circular road (VCI, see Figure 2), indicating deficit areas that could receive new sites in order for access to be more equitable within the city (Llewelyn-Davies, 2007; World Health Organization - Regional Office for Europe, 2017; UN-Habitat, 2020b). The map also shows that outside this VCI perimeter, the absence of PUPGs coincides with the areas that register lower values for global integration (see Figure 11), a few exceptions towards the Douro's mouth. Many of these emptier areas have proposed PUPGs in Porto's masterplan, some of which belong to UOPGs (Direção Municipal de Urbanismo, 2021c).

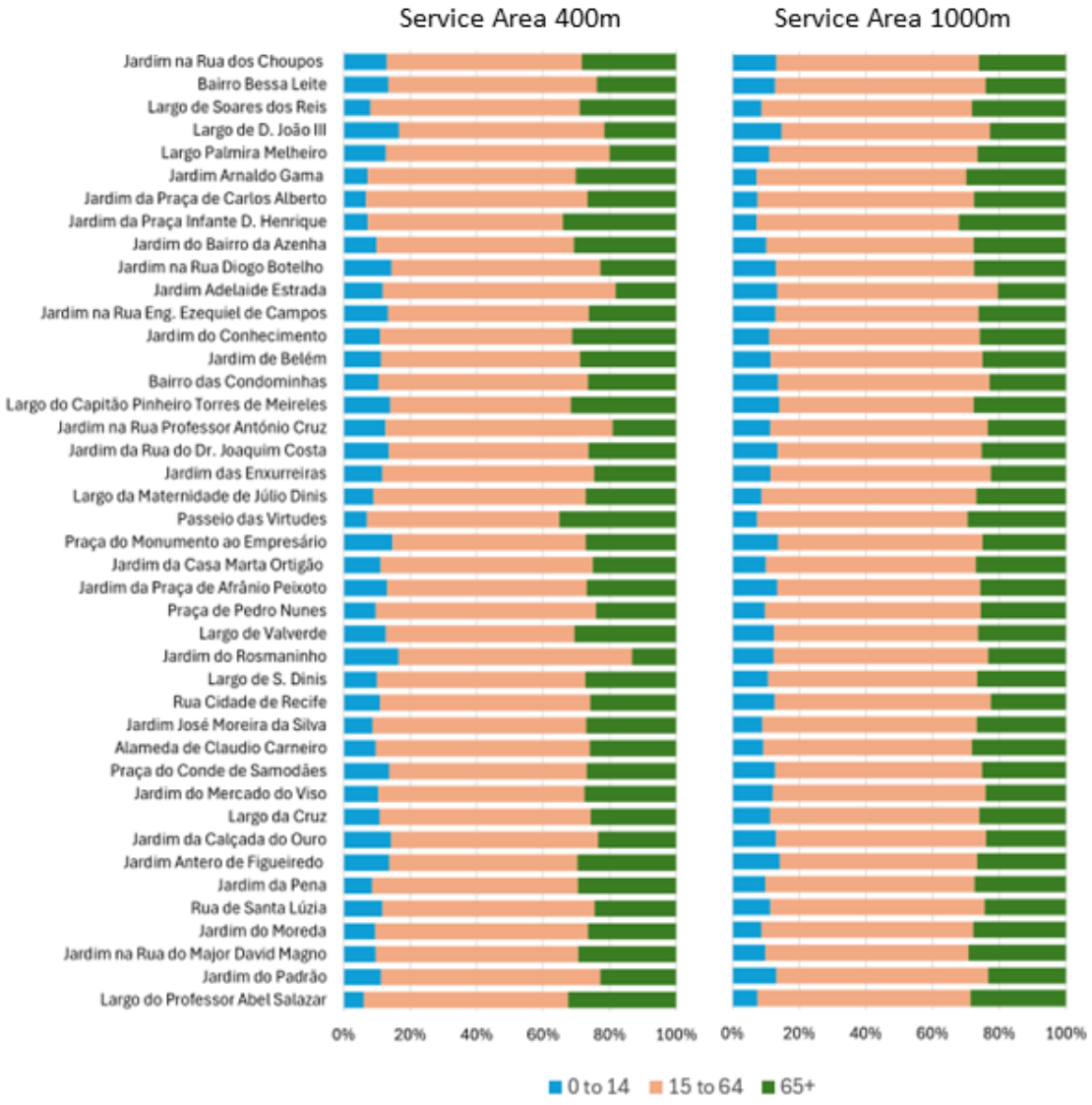


Figure 17 – Neighborhood PUPGs potential resident patronage by age group and catchment.

For the neighborhood and local PUPGs, as seen on Figures 17 and 18, the resident population comprising children from 0 to 14 years-old living within 400m varies from as low as 6% to as high as 17%, the average being 11%. When it comes to older adults (65 years-old and above), it varies from 13% to 35%, the average being 26,5%. Given that in Portugal, people of 65 years-old and above represent 23,4% of the population and children from 0 to 14 years-old 12,4% (Instituto Nacional de Instituto Nacional de Estatística, 2022a), these data can inform which PUPGs have more demand for amenities and facilities catering to these specific groups, particularly as the 400m is

better suited as a cut-off walking distance for them and the recommended distance to residence for neighborhood and local PUPGs. (Llewelyn-Davies, 2007; Gehl & Svarre, 2013; UN-Habitat, 2018).

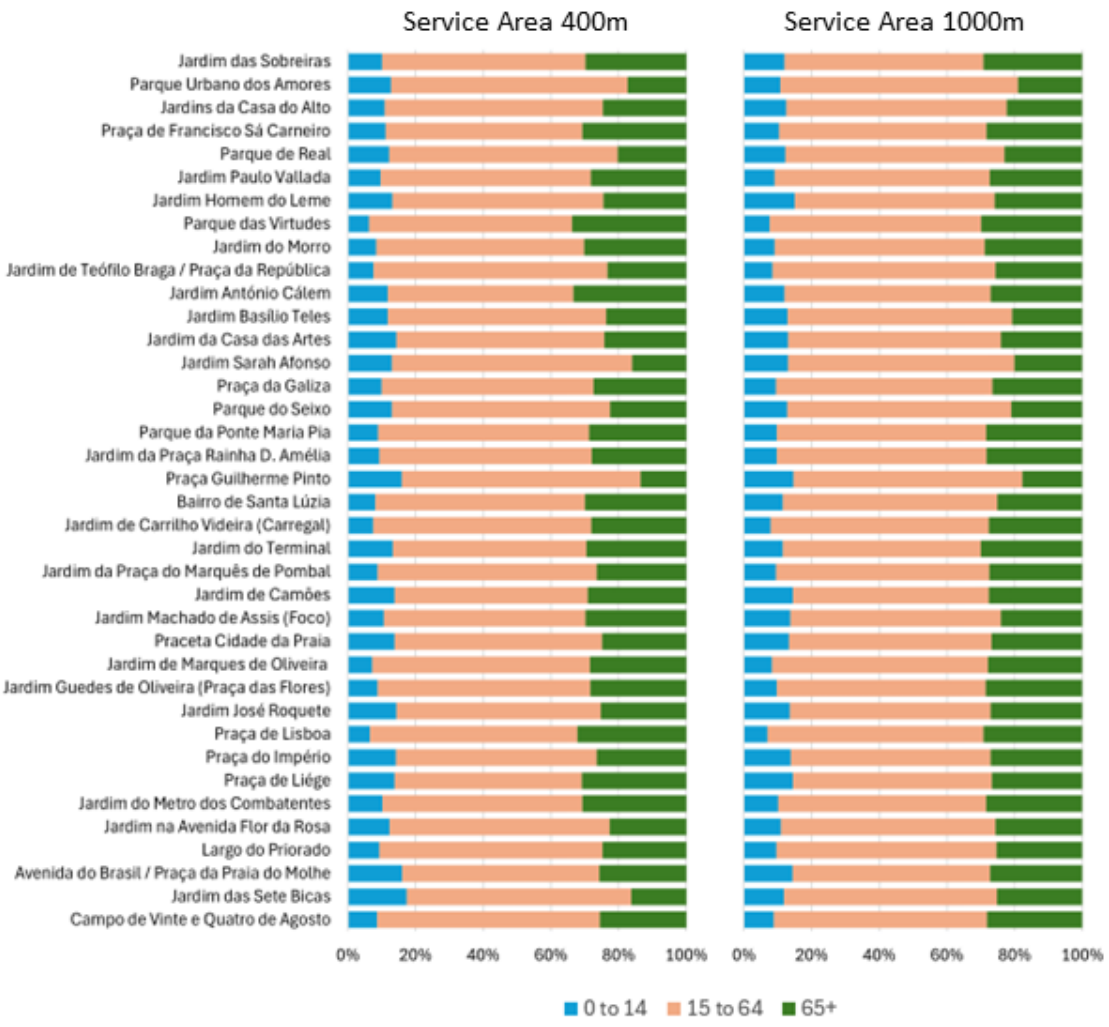


Figure 18 – Local PUPGs potential resident patronage by age group and catchment.

