

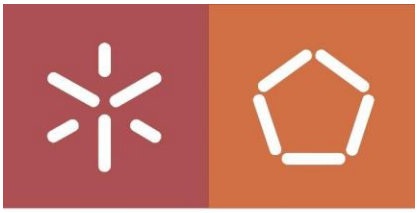
Universidade do Minho
Escola de Engenharia

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WHAT KIND OF CITY DO YOU WANT BY YOUR DOORSTEP? Applicability of the Fifteen-minute City Model in Matosinhos

Masters Dissertation
Masters in City Challenges

January 2026



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Work under the orientation of
Professor Lígia Maria Marques de Oliveira Torres Silva,
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January 2026

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Dedication

À minha família - Avô, Mãe, Luísa e André - por me darem força, carinho e amizade incondicional. À Matilde e à Joana, companheiras de estudo e amigas do coração. A mim, pelo esforço e resiliência.

Declaration of Integrity

I hereby declare that I have acted with integrity in the preparation of this academic work and confirm that I have not engaged in plagiarism or in any form of misuse or falsification of information or results at any stage of its development. I further declare that I am aware of and have complied with the University of Minho's Code of Ethical Conduct.

QUE TIPO DE CIDADE QUER À PORTA DE CASA? Aplicabilidade do modelo da Cidade dos 15 minutos em Matosinhos

Resumo

Esta dissertação tem como objetivo avaliar a aplicabilidade do modelo da Cidade de 15 Minutos (FMC) na Unidade Operativa de Planeamento e Gestão 5 (UOPG 5), no concelho de Matosinhos. O modelo FMC responde à necessidade de repensar a urbanização dispersa e de promover bairros compactos, policêntricos e autossuficientes. A metodologia adotada, baseada no enquadramento desenvolvido por Guzman et al. (2024), combina uma avaliação objetiva através da análise espacial e avaliação subjetiva recorrendo a um inquérito por questionário para avaliar a aplicabilidade do modelo FMC na área de estudo. Foram desenvolvidas três dimensões analíticas: um Índice de Acessibilidade, que avaliou a distribuição espacial dos equipamentos e infraestruturas; um questionário de Preferências Individuais, que identificou a importância atribuída pelos residentes a diferentes categorias de serviços; e um Índice de Diversidade, que mediu a variedade e o equilíbrio dos usos do solo na área em análise. Os resultados revelaram que, embora a UOPG 5 apresente uma boa cobertura de serviços essenciais como saúde, educação e comércio, persistem disparidades significativas na oferta de transportes públicos e de espaços de recreio, limitando a concretização plena do modelo FMC. A discussão dos resultados demonstrou que a implementação eficaz do modelo requer uma coordenação mais robusta entre o planeamento municipal e a mobilidade sustentável. Concluiu-se, assim, que a UOPG 5 revela potencial para evoluir no sentido de território de 15 minutos, embora sejam necessários ajustamentos estratégicos que assegurem uma distribuição equitativa e integrada dos serviços urbanos.

Palavras-chave: acessibilidade centrada na proximidade, cidade dos 15 minutos, resiliência urbana

WHAT KIND OF CITY DO YOU WANT BY YOUR DOORSTEP? Applicability of the Fifteen-minute City Model in Matosinhos

Abstract

This dissertation aims to assess the applicability of the Fifteen-Minute City (FMC) model within Operative Planning and Management Unit 5 (UOPG 5) in the municipality of Matosinhos. The FMC addresses the need to rethink dispersed urbanisation and promote compact, polycentric, and self-sufficient neighbourhoods. The adopted methodology, a framework developed by Guzman et al. (2024) combines an objective assessment, through spatial analysis, with a subjective evaluation conducted via a questionnaire survey to assess the applicability of the FMC model in the study area. Three analytical dimensions were developed: an Accessibility Index, which assessed the spatial distribution of facilities and infrastructure; a questionnaire of Individual Preferences, which identified residents' perceived importance of different categories of amenities; and a Diversity Index, which measured the variety and balance of land uses within the area. The results revealed that, although UOPG 5 presents good coverage of essential services such as healthcare, education, and retail, significant disparities remain in public transport provision and recreational spaces, constraining the full realisation of the FMC model. The discussion demonstrated that the effective implementation of the model requires stronger coordination between municipal planning and sustainable mobility. It was therefore concluded that UOPG 5 shows potential to evolve into a fifteen-minute territory, but strategic adjustments are needed to ensure an equitable and integrated distribution of urban services.

Keywords: fifteen-minute city, proximity-centred accessibility, urban resilience

List of Abbreviations and Acronyms

FMC – Fifteen-Minute City
UOPG – Operative Planning and Management Unit (Unidade Operativa de Planeamento e Gestão)
PDM – Municipal Master Plan (Plano Diretor Municipal)
POI – Points of Interest
OD – Origin-Destination

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1. INTRODUCTION

By 2050, the world's urban population is expected to nearly double, making urbanization one of the twenty-first century's most transformative trends" (New Urban Agenda, Article 2, 2017)

The Fifteen-Minute City (FMC) model offers a compelling solution to the problems of dispersed urban planning. By focusing on the proximity of essential services and amenities, the FMC model reduces the need for long commutes and encourages walking and cycling. This approach not only lowers carbon emissions but also fosters a sense of community by bringing people closer to local facilities. It supports mixed land use and higher density, ensuring that urban spaces are utilised efficiently and sustainably. It addresses the core issues of urban sprawl by creating vibrant, self-sufficient neighbourhoods that enhance social cohesion and improve the overall quality of life for residents.

Having gained much recognition since the COVID-19 pandemic, this concept has been applied in many cities around the world (Allam et al., 2022a; Allam et al., 2022b; Allam et al., 2022c; Guzman et al., 2021; Mocák et al., 2022; Olivari et al., 2023; Pozoukidou & Chatziyiannaki, 2021; Staricco, 2022). Despite this, little has been done to study its applicability in Portugal.

Matosinhos stands out as a prime candidate for studying the applicability of the FMC model, as it is one of the few municipalities with a Municipal Housing Charter that explicitly addresses habitat concerns (p. 11, 14-15 of the Municipal Housing Charter (Carta Municipal de Habitação), CMM, 2024). The Municipality adopts the definition of habitat from the Portuguese Housing Basic Law, which comprises habitat "as the territorial and social context external to the housing unit in which it is inset, namely where it comes to the surrounding space, to the infrastructures and collective facilities, as well as to the access to essential public services and to transportation and communication networks." (Housing Basic Law (Lei de Bases da Habitação), Article 14, no. 1).

The Charter highlights the importance of integrating housing with essential urban services, infrastructure, and green spaces, ensuring that all citizens can enjoy a well-connected and cohesive urban environment. It emphasises that access to public services, efficient

transport networks, and community facilities is crucial to fostering social inclusion and reducing socio-territorial segregation (p. 16, Municipal Housing Charter).

Thus, this dissertation assesses whether the proximity of local amenities in UOPG 5 follows the FMC model. The aim is to address the following research question: What is the degree of applicability of the 15-Minute City model in UOPG 5?

To answer the research question, this dissertation aims to:

1. identify the existing distribution of infrastructure in UOPG 5;
2. understand the individual preferences of the local community concerning the relative importance of different amenities within walking distance;
3. assess the degree of alignment between the current spatial configuration of infrastructure, community preferences, and the principles of the FMC framework.

This dissertation adopts part of the methodological framework proposed by Guzman et al. (2024), who proposed a 15-Minute City Index grounded in the dimensions of diversity and walkability. The focus will be on the Diversity Index, which measures the availability and distribution of points of interest (POI) within a 15-minute walking radius of each building, considering the street network configuration. Each POI is assigned a weight based on the relative importance attributed by residents, determined through a questionnaire. By combining geography-based proximity with individual preferences, this analysis seeks to assess the degree of applicability of the FMC model within the study area, particularly in relation to the proximity and diversity of essential services.

Figure 1 shows the relationship between the relevance, methodological framework, and the research objectives of the present dissertation.

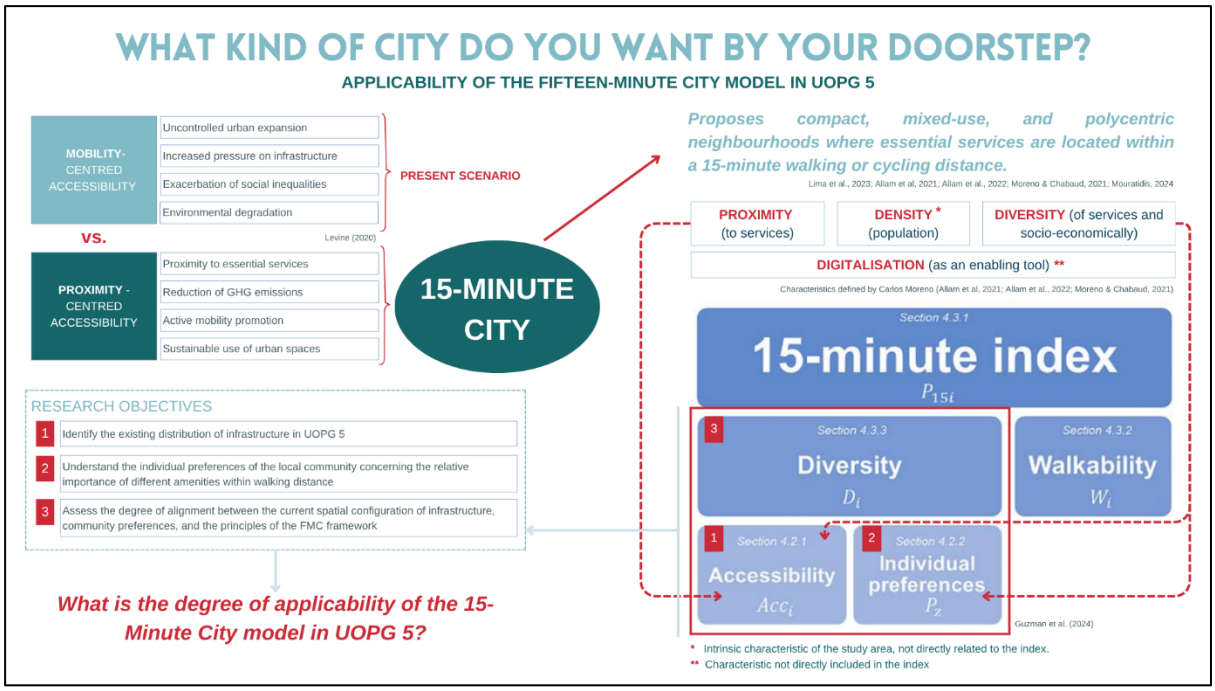


Figure 1 - Relevance and methodological framework of the dissertation

This dissertation is structured into five sections. The present chapter, *Introduction*, outlines the objectives of this dissertation and provides an overview of the framework adopted. Section 2, *Theoretical Framework,* explores the FMC concept by explaining the relevance and resurgence of proximity-centred accessibility, defining and characterising the model through academic literature, and presenting its benefits, limitations and assessment methods. Section 3, *Methodology*, describes the framework developed by Guzman et al. (2024) and how it was adapted and applied to the context of UOPG 5. Section 4, *Analysis and Discussion*, presents, step-by-step, the framework implementation within this research and interprets the results in relation to proximity and liveability in the study area. Section 5, *Conclusion*, summarises the main findings and key insights derived from this dissertation.

2. THEORETICAL FRAMEWORK

As outlined by the Cambridge Dictionary, accessibility is defined as the ease with which something can be reached or obtained. Levine (2020) traces the modern conception of accessibility back to the 1970s, describing it as the "measured potential to interact with destinations," incorporating both proximity and mobility. Hence, accessibility can be categorised into two main types: proximity-centred (local accessibility) and mobility-centred (regional accessibility).

The intricate relationship between proximity and mobility within the framework of accessibility was first delineated by Handy in the early 1990s. Handy's work brought to light the dual nature of accessibility - local and regional - which the author described as being influenced by the substitutability of transport systems and the distribution of activities. This distinction was further explored by Silva & Altieri in 2022, who argued that while mobility, particularly speed, plays a crucial role in enabling regional accessibility, local accessibility is predominantly a result of proximity.

This evolving understanding emphasises the dual strategies required to enhance accessibility through both local (proximity-centred) and regional (mobility-centred) approaches. As highlighted by Silva & Altieri (2022), the scholarly focus has predominantly been on mobility, often overlooking the critical component of proximity, despite its profound implications for sustainable urban development. This oversight is particularly pertinent in the context of growing car dependency and urban sprawl, underscoring the need to revisit and balance our accessibility strategies.

Urban sprawl, characterised by the widespread development of low-density, car-dependent areas, has led to numerous challenges in modern cities. This growth model has increased reliance on private vehicles, extended commute times, and contributed to heightened air and noise pollution, as well as significant greenhouse gas emissions (Allam et al., 2022a; Mocák et al., 2022; Wolański, 2023). As cities have grown outwards, residents have become increasingly dependent on private vehicles, resulting in severe consequences for the environment and public health, as well as a diminished quality of urban life (Beltsiou et al., 2023; Teixeira et al., 2024).

This dependency on automobiles has led to high CO_2 emissions and noise pollution, negatively impacting social cohesion by encouraging low-density, car-centric infrastructure that separates communities rather than connecting them (Gaxiola-Beltrán et al., 2021). The expansion of urban areas without sufficient infrastructure to support local needs has created unsustainable environments, placing strain on resources and creating substantial barriers to accessibility (Mouratidis, 2024; Pozoukidou & Chatziyiannaki, 2021).

The COVID-19 pandemic brought these issues into sharper focus, revealing the fragility of cities that rely on extensive commuting for basic needs. During lockdowns, the neighbourhood became the focal point for residents, as movement restrictions forced people to rely on local services. This situation highlighted the inadequacy of urban areas lacking nearby amenities, showing the potential benefits of urban designs that emphasise proximity and local access (Pozoukidou & Chatziyiannaki, 2021). Simultaneously, the climate crisis underscores the urgent need for decarbonised urban spaces, as cities account for about 70% of global greenhouse emissions (UN Environment, 2022). Immediate action is required to transition to sustainable city models that reduce emissions and address the deep-rooted environmental issues stemming from current urban structures (Knap et al., 2023).

Proximity-centred accessibility encompasses various urban concepts, including human-scale cities, local living, and the FMC. This dissertation will specifically concentrate on the FMC, a concept that has recently attracted significant attention due to its practical applications in urban planning and its potential to enhance urban quality of life (Silva et al., 2023; DUT, 2024; Teixeira et al., 2024).

2.1. The Fifteen-Minute City

As previously mentioned, the pandemic has highlighted the potential of the 15-minute city (FMC) concept, which proposes compact, mixed-use, polycentric neighbourhoods where essential services are within a 15-minute walk or bike ride (Lima et al., 2023; Allam et al., 2021; Allam et al., 2022a; Allam et al., 2022b; Allam et al., 2022c; ETI Chair, 2021; Mouratidis, 2024). Created by Carlos Moreno in 2016, this model aims to address the issues associated with urban sprawl by decentralising services and fostering more compact, mixed-use areas that are accessible by non-motorised modes of transport (Graells-Garrido et al., 2021; Sun & Luo, 2024). The FMC reduces car dependency, cuts down on emissions, and promotes active, healthier lifestyles by shifting the focus from long-distance mobility to proximity-based access. By reducing travel distances and integrating diverse functions within each neighbourhood, the FMC not only enhances liveability but also supports efforts to combat climate change and meet international sustainability targets (Leániz & Lobo, 2023).

The FMC represents an innovative urban model focused on creating neighbourhoods where residents can meet their essential needs within a short walk or bike ride. Defined as a city structure where key activities, such as living, working, shopping, and leisure, are accessible within fifteen minutes of active travel, the FMC combines spatial and temporal dimensions to improve the quality of urban life (Staricco, 2022).

At its core, the FMC concept is rooted in understanding human spatial behaviour and perception, aiming to reconnect people with their local communities. It emphasises attributes such as walkability, density, mixed land use, and urban design diversity, all of which bring activities closer to residential areas rather than pushing people to travel further for basic services (Mocák et al., 2022; Pozoukidou & Chatziyiannaki, 2021). To achieve this, the FMC decentralises services across neighbourhoods, aiming to create self-sufficient zones that support localised living. This structure requires an organised hierarchy of public services and a well-coordinated transport network, ensuring that local facilities are accessible and effectively distributed to balance resources citywide (Pozoukidou & Chatziyiannaki, 2021).

The FMC is built upon three foundational principles - chrono-urbanism, chronotopia, and topophilia—each contributing to its emphasis on sustainability, accessibility, and community-centred urban experiences.

Chrono-urbanism, a core element, links urban quality of life to reduced travel time, giving residents more time for personal and social activities within their neighbourhoods (Khavarian-Garmsir et al., 2023). Supporting the FMC's focus on proximity, chrono-urbanism brings essential services and residential areas close together, enabling daily needs to be met within a short walk or bike ride (ETI Chair, 2021). This approach promotes accessibility and sustainability by encouraging active mobility, reducing energy use, and decreasing dependency on private vehicles for commuting (Allam et al., 2022a).

Building on chrono-urbanism, chronotopia advocates for urban spaces that adapt flexibly to different times of the day, week, or year. This principle promotes multipurpose use of public spaces to maximise their utility, such as a schoolyard doubling as a weekend gathering spot or a parking lot becoming a market during off-peak hours (Staricco, 2022). By creating environments that accommodate various social activities, chronotopia enables the FMC to meet residents' changing needs, fostering a dynamic and interactive urban atmosphere.

Lastly, topophilia, or "love of place," emphasises cultivating emotional connections between residents and their neighbourhoods. This principle seeks to inspire a sense of belonging, identity, and pride among residents, thereby enhancing community resilience and engagement (ETI Chair, 2021). Topophilia in FMC design emphasises human-scale, locally reflective spaces that strengthen bonds between people and place, enhancing social cohesion and enriching urban life (Pozoukidou & Chatziyiannaki, 2021).

Complementing these pillars, the FMC model also focuses on four core characteristics: proximity, density, diversity, and digitalisation, each critical to creating sustainable, resilient, and inclusive urban settings. Khavarian-Garmsir et al. have broadened these characteristics to seven, adding human-scale design, connectivity, and flexibility, reflecting the need for FMC neighbourhoods to be adaptive, cohesive, and resident-centred (Khavarian-Garmsir et al., 2023).

Proximity is foundational to the FMC framework, as it aims to decentralise essential services, bringing amenities like healthcare, education, and retail within walking or cycling distances. This approach redefines urban access by focusing not on the speed of transport but on the geographical closeness of services, which inherently reduces car dependency and lowers greenhouse gas emissions (Pozoukidou & Chatziyiannaki, 2021). By promoting a neighbourhood-centric design, the FMC fosters local engagement and helps balance urban infrastructure across various districts, addressing urban inequalities in service distribution (ETI Chair, 2021; Teixeira et al., 2024). This focus on proximity is also informed by the principle of chrono-urbanism, which stresses that the quality of life is significantly affected by how residents use their time within urban spaces. By reducing travel time, chrono-urbanism advocates for time spent on meaningful activities rather than commuting, which in turn fosters a closer relationship between residents and their local environment.

Density within the FMC concept goes beyond the traditional urban planning focus on building quotas, shifting instead toward an optimal density that supports economic and social sustainability. Compact neighbourhoods allow urban resources to be used more efficiently and make active mobility - like walking and cycling - more viable, reducing the need for extensive transport infrastructure (Allam et al., 2022b). Density helps create a critical mass for local businesses and services to thrive, providing both job opportunities and accessible daily necessities within walking distances (Pozoukidou & Chatziyiannaki, 2021). By facilitating compact growth, the FMC supports eco-friendly urban expansion that minimises land use and resource consumption, aligning with sustainable development goals (Khavarian-Garmsir et al., 2023). The principle of optimal density ensures that resources are equitably distributed, further enhancing FMC neighbourhoods' social inclusivity and local engagement.