The city and metropolitan PUPGs, whose graphs can be seen in Figure 19, have similar age-group distribution, with the children population going from 6% to 15% (average of 12%) and the older adults, from 22% to 34% (average of 27%). For these PUPGs residential proximity carry less importance as they have a more urban character, attracting visitors from outside their catchment (Llewelyn-Davies, 2007; UN-Habitat, 2018; Phillips et al., 2023).

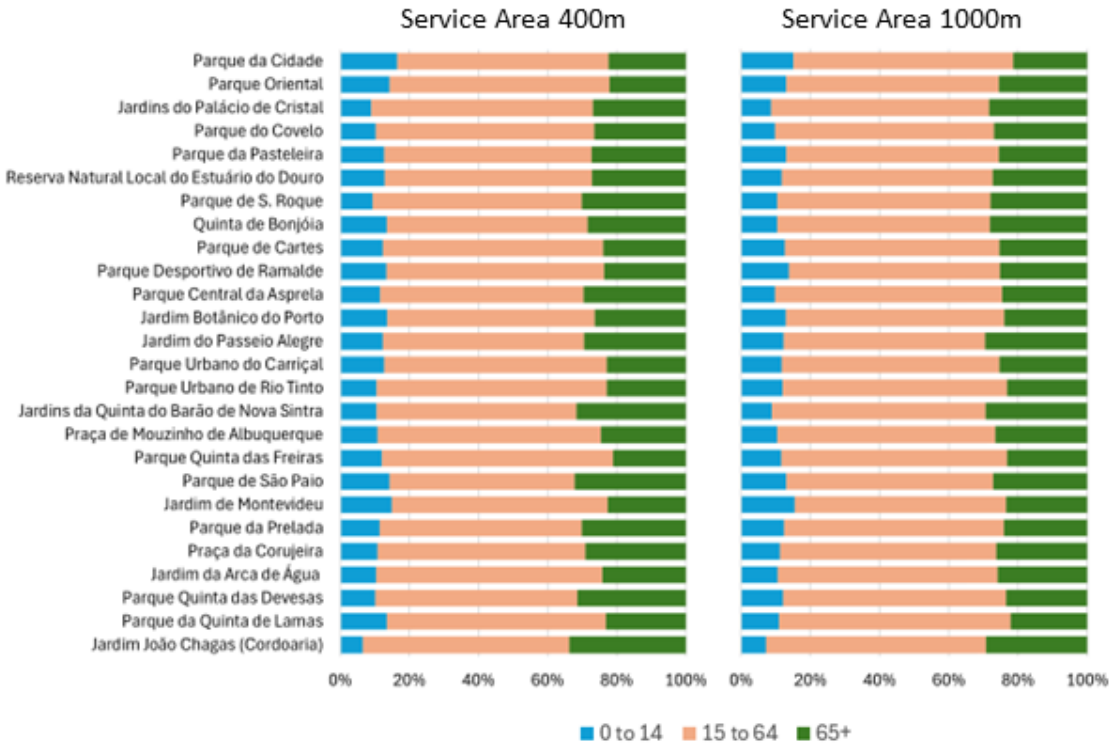
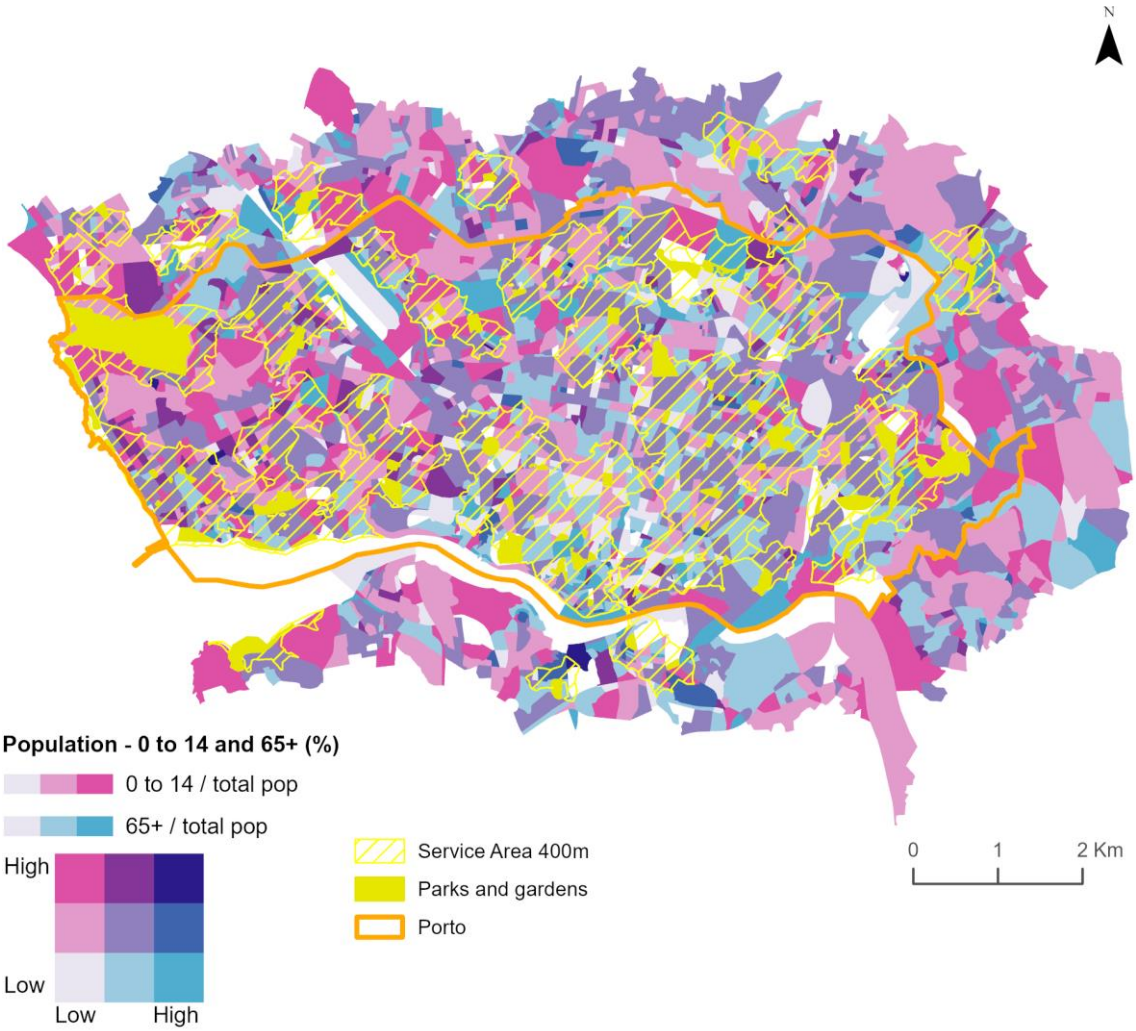


Figure 19 – City and metropolitan PUPGs potential resident patronage by age group and catchment.

In order to better visualize the results, Figure 20 shows the percentual distribution of the resident population aged 0 to 14 and 65 and above, divided by natural breaks. Some subsections have above average percentage of older adults, others have above average percentage of children under 14, and a few have above average percentage of both older adults and children up to 14. There is an overall tendency of the more central subsections within the VCI having a higher percentage of older adults, whereas the more peripheric subsections showing higher percentages of kids, particularly the ones outside Porto, which reflects the recent population loss Porto has faced, with families migrating to the neighbor cities (Oliveira, 2014; ClimA daPT.Local, 2016). Many of these subsections are currently not served by any PUPG, as seen before in Figure 16. The map helps identify areas that are lacking PUPGs as well as providing relevant information to its potential when it comes its most prevalent user group identity, which can be useful both for new PUPGs provision and to inform improvements in existing ones.



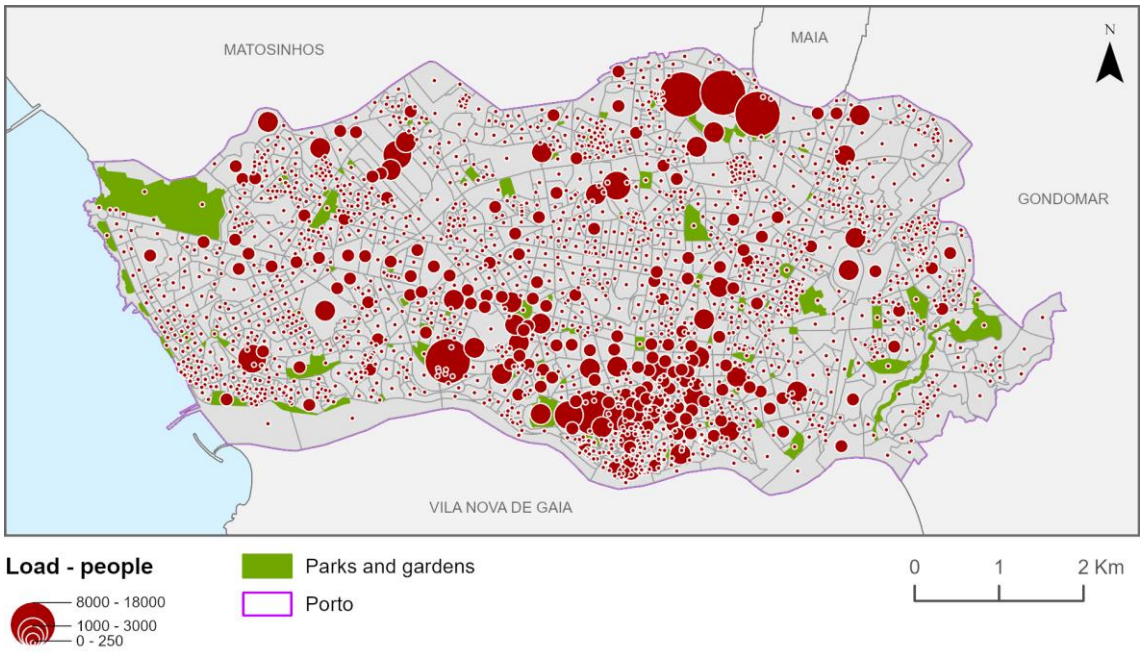
Sources: Administrative limits - CAOP (2022) - DGT / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Residential population - Census (2021), INE

Figure 20 – Percentual distribution of residents aged 0 to 14 and 65+ by census subsection.

Accessibility – Catchment – Potential visitors

The next results look into the potential visitors' load, with Figure 21 showing its distribution. The city concentrates commerce, services and higher education in a few areas: downtown; around the Campo Alegre and Asprela university campuses; alongside Boavista Avenue, Associação Empresarial de Portugal Avenue and Fernão de Magalhães Avenue (see Figure 2). Some of these areas correspond to the job's hotspot analysis conducted by AMP (see Figure 3). There is also correspondence with the global analyses for paths and connectivity, seen in Figures 10 and 11. Of all these, the most noticeable

areas with high movement and very little availability of PUPGs are the areas alongside Associação Empresarial de Portugal Avenue and Fernão de Magalhães Avenue.



Sources: Administrative limits - CAOP (2022) - DGT / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Data: Informa D&B (2017); Registo Nacional de Turismo (2017); GEP - Gabinete de Estratégia e Planeamento; MTSSS - Carta Social (2018), Ministério da Educação; DGEEC (2020); Ministério da Cultura (2018); CP (2017); C.M.P (2016); Ministério da Saúde e Portal SNS (2020); FLUP-DG/CEGOT

Figure 21 – Distribution of Porto's potential visitors by census subsection.

By calculating the potential visitors[13] within each PUPGs catchment (400m), it is possible to determine the sites that are more likely to be accessed by non-residents. The graphs on Figure 22 show the results grouped by site's size. A few of the PUPGs in all size groups have very high potential visitors' loads, particularly the ones located downtown, whereas a third of the city and metropolitan PUPGs, the ones which in theory have more capacity, have low potential visitors' loads. As an example, Parque da Cidade, the largest park in Porto, has a significantly low visitor load and a small local catchment reach, as it is located at the border with Matosinhos city and by the ocean (see Figure 5).

[13] It's important to note that there can be overestimation due to the fact the load might have repeated counts, for there are people who might reside in the same area from which data was gathered, or work and study in the same subsection, as examples. Therefore, the numbers should be taken as an estimate of visitor potential, a representative of centralities.