Diversity within the FMC is twofold, encompassing both land use and social inclusivity. In terms of land use, the FMC promotes mixed-use development, integrating residential, commercial, and recreational spaces in close proximity, allowing residents to fulfil daily needs locally without the need for motorised transport. Such land-use diversity not only supports environmental goals by reducing vehicular trips but also enriches local economies by fostering a dynamic mix of businesses and services within each neighbourhood (ETI Chair, 2021). Socially, the FMC encourages diversity by promoting multicultural and mixed-income

communities, where people from various backgrounds, economic classes, and ethnicities coexist. This diversity is crucial for fostering social inclusiveness, reducing inequalities, and creating vibrant neighbourhoods that reflect a sense of community and belonging (Allam et al., 2022c). The emphasis on diversity also aligns with topophilia - a concept highlighting emotional attachment to place - by encouraging neighbourhoods where residents can develop strong emotional connections with their surroundings, making them invested in the community's well-being and growth (ETI Chair, 2021).

Digitalisation enhances the FMC's adaptability and efficiency, enabling the other core principles to function optimally in an urban setting. Through the integration of smart technologies, such as IoT devices, data-driven urban planning, and digital platforms, digitalisation facilitates real-time monitoring and data collection that inform urban decision-making processes (Mocák et al., 2022). For example, sensors and smart cameras can track the usage of bike lanes and parks, helping planners adjust resources to better serve resident needs (Wu & Divigalpitiya, 2023). Digitalisation also allows for greater citizen participation in urban planning by creating online platforms where residents can engage with local governance, thus making the city's infrastructure more responsive to community needs. Additionally, digitalisation supports mobility solutions like bike-sharing and remote work, further enabling the FMC's goals of reducing reliance on private vehicles and decentralising daily activities (Allam et al., 2022a; Allam et al., 2022b; Allam et al., 2022c).

Human-scale design centres on making cities more walkable and accessible, prioritising pedestrians and cyclists over cars, and focusing on creating safe, attractive public spaces (ETI Chair, 2021). This shift away from car-oriented planning to pedestrian-friendly environments reflects FMC's commitment to environmental and social sustainability, as it reduces pollution, fosters social interactions, and promotes a healthier, active lifestyle (Khavarian-Garmsir et al., 2023).

Connectivity complements this approach by linking neighbourhoods through efficient public transportation, avoiding isolated urban areas, and ensuring that FMC neighbourhoods remain integrated into the wider urban ecosystem. Enhanced connectivity enables residents to travel easily beyond their neighbourhood when necessary, reducing the need for car ownership while supporting the FMC's proximity goals (Pajares et al., 2021).

Flexibility within the FMC highlights the concept's adaptability in responding to changing urban needs, aligning closely with the principle of chronotopia, where urban spaces are designed to shift functions throughout different times of the day, week, or year (ETI Chair, 2021). It enhances resource efficiency and ensures cities can quickly adapt to challenges, from public health crises to evolving social behaviours (Balleto et al., 2021).

These characteristics of the 15-minute city illustrate a paradigm shift towards more human-centred, inclusive, and adaptable urban environments. By integrating the before-mentioned characteristics, the FMC can offer a holistic response to urban challenges, providing a blueprint for urban resilience, environmental sustainability, and improved quality of life (ETI Chair, 2021; Khavarian-Garmsir et al., 2023).

2.2. Origin of the Fifteen-Minute City

The FMC model, though increasingly popular today, is deeply rooted in a legacy of urban planning concepts focused on accessible, human-centred, and sustainable spaces. This model refines earlier ideas to tackle modern issues like climate change and urban resilience. Core principles of the FMC - proximity, walkability, and decentralization - are not novel but evolve from over a century of planning theories (Guzman et al., 2024; Staricco, 2022; Wolánski, 2023).

The concept originates from Ebenezer Howard's 1898 Garden City, which proposed self-contained towns linked by green belts, aiming to address industrial urban challenges by integrating residential and commercial spaces. This self-sufficient layout informed the FMC's approach of mixed-use neighbourhoods that reduce travel demands (ETI Chair, 2021). Clarence Perry's 1929 neighbourhood unit added a structure of local living by incorporating essentials like schools and parks within walkable distances, reinforcing the FMC's goal of minimizing car dependency and building polycentric urban areas (Pozoukidou & Chatziyiannaki, 2021).

Further contributions include Walter Christaller's Central Place Theory (1933), which suggested a spatial hierarchy where central places serve surrounding areas. The FMC adapts

this by establishing neighbourhoods as "centres" for daily needs, reducing the socio-spatial inequalities that emerge from centralized service models (Pozoukidou & Chatziyiannaki, 2021). Jane Jacobs' 1960s urban vitality theory emphasized mixed-use spaces and social interaction, aiming for vibrant communities, a central tenet echoed in FMC's design for active, community-oriented spaces (Ferrer-Ortiz et al., 2022).

Later influences include Torsten Hägerstrand's time geography, which introduced "chrono-urbanism (Ferrer-Ortiz et al., 2022; Ramirez Saiz et al., 2022). Human-scale design principles from Christopher Alexander and Jan Gehl emphasize walkability and pedestrian-friendly infrastructure, aligning with FMC's aim for close-knit, connected communities (ETI Chair, 2021).

Transit-Oriented Development (TOD) and New Urbanism movements of the late 20th century also impacted the FMC by promoting compact, mixed-use, transit-focused areas. While TOD centres around transport hubs, the FMC disperses services across neighbourhoods, reducing even public transit dependency. Eco-urbanism and compact city models focused on energy and resource efficiency, underscoring the FMC's commitment to sustainability through walkable, low-impact neighbourhoods (Khavarian-Garmsir et al., 2023).

Ultimately, the FMC synthesises these diverse influences to create a resilient, community-centric model addressing both modern urban challenges and historical insights on sustainable, inclusive urban design.

2.3. The Flexibility of the Fifteen-Minute City Model

The flexibility of the FMC model lies in its adaptability to various urban morphologies, densities, and local needs, enabling cities worldwide to tailor proximity-based strategies to their unique contexts. This flexibility has led to multiple versions of the time-based proximity concept, ranging from Five-Minute to Thirty-Minute cities, each designed to fit different urban settings and demographic needs (Staricco, 2022; Mocák et al., 2022). While the core aim remains the same - ensuring that residents can access essential services and amenities within a specified time - the variations in travel thresholds reflect the different scales of proximity that diverse cities can feasibly support. As such, the FMC model

embodies a pragmatic approach to urban design, prioritising a flexible, context-sensitive application rather than a rigid timeframe (Knap et al., 2023).

The most common variations of the FMC model include the Fifteen-Minute and Twenty-Minute frameworks. The FMC, which originated in Paris and are now prominent in European and Asian cities, focus on dense urban areas where services can be effectively distributed to meet needs within a shorter radius. European and Asian cities typically favour this model due to their compact nature, high population density, and strong public transport systems that support active modes of transportation like walking and cycling (Staricco, 2022; Mocák et al., 2022). In contrast, Twenty-Minute cities have been widely adopted in cities across the United States and Australia, where suburban sprawl and lower population densities necessitate slightly longer travel times to achieve accessibility. Melbourne's Twenty-Minute Neighbourhoods and Portland's Complete Neighbourhood Strategy are prominent examples of this model, offering most daily needs within a twenty-minute walk, bike ride, or local public transport trip (Capasso Da Silva et al., 2021).

The FMC model has also evolved beyond the fifteen- and twenty-minute frameworks, with some cities exploring the concept of Ten-Minute cities, such as Utrecht in the Netherlands and Hamburg in Germany (Knap et al., 2023). These models aim to offer more immediate accessibility in very dense or highly localised environments, where the scale of urban design allows for even closer access to essential services. Cities such as Oslo and Hailsham have also considered ten-minute neighbourhoods, reinforcing the adaptability of the FMC concept across varying urban scales (Teixeira et al., 2024). On the opposite end, cities like Sydney employ a thirty-minute framework to ensure metropolitan-level accessibility, connecting suburban residents to key city centres where employment and services are concentrated (Staricco, 2022).

Various other terms have been developed to describe similar models tailored to specific cultural or planning contexts. For example, 15-Minute Community Life Circle (CLC) in China is a culturally grounded interpretation of the FMC, adapted to meet the spatial and social dynamics of the region (Wu & Divigalpitiya, 2023). Singapore, which employs a "twenty-minute town" model, seeks to provide local accessibility within twenty minutes while

maintaining workplace and commercial accessibility within a forty-minute travel window by active transport modes like walking, cycling, or e-scooters (Staricco, 2022).

Ultimately, by permitting varied proximities, the FMC framework can integrate diverse urban environments, making it an inclusive, universally applicable model that centres on enhancing urban liveability and sustainability (ETI Chair, 2021; Mocák et al., 2022).

2.4. The 15-Minute City Model in the Context of Urban Sustainability

The 15-minute city (FMC) model, grounded in principles of sustainability, offers potential environmental, social, and economic benefits, although it also faces critical challenges. From an environmental perspective, the FMC model aligns closely with the global push for low- to zero-carbon development, addressing climate change through the reduction of private vehicle use and the decentralisation of urban services. Socially, it promotes equality and inclusivity by improving accessibility and quality of life for urban residents. Economically, the model supports local businesses, reduces transportation costs, and lowers infrastructure maintenance expenses. However, each of these benefits is accompanied by challenges that require thoughtful policy interventions to ensure inclusivity and mitigate unintended consequences like gentrification and social segregation (Olivari et al., 2023).

2.4.1. Environmental Sustainability

In the context of environmental sustainability, the FMC model is celebrated for its potential to promote deep decarbonisation, primarily by reducing car dependency and supporting active modes of transportation like walking and cycling (Knap et al., 2023). This model minimises the need for energy-intensive car journeys by making essential services easily accessible within a 15-minute walk or bike ride, thereby lowering CO_2 emissions and air pollution (Khavarian-Garmsir et al., 2023). Decentralising urban services and encouraging

micromobility can also help cities transition to a circular economy, reducing resource use and environmental impacts associated with industrial production (Pozoukidou & Chatziyiannaki, 2021). As Mocák et al. (2022) note, the FMC model aligns with a global shift toward low- and zero-carbon urban planning, making it a viable approach in light of the urgent need to address climate change.

The compact, walkable design of FMC neighbourhoods reduces energy consumption and pollution by clustering work, services, and recreation in close proximity to residential areas, thus limiting transportation needs and lowering reliance on energy-intensive infrastructure (Allam et al., 2022a). Additionally, the FMC concept protects green and agricultural lands by optimising urban land use, preserving biodiversity, and reducing the pressure of unregulated urban expansion on rural areas. By improving the efficiency of public transportation and addressing last-mile connectivity issues, the FMC model facilitates a transition to more sustainable urban mobility, further reducing the ecological footprint of cities (Khavarian-Garmsir et al., 2023).

2.4.2. Social Sustainability

Social sustainability within the FMC model is achieved by reducing spatial inequalities and promoting inclusivity in urban environments. By decentralising urban infrastructure and making essential services more accessible, FMCs work to bridge the gap between different socio-economic groups, addressing issues like spatial segregation and social exclusion that are often exacerbated in sprawling urban environments (Mocák et al., 2022). The proximity-focused design promotes active mobility, contributing to public health by encouraging physical activity and reducing crime through enhanced natural surveillance (Allam et al., 2022a). This close-knit urban structure also fosters social cohesion and a sense of community, as residents are more likely to engage in social encounters and develop a stronger sense of place and identity within their neighbourhoods (Khavarian-Garmsir et al., 2023).

However, implementing the FMC model also poses potential social challenges. While the FMC aims to improve accessibility for all, there is a risk of gentrification, as improved

services and infrastructure can lead to rising property values, pricing out lower-income residents and potentially displacing long-standing communities (Casarin et al., 2023). Additionally, while FMCs promote active mobility, this focus may inadvertently limit mobility for elderly or disabled residents unless complemented by accessible public transport solutions. To ensure inclusivity, urban planners must carefully balance investments in active mobility infrastructure with enhancements to public transportation and affordable housing provisions, maintaining the diverse social fabric that the FMC model seeks to support (Ulloa-Leon et al., 2023).

2.4.3. Economic Sustainability

Economically, the FMC model provides numerous advantages by concentrating resources within compact, mixed-use neighbourhoods. This approach can stimulate local economies by encouraging residents to shop locally, thus supporting small businesses and creating more job opportunities within the community (Khavarian-Garmsir et al., 2023). The emphasis on local job opportunities and proximity to workplaces also enhances economic productivity by reducing commute times, leading to higher worker satisfaction and potentially increasing employment rates as job accessibility improves (Allam et al., 2022a). Additionally, FMCs lower the costs of maintaining infrastructure, as the compact urban form requires less extensive and less costly infrastructure, reducing both financial and environmental maintenance costs associated with car-dependent suburban sprawl (Mocák et al., 2022).

Nevertheless, the economic sustainability of the FMC model is not without challenges. Increased accessibility and neighbourhood revitalisation efforts may lead to rising living costs and rental prices, particularly in areas with high demand, leading to affordability issues for lower-income residents (Glock & Gerlach, 2023). This could counteract the pro-poor aspect of the FMC model and undermine its goal of providing affordable housing and equitable access to urban services. Economic interventions are needed to regulate housing markets in FMC neighbourhoods to prevent excessive price hikes and ensure that low-

income residents continue to benefit from improved services and job opportunities (Allam et al., 2022c).

The FMC model embodies a sustainable urban planning approach that addresses environmental, social, and economic sustainability through proximity, active mobility, and compact urban design. Its ability to reduce emissions, enhance public health, and stimulate local economies makes it a promising model for future cities. However, the model's success in promoting equity and inclusivity hinges on mitigating risks such as gentrification and social segregation. Policymakers and urban planners must implement complementary measures, such as affordable housing policies, accessible public transportation, and economic regulations, to ensure that the benefits of the FMC model are equitably distributed and support a truly sustainable urban future (Olivari et al., 2023).

2.5. Type of Facilities Considered and Respective Frequency of Use

The categorisation of essential facilities in the FMC model primarily originates from Carlos Moreno's initial framework, which identified six core urban functions - living, working, supplying, caring, learning, and enjoying - that would enhance urban quality of life when accessible within a short walking distance. Moreno's approach emphasises essential services like housing, workplaces, shops, healthcare, education, and entertainment to meet daily needs and improve residents' well-being by reducing travel time and increasing local accessibility (ETI Chair, 2019; ETI Chair, 2021). According to Moreno, these six categories can comprise the following services:

- Living: it prioritises residential needs, focusing on sustainable housing options that reduce energy consumption and promote environmental health. Services under this category include access to parks, social housing, public transportation, and local services that support daily life, like laundry facilities and shared bike stations;
- Working: it encompasses diverse job opportunities within the community. Key facilities include coworking spaces, banks, and local services that support employment, like workshops and business incubators;

- Supplying: it ensures access to essential goods and services, such as grocery stores and markets. It also includes facilities supporting local agriculture and sustainable practices, such as bulk grocery stores and urban agriculture zones, which reinforce community resilience and eco-friendly consumption habits;
- Caring: it covers health and well-being, ensuring residents have nearby access to healthcare facilities like pharmacies, hospitals, fitness centres, and wellness activities, including meditation and sports fields. By supporting physical and mental health, this function enhances overall community welfare;
- Learning: access to educational resources and facilities for all ages, from nursery schools to adult education centres;
- Enjoying: it supports recreation and cultural engagement, encompassing spaces for leisure activities. Facilities under this category include theatres, museums and sports venues, which enrich the cultural fabric of the neighbourhood and provide spaces for social interaction.

Other researchers have expanded on Moreno's foundational framework by adding additional categories or adjusting the types of services based on contextual needs. For instance, Graells-Garrido et al. (2021) incorporate green spaces, government facilities, and additional retail options, recognising the importance of recreational and civic facilities in enhancing urban resilience and social engagement. Similarly, Pozoukidou and Chatziyiannaki (2021) emphasise the inclusion of healthcare and education as critical services, especially in low-density cities where public transport access to more distant services may be necessary. This approach acknowledges that accessibility in the FMC model is not a one-size-fits-all solution; different cities may prioritise facilities based on local demographics, densities, and transport networks.

Annex 1 consolidates various interpretations of the FMC concept from multiple studies, demonstrating how authors categorise and prioritise services. Common categories include essential services such as grocery stores, schools, healthcare centres, green spaces, and entertainment venues. This broad consensus highlights the flexibility of the FMC model, as urban planners adapt the concept to meet specific needs, whether through varying travel thresholds or by introducing culturally and locally relevant amenities. This adaptability

allows the FMC model to be both universal in its aims and specific in its application, addressing diverse urban challenges across global contexts.

To further refine accessibility measures, Ulloa-Leon et al. (2023) propose a two-tier hierarchy for services based on frequency of use and spatial reach. Primary facilities, such as grocery stores, primary healthcare, and parks, are essential for everyday needs and should ideally be within a 15-minute walk. In contrast, services used less frequently, such as hospitals and regional employment centres, can be located further away and accessed via public transport. While the FMC model emphasises proximity, this hierarchical structure recognises that some facilities necessitate a broader urban reach to function effectively and inclusively.

2.5.1. Frequency of Use

Megahed et al. (2024) highlight a significant limitation in existing studies: the lack of assessment regarding the frequency of use of local amenities and the perceived importance that communities assign to these facilities. It is also stressed the need for more observational studies and survey-based analyses to better understand the specific needs of communities for local amenities. However, there are some exceptions.

Knap et al. (2023), using recorded data from the Dutch Mobility Plan, found that the most frequent destinations for their sample population were offices (approximately 30% of trips) and commercial amenities, (excluding grocery stores, fresh produce outlets, delis, and bakeries) which accounted for around 20% of trips. Food-related destinations, such as grocery stores, delis, bakeries, and fresh produce outlets, along with education-related amenities, each comprised roughly 15% of trips.

Contradicting these findings, Gaxiola-Beltrán et al. (2021) observed that supermarkets are among the most frequented destinations for local populations.

Meanwhile, Guzman et al. (2024), through survey-based research, identified healthcare and grocery categories as the most preferred essential facilities, while recreational amenities ranked as the least significant. Their study also revealed that preferences vary based on

factors such as age, gender, and socio-economic strata (SES). For instance, individuals from lower SES backgrounds and older adults showed a strong preference for proximity to healthcare facilities, likely due to higher vulnerability to health risks. Similarly, women tended to prioritise access to educational and recreational facilities more than men.

Understanding amenity usage patterns is essential for aligning urban design and planning efforts with the needs of local communities. However, there remains limited information about the frequency of facility use, which varies significantly depending on the geographical context and demographic characteristics of the area under study. The lack of observational and survey-based methodologies further restricts insight into the behavioural dimensions of amenity use. Addressing these gaps through localised studies and robust data collection is crucial to ensure that urban planning effectively caters to the diverse requirements of different populations.

2.6. Assessing proximity within the FMC framework

As interest in implementing the FMC model grows, an increasing number of studies have adopted proximity as a core metric for analysis, applying it across different spatial and analytical scales. Megahed et al. (2024) systematise how authors measure proximity within the x-minute cities by grouping adopted approaches into six categories:

- Approach 1 (A1): Grid-based approach/ Origin-Destination approach
- Approach 2 (A2): POI catchment area approach
- Approach 3 (A3): Building catchment area
- Approach 4 (A4): Mixed approach
- Approach 5 (A5): Network-based method /graph representation method
- Approach 6 (A6): Indicator/index-based method

Not all approaches strictly assess proximity - some focus on accessibility or the FMC framework, which still aligns with proximity due to their conceptual overlap. Based on this categorisation, the literature read (when applicable) was categorised according to the approaches set by Megahed et al. (2024). The following tables aim to make clearer

comparisons between methodologies but also serve to identify patterns, gaps, and opportunities within current research on proximity assessment.

2.6.1. A1: Grid-based approach/ Origin-Destination approach

The A1 approach begins by dividing the study area into a grid using GIS tools. Within each cell, residential locations are identified and assessed based on their proximity to surrounding services. A geographic centroid is calculated for each cell, and the distance from this point to various amenities is measured. Each cell is then evaluated according to the proportion of services accessible within a defined distance.