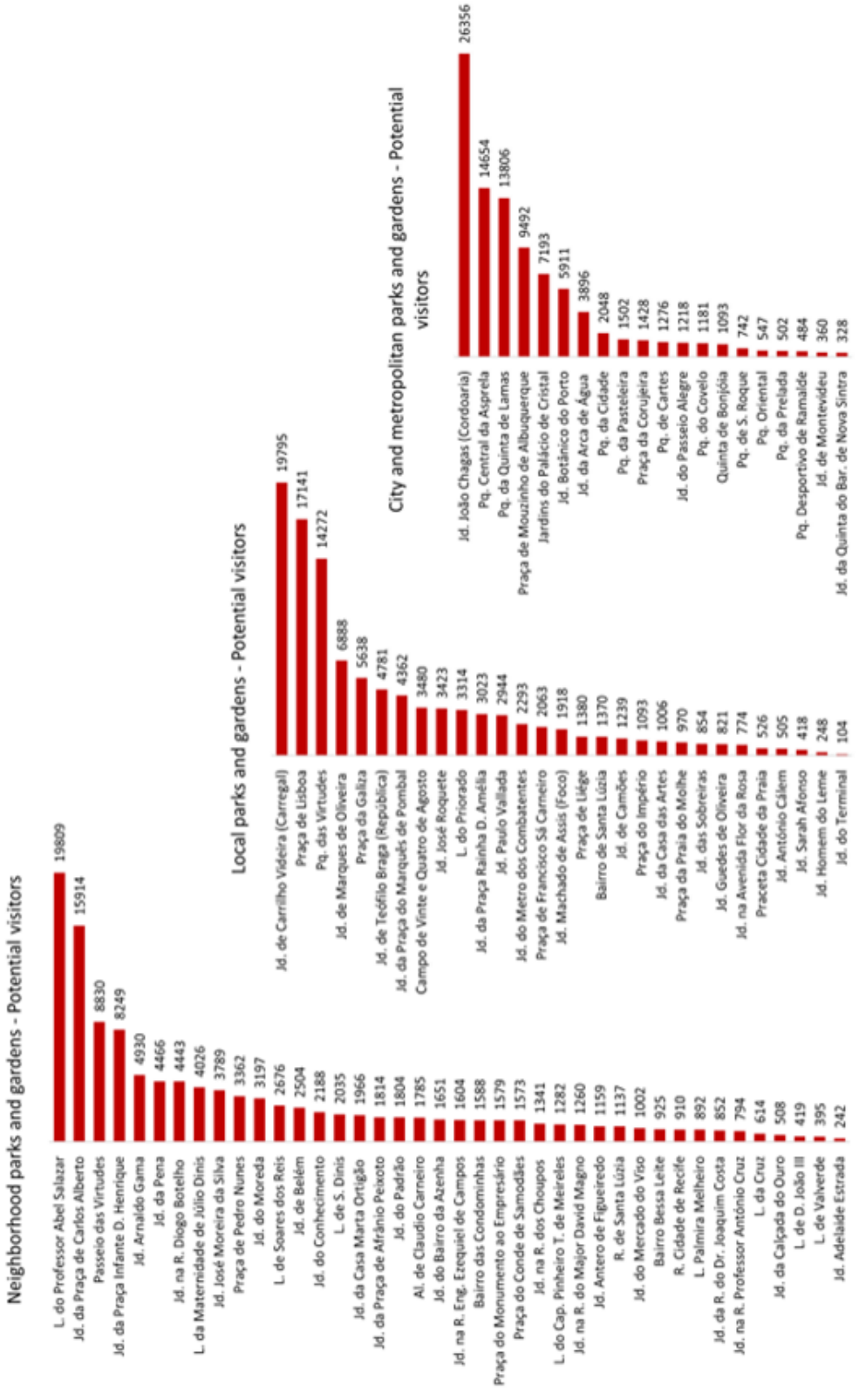


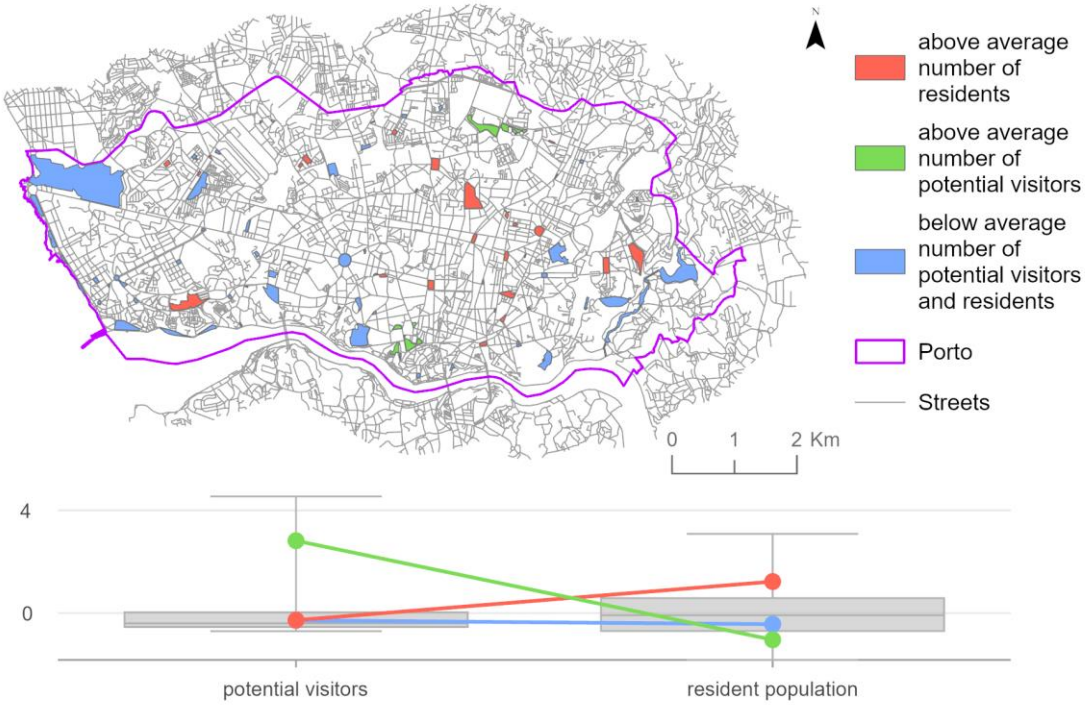
Figure 22 – PUPGs potential visitors by catchment (400m) grouped by site's size.

Parque Oriental, the second largest, has a long shape that allows for many access points (7 entrances), but is located in an area of very low integration and choice values (see Figures 10 and 11), with mostly low-density resident subsections surrounding it, as seen on Figure 16. The data utilized for the potential visitor load does not cover every category that could be considered for a realistic picture, which results in abnormalities such as the recently inaugurated Jardim do Terminal (Campanhã station) getting the lowest number of potential visitors in the local PUPGs, as the number of passengers was not computed.

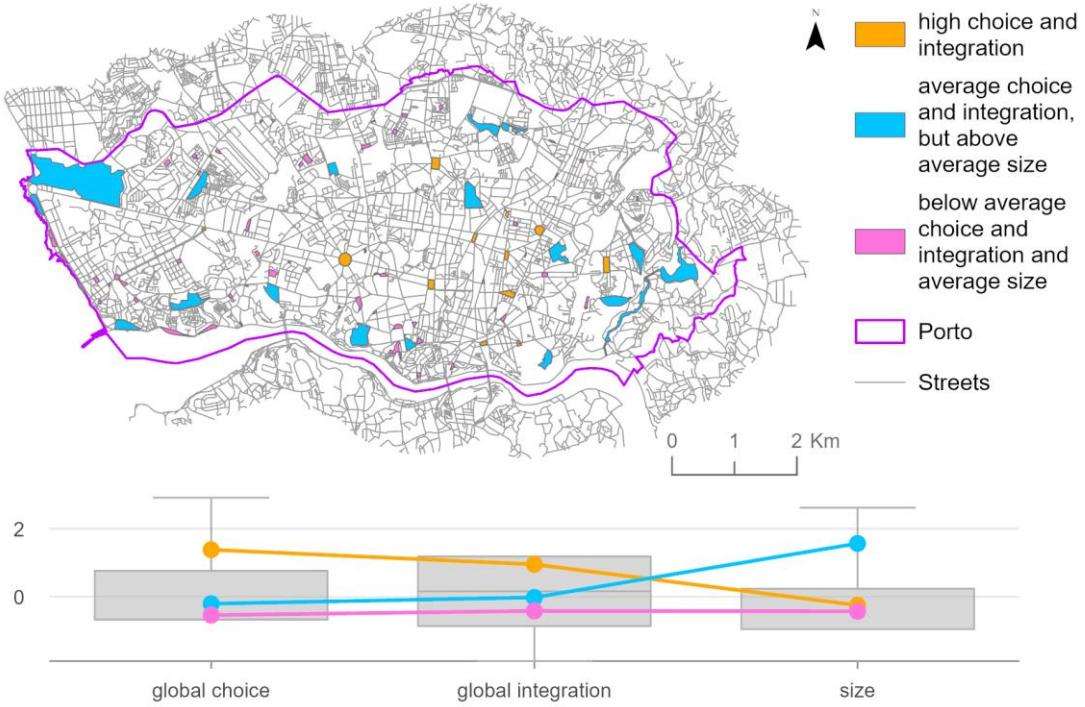
By crossing this data with that of the total resident population, as seen on Figure 23, in the first map, it is possible to differentiate the PUPGs which have more vocation to cater to residents (in red) and those whose visitors are more likely to be non-residents (in green). The PUPGs in blue have less potential demand from both groups. This can mean, particularly for the largest sites, that programming, specific features and public transport can be significant to ensure regular use (Jacobs, 1961; Lin et al., 2014; Phillips et al., 2023).

The second map in Figure 23 show clustering based on the results of the highest value entrance analysis, for both paths (global choice) and connectivity (global integration), together with size. In this analysis, choice and integration are represented by class (from 1 – lowest – to 6 – highest), in accordance with results (see Figure 13). This helps to determine the PUPGs which have a more urban character despite their size (in orange), meaning they are more likely to be receive chance visits. The PUPGs in blue are not as well located, considering the street network configuration, but due to their size they have great capacity and so accessibility can be improved considering other transport means and perhaps even studying new access points in the case of enclosed sites. The PUPGs in pink are not well located, but smaller, so there is a chance many of them work on the neighborhood or local scale. By combining these results, a future analysis could help determine which PUPGs might need interventions to mitigate overcrowding effects and guarantee comfort, such as providing for more seating, shade, drinking fountains, to mention a few.

Multivariate Clustering - PUPGs and demand (residents and potential visitors within 400m)



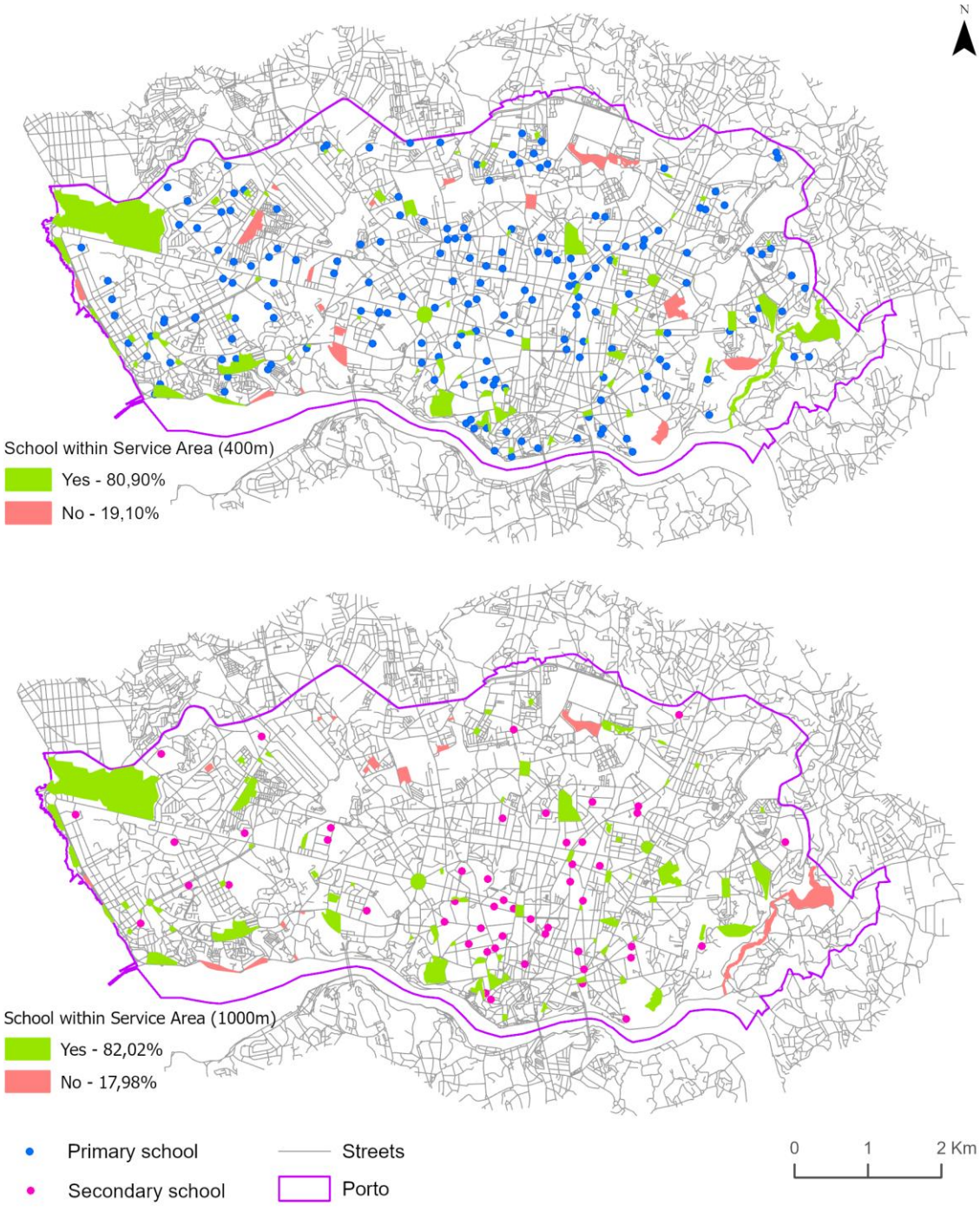
Multivariate Clustering - PUPGs highest value entrance / street network configuration



Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Residential population - Census (2021), INE / Data: Informa D&B (2017); Registo Nacional de Turismo (2017); GEP - Gabinete de Estratégia e Planeamento; MTSSS - Carta Social (2018), Ministério da Educação; DGEEC (2020); Ministério da Cultura (2018); CP (2017); C.M.P (2016); Ministério da Saúde e Portal SNS (2020); FLUP-DG/CEGOT

Figure 23 – Multivariate Clustering – population demand and street network configuration.

Accessibility – Catchment – Proximity to schools



Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Schools - Ministério da Educação and Direção-Geral de Estatísticas da Educação e Ciência (DGEEC) - Rede escolar (2018)

Figure 24 – PUPGs by proximity to schools.

Figure 24 shows the results of the catchment analyses aimed at the student population by considering PUPGs proximity to schools. Primary schools are more evenly

distributed throughout the city, compared to secondary schools, but, because the secondary school's analysis considered a threshold of 1000m, the results have similar values. 80,90% of PUPGs have at least one primary school within 400m and 82,02% have at least one secondary school within 1000m. This can help inform types of amenities and facilities as well as programming.

5.5. Quality assessment – Amenities / facilities

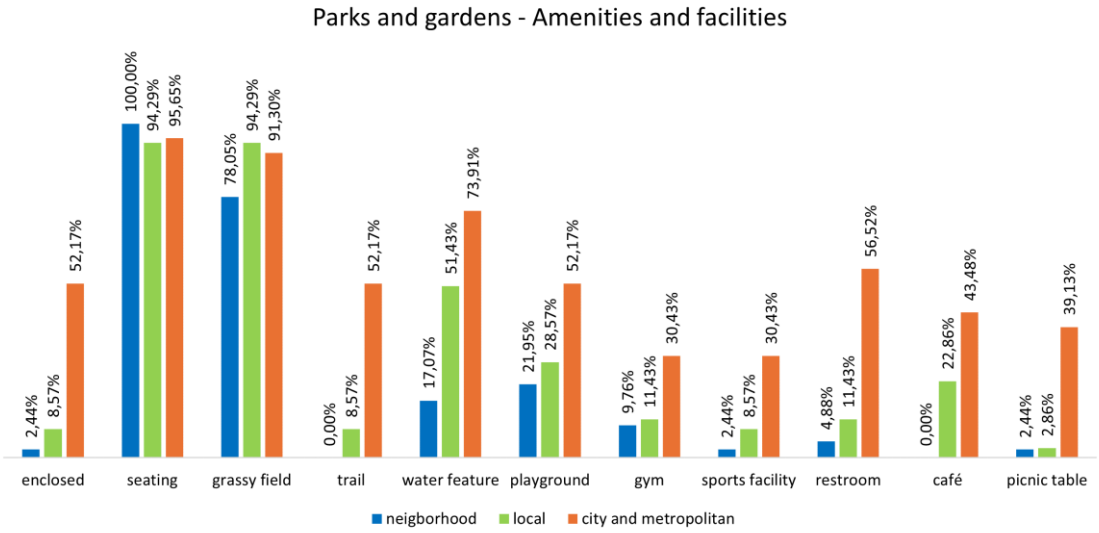


Figure 25 – Presence of amenities and facilities by site's size.

Figure 25 presents the amenities and facilities present in the PUPGs, grouped by size, for it is expected that larger sites have more features. For the neighborhood PUPGs, all have some sort of formal seating (though the amount was not a criterion, which would have to be evaluated case by case) and 78,05% have at least one patch of grassy field. Only 2,44% of them are enclosed, and 21,95% have a playground. Considering their size and purpose, they seem to correspond to expectations (see Tables 3 and 4) (Llewelyn-Davies, 2007; UN-Habitat, 2018).

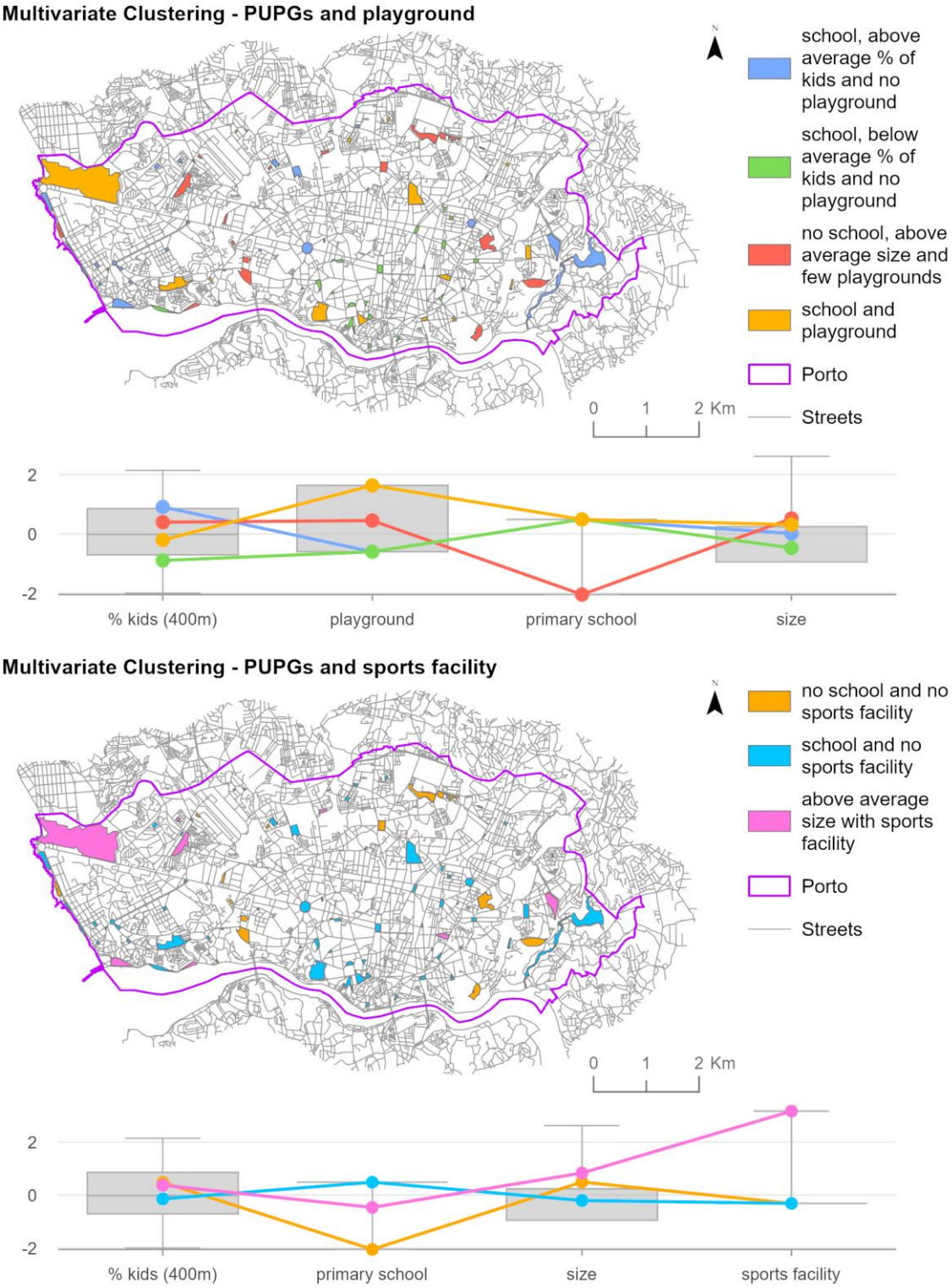
Of the local PUPGs, 94,29% have both seating and grassy field, with the second highest prevalent characteristic being water feature, at 51,43%. A few more boast a playground (28,57%), in comparison with the neighborhood PUPGs, and 22,86% host a

café. According to the referred guidelines (Tables 3 and 4), more of them could have a sports facility, which is present in only 8,57%.

Finally, 95,65% and 91,30% of city and metropolitan PUPGs have formal seating and grassy field, the two most common feature among all sites. Considering their size, the fact that a few don't have formal seating could be addressed. Trail and playground are present in 52,17%, important features to cater to older adults and children, respectively (Douglas et al., 2017; Ayala-Azcárraga et al., 2019; Talal & Santelmann, 2021; Veitch et al., 2022; Chen et al., 2024) and 56,52% have a public restroom, which could be improved given its importance to vulnerable groups (Douglas et al., 2017; Talal & Santelmann, 2021). Features that are important to the youth and adults in general, such as gym and spots facilities, are only present in 30,43% (Douglas et al., 2017; Madureira et al., 2018; Ayala-Azcárraga et al., 2019). Café and picnic tables, found to be of relevance to boost social interaction (Whyte, 1980; Gehl, 2013; Veitch et al., 2022), are only present in 43,48%.

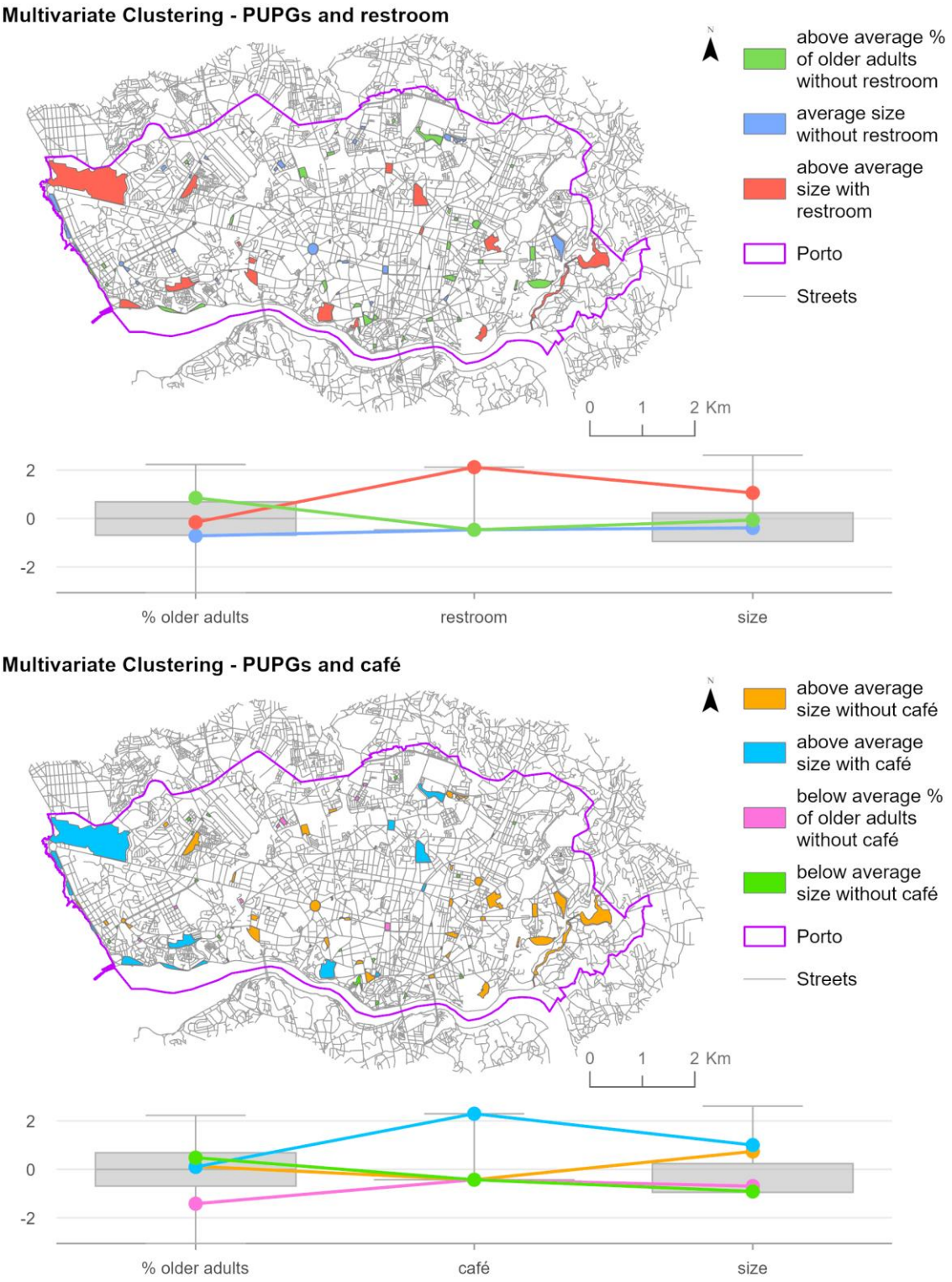
The combination of accessibility results and the amenities and facilities analysis can help identify the parks and gardens which could receive investment towards seeing to different age-group needs. To get a general understanding of the scenarios, four multivariate clustering analyses were done, two focused on the children and two on older adults.

Figure 26 shows the analyses focused on children needs by assessing the combinations of the presence of a school within 400m, the percentage of the resident population of 0 to 14 years-old within 400m, size and the presence or absence of either a playground or a sports facility, as representatives of features related to this age-group (see Table 11). In the first map, PUPGs in blue show the sites with more potential to receive a playground, whereas in the second map, they show the ones which could receive a sports facility.



Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Schools - Ministério da Educação and Direção-Geral de Estatísticas da Educação e Ciência (DGEEC) - Rede escolar (2018) / Residential population - Census (2021), INE

Figure 26 – Multivariate Clustering – playground and sports facility assessment.



Sources: Administrative limits - CAOP (2022) - DGT / Street network - OSM (2023) (edited) / Porto's parks and gardens - Plano Diretor Municipal do Porto (2021) (edited) / Residential population - Census (2021), INE

Figure 27 – Multivariate Clustering – restroom and café.

Figure 27 shows the analyses focused on older adults by combining the percentage of the resident population aged 65 or older within 400m, size and the presence or absence of a restroom (first map) and a café (second map), as representatives of features related to this age-group (see Table 11). For the restroom, PUPGs in green show more potential due to their above average percentage of older residents within 400m. In the case of the café, PUPGs in orange have greater potential due to their above average size.

Other analyses could be done, as the utilized data allows for analyses focused on older teenagers and adults, as well as other features. When it comes to planning, outside of the scope of this dissertation, one possibility is to develop multicriteria analyses focused on different goals, by selecting variables and giving different weight to results based on purpose. The choice for the multivariate clustering analysis here comes from the fact that it is a relatively simple way to test the relevance of the results and which variables carry more or less impact for each assessment.

5.6. Compilation of results

Three tables were created summarizing the results by PUPGs size to get a clearer picture of each PUPG. They can be seen on the following pages, as Tables 12, 13 and 14. Neighborhood PUPGs are small sites, meaning they couldn't hold many different amenities and facilities, but they have good potential for catering to older adults and to children due to their character. From Table 12 it is possible to see that several sites which have above average percentage of kids within their 400m catchment don't have playgrounds, but show low global choice value, making them good candidates, particularly the ones with higher resident population. For older adults, while all PUPGs within this class have some sort of formal seating, many present high global integration values, which can be controversial for this age-group. A site-specific assessment would be then indicated to determine whether possible negative effects of high integration – such as vehicular traffic and noise – are attenuated by other features, such as vegetation and universal design, making the place more attractive to older adults.

Table 12 – Neighborhood PUPGs compiled results.