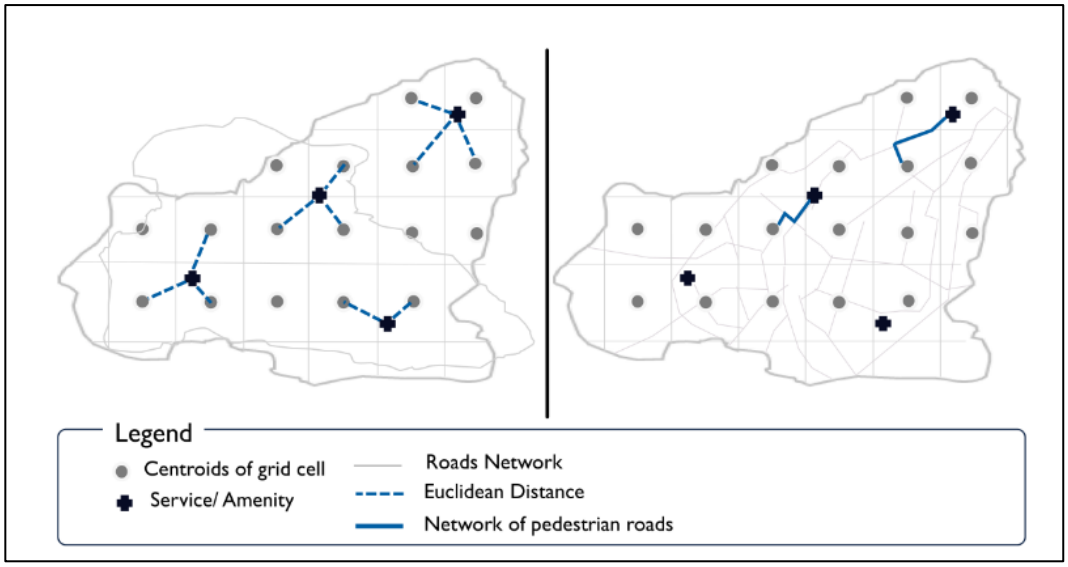


Figure 2 - The concept behind the OD/grid-based approach (Megahed et al., 2024)

Table 1 briefly describes the methodologies used under this approach.

Table 1 - Authors who used an OD/grid-based approach

Authors	Methodology used
Birkenfeld et al. (2024)	Use Geographic Information Systems (GIS)-based grid analysis and Origin-Destination Surveys
Calafiore et al., 2022	Compute the walking time required to reach the five closest destinations from each postcode for every service category, determined based on Euclidean distance

Graells-Garrido et al., 2021	Define a bipartite origin-destination (OD) graph between neighbourhoods of residential origin and cells of visitor destination
Hosford et al., 2022	Use the R package R5R to generate travel time matrices between dissemination block cen-troids and destinations
Silva et al., 2023	Measure accessibility for each census tract (using over 10.000 unique cells), resorting to the use of a cumulative-opportunity measure for a set of ten activities within a 15-minute walking threshold
Ulloa-Leon et al., 2023	Did a multivariate geostatistical analysis, involving grid-based spatial analytics
Willberg et al., 2023	Use statistical grid database cells as origin points

2.6.2. A2: POI catchment area approach

This second method focuses on the spatial relationship between buildings (treated as cadastral parcels) and nearby urban services. POI focuses on classifying the coverage area of services by calculating walking distances from these services to all buildings within the selected study area. Buffers are then created around each POI to represent cut-off distances. This approach often includes estimating the population within each catchment area, providing valuable insights into the distribution and equity of urban services.

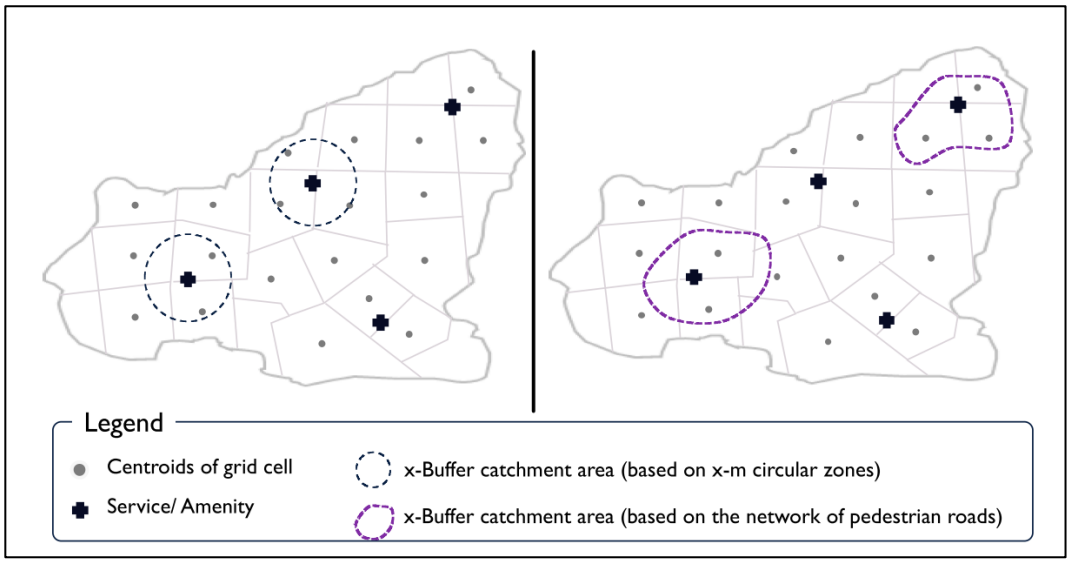


Figure 3 - The concept behind the POI Catchment Area approach (Megahed et al., 2024)

Table 2 illustrate how different researchers have applied and adapted this approach to diverse urban contexts.

Table 2 - Authors who used a POI Catchment Area approach

Authors	Methodology used
Capasso da Silva et al., 2019	Use GIS software to load facility points, run travel sheds around destination points and bus stops, identify relevant bus routes, buffer the travel sheds, and intersect these buffers with residential areas to analyse coverage
Caselli, 2021	Determines the catchment areas of selected facilities, using ArcGIS Network Analyst tools to produce various simulations
Caselli et al., 2022	Process data to determine the catchment areas of selected collective facilities in the neighbourhood. Used the Service Area analysis, an ArcGIS Network Analyst tool, to do so
Gaglione et al., 2022	Define a matrix of Euclidean distances from the centroids of the census sections to the related local urban services
Kesarovski, 2023	Use Network Analyst to estimate service areas around the selected POIs within 10-minute isochrones
Noworól et al., 2022	Create a spatial database containing relevant POI with their locations corresponding to individual facilities of interest to local residents
Sun & Luo, 2024	Use the Gaussian Two-step Floating Catchment Area to calculate the 15-minute accessibility of locations

2.6.3. A3: Building catchment area

A3 establishes a geographic catchment for a specific facility or service, typically based on standard walking distances. Buffers are drawn around residential buildings, and demographic and population data are analysed within these catchments to understand who is served and who is excluded. Essentially, it evaluates proximity from the perspective of residential buildings or housing units, rather than from services or street centroids.

The studies presented in Table 3 have applied or adapted this approach to assess proximity and accessibility in the context of the 15-minute city.

Table 3 - Authors who used a Building Catchment Area approach

Authors	Methodology used
Akrami et al., 2024	Assess accessibility to different facilities within a 15-minute walk from all places of residence using GIS analysis tools
Balleto et al., 2021	Calculate the service areas of disused public properties using centroids of the selected locations
Di Marino, 2023	Assess the number of facilities one can reach from different coworking spaces
Gaxiola-Beltrán et al., 2021	Use the Urban Mobility Accessibility Computer (UrMoAC) tool that calculates the minimum time and distance required to reach nearest specified destinations
Glock & Gerlach, 2023	Use the Closest Facility Analysis from ArcGIS with residential addresses as origins and a set of basic services as destinations.
Guzman et al., 2021	Compute radius isochrones from household locations, varying the walking time threshold

2.6.4. A4: Mixed approach

This approach combines elements of the previous methods to provide a more comprehensive analysis. For instance, tools like GOAT (Geo Open Accessibility Tool) incorporate both single-time isochrones (as in Approach 3) and multi-isochrones (as in Approach 2) to assess pedestrian accessibility. Thus, A4 blends elements of different proximity-assessment models to deliver a more comprehensive, context sensitive analysis. Table 4 identifies the studies that follow this mix of methods.

Table 4 - Authors who used a Mixed approach

Authors	Methodology used
Alessandrini et al., 2023	Present the Geo Open Accessibility Tool (considered a mixed approach according to Megahed et al., 2024)
Pajares et al., 2021	Use the Geo Open Accessibility Tool (considered a mixed approach according to Megahed et al., 2024)

2.6.5. A5: Network-based method /graph representation method

A5 models proximity using a planar graph. The street network is translated into a graph structure, where intersections function as nodes and streets as edges. This method shifts the analytical focus from straight-line or network travel distances to the topological structure of the urban network itself. It allows for simulation and diagnosis of spatial cohesion, the distribution of services, and the configuration of accessible zones with a high degree of precision.

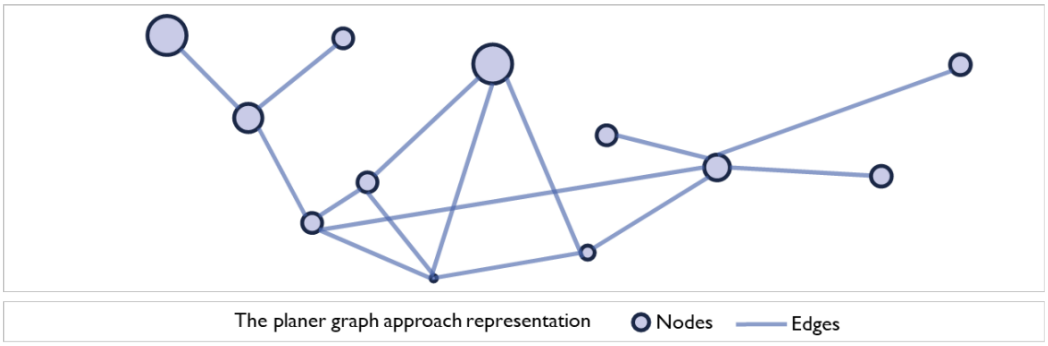


Figure 4 - The concept behind the Network-based method /graph representation method (Megahed et al., 2024)

Table 5 synthetises the methodology used by Barbieri et al. (2023).

Table 5 - Author who used a Network-based method /Graph Representation method

Authors	Methodology used
Barbieri et al., 2023	Develop a methodology to calculate pedestrian travel time to reach selected services across all the potential paths on urban graphs

2.6.6. A6: Indicator/index-based method

This method aggregates multiple dimensions of accessibility and proximity into a single or set of indexes, often combining both quantitative spatial indicators (e.g., number of services, distances, densities) and qualitative or contextual variables (e.g., user preferences, infrastructure quality, demographic needs). This approach provides a synthesised measurement of how "15-minute" a city or area is, often enabling comparison across territories or simulation of policy scenarios. It is important to note that, unlike other approaches that merely assessed proximity, the following authors always combined other factors to formulate the indexes presented.

Table 6 - Author who used an Indicator/index-based method

Authors	Methodology used
Bartzokas-Tsiompras, 2023	Develop a 15-minute walking city index to evaluate the walkability of cities
Guzman et al., 2024	Define a 15-minute city composite index that considers aspects such as walkability, the diversity of establishments, accessibility and individual preferences of locals
Knap et al., 2023	Develop a composite metric that combines accessibility scores with the frequency of different destinations
Lima et al., 2022	Use the Physical Proximity Calculator, which computes the smallest distance between two or more POI and assigns a Physical Proximity Index

Liu et al., 2024	Propose a 15-minute city index model and its computability approach. The model aims to measure the degree to which a city can be considered a 15-minute city
Monteiro, 2023	Adopt the “15-minute city” indicator in combination with three additional indicators to assess the potential benefits of urbanizing vacant spaces within a city
Murgante et al., 2024	Combine space syntax, place syntax, and spatial analysis tools to determine a set of local, district-scale, and urban-scale indicators and to evaluate the degree of realization of the 15-minute city concept

This systematisation is presented in Annex 2, an academic paper submitted for the CIRMARE 2025 conference, which will be published by Springer in late 2025.

2.7. Limitations if the Fifteen-Minute City

The concept of the FMC, while widely praised for its sustainable, accessible urban planning, faces several notable criticisms that challenge its effectiveness, equity, and feasibility in diverse urban contexts.

One significant critique is that the FMC concept may overlook complex social and economic inequalities embedded within urban areas. By focusing on physical proximity alone, the FMC framework risks oversimplifying the accessibility needs of disadvantaged communities who may lack quality resources despite living within close distances to them (Guzman et al., 2024). This model often fails to account for disparities in service quality and infrastructure across different neighbourhoods, which can perpetuate existing inequalities rather than alleviate them. For instance, in rapidly urbanizing areas or cities with high socio-economic stratification, such as Bogotá, Colombia, proximity to essential services does not guarantee equitable access if services are substandard or if the infrastructure is not supportive of all demographics, especially those with limited mobility or differing social needs (Guzman et al., 2024).

Another point of contention is the potential for gentrification, as seen in various urban renewal efforts under similar planning models. The FMC's emphasis on mixed-use neighbourhoods and compact urban forms can inadvertently raise property values, displacing long-term residents and altering neighbourhood demographics (Casarin et al., 2023). This so-called "social mix" effect assumes that introducing diverse income groups within a neighbourhood will enhance social integration and cohesion. However, past attempts at social mixing have shown that these approaches often lead to displacement of low-income residents due to rising costs, ultimately failing to address deeper socio-economic divides (Mouratidis, 2024).

Additionally, the practical application of the FMC model raises questions about its scalability and adaptability to various urban structures. While FMC principles may work well in compact, walkable cities, they are less feasible in sprawling or car-dependent environments without extensive redevelopment efforts (Khavarian-Garmsir et al., 2023). Implementing an FMC structure also requires substantial investment in pedestrian-friendly infrastructure, which may be financially unfeasible or deprioritized in certain municipalities (Marquet et al., 2024).

Finally, scepticism surrounding the FMC's originality and ideological motivations has led to public backlash, especially in the context of increasing anti-urbanist sentiments and conspiracy theories. Some critics view the FMC model as a top-down imposition aimed at restricting personal freedoms, framing it as a form of "social engineering" rather than a grassroots-led movement for sustainable cities (Marquet et al., 2024). These critiques suggest that any successful implementation of the FMC concept must be accompanied by transparent communication and meaningful public engagement to mitigate fears and enhance public acceptance.

In sum, while the FMC offers a compelling vision of urban accessibility and sustainability, its limitations underscore the need for a nuanced, context-sensitive approach that prioritizes equity, inclusivity, and adaptability across diverse urban landscapes. As the model is still gaining traction and remains largely theoretical, with only recent practical applications, the framework will need further research and practices to fully address these limitations.

3. CASE STUDY

3.1. Delimitation and Characterisation of the Study Area

3.1.1. Demographic Profile of Matosinhos

The municipality of Matosinhos is one of the most populous in Portugal, with a population of 179.558 (PORDATA, 2023) and covering an area of 62,42 km² (CAOP, 2024). Its population density reaches 2.876 inhabitants per km², considerably above both the AMP and national averages (864,6 and 116,6 inhabitants per km², respectively) (INE, 2022). Despite the wider trend of depopulation both at a national level and within the Porto Metropolitan Area (AMP) (Silva et al., 2023), Matosinhos has shown relative population stability rather than a strong decline, much like the most core municipalities of the AMP (AMPCM) – Gondomar, Maia, Matosinhos, Porto, Valongo and Vila Nova de Gaia (Silva et al., 2023). The only AMPCM municipality that follows the depopulation trend is Porto, whose population has severely declined since the 1990s. This decline, shown in Figure 5, contrasts with the growth observed in other AMPCMs, indicating an ongoing process of demographic redistribution within the metropolitan area.

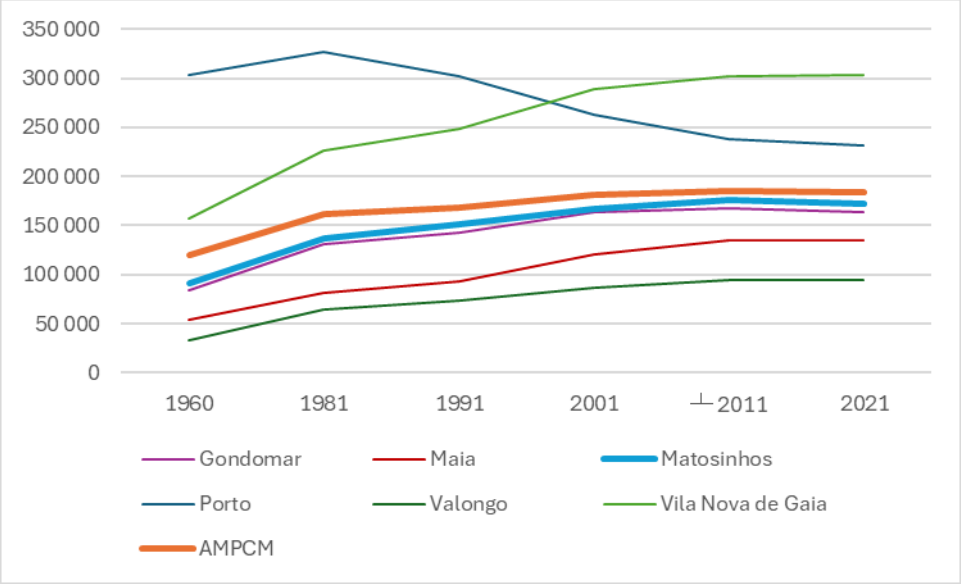


Figure 5 - Population variation within AMPCM (1960-2021) (INE, 2022)

The age structure of Matosinhos closely mirrors that of the AMPCM. In both cases, the population is predominantly of working age (approximately 65%), while older residents (65

years and over) account for around 22%, and children and adolescents under 15 years represent about 12%. This ageing profile, characterised by a high dependency ratio, presents challenges for future and inclusive urban planning. Figure 6 shows the age structures of Matosinhos and AMPCM.

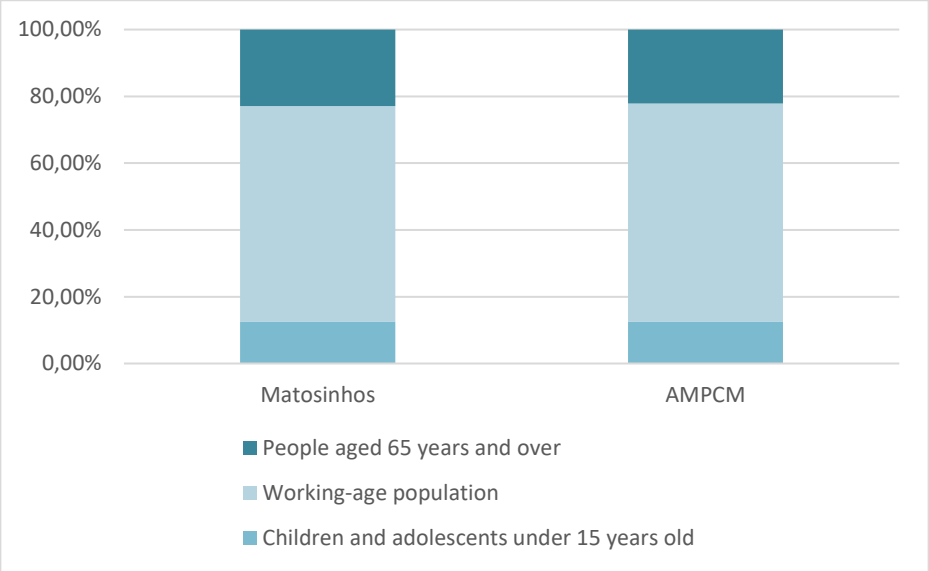


Figure 6 - Age structures of Matosinhos and AMPCM (INE, 2022)

3.1.2. Socio-economic Profile of Matosinhos

Matosinhos presents a socio-economic profile marked by significant progress in education and income, positioning it above national and metropolitan averages. However, persistent challenges remain, particularly in income inequality and acute housing affordability pressures.

Educational attainment has improved significantly in the last two decades: according to the 2021 Census, the proportion of residents with higher education rose to 22%, up from 15% in 2011, while the share of those without formal schooling fell to 11%.

The labour market is dominated by the service sector, which accounts for more than 80% of employment, followed by the secondary sector, which accounts for approximately 18%. Agriculture and the extraction of raw material play a residual role, occupying 1% of the active population. Employment levels have fluctuated in response to wider economic

cycles, with unemployment peaking after the 2008 financial crisis and again during the COVID-19 pandemic, before declining steadily in recent years.

In terms of income, Matosinhos stands out positively: the median gross declared income in 2022 was €11.514, above the national average (€10.679) and among the highest in the AMP, only surpassed by Porto and Maia. The average monthly wage of employees reached €1.536,50, placing the municipality second in the AMP. Nevertheless, Matosinhos also registers one of the highest income inequality levels in Portugal, according to the Gini coefficient.

Housing affordability is one of the most pressing issues. Between 2019 and 2022, the median sale price per m² increased by 41%, surpassing €2.000/m², one of the ten highest in Portugal. Rents followed the same trend: in 2023, the median rent for new contracts reached €10/m², keeping Matosinhos among the most expensive municipalities nationwide. This pressure is reflected in the 1.601 households registered for public housing in 2023, representing 3,472 people, many of them elderly or living in substandard housing.

3.1.3. Land use of Matosinhos

Matosinhos is part of a polycentric metropolitan structure, in which the city of Porto functions as the primary node surrounded by several urban sub-centres, including Senhora da Hora and São Mamede de Infesta. These centres play a crucial role in the spatial organisation of the AMP, which is marked by a transition from high-density urban cores to scattered suburban and rural settlements (Silva et al., 2023).

Matosinhos encompasses a mix of territorial typologies: a compact and urbanised area adjacent to the municipality of Porto (designated as espaços centrais), a substantial area dedicated to economic activities (espaços de atividades económicas), and a more dispersed, largely rural territory composed of forested areas, low-density urban spaces and agricultural land (espaços florestais, espaços urbanos de baixa densidade e espaços agrícolas). These characteristics mirror the territorial composition of neighbouring municipalities such as Maia and Vila do Conde, which also retain expansive rural landscapes.

Annex 3, the Land Classification and Use Map of Matosinhos (Planta de Ordenamento de Classificação e Qualificação do Solo do Plano Diretor Municipal), represents graphically the different classification and land uses mentioned.

In response to the municipality's territorial diversity, the Municipal Plan of Matosinhos (PDM) divides the territory into 6 Operative Planning and Management Units (Unidades Operativas de Planeamento e Gestão – UOPG). A UOPG is a continuous portion of territory, delimited in an intermunicipal or municipal master plan, or in an urban development plan and it aims to programme the implementation of the plan or to carry out urban development operations (Decreto Regulamentar nº5, 2019). These units are defined based on intrinsic characteristics of each territory, such as biophysical features, land use patterns, urban density, and socio-cultural and economic attributes, using criteria of situational or territorial homogeneity to delineate distinct landscape units. From the 6 UOPG, 3 are located in urban land and encompass one of the municipality's three cities and their respective central areas: UOPG 4 includes Matosinhos (Cidade Atlântica), UOPG 5 covers Senhora da Hora (Cidade Nova), and UOPG 6 includes São Mamede de Infesta (Cidade Nascente). Annex 4, the Land Use Zoning Map of Matosinhos (Planta de Ordenamento de Programação do Solo), presents the division of the UOPG as well as the various Territorial Projects (Projetos Territoriais) planned for the municipality.

The division of the territory into UOPGs, based on local conditions, is intended to address the challenges of urban sprawl and fragmented development. Complementing this, the municipality has adopted a strategic planning approach in the PDM, which prioritises the densification of urban areas south of the A4 motorway, while safeguarding rural and agricultural land in the northern part of the municipality and along the Leça River valley. The intention is twofold: to reinforce the cohesion of existing urban spaces by improving and completing critical vacant plots, thereby supporting compact and efficient urban forms; and to contain peripheral urban expansion by limiting new development to areas contiguous with existing infrastructure. This strategy positions Matosinhos in alignment with broader principles of sustainable urban development and the proximity-based model of the 15-Minute City.

3.1.4. Mobility Patterns of Matosinhos

Commuting dynamics in Matosinhos reveal strong interconnections within the Porto Metropolitan Area, namely the AMPCM. According to the 2021 Census, approximately 53% of employed residents work outside the municipality, with 37% commuting specifically to other AMPCM municipalities, while 47% both live and work locally. This balance underlines the municipality's dual role as both an employment hub and a residential area dependent on neighbouring centres, especially Porto.

Daily mobility is marked by a predominance of private car use (54% among both employed residents and students), reflecting the ongoing dependence on individualised transport. Public transport still accounts for a significant share (30%), with the metro and bus systems providing the backbone of intermunicipal connectivity. Meanwhile, 14% of trips are carried out by active modes, such as walking and cycling, a relatively high figure in the metropolitan context that points to the municipality's compact urban fabric and proximity between residential areas, services, and employment zones. The majority of the residents travel 15 minutes or less to commute, meaning that long commutes are the exception. This contrasts with the paradigm of the metropolitan periphery, reinforcing the urban importance of the municipality.

Matosinhos also functions as a destination for inbound mobility. Around 23% of Portuguese who leave their municipality to work or study commute into Matosinhos, a value close to the AMPCM average of 26%. Although the census does not provide disaggregated information on the exact municipalities of origin, most of these commuters likely come from neighbouring municipalities such as Porto, Maia, and Vila do Conde, given their geographical proximity and strong transport links.

Matosinhos' mobility patterns reinforce the municipality's central role in shaping intermunicipal mobility flows.

3.1.5. Definition of the Study Area

Due to the focus of this dissertation, and in recognition of the fact that the 15-Minute City model presupposes high population density to function effectively, only the central areas of Matosinhos will be considered. These zones, identified in municipal planning instruments as "high-density and compact urban areas" (Relatório do PDM de Matosinhos, p. 65), reflect the municipality's vision for concentrated, multifunctional urban development. Within these areas, a series of regulatory principles has been established. Notably, the principle promoting urban amenities with a focus on functional diversity and flexibility is particularly relevant, as it resonates with the concept of chronotopia, which advocates for the temporal adaptability of spaces to accommodate a variety of everyday uses (ETI Chair, 2021; Silva et al., 2023).

All three cities of Matosinhos have been classified as a "Type 1" areas within the typology of 15-Minute City conditions developed by Silva et al. (2023). This classification indicates that residents within these areas can access all ten essential amenities - schools, food and non-food retail, restaurants, pharmacies, clinics, public services, leisure and cultural facilities, sports infrastructure, and parks - within a 15-minute walk. While this level of accessibility is rare across the AMP, covering just 9% of the territory, it serves approximately 18% of the population, positioning Matosinhos (municipality) as a leading example of proximity-centred accessibility in the region. This high accessibility supports the viability of implementing the FMC model with minimal additional investment. However, as Silva et al. (2023) note, there is still a need to reinforce access to green and cultural amenities in some areas to realise the potential of the model fully.

Ultimately, UOPG 5 was selected as the study area due to its high population density and strategic role as a key mobility hub, both within the municipality of Matosinhos and in the broader context of the AMP. Its central location, combined with a strong concentration of public transport connections - including metro and bus services - makes it a critical interface for daily commuting and regional accessibility. These characteristics, along with its functional diversity, make UOPG 5 particularly suitable for assessing the applicability and potential of the 15-Minute City model in a metropolitan setting. Additionally, given that

UOPGs were designed based on similar characteristics of the territory, it is assumed that this delimitation is not administrative but rather functional, which fits under the FMC framework. Figure 7 shows the delimitation of the study area.

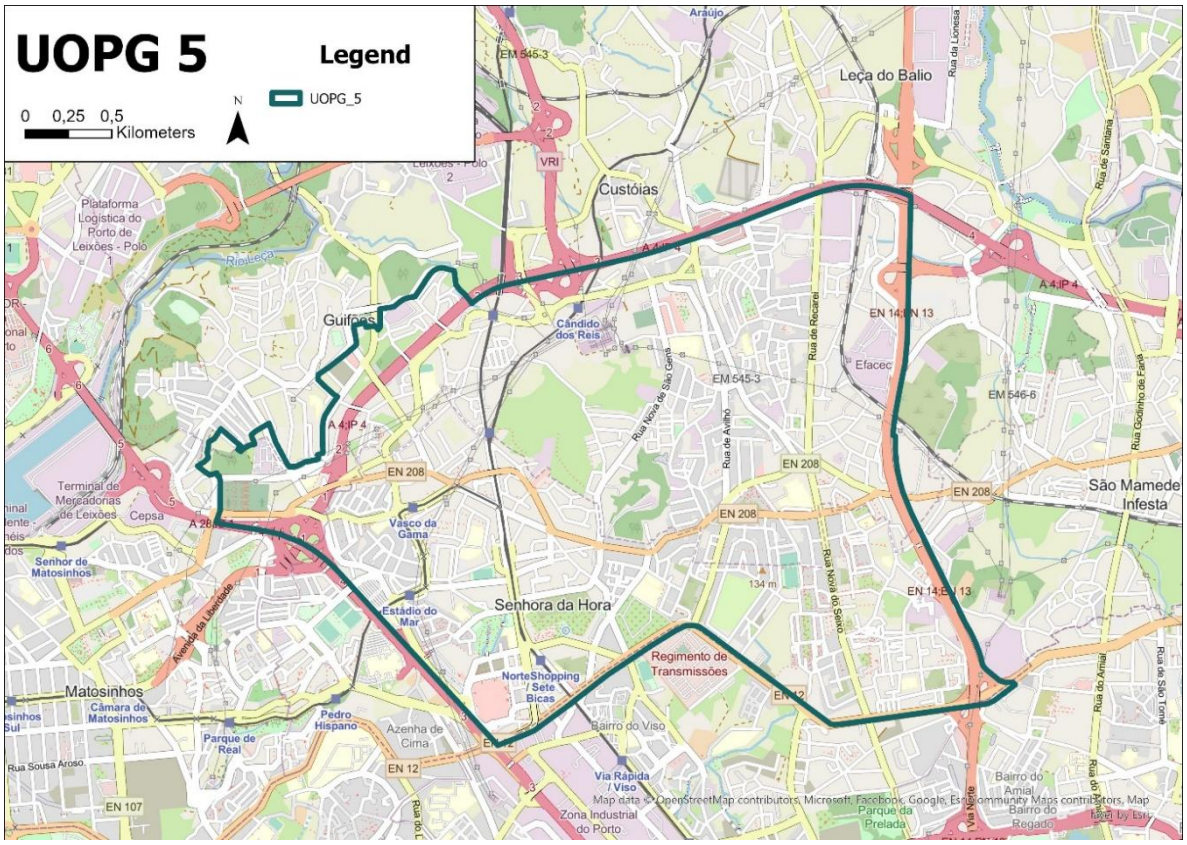


Figure 7 - Delimitation of UOPG 5

According to Annex 4, UOPG 5 comprises two Territorial Projects: Cidade Nova and Coesão Urbana 5. Both share a common objective of promoting sustainable urban development and improved accessibility, while addressing different spatial and functional priorities. Cidade Nova focuses on the installation of new economic activities, the creation of public green spaces, and the enhancement of infrastructure networks to support innovation and attract investment. It also seeks to improve mobility and accessibility for all modes of transport and promote a more balanced distribution of travel opportunities within the area. In contrast, Coesão Urbana 5 prioritises the requalification and reorganisation of existing urban areas, reinforcing economic and residential integration. It aims to rehabilitate public spaces, support mixed-use development, and enhance the quality and inclusiveness of the urban environment, ensuring that future growth contributes to social cohesion and sustainable mobility.

Furthermore, and because UOPG 5 is a functional unit, the availability of official statistical data for its characterisation is limited. Consequently, the following description is based on the aggregation of data from the subsections that compose UOPG 5.

UOPG 5 is a densely populated and consolidated urban area, with an estimated population density of around 5.539 inhabitants per km² (INE, 2022) - almost double the municipal average of Matosinhos (2,876 inhabitants per km²), which underlines the area's compact urban structure, essential to the FMC framework. Its age structure closely mirrors that of the municipality, being primarily composed of working-age residents, along with a notable share of older adults (aged 65 and over) and a smaller proportion of children and adolescents under 15 years old. Figure 8 shows the age structures of UOPG 5 and Matosinhos.

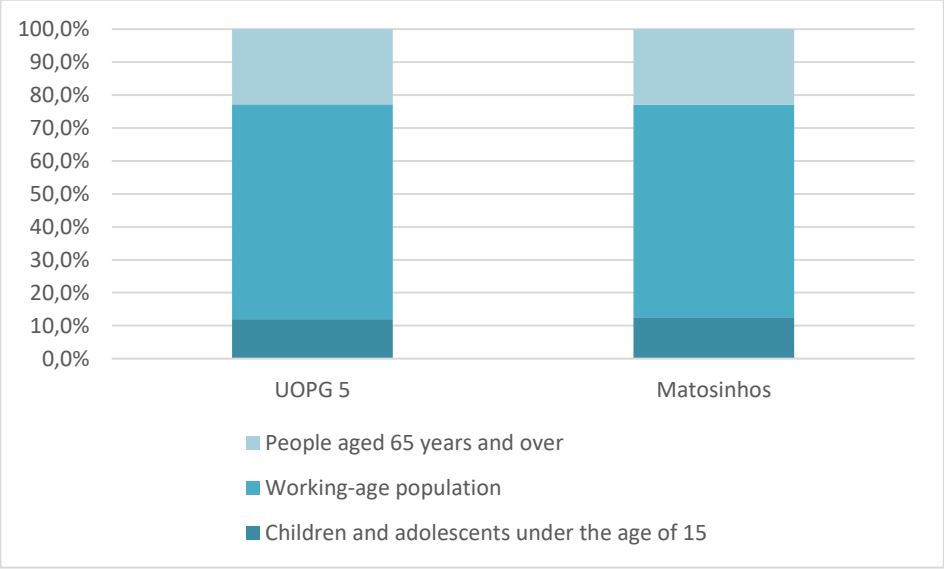


Figure 8 - Age Structures of UOPG 5 and Matosinhos

In terms of housing, most buildings consist of family dwellings used as usual residences (22.280 units), with only a small share corresponding to secondary or vacant dwellings (3.142 units). Figure 9 displays the types of family dwellings in UOPG 5.

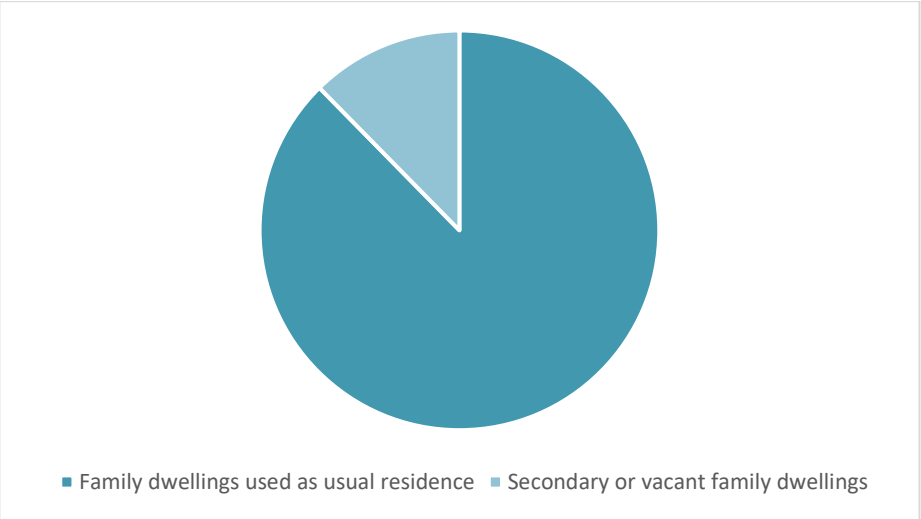


Figure 9 - Types of Family Dwellings in UOPG 5

3.2. Methodology

As outlined, this dissertation seeks to measure the applicability of the FMC model in UOPG 5. The FMC comprises four key principles: proximity, density, diversity and digitalisation. Among these, three stand out as the most tangible and measurable: density, diversity, and proximity. This is because, while digitalisation also plays a role within the FMC framework, it is generally considered a facilitating mechanism rather than a defining spatial factor.

As the criteria of density has already been addressed during the selection and delimitation of the study area, proximity and diversity remain to be explored. As such, these become the central focus of this research. Among them, proximity assumes particular significance owing to its direct and foundational relationship with the FMC model. This stems from the fact that the FMC is, at its core, a proximity-based framework. In this sense, proximity is not merely one of the model's defining features; it is the very condition that makes the FMC concept operational. Conversely, the FMC also provides a normative and methodological structure through which proximity can be meaningfully assessed, extending its relevance beyond simple measures of distance to include questions of accessibility, equity, and quality of life. This reciprocal relationship underscores why proximity, as both a metric and a guiding principle, stands at the heart of the present investigation.

From the systematisation in section 2.6. Assessing proximity within the FMC framework, it has become clear that proximity and, in turn, the FMC model require the support of other variables and data to be assessed more reliably. This is consistently demonstrated across methodologies and case studies. Proximity as a spatial construct may indicate how close amenities are, but alone, it does not tell us whether those amenities are used, adequate, or accessible to all social groups. Hence, it is pivotal to include factors such as urban equity, infrastructure, and lived experience. From the literature, the methodology adopted by Guzman et al. (2024) stands out. The authors create an index that stems from including not only geography-based proximity but also factors such as perceived safety and individual preferences.

The Fifteen-Minute City Index, according to the authors, is a composite measure designed to capture the extent to which residents can access essential services within a short walking distance under appropriate urban conditions. It comprises two main components: diversity and walkability. Diversity refers to the range and balance of essential services available within a fifteen-minute walk from each residential block. It is itself composed of two variables: accessibility, which measures the actual presence of services, and individual preferences, which weigh those services according to their perceived importance. Walkability reflects the quality of the pedestrian environment, capturing how safe, comfortable, and feasible it is for residents to walk to those services.

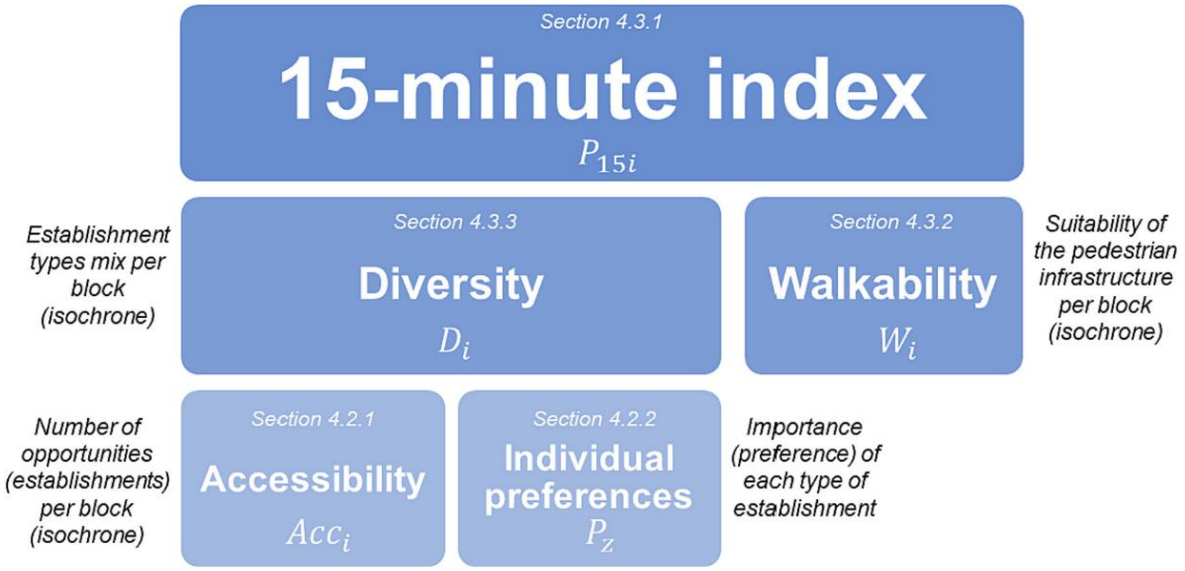


Figure 10 - Structure of the 15-minute index (Guzman et al., 2024)

In this dissertation, particular emphasis will be placed on the diversity component, as it encapsulates not only the physical distribution of services but also the social and behavioural dimensions that condition their relevance to urban life. Thus, two main analyses will take place. Firstly, an objective study that identifies the existing distribution of infrastructure in UOPG 5 (Accessibility). Secondly, an inquiry to the local communities to understand their individual preferences regarding the relative importance of different amenities within walking distance (Individual Preferences). Lastly, the degree of diversity will be computed taking the previous two analyses into account.