#	neighborhood PUPG	paths and connectivity		catchment (400m)						quality assessment										
		global integration	global choice	residents	0 to 14 (%)	65+ (%)	potential visitors	secondary school	primary school	1 - enclosed gym	2 - seating	3 - grassy field	4 - trail	5 - water feature	6 - playground	7 -	8 - sports facility	9 - restroom	10 - café	11 - picnic table
										1	2	3	4	5	6	7	8	9	10	11
6	L. do Prof. Abel Salazar	4	1	827	6,0	32,4	19809	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
73	Jd. do Padrão	5	3	2619	11,2	22,8	1804	-	yes	-	yes	-	-	yes	-	-	-	-	-	-
79	Jd. na R. do Major David Magno	6	3	3331	9,6	29,3	1260	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
8	Jd. do Moreda	6	1	2873	9,4	26,5	3197	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
82	R. de Santa Lúzia	6	2	3734	11,6	24,5	1137	-	yes	-	yes	yes	-	-	yes	-	-	-	-	-
87	Jd. da Pena	5	1	1326	8,6	29,5	4466	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
65	Jd. Antero de Figueiredo	4	1	2330	13,7	29,6	1159	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
84	Jd. da Calçada do Ouro	4	2	827	14,1	23,3	508	-	-	-	yes	yes	-	yes	-	-	-	-	-	-
23	L. da Cruz	6	4	2076	10,8	25,7	614	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
80	Jd. do Mercado do Viso	4	1	2596	10,4	27,5	1002	-	yes	-	yes	yes	-	-	-	-	-	-	-	-
36	Praça do Conde de Samodães	5	1	1100	13,6	26,9	1573	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
74	Al. de Claudio Carneiro	6	3	2154	9,6	26,0	1785	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
40	Jd. José Moreira da Silva	6	5	2605	8,7	27,1	3789	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
81	R. Cidade de Recife	4	1	2398	11,0	25,9	910	-	yes	-	yes	yes	-	-	-	-	-	-	-	-
29	L. de S. Dinis	6	5	3577	10,0	27,3	2035	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
39	L. de Valverde	3	1	2042	12,6	30,5	395	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
16	Praça de Pedro Nunes	6	1	2225	9,5	24,1	3362	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
69	Jd. da Praça de Afrânio Peixoto	5	3	2889	13,0	26,9	1814	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
17	Jd. da Casa Marta Ortigão	6	3	1956	11,1	25,1	1966	yes	yes	yes	yes	-	-	yes	-	-	-	yes	-	-
38	Praça do Monumento ao Empresário	5	3	1477	14,6	27,1	1579	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
63	Passeio das Virtudes	4	1	1551	7,0	35,1	8830	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
54	L. da Maternidade de Júlio Dinis	5	1	1888	8,9	27,2	4026	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
66	Jd. da R. do Dr. Joaquim Costa	5	4	2996	13,6	26,3	852	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
85	Jd. na R. Prof. António Cruz	5	1	3615	12,5	19,1	794	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
53	L. do Cap. Pinheiro T. de Meireles	4	1	1981	13,9	31,7	1282	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
72	Bairro das Condominhas	4	3	2249	10,4	26,5	1588	-	yes	-	yes	yes	-	-	yes	-	-	-	-	-
21	Jd. de Belém	5	1	2474	11,2	28,9	2504	yes	yes	-	yes	-	-	-	yes	yes	-	-	-	yes
43	Jd. do Conhecimento	6	1	3391	10,9	31,3	2188	yes	yes	-	yes	yes	-	-	yes	-	-	-	-	-
19	Jd. na R. Eng. Ezequiel de Campos	5	1	1344	13,3	26,2	1604	yes	-	-	yes	yes	-	-	-	yes	-	-	-	-
20	Jd. Adelaide Estrada	3	1	3040	11,6	18,2	242	-	-	-	yes	yes	-	-	yes	-	-	-	-	-
75	Jd. na R. Diogo Botelho	4	2	1633	14,4	22,8	4443	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
86	Jd. do Bairro da Azenha	4	1	2428	9,8	30,7	1651	yes	yes	-	yes	yes	-	-	yes	-	-	-	-	-
87	Jd. da Praça Infante D. Henrique	5	1	1618	7,2	33,9	8249	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
68	Jd. da Praça de Carlos Alberto	6	1	1334	6,7	26,6	15914	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
76	Jd. Arnaldo Gama	6	1	1149	7,2	30,1	4930	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
11	L. Palmira Melheiro	5	1	1727	12,7	20,0	892	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
46	L. de D. João III	4	1	1596	16,6	21,6	419	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
49	L. de Soares dos Reis	6	5	2456	8,0	29,0	2676	yes	yes	-	yes	yes	-	-	yes	-	-	-	-	-
22	Bairro Bessa Leite	4	1	1983	13,5	23,9	925	yes	-	-	yes	yes	-	-	yes	yes	-	yes	-	-
77	Jd. na R. dos Choupos	4	1	1557	12,8	28,3	1341	yes	yes	-	yes	yes	-	-	-	yes	yes	-	-	-

Table 13 – Local PUPGs compiled results.

#	local PUPG	paths and connectivity		catchment (400m)						quality assessment										
		global integration	global choice	residents	0 to 14 (%)	65+ (%)	potential visitors	secondary school	primary school	1 - enclosed gym	2 - seating	3 - grassy field	4 - trail	5 - water feature	6 - playground	7 - 8 - sports facility	9 - restroom	10 - café	11 - picnic table	
										1	2	3	4	5	6	7	8	9	10	11
9	Campo de Vinte e Quatro de Agosto	6	1	3240	8,6	25,5	3480	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
24	Praça da Praia do Molhe	4	3	1837	16,1	25,6	970	-	yes	-	yes	-	-	yes	-	-	-	-	-	-
59	L. do Priorado	6	1	2933	9,3	24,8	3314	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
10	Jd. na Av. Flor da Rosa	5	1	2770	12,3	22,6	774	yes	yes	-	yes	yes	-	-	yes	-	-	-	-	-
78	Jd. do Metro dos Combatentes	6	4	3730	10,3	30,6	2293	yes	yes	-	-	yes	-	-	-	-	-	-	-	-
26	Praça de Liége	4	1	2659	13,8	30,8	1380	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
58	Praça do Império	4	2	2283	14,1	26,5	1093	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
3	Praça de Lisboa	4	1	1197	6,5	32,1	17141	yes	yes	-	-	yes	-	-	-	-	-	-	yes	-
1	Jd. José Roquete	4	2	2176	14,3	25,3	3423	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
28	Jd. Guedes de Oliveira	5	2	2361	8,8	28,3	821	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
42	Jd. de Marques de Oliveira	6	5	3521	7,1	28,5	6888	yes	yes	yes	yes	yes	-	yes	yes	-	-	-	-	-
83	Praceta Cidade da Praia	4	1	3128	13,7	24,9	526	-	yes	-	yes	yes	-	-	-	-	-	-	-	-
27	Jd. Machado de Assis (Foco)	5	1	1610	10,6	29,9	1918	yes	-	-	yes	yes	-	-	yes	yes	-	-	-	-
33	Jd. de Camões	3	1	2203	13,8	29,1	1239	yes	yes	-	yes	yes	-	yes	-	-	-	-	yes	-
45	Jd. da Praça do Marquês de Pombal	6	6	3949	8,8	26,4	4362	yes	yes	-	yes	yes	-	yes	-	-	-	yes	yes	-
71	Jd. do Terminal	4	1	248	13,3	29,4	104	yes	yes	-	yes	yes	-	yes	yes	-	-	-	-	-
5	Jd. de Carrilho Videira (Carregal)	5	1	1286	7,5	28,0	19795	yes	yes	-	yes	yes	-	yes	-	-	-	-	-	-
35	Bairro de Santa Lúzia	5	1	2249	8,1	29,8	1370	-	-	-	yes	yes	-	-	-	-	yes	-	-	-
13	Jd. da Praça Rainha D. Amélia	6	4	5770	9,3	27,9	3023	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
31	Praça da Galiza	4	1	2455	9,9	27,3	5638	yes	yes	-	yes	-	-	-	-	-	-	-	-	-
37	Jd. Sarah Afonso	4	1	4264	13,0	16,0	418	-	yes	-	yes	yes	-	-	-	yes	-	-	-	-
18	Jd. da Casa das Artes	4	1	2107	14,4	24,3	1006	yes	-	yes	yes	yes	-	yes	-	-	-	yes	-	-
34	Jd. António Cálem	4	1	963	11,8	33,4	505	-	-	-	yes	yes	-	yes	yes	yes	yes	-	yes	-
14	Jd. de Teófilo Braga (República)	6	2	3325	7,5	23,3	4781	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
55	Pq. das Virtudes	4	1	1386	6,3	33,8	14272	yes	yes	yes	yes	yes	yes	yes	-	-	-	yes	-	-
25	Jd. Homem do Leme	3	1	515	13,2	24,5	248	yes	-	-	yes	yes	-	yes	yes	-	-	-	yes	-
15	Jd. Paulo Vallada	6	2	4971	9,7	28,2	2944	yes	yes	-	yes	yes	-	-	yes	yes	yes	-	-	-
62	Praça de Francisco Sá Carneiro	6	3	4068	11,2	30,7	2063	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
60	Jd. das Sobreiras	3	1	899	10,1	29,7	854	-	yes	-	yes	yes	-	yes	-	-	-	-	yes	-