3.2.1. Accessibility

Accessibility is operationalised as the number of establishments of a given type that fall within a fifteen-minute walking isochrone drawn from each residential block. In this context, it translates to measuring the proximity of different amenities to each residential block. Isochrones are constructed using the street network rather than Euclidean distance, thereby reflecting realistic pedestrian movement. Hence, the accessibility analysis comprises two main steps:

1) Calculating accessibility per subcategory, where, for each origin and service type, the number of destinations reachable within 15 minutes on foot is counted using a cumulative opportunities approach based on the network distance. The authors used the following equation:

$$Acc_{ie} = \sum_{1}^{e} Establishment_{ie} \cdot T_h \qquad \text{(Equation 1)}$$

where i indicates an origin point in the study area and e indicates the total number of essential urban opportunities per category k measured as the number of corresponding establishments T_h will be 1 if the walking travel time threshold is a maximum of 15 min walking; 0 otherwise.

2) Normalise the accessibility values, to allow for comparison between origins and services.

Thus, to do so, ArcGIS Pro, and particularly the OD Cost Matrix tool from Network Analysis, were used to measure the distance between origins and destinations. Furthermore, to

convert the 15-minute time frame into a measurable distance, the authors consider an average walking speed of 3,2 km/h. However, the literature suggests that the average walking speed of an adult lies between 4 km/h and 5 km/h (Ferrer-Ortiz et al., 2022; Papadoulas et al., 2023), which corresponds to an average walking range of 1.000 to 1.250 metres. Hence, in this study, the walking speed considered will be of 4 km/h (1.000 meters).

3.2.1.1. Data collection

Assessing proximity-centred accessibility requires the integration of three key elements: origins (where people are), destinations (where people want to go) and the street network (how people can get there).

To collect the data required for this analysis, information was sourced from Geofabrik, a reliable distributor of OpenStreetMap (OSM) data widely used in spatial and urban studies (e.g., Kesarovski et al., 2023; Pajares et al., 2021; Silva et al., 2023). Geofabrik provides regularly updated extracts of OSM data in a structured format, allowing users to access detailed information about urban infrastructure, buildings (origins), services (destinations), and the street network. As the platform publishes updated datasets daily, the data used in this dissertation was downloaded on 30 September 2025 to ensure accuracy and temporal consistency. This dataset served as the foundation for the data collection process, forming the backbone of the spatial analysis carried out in this research.

To identify destinations, or Points of Interest (POI), two additional data sources were used. The first comprised municipal data, which include institutional POI such as education, healthcare, and recreational facilities, thus complementing Geofabrik's information. The merged POI were subsequently validated through fieldwork. For this purpose, the Field Maps mobile application, synchronised with ArcGIS Pro, was employed to add or remove POI and to adjust the centroids of larger facilities (e.g., schools).

Additional datasets were obtained from the National Statistics Institute (INE) and the Land Use and Occupation Map (COS). INE data included statistical subsections and information on buildings and residents (2021 Census), georeferenced at the subsection level. The COS

dataset was used to identify different land uses within the UOPG 5 study area. Table 7 summarises the datasets used for this analysis.

Table 7 - Datasets used in the Accessibility analysis

Dataset	Description	Source	Year
OpenStreetMap	Building footprints (origins), POI (destinations), and street network data	Geofabrik	2025
Municipal POI Database	Institutional services such as schools, healthcare centres, and recreational facilities	Municipality of Matosinhos	2025
Field Maps validation	Field-verified POI locations and centroid adjustments for large facilities	Own Production	2025
Statistical Subsections	Population and residential data from the 2021 Census, georeferenced at the subsection level	INE (National Statistics Institute)	2021
Land Use and Occupation Map (COS)	Identification of land uses within UOPG 5	DGT (Directorate General for Territory)	2023

3.2.2. Individual Preferences

Individual preferences are measured through a ranking survey in which participants ordered both the six service categories and the specific sub-types within each category according to their perceived importance. These were gathered through a questionnaire addressed to the residents of UOPG 5. The main purpose of the questionnaire was to estimate the relative importance, or weight, of each type of establishment, and, thereby, to understand how residents from different socio-economic and demographic backgrounds value and prioritise the selected essential services. In addition, the survey sought to identify which services residents considered to be lacking in their vicinity.

The questionnaire comprised the following sections:

- Section 1 – Introduction: an introductory section outlining the purpose of the study and its target population (every resident of UOPG 5);
- Section 2 – Privacy Policy and Informed Consent: clarifies data protection procedures and ensures participants' anonymity and voluntary participation;
- Section 3 – Socio-demographic Data: following Guzman et al. (2024), this section establishes the socio-demographic profile of each respondent, as different segments of the population exhibit different preferences regarding proximity services. It collects data on gender, age, occupation, education level, and household income. All questions were multiple choice;
- Section 4 – Mobility Patterns: although not included in Guzman et al.'s framework, this section was added to provide insight into residents' mobility patterns. All questions were multiple choice, except for the postal code question. Owing to the spatial heterogeneity of the study area, this question is intended to locate the respondent within the different sectors of UOPG 5;
- Section 5 – Individual Preferences: participants were asked to rank, first, the six categories defined by the authors and then, the different services within each category, according to perceived importance. Rank-order questions were used for this purpose;
- Section 6 – Lacking Services: this section asks residents which services they believe are missing in their vicinity. It includes a multiple-choice question where and then leave space through an open question, a space where residents can check which categories are lacking. There is also an open-ended question where participants can freely express their opinions on this matter. This is the only question whose answer was not mandatory;
- Section 7 – Acknowledgements: a brief closing note thanking participants for their time and contribution.

In total, the questionnaire comprised 20 questions. Responses were collected online between the 2nd and the 28th October 2025. An informal pre-test was conducted to adjust

the expected response time as well as to assess participants' willingness to share personal information.

3.2.2.1. Dissemination Strategy

To reach as many residents as possible, some dissemination strategies were employed:

- Institutional Collaboration Requests: the municipality and the parishes located within the study area were contacted and asked to share the questionnaire with residents. Unfortunately, none of the parishes responded, and the municipality's Communication Department declined the request;
- QR Codes: a total of 200 stickers containing QR codes linked to the questionnaire were placed in various points of interest (POIs), including schools, universities, bakeries, grocery shops, markets, health centres, clinics, bus stops, metro stations, sports centres, beauty salons, cafés, petrol stations, hairdressers, laundries, newsagents, pharmacies, and restaurants. Figure 11 shows the placement of the QR Codes in different amenities;
- Social Media: The questionnaire was also shared on social media platforms, both directly with residents of the area and through local community Facebook groups managed by citizens;
- Institutional Email: The link was distributed to colleagues within the University of Minho.

The questionnaire format was maintained, as this method is commonly when the aim is to reach a large number of individuals in order to characterise the defining traits of broad population groups (Coutinho, 2018). In Guzman et al. (2024), this was done by combining sociodemographic data with individual proximity preferences. Their findings revealed, for instance, that women tend to prefer living near education facilities, whereas young people favour recreation services.

Using QR codes and online dissemination ensured that respondents' privacy was protected and that data collection was according to GDPR standards. Nevertheless, this method

inevitably excluded individuals with low levels of digital literacy, such as the elderly or those without access to smart phones – representing, thus, a clear limitation of the study.



Figure 11 - Placement of QR Codes in different amenities

3.2.3. Diversity Index

The Diversity Index captures the equilibrium across different categories of services and incorporates the relative importance that residents assign to each. The diversity score for each block is calculated through a weighted geometric mean of the normalised accessibility values, using the individual preference weights as coefficients. The authors chose the geometric mean as it deliberately penalises imbalance, meaning that the absence or scarcity of any essential service substantially lowers the overall diversity score, even when other services are abundant. Conversely, blocks with relatively balanced accessibility across categories achieve higher diversity values.

The authors applied the following equation to calculate the Diversity Index for each category:

$$D_{ik} = \frac{exp\,(\sum_{e \in k} log(Acc_{ie}) \cdot w_e)}{\sum_{e \in k}(w_e)}$$ (Equation 2)

where D_{ik}represents the diversity index for origin $i$and category k; Acc_{ie}denotes the (normalised) accessibility to subcategory e; and $w_e$corresponds to the weight of that subcategory.

Since, in this study, the sum of the subcategory weights within each category equals 1, the denominator of the equation becomes redundant. Therefore, the equation used to compute the Diversity Index in this dissertation was simplified to include only the numerator:

$$D_{ik} = exp\,(\sum_{e \in k} log(Acc_{ie}) \cdot w_e)$$ (Equation 3)

Accordingly, the diversity index was calculated for each origin and for each service category. Once these individual category indices were computed, an overall diversity index per origin (or building) was obtained by calculating the weighted sum of each category's diversity value multiplied by its corresponding category weight (Equation4):

$$D_i = \sum_k W_k \cdot D_{ik}$$ (Equation 4)

where D_i represents the overall accessibility score for origin i, W_k denotes the global weight assigned to each category (e.g., health, education, groceries), and D_{ik} is the diversity index previously computed for that category.

4. RESULTS, ANALYSIS AND DISCUSSION

4.1. Accessibility Index

As previously mentioned, when assessing proximity-centred accessibility, three elements are key: origins (where people are), destinations (where people want to go) and the street network (how people can get there).

4.1.1. Data Collection

4.1.1.1. Origins

Guzman et al. (2024) employed residential blocks as the spatial unit for assessing accessibility, which is appropriate given the metropolitan scale of their study. However, considering the different spatial scale of the present research, residential buildings were adopted as the unit of analysis instead. Buildings were already mapped in the Geofabrik database, which also provided information on building typology. Nonetheless, 4.019 buildings were found to be unclassified.

To address this limitation, the COS was consulted to categorise these buildings accordingly. This was done by using the Spatial Join tool in ArcGIS Pro, which joined the features of the Buildings and COS layers. Initially, there were 5.464 buildings.

The following criteria were used to exclude buildings:

1. The COS typology is not a residential area (1.1.1.1., 1.1.1.2, 1.1.2.1., 1.1.2.2.) (341 buildings excluded).
2. Buildings who, according to the respective subsection data, have 0 individuals living in (7 buildings excluded).
3. The buildings layer with typology is different from apartments, detached, house, residential, terrace or blanks (103 buildings excluded).
4. The buildings' minimum area is 35m2 – minimum area established by General Regulation of Urban Buildings (*Regulamento Geral de Edificado Urbano*) for the smallest Typology, T0 (192 buildings excluded).
5. The building coincides with a POI (19 buildings excluded).

6. The buildings which have a name in the table and are not of residential nature (24 buildings excluded).

In total, 686 buildings were excluded, which means that there are, at a first glance, 4.778 buildings considered in the analysis.

Next, the building polygons were turned into points using the Feature Polygon to Point tool from ArcGIS. This has left the buildings' centroids in the middle of the polygon, which calls for unreliable distance measurement. Thus, having already the street network, centroids were relocated from the centre of the polygons to the street surface.

Lastly, when importing the Origins layer into the Origin–Destination Cost Matrix using the Add Locations tool with a search tolerance of 40 metres, a total of 203 buildings could not be located. Hence, a manual verification of the origin points was undertaken, resulting in the removal of 193 origins, corresponding to garages, annexes, and other non-residential buildings. The remaining 10 origins were manually repositioned to their respective entrances, ensuring proximity to the street network. In total, 4.585 residential buildings (origins) were considered. Figure 12 shows the valid Origin Points within UOPG 5.

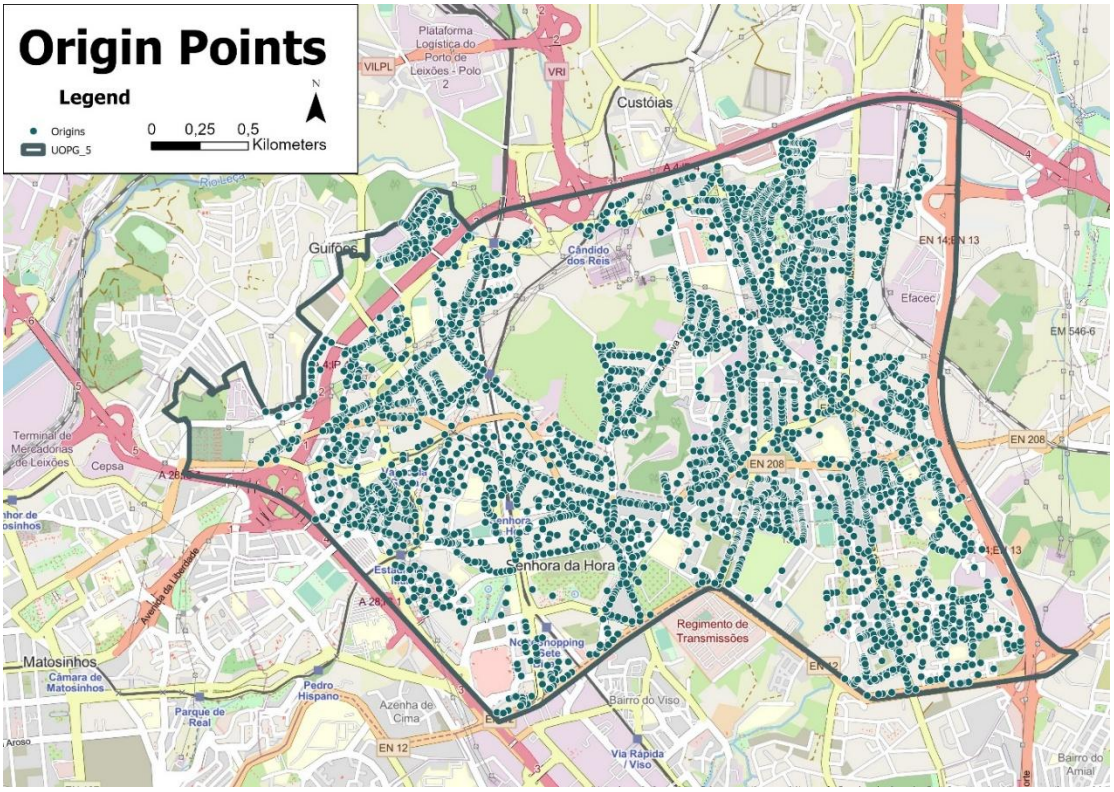


Figure 12 - Origin Points

4.1.1.2. Destinations

While Moreno (ETI Chair, 2019) divided urban destinations into six categories (see Table 1), Guzman et al. (2024) proposed an alternative classification, also comprising six categories, yet conceptually aligned with Moreno's framework. Figure 13 presents the correspondence between both sets of categories.

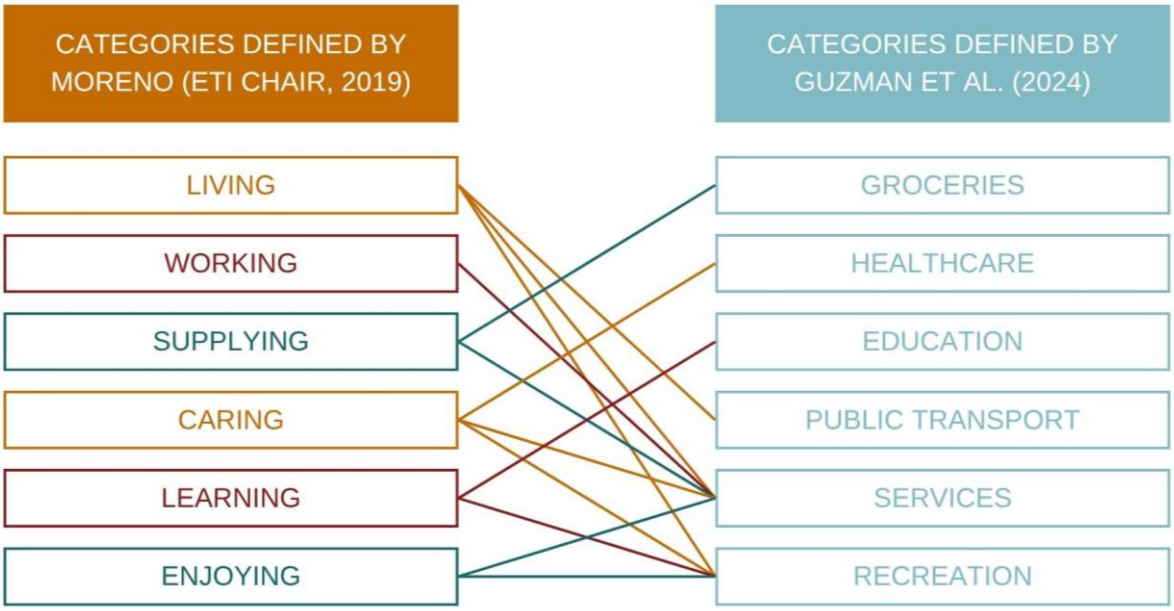


Figure 13 - Correspondence between the categorisation of Moreno (2019) and Guzman et al. (2024)

Guzman et al. (2024) selected specific amenities for each category, which were reviewed to the context of UOPG 5. To avoid limiting the analysis solely to the authors' original selection, a preliminary screening of relevant amenities was conducted using the *fclass* attribute of the Geofabrik database. Following this classification, the identified amenities were compared with those chosen by Guzman et al. (2024).

Annex 5 (sheet POI considered) provides a detailed account of this process, including the definition of each amenity according to Geofabrik and the correspondence established between its *fclass* values and the subcategories proposed by Guzman et al. (2024).
In the end, Table 8 summarizes the subcategories considered for each category.

Table 8 - Subcategories chose for the Accessibility analysis

Category	Subcategory
Groceries	Bakeries, butchers, grocery shops, greengrocers, supermarkets and local markets (*feiras ou mercados*)
Healthcare	Hospitals, clinics and health centres
Education	Nurseries, kindergartens, primary schools (*escolas básicas*), secondary schools (*escolas secundárias*) and universities
Public Transport	Bus stops, railway and metro stations
Services	Banks, bars, cafés, hairdressers and beauty shops, gas stations, newsagents, laundry shops, pharmacies, post offices and restaurants
Recreation	Cultural venues (arts centres, cinemas, community centres, museums, libraries) Sports-related amenities (golf courses, gyms, sports' centres, swimming pools, tennis courts and pitches) Parks and green areas (parks and playgrounds)

As previously mentioned, a triangulation of data was undertaken to ensure the reliability of the set of destinations.

The first source, Geofabrik, comprised a total of 419 POI. This dataset was complemented by additional POI provided by the CMM. The Near Analysis tool was employed to identify duplicates between both sources, using a 25-metre search radius. After identifying and removing duplicates, the municipal dataset contributed an additional 53 POI.

To verify the accuracy of these databases, a fieldwork visit was conducted. In total, 472 (419 + 53) destinations were validated, and 317 POI were manually identified during the fieldwork. The fieldwork was carried out using the Field Maps application within ArcGIS Pro. Prior to the fieldwork, relevant layers, such as the study area boundary and the POI datasets, were prepared and shared as Web Layers, enabling their direct access through the mobile application, as shows Figure 14.

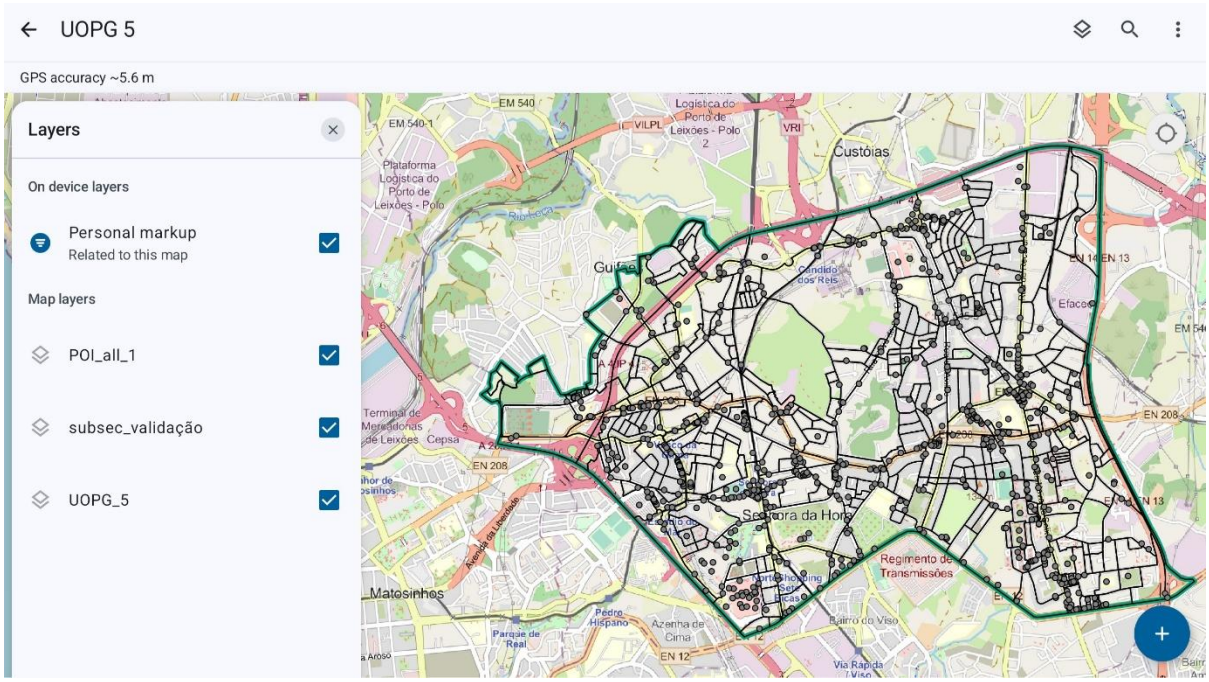


Figure 14 - Print screen of the Field Maps application

By the end of the triangulation process, a total of 789 POI were identified – as shows Figure 15.

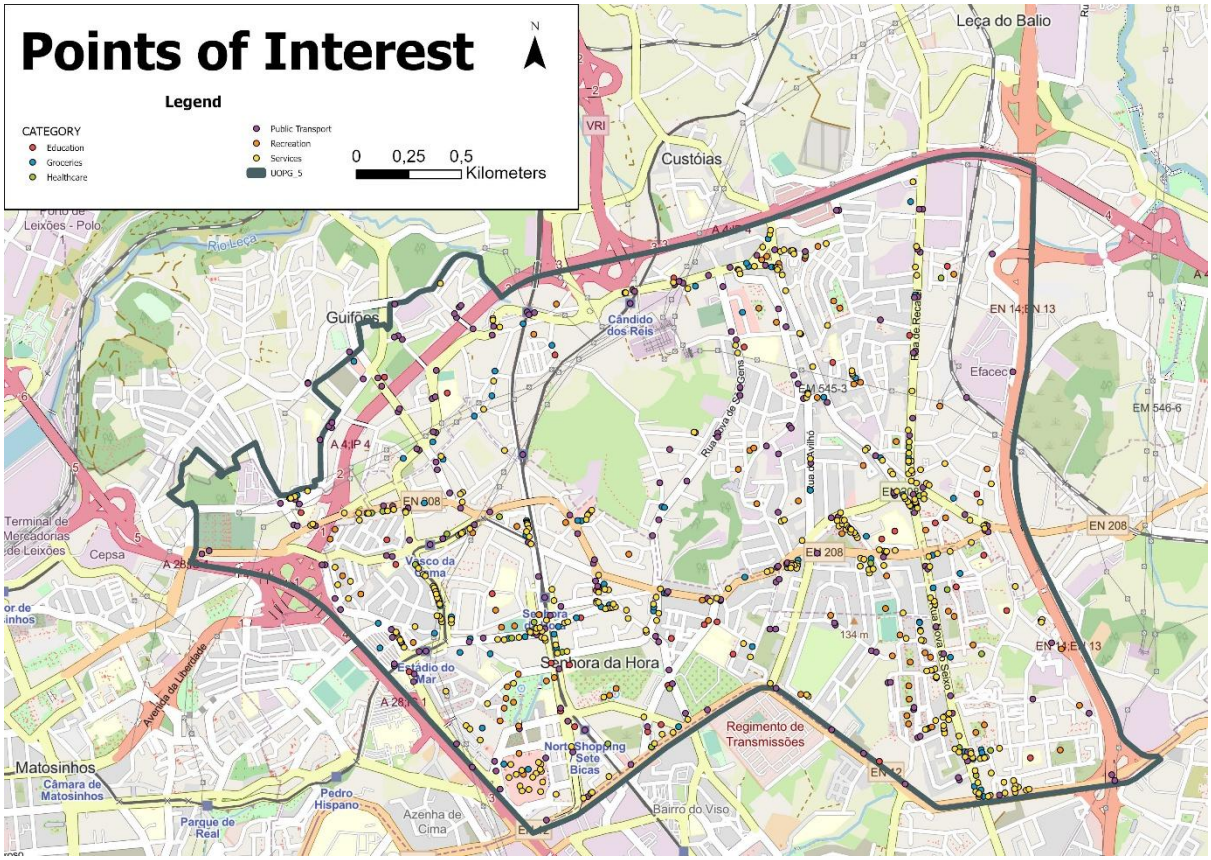


Figure 15 - Points of Interest within UOPG 5

4.1.1.3. Street Network

The Geofabrik database also included the street network. To obtain the walkable street network, non-walkable segments were excluded, specifically cycleways and roads where the maximum speed exceeded 50 km/h, such as motorways, trunk roads, and their respective links. The resulting network was compared with the street network provided by the CMM, but no additional features were identified, indicating that the Geofabrik network was already comprehensive and robust.

To prepare the network for analysis, a Network Dataset was created, establishing the analytical framework for the subsequent accessibility assessment. Within this dataset, a New Travel Mode was defined to represent pedestrian mobility, ensuring that the model accurately reflected walking conditions across the study area. The following attributes were selected (shown in greater detail in Figure 16):

- Type: Walking, as it simulates pedestrian movement.
- Impedance: WalkTime (minutes), chosen to prioritise time-based accessibility.
- Time Cost: WalkTime (minutes), same attribute used for consistency.
- Distance Cost: Length (metres), retained for secondary distance analysis.
- U-turns: “None – excluded”, as not applicable to pedestrians.

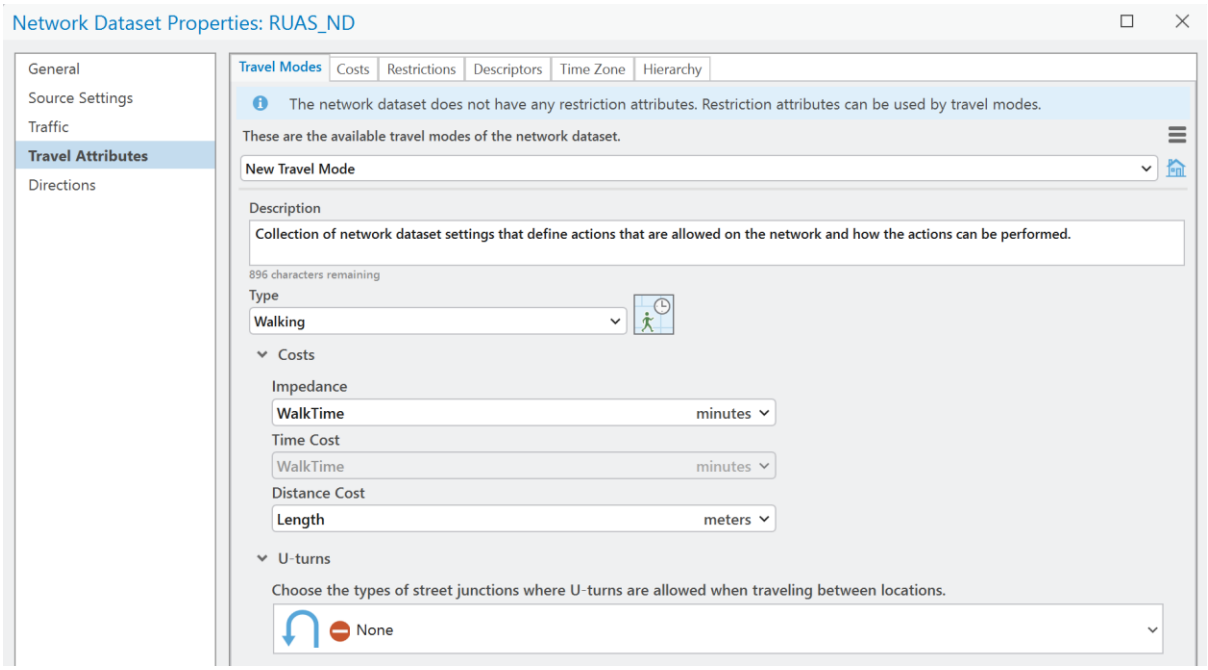


Figure 16 - Print screen of the attributes used to set the New Travel Mode

Next, the Cost Attributes of the network were configured. Two attributes were defined: the impedance, represented by WalkTime, and the distance cost, represented by Length. The Length attribute, serving as the independent variable, was implemented through a Field Script in which Length was set equal to the *Shape_Length* attribute. This attribute stores the geometric length of each segment in the street network (in metres), providing the fundamental distance measure for all subsequent calculations.

The WalkTime attribute, representing the dependent variable, was defined to express the time required to traverse each network segment. This was achieved through a Python script in the Field Script Evaluator, written as: *result = !Shape_Length! / 66.67*. This expression converts each segment's length (in metres) into travel time (in minutes), assuming an average walking speed of 4 km/h, equivalent to 66.67 metres per minute.

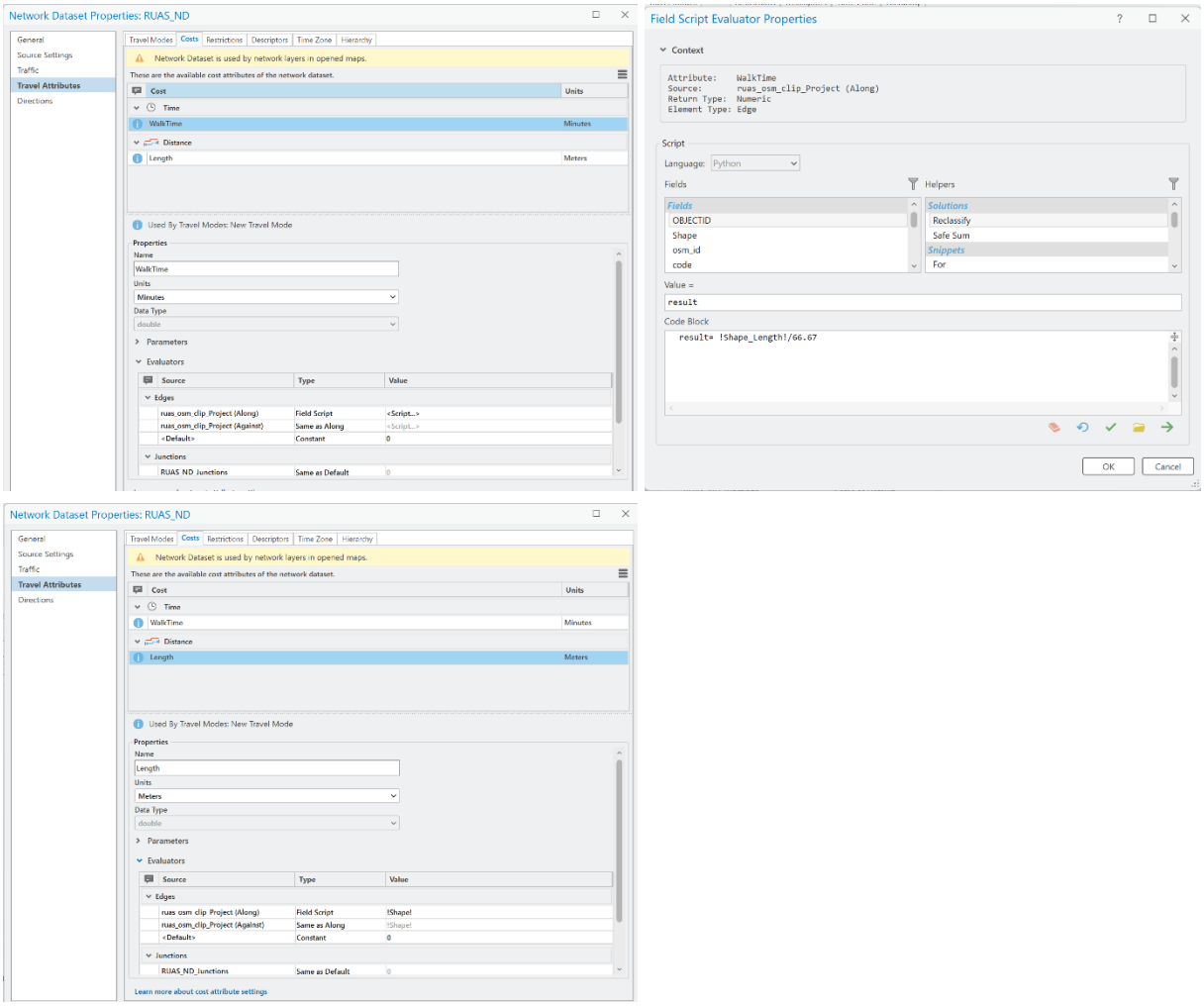


Figure 17 - Print screens that show how to set the Impedance and the Distance Cost

4.1.2. Analysis

Following the preparation of the pedestrian network dataset, an Origin–Destination (OD) Cost Matrix was generated to calculate the shortest travel times between each origin and all reachable destinations within the study area. The analysis initially produced a total of 3.586.929 Lines, each representing a potential connection between an origin and a destination.

To refine the results, a selection query was applied to extract only the routes where WalkTime was less than 15,5 minutes. This additional half-minute buffer was introduced to include connections that were effectively within the 15-minute walking range but might otherwise be excluded due to rounding or minor network irregularities. After this filtering process, a total of 691.840 records were selected and, subsequently, exported to Excel. It is important to note that the Output Lines parameter was set to Straight Lines to simplify the visualisation of origin–destination connections while retaining the underlying travel-time information.

To determine how many destinations were reachable from each origin, and to distinguish these by category and subcategory, a PivotTable was created in Excel (see sheet ACC_No., Annex 5). Each cell in the PivotTable represented the number of destinations accessible within 15 minutes for a given origin and amenity type.

Table 9 shows the mean accessibility that origins have for each for destination, as well as the maximum and minimum number of establishments per subcategory. The Services category stands out in regard to the mean accessibility, having, on average, a high number of hairdressers and beauty shops, cafés and restaurants. Conversely, Recreation presents a low number of destinations for origins.

Table 9 - Mean accessibility, maximum and minimum number of amenities per subcategory

CATEGORIES	SUBCATEGORIES	MEAN	MAX	MIN
Education	kindergarten	2,05	6	0
	school	4,07	8	0
	university	0,33	3	0
Groceries	bakery	6,86	17	0
	butcher	3,27	8	0
	general	4,59	10	0
	greengrocer	1,48	5	0
	market_place	0,33	1	0
	supermarket	2,51	6	0
Healthcare	clinic	5,61	15	0
	health_centre	0,56	2	0
	hospital	0,07	1	0

Public Transport	bus_stop	39,50	70	0
	metro_station	1,07	5	0
	railway_station	0,15	1	0
Recreation	arts_centre	0,06	1	0
	cinema	0,05	1	0
	community_centre	1,03	3	0
	golf_course	0,14	1	0
	gym	2,14	8	0
	museum	0,35	1	0
	park	1,12	6	0
	pitch	3,76	10	0
	playground	3,95	9	0
	sports_centre	1,01	2	0
	swimming_pool	0,82	2	0
	tennis_court	0,35	1	0
Services	bank	1,15	6	0
	bar	0,74	2	0
	hairdresser	19,28	47	0
	cafe	16,25	34	0
	fuel	1,21	3	0
	laundry	5,59	12	0
	newsagent	4,23	10	0
	pharmacy	1,82	6	0
	post_office	0,25	2	0
	restaurant	12,63	24	0

Following the approach proposed by Guzman et al. (2024), the resulting data were then normalised to enable cross-category comparison. While Guzman et al. employed the percentile-based empirical normalisation method (using the 5th and 95th percentiles), this dissertation adopted a min–max normalisation approach.

The main purpose of the normalisation process is to enable the comparison of accessibility levels across all origins. Guzman et al. (2024) illustrate this with the example of educational services: if an origin is located near the maximum number of eight schools (the highest observed value in the dataset), it receives a normalised score of 1, representing the best context-related accessibility. In turn, if an origin has no schools within the 15-minute radius, it receives a score of 0, indicating the lowest possible accessibility level. Annex 5, sheet ACCESSIBILITY INDEX (NORM) has the computations of the normalisation process for each origin.

4.2. Individual Preferences

Within the previously defined response period (2nd to 28th October 2025), 86 answers were received. Before proceeding with data analysis, it was necessary to identify and apply exclusion criteria. Thus, the following responses were excluded:

1. Responses where respondents did not agree to the Privacy Policy and Informed Consent terms (4)
2. Responses containing disrespectful or deliberately unreliable content (1)
3. Responses in which the zip codes submitted were void or incomplete (4)
4. Responses in which the zip codes fall outside of the study area (11)

After applying these exclusion criteria, the questionnaire resulted in a total of 66 valid responses for analysis.

It is important to note that, in addition to determining the relative weights the population assigns to each category and subcategory, Guzman et al. (2024) also cross-analysed socio-demographic characteristics with the respondents' preferences. This allowed the authors to identify potential variations in accessibility priorities among different population groups. However, given the low answer turnout, such cross-referenced analysis could not be meaningfully performed and was therefore excluded from the present research scope.

4.2.1. Socio-demographic Data

The sample comprised 66 respondents, of whom 68% were women, 30% men, and 2% preferred not to specify their gender. Regarding age distribution, most participants were between 20 and 24 years old (26%), followed by the 55–59 age group (17%) and 25–29 years old (9%), indicating a predominance of young adults and late-career respondents. Table 10 details the age distribution of all participants.

Table 10 - Participants' age distribution

Age	No.	%
Less than 15 years old	0	0%
15-19 years old	7	11%
20-24 years old	17	26%
25-29 years old	6	9%
30-34 years old	5	8%
35-39 years old	0	0%
40-44 years old	3	5%
45-49 years old	4	6%
50-54 years old	2	3%
55-59 years old	11	17%
60-64 years old	6	9%
65-69 years old	4	6%
79-75 years old	0	0%
More than 75 years old	1	2%

In terms of educational attainment, most respondents reported a tertiary education level (64%), while 32% had completed secondary education. Only 4% possessed lower levels of education (1st–3rd cycle of basic education), and no participants reported having no formal education, suggesting a highly educated sample.

With respect to occupation, the majority were working individuals (65%), followed by students (23%), and a smaller proportion of retired (5%) or unemployed participants (3%). A small share (2%) identified as working students, indicating a workforce-dominated respondent base.

As for annual household income, the distribution was relatively balanced across income brackets. The largest shares were found within the 27,931€–37,240€ range (17%), 18,621€–27,930€ range (14%), and 37,241€–55,860€ range (15%), while 11% reported earning less than 9,310€. About 12% of respondents declared that they did not know their household income, and another 12% preferred not to answer.

Overall, the sample represents a highly educated, economically active population, primarily composed of women and young adults, with relatively even income distribution and minimal representation of low-education groups. This demographic composition was

expected, given the dissemination strategy adopted for the questionnaire, which primarily reached individuals with greater digital access and higher educational attainment.

4.2.2. Mobility Patterns

Apart from the outliers mentioned in the excluding criteria, most of the postal codes fall within UOPG 5, with a higher concentration of responses in Padrão da Légua and Montes Burgos.