#	city and metropolitan PUPG	paths and connectivity: global integration	paths and connectivity: global choice	catchment (400m): residents	catchment (400m): 0 to 14 (%)	catchment (400m): 65+ (%)	catchment (400m): potential visitors	secondary school	primary school	quality assessment: 1	2	3	4	5	6	7	8	9	10	11
57	Jd. João Chagas (Cordoaria)	5	1	1687	6,5	33,7	26356	yes	yes	-	yes	-	-	yes	yes	-	-	-	-	yes
32	Pq. da Quinta de Lamas	5	2	207	13,5	23,2	13806	yes	-	-	yes	yes	-	-	-	-	-	-	-	-
52	Jd. da Arca de Água	6	5	3270	10,4	24,1	3896	yes	-	-	yes	yes	-	yes	yes	yes	-	yes	yes	-
12	Praça da Corujeira	5	5	3503	10,8	29,1	1428	yes	yes	-	yes	yes	-	-	yes	yes	-	-	-	-
50	Pq. da Prelada	5	1	1271	11,4	30,1	502	-	yes	yes	yes	yes	-	yes	-	-	-	-	-	-
30	Jd. de Montevideu	6	1	618	14,9	22,7	360	yes	yes	-	yes	yes	-	yes	-	-	-	-	yes	-
48	Praça de Mouzinho de Albuquerque	6	6	2631	10,7	24,6	9492	yes	yes	-	yes	yes	-	-	-	-	-	-	-	-
41	Jardins da Quinta do Bar. de Nova Sintra	6	1	905	10,6	31,8	328	yes	-	yes	yes	yes	yes	yes	-	-	-	yes	-	yes
4	Jd. do Passeio Alegre	3	1	1735	12,3	29,4	1218	yes	yes	-	yes	yes	-	yes	-	-	yes	yes	yes	-
89	Jd. Botânico do Porto	5	2	1132	13,6	26,4	5911	yes	-	yes	yes	-	-	yes	-	-	-	yes	-	-
70	Pq. Central da Asprela	4	1	819	11,5	29,5	14654	-	-	yes	yes	yes	yes	yes	-	-	-	-	yes	-
51	Pq. Desportivo de Ramalde	4	1	1118	13,3	23,6	484	yes	-	yes	-	yes	-	-	yes	-	yes	yes	-	-
61	Pq. de Cartes	4	2	5078	12,2	23,9	1276	yes	yes	-	yes	yes	yes	-	-	-	yes	-	-	-
56	Quinta de Bonjóia	3	1	474	13,5	28,5	1093	yes	-	yes	yes	yes	-	yes	-	-	-	-	-	-
44	Pq. de S. Roque	6	2	2632	9,3	30,1	742	yes	-	yes	yes	yes	yes	yes	yes	yes	-	yes	-	-
47	Pq. da Pasteleira	4	2	5188	12,6	27,3	1502	yes	yes	yes	yes	yes	yes	yes	yes	yes	-	yes	yes	yes
2	Pq. do Covelo	6	1	3077	10,2	26,5	1181	yes	yes	yes	yes	yes	yes	yes	yes	yes	-	yes	yes	-
64	Jardins do Palácio de Cristal	5	1	1761	9,0	26,9	7193	yes	yes	yes	yes	yes	yes	yes	yes	yes	-	yes	yes	yes
88	Pq. Oriental	5	4	1722	14,2	22,1	547	-	yes	-	yes	yes	yes	yes	-	-	-	yes	-	yes
67	Pq. da Cidade	6	4	2154	16,4	22,2	2048	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes

Quality assessment key: 1 - enclosed 2 - seating 3 - grassy field 4 - trail 5 - water feature 6 - playground 7 - gym 8 - sports facility 9 - restroom 10 - café 11 - picnic table

Table 14 – City and metropolitan PUPGs compiled results.

Local PUPGs, as seen in Table 13, share the same aforementioned contexts. Though slightly larger, one noticeable pattern is that few hold more than one feature – not counting seating and grass – which is something to be considered given their potential for more. This underutilization is less pronounced for the city and metropolitan PUPGs, whose results are summarized in Table 14. However, two of them – Parque Quinta das Lamas and Praça Mouzinho de Albuquerque – currently have no feature except seating and grassy field, even though they both score high on potential visitors.

These scales – city and metropolitan – are also the ones better fitted to host public restrooms and cafés, which could be studied based on each site's immediate surroundings and general purpose. Finally, though these PUPGs are more capable of serving people outside their immediate catchment, some of them present above average percentages of kids and older adults, as well as some being in the vicinity of high number of residents, which can help inform their design and purpose. One example is that out of the seven PUPGs with above average % of kids in their 400m catchment, only one has a playground.

As mentioned before, multicriteria analysis could be created for each goal by selecting the relevant variables according to literature review. Take, for example, an analysis which would consider the suitability of PUPGs to cater to children or to older adults: the analyses would select for different variables, and some of the variables which would be common to both may get different weights. Playground is not crucial to older adults, for instance, whereas formal seating is less important to children. High global choice is not ideal for playground use or older adults, however, their weight would have to be adjusted for the larger city and metropolitan PUPGs as they serve a larger area, in which case high global integration and choice values would be welcome. Therefore, the tables help paint the picture of each of Porto PUPG's potentials, but more calibrated analyses can be achieved with this data.

6. Final considerations

The present work had the objectives of finding which metrics could be used for a PUPGs city-wide planning strategy from a human-centered approach, interested in equality and inclusivity, in order to create a framework and apply it to a case study, the city of Porto.

The literature review has shown that there are many possible ways of going about accessibility and quality assessment when it comes to public open spaces and urban green spaces, and not even the UN has established a methodology for the SDGs targets related to these spaces. This difficulty is proportionate to the complexity of the theme. The proposed framework of city-wide planning metrics attempted to combine different accessibility and quality assessment analyses in order to cover the subjects found to be of importance for the equitable distribution and effective and successful use of PUPGs, while being mindful of data requirements.

When it comes to the question of how PUPGs can best serve the population from a human-centered approach, the literature review provided some directions. Walking was found to be the most used transport mean to get to PUPGs, particularly for nearby sites, as well as being an active mobility mean, in accordance with the SDGs. Given that the literature review showed proximity metrics were especially important for vulnerable groups such as children and older adults, and that other means of transport gain relevance for larger and/or more urban PUPGs, pedestrian accessibility was chosen as the focus for the accessibility analyses.

Catchment was chosen for its capacity for calculating demand and potential patronage. Choice and integration were chosen for their role in street network configuration, helping determine the character of a street within the system. The analyses were performed using an unofficial street network specially edited for this work's purposes, which, as best as possible, represents the pedestrian network currently available in the study area. There could, therefore, be errors, but the city's official network is aimed at vehicular traffic and would not be appropriate.

Some of the quality assessment metrics which were deemed important in people's preferences could not be included in the present study as they require data that would have to be gathered in ways outside the timeframe of this research, or that were not directly available, such as people's perceptions on maintenance and cleanliness or levels of naturalness. This limitation would likely not be an issue in another context, as they could be addressed with more time and resources. The analyses performed, which related to people's preferences of amenities and facilities, organized by age-groups as representative of demographics, could also be more nuanced according to available data. Portugal has disaggregated data on sex, for example, but not for disabilities.

With that said, objectives were achieved. Though some variables had to be left-out due to the aforementioned constraints, the ones which were applied in the framework brought out relevant information in accordance with the literature review, which can be used for planning PUPGs from a human-centered approach and can be performed on a city-wide scale with secondary data.

The analyses have pointed out areas that aren't currently serviced within 400m, as well as helping determine the type of public and demand in both these areas and in existing PUPGs. The city has many empty lots, some of which are already highlighted in its masterplan as potential future PUPGs, a few of which are part of UOPGs. The paths and connectivity analyses can inform the best places for entrance points based on site's size and purpose, improvements to the pedestrian network and whether public transport might be needed, whereas the catchment analyses can help determine residents demand and potential visitors, both in numbers and user profiles.

As a first planning phase, the framework proves useful. The analyses can be combined in different ways to result in partial diagnoses, such as the ones shown in chapter 5, which are meaningful in themselves for different goals. As discussed, they could be improved, for example, by creating multicriteria analyses for each specific goal. As covered in the literature review, PUPGs serve several purposes concomitantly. Analyzing the suitability of the PUPG network focused on children requires different

variables than doing the same for older adults, for example, but the same site could potentially cater for both.

Therefore, the framework unites a series of analyses that can be used for a first city-wide assessment in planning for PUPGs, and from these results, a second phase could cover gravity-based models to include public transport and, following best practices in urban design, go to the field and do site-specific assessments, as well as involving the community in the planning.

The virtue of the city-wide planning metrics is that it provides a macro analysis considering PUPGs as a system (Llewelyn-Davies, 2007; Brandão et al., 2018; UN-Habitat, 2020a, 2020b). Given Porto's ambitions to increase and requalify its green spaces and its strategic goals which emphasizes the need to address all age-groups and resolve inequalities, the framework proposed could help inform planning decisions to make the most of PUPGs potentials from a human-centered approach.

7. References

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