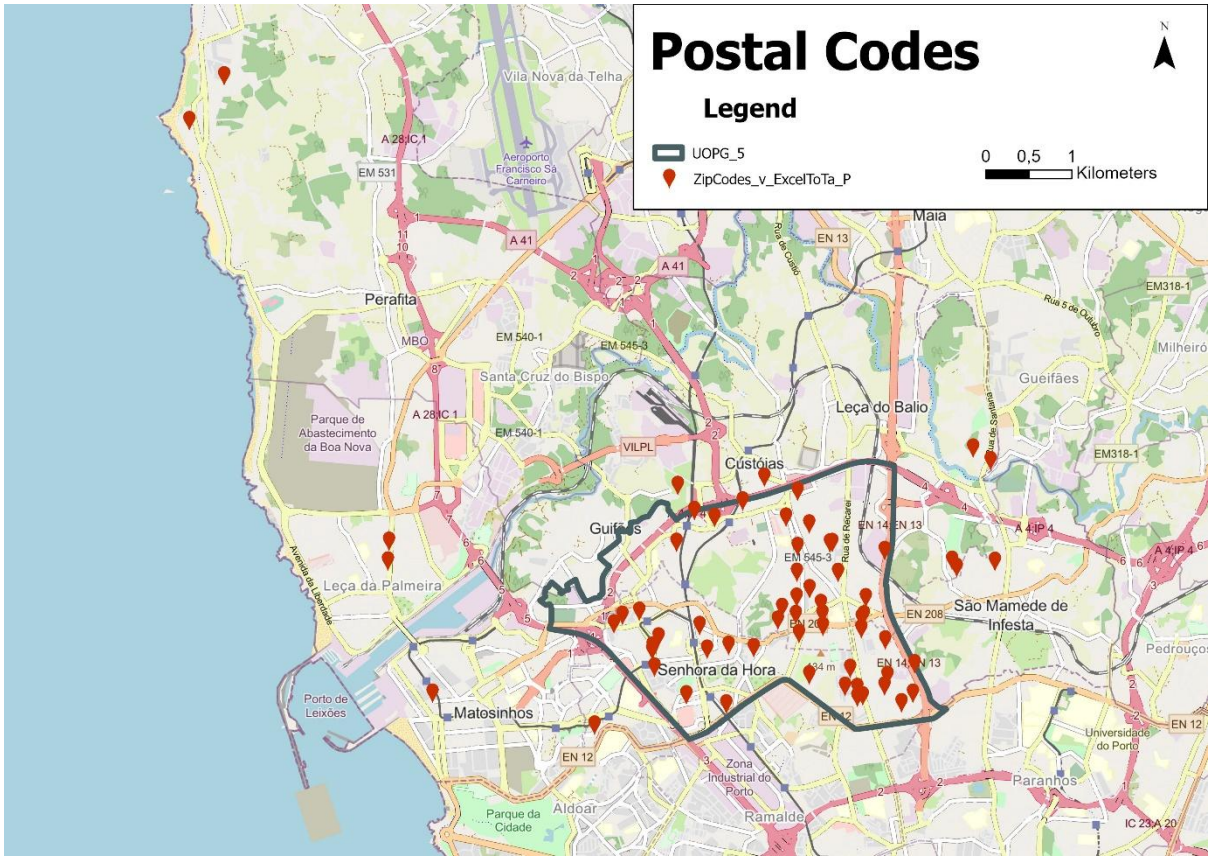


Figure 18 - Postal codes of respondents

Most respondents have been residing in their current area for over 10 years (64%), indicating a predominantly stable and long-term resident population. A smaller proportion has lived in the area for 1 to 5 years (17%) or 6 to 10 years (12%), while only 8% reported residing there for less than a year. This suggests that the sample is largely composed of established residents with a strong connection to their local environment.

Regarding commuting time, almost half of the respondents (44%) reported journeys between 15 and 30 minutes, while 21% commute for less than 15 minutes, and smaller proportions travel 31–45 minutes (5%), 46–60 minutes (14%), or more than 60 minutes (5%). Approximately 12% selected Not applicable. These results show that most respondents experience short to moderate commuting times. This does not necessarily align with the 15-minute city framework as the main mode of transportation used is unknown. Nevertheless, considering that nearly half of the respondents commute to another AMPCM, it is reasonable to assume that these journeys are undertaken primarily by public transport or private vehicle.

Additionally, 18% of respondents travel within the same municipality but to a different parish, and 11% work in the same parish they reside in. Smaller shares work from home (6%) or in another municipality (6%), while 11% reported Not applicable. Overall, this distribution reinforces the predominance of local and intra-metropolitan mobility patterns, with limited evidence of long-distance commuting among participants.

From these findings, it is plausible to anticipate that the Public Transport category will emerge as one of the most valued in the individual preference analysis - either because a significant portion of respondents already rely on public transportation for daily mobility, or because they express a desire to do so in the future.

4.2.3. Individual Preferences

To determine the weights of individual preferences, Guzman et al. (2024) employed a discrete choice modelling approach using a rank explosion procedure. In this dissertation, a Weighted Linear Combination (WLC) method was adopted, which integrates the evaluation criteria and their corresponding weights through a weighted average.

Following this methodology, weights were assigned to each service category (see sheet IPW, Annex 5). The categories most valued by respondents were Healthcare and Public Transport, while Recreation emerged as the least prioritised. Table 11 presents the resulting weights for each category.

Table 11 - Weights of each category

CATEGORY	Education	Groceries	Healthcare	Public Transport	Recreation	Services
WEIGHTS	0,17	0,19	0,22	0,20	0,10	0,12

Once the category weights were established, subcategory weights were subsequently calculated within their respective parent categories. Table 12 summarises these results. The Weights column represents the relative preference of each subcategory within its own category, while the Nested Weights column results from multiplying each subcategory's weight by that of its parent category. This adjustment ensures that all values are comparable across categories, allowing for a consistent evaluation of their relative importance within the overall framework.

The subcategories with the highest preference include bus stops, metro stations, clinics, health centres, kindergartens, and schools, which correspond, overall, to the most valued parent categories - Healthcare and Public Transport. Conversely, subcategories within Services and Recreation show lower weights, consistent with respondents' lower prioritisation of these categories.

Table 12 - Weights and nested weights for each subcategory

CATEGORY	SUBCATEGORY	WEIGHTS	NESTED WEIGHTS
Education	kindergarten	0,43	0,07
	school	0,38	0,07
	university	0,19	0,03
Groceries	bakery	0,23	0,04
	butcher	0,13	0,02
	general	0,15	0,03
	greengrocer	0,19	0,04
	market_place	0,11	0,02
	supermarket	0,19	0,04
Healthcare	clinic	0,22	0,05
	health_centre	0,41	0,09
	hospital	0,37	0,08
Public Transport	bus_stop	0,39	0,08
	metro_station	0,44	0,09
	railway_station	0,17	0,03
Recreation	arts_centre	0,29	0,03
	cinema	0,29	0,03
	community_centre	0,29	0,03
	golf_course	0,29	0,03

	gym	0,29	0,03
	museum	0,29	0,03
	park	0,43	0,04
	pitch	0,29	0,03
	playground	0,43	0,04
	sports_centre	0,29	0,03
	swimming_pool	0,29	0,03
	tennis_court	0,29	0,03
Services	bank	0,12	0,01
	bar	0,05	0,01
	cafe	0,12	0,01
	fuel	0,10	0,01
	hairdresser	0,09	0,01
	laundry	0,08	0,01
	newsagent	0,10	0,01
	pharmacy	0,17	0,02
	post_office	0,10	0,01
	restaurant	0,07	0,01

4.2.4. Lacking Services

This section consisted of two questions: one multiple-choice question asking respondents to identify the types of services lacking in their vicinity, and one open-ended question inviting respondents to elaborate on what they considered missing and why. The majority of respondents chose Recreation (37 responses) and Public Transport (27 responses) as the most deficient categories. Those who mentioned recreation, emphasised the need for more parks and green areas within walking distance, but also noted the absence of cultural venues, stating that these urban equipments are usually located outside UOPG 5. Respondents concerned with public transport described it as unreliable, complaining about long waiting times and limited destinations. The lack of metro coverage across the municipality was also a popular critic to the current public transportation paradigm.

This section plays a key role in shaping a diagnostic understanding of residents' perceptions. During the fieldwork, when the questionnaire and QR codes were distributed, this part of the survey sparked the most engagement and discussion among participants. The insights gathered here provide valuable guidance for urban planners and decision-makers, highlighting the areas of improvement most relevant to the community's daily life.

4.3. Diversity Index

To calculate the diversity index, two types of analyses were performed: one for each individual category and another for the overall diversity index. These calculations were initially done in Excel (see the DIVERSITY sheet in Annex 5) and later imported into ArcGIS Pro. The data was first added as a standalone table, then joined to the origins point layer using the Add Join tool.

However, since the origins layer consisted of points, it was not ideal for visualising spatial patterns of the diversity index. To address this, the attribute data from the points was transferred to the buildings layer - the original source of the points.

4.3.1. Education

Figure 19 illustrates the spatial distribution of educational diversity across the study area at the building level. As expected, higher diversity scores (in blue) are concentrated in areas with a greater number of educational facilities, such as Senhora da Hora, which is the only area that hosts not only schools but also universities and kindergartens.

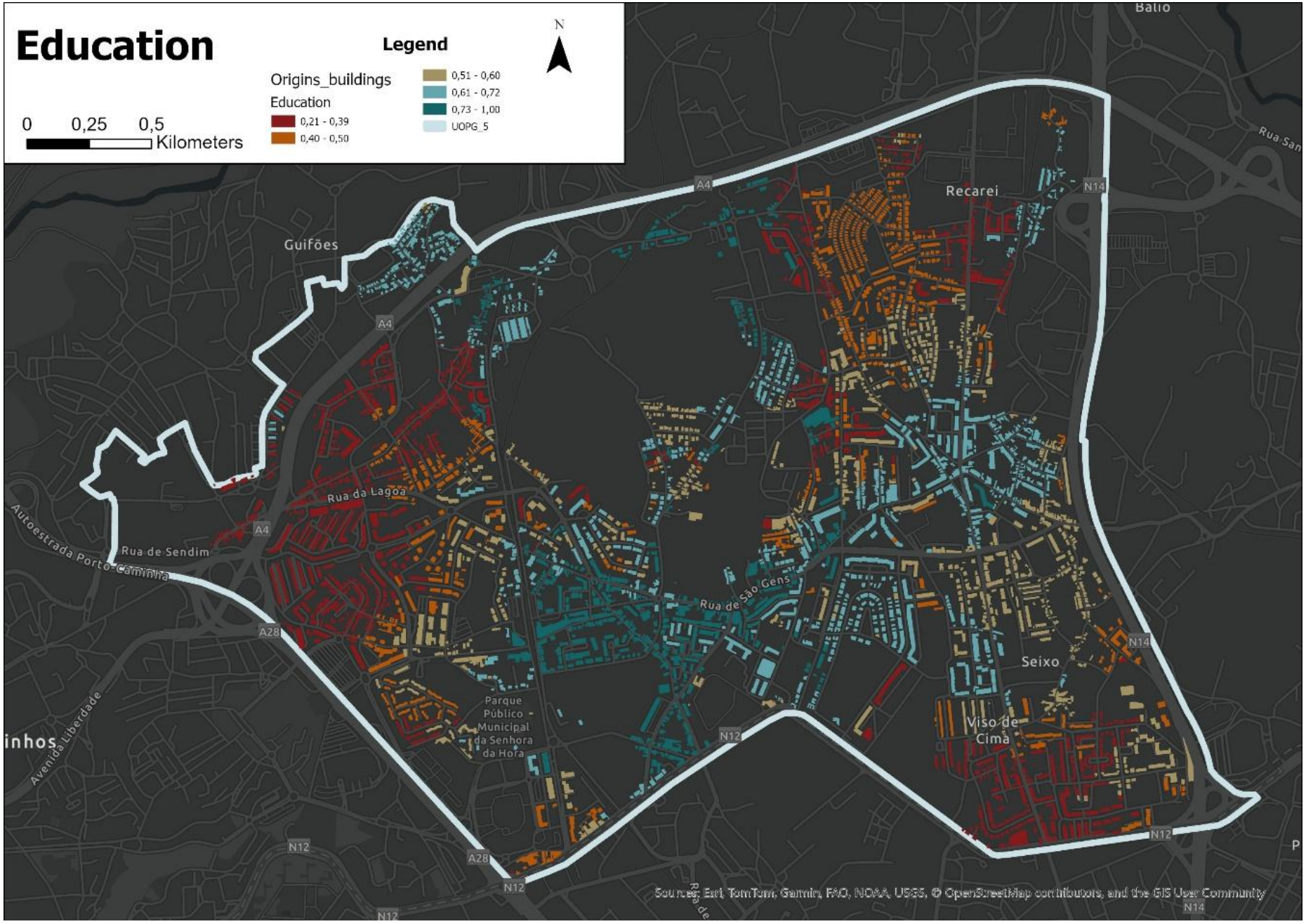


Figure 19 - Diversity Index: Education

4.3.2. Groceries

Figure 20 reveals that buildings in Senhora da Hora and Padrão da Légua have a denser distribution of grocery outlet, which roughly corresponds to areas with greater commercial activity and mixed-use buildings. In contrast, peripheral areas, particularly in the north and southeast, exhibit noticeably lower scores, pointing to potential gaps in everyday retail diversity.

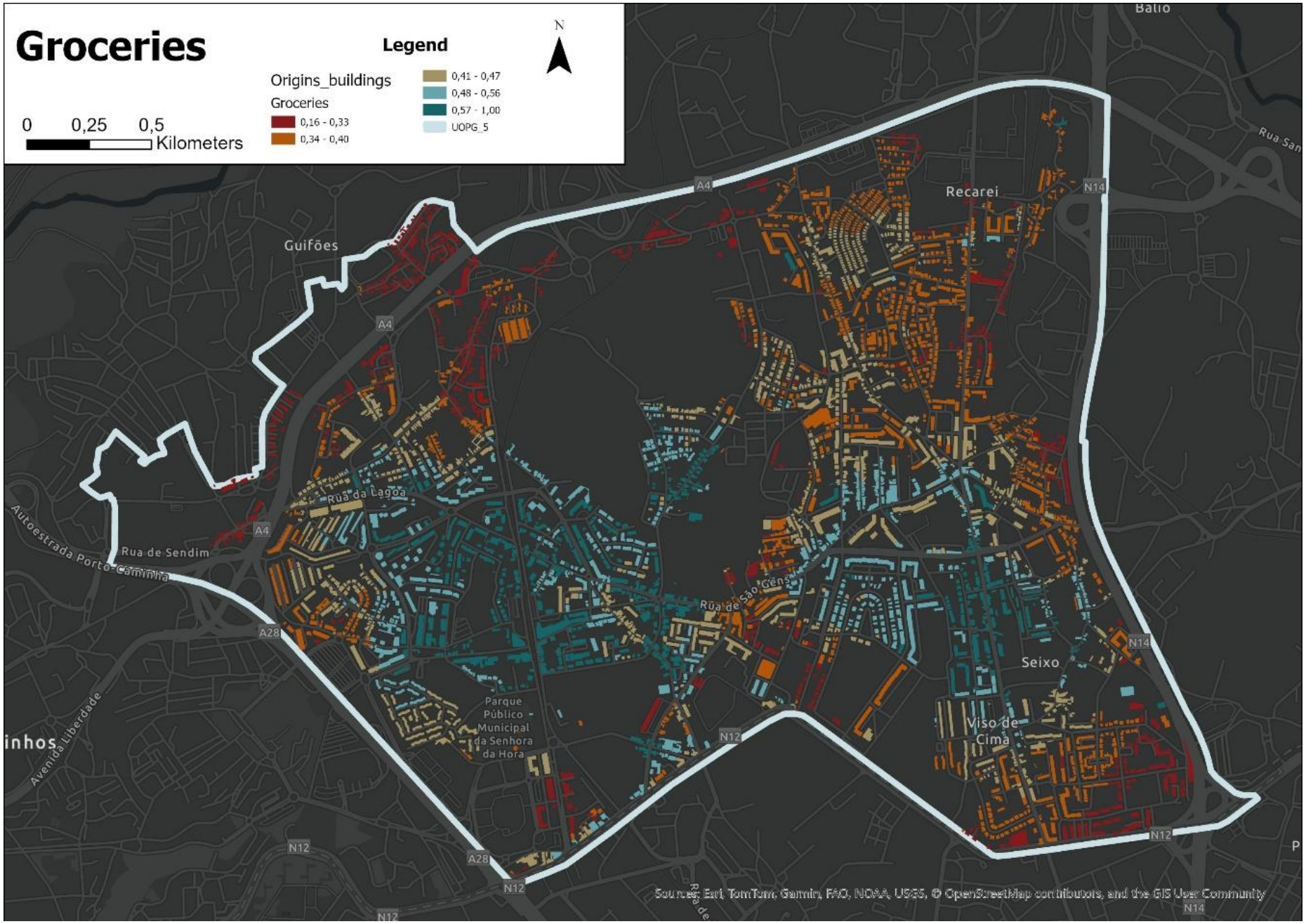


Figure 20 - Diversity Index: Groceries

4.3.3. Healthcare

Figure 21 reveals notably higher healthcare diversity in the southeastern area. This is particularly interesting, as there are no hospitals or health centers nearby - the subcategories with the highest weights in the index. It is the presence of many dental clinics in this zone that contributes to the higher scores observed. In contrast, the northeastern and far western areas show lower diversity, indicating limited proximity to healthcare services overall.

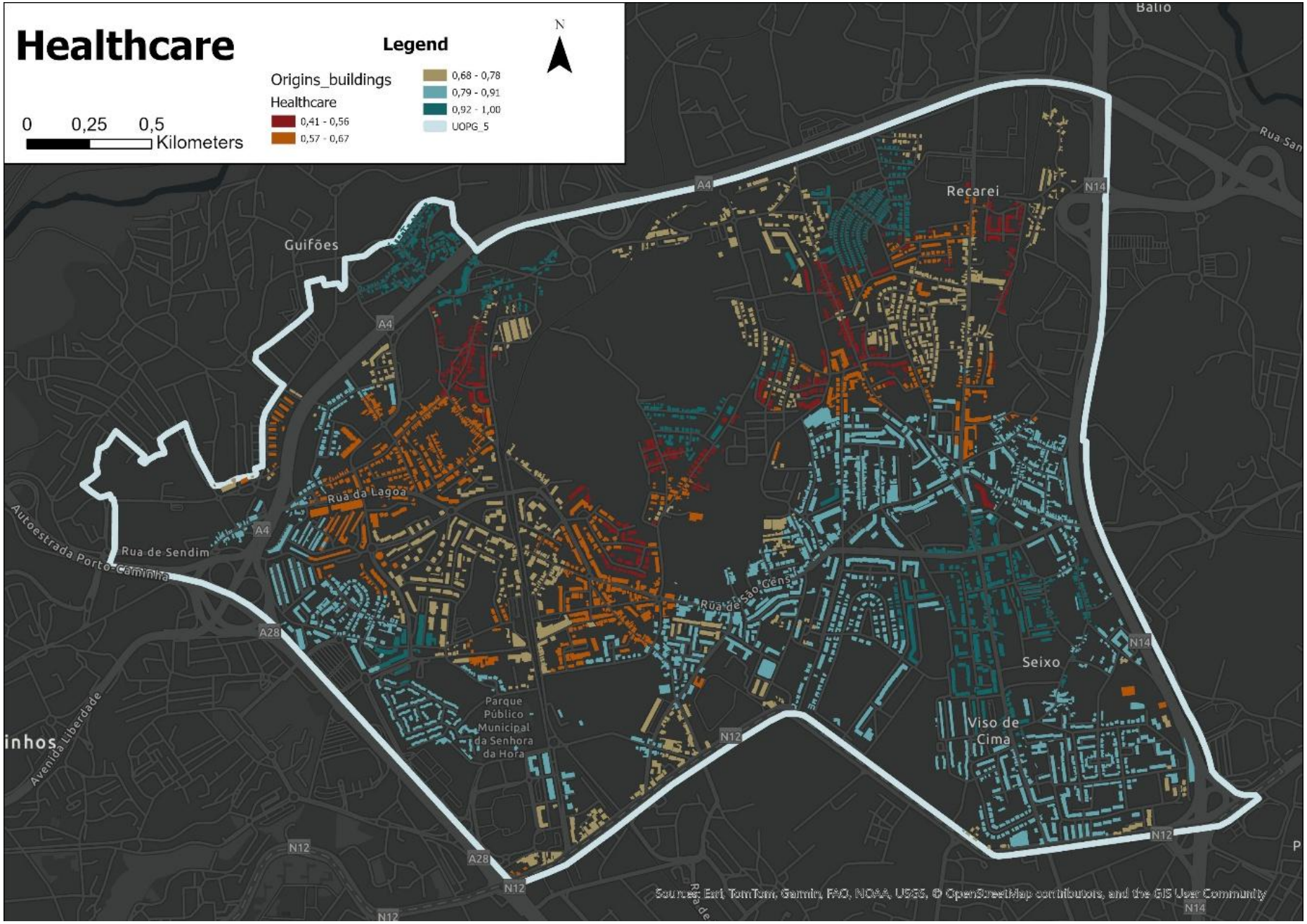


Figure 21 - Diversity Index: Healthcare

4.3.4. Public Transport

Figure 22 presents the spatial distribution of public transport diversity at the building level. Interestingly, the highest diversity scores are found in the central and eastern areas of UOPG 5, parts of which are exclusively served by bus routes, with no metro station nearby. This pattern becomes even more noteworthy when compared to the survey responses, as these areas correspond to where residents reported higher concerns about the lack of reliable public transport.

This raises an important question - does quantity equate to quality? While the model reflects a higher number of transport options, this does not necessarily translate into effective service, especially in the case of unreliable bus routes and inconsistent schedules, which respondents frequently criticised.

Another limitation of the current analysis lies in the way services are weighted: this model treats a single bus stop as equivalent to a metro station, which significantly oversimplifies real-world accessibility differences.

Moreover, it is particularly striking that areas located near key urban arteries show such poor public transport coverage. This lack of investment forces residents in relatively central locations to rely on private vehicles for daily commuting, undermining both mobility equity and the principles of the FMC framework.

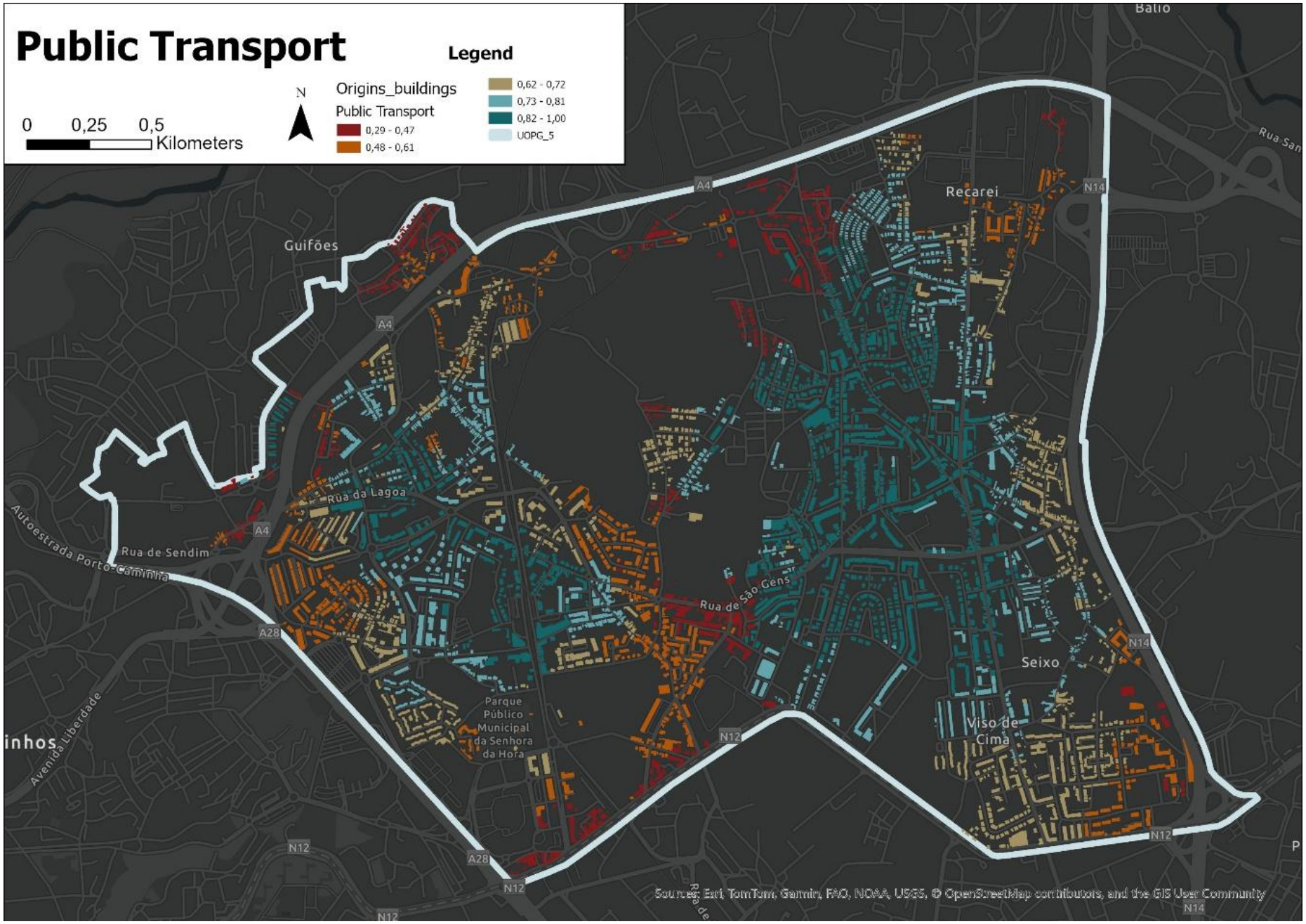


Figure 22 - Diversity Index: Public Transport

4.3.5. Recreation

Figure 23 displays higher diversity scores in areas where parks/green areas and sports-related facilities are combined. Cultural venues, on the other hand, have minimal impact on the overall scores due to their limited number and uneven distribution across UOPG 5. In the eastern part of the study area, small playgrounds and sports pitches are common, often accompanied by small green areas. On the western side, Parque do Carriçal stands out, not only because of its size, but also because each of its entrances was counted as an individual POI, acknowledging its accessibility and local relevance. The park also includes a municipal swimming pool and playgrounds, further enhancing its recreational value. In contrast, the northeastern and southeastern zones, particularly Recarei and Seixo/Viso de Cima, show significantly lower recreation diversity. These areas lack parks, public sports facilities, and cultural venues. This spatial pattern is consistent with survey responses, where over half of the participants reported that recreational opportunities were insufficient in their neighborhoods.

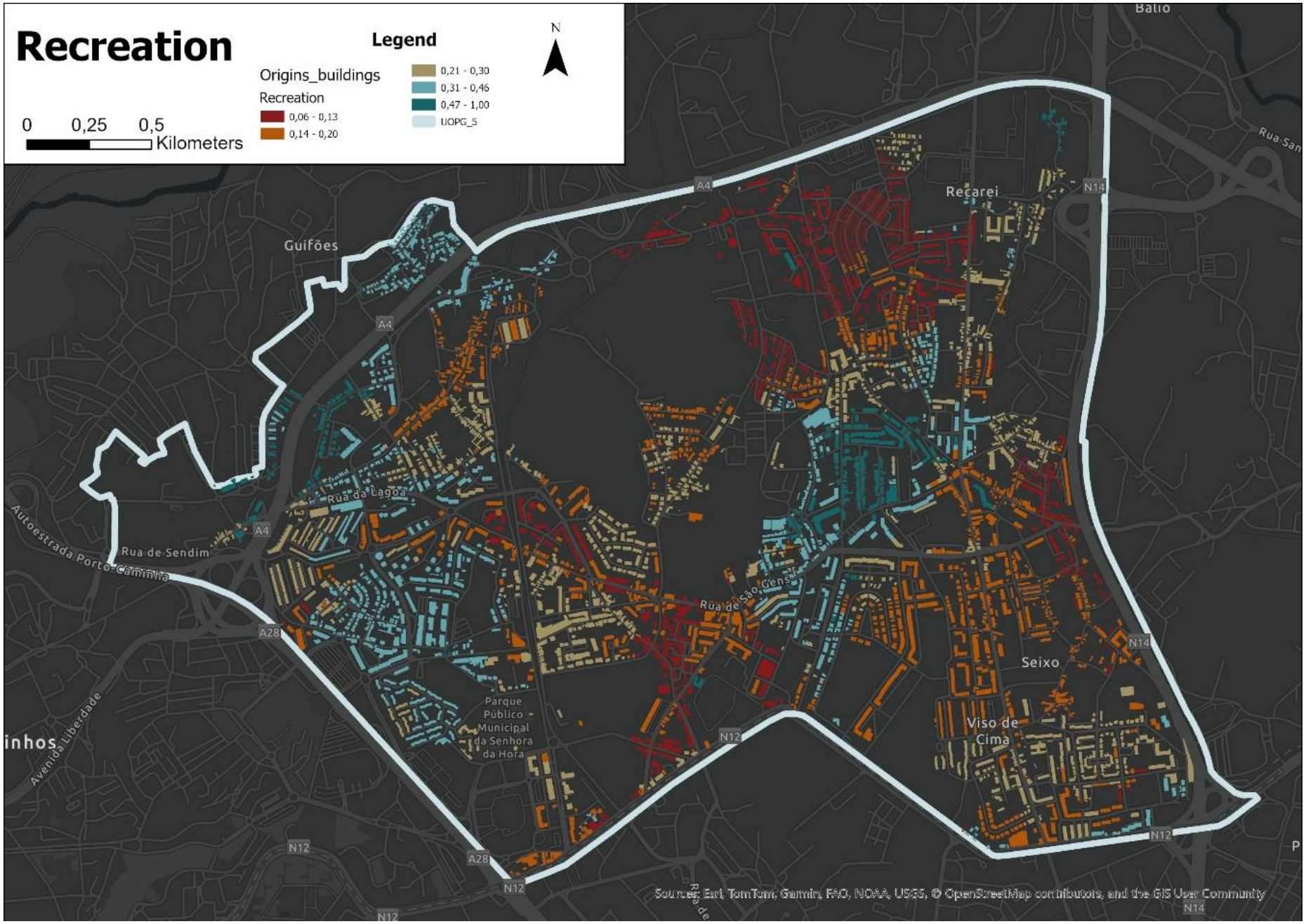


Figure 23 - Diversity Index: Recreation

4.3.6. Services

Figure 24 illustrates the spatial distribution of diversity to general services at the building level. The pattern closely resembles that observed for grocery diversity, with higher diversity scores concentrated in the central and southwestern areas of UOPG 5. This alignment can be attributed to the presence of local commercial hubs in these areas, where a greater variety and quantity of services - such as hairdressers, banks, and other daily-use establishments – are clustered. These centralities foster mixed-use development, which naturally enhances access to both goods and services. In contrast, peripheral neighborhoods, especially in the northeast and southeast, continue to show lower diversity, reflecting the lack of local commerce and fewer service options in those areas.

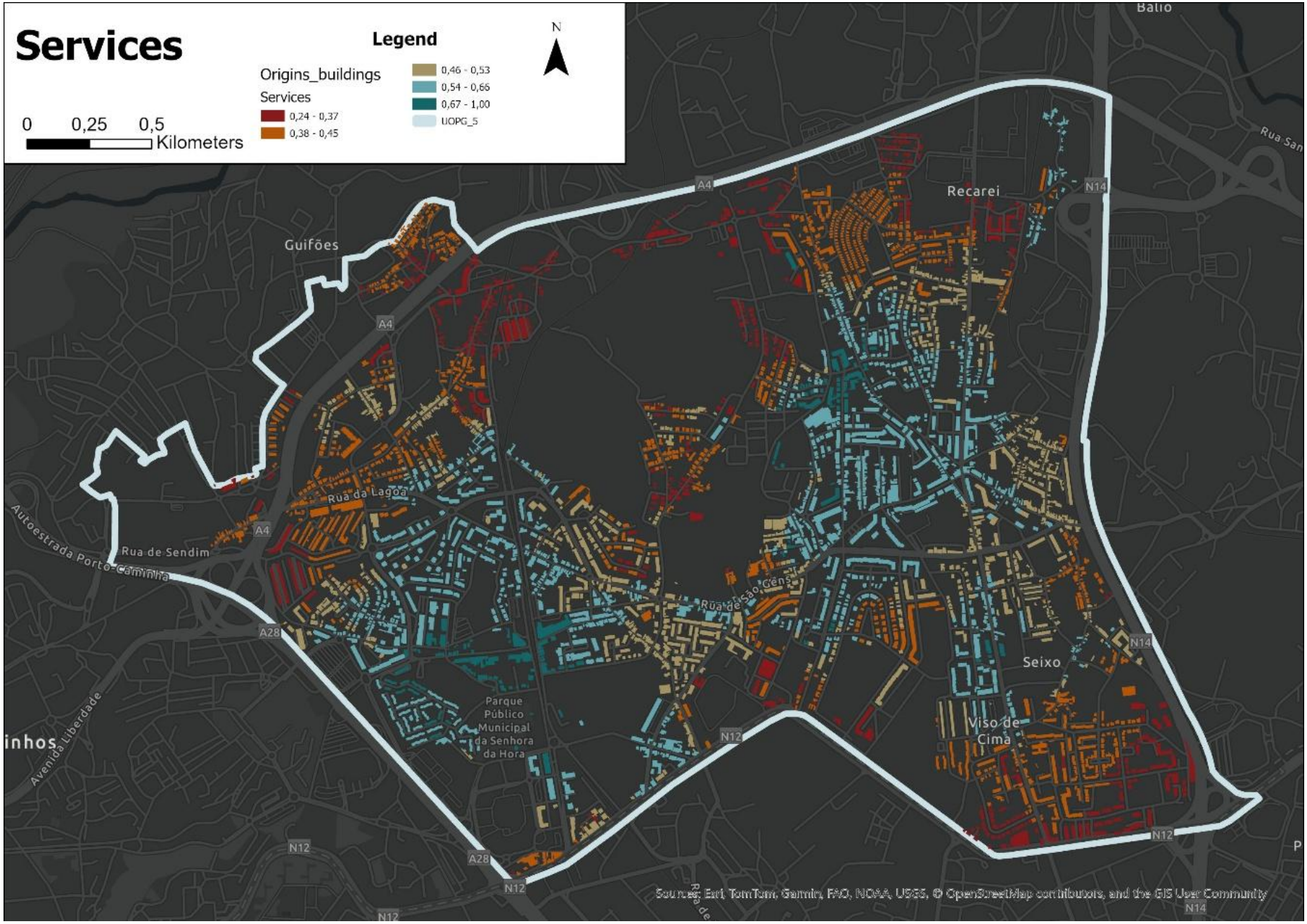


Figure 24 - Diversity Index: Services

4.3.7. Diversity Index

The overall diversity index (Figure 25) largely aligns with the centralities previously identified in the Groceries and Services categories. Areas with low diversity scores tend to be mono-functional residential zones, which explains their lack of variety in accessible services. This pattern is to be expected, given their land use.

However, both the mean and median diversity index values are 0.57, indicating only a moderate level of functional diversity within the FMC framework in UOPG 5. While this may reflect the current urban structure, it also suggests that many residents may not have local access to a full range of daily services. Only 11% of origins fall above the 90th percentile of the Diversity Index, indicating that only a small share of residents benefits from such a high level of diversity and, consequently, fully experience the potential of the FMC model.

This spatial imbalance poses challenges for equitable diversity and reinforces car dependency, particularly in underserved neighborhoods. Planners might consider targeting these areas with policies that promote mixed-use development, small-scale commerce, or community facilities. Improving diversity in these zones could contribute to a more resilient and inclusive urban fabric.

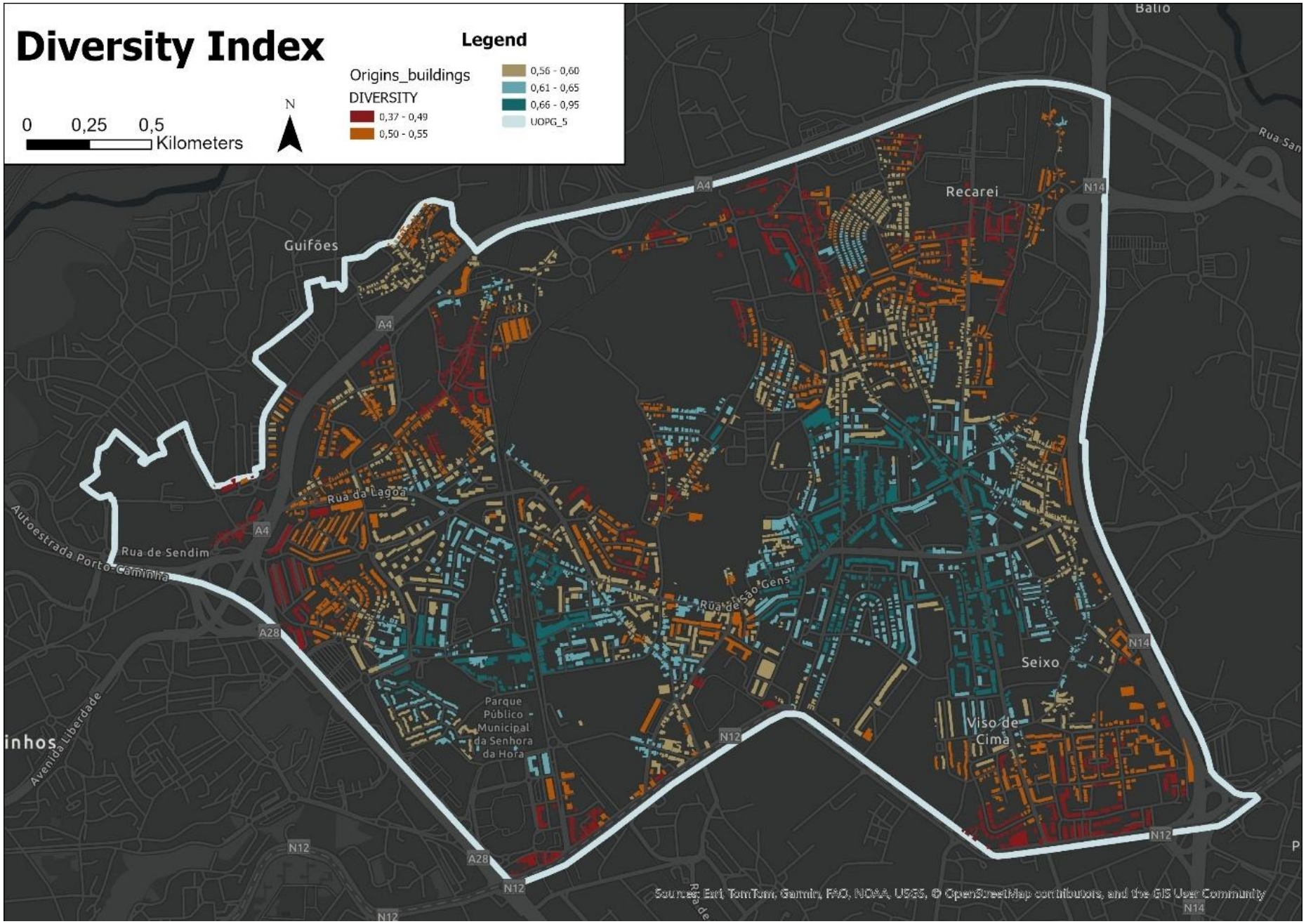


Figure 25 - Diversity Index

4.4. Discussion

The results indicate that UOPG 5 presents, overall, favourable conditions for the implementation of the FMC model, particularly within its more central zones. Areas with consolidated urban centralities and diversified land-use patterns are better positioned to support proximity-based accessibility, whereas predominantly residential zones remain constrained. These territorial disparities reflect the long-standing configuration of the urban form, which cannot be easily or rapidly transformed.

Mobility emerges as a critical enabling factor. Enhancing sustainable transport options and improving network connectivity are essential to mitigate accessibility gaps, especially in a context marked by strong inter-municipal commuting dynamics. Without effective alternatives to private car use, the principles underpinning the FMC risk remaining aspirational rather than operational.

Therefore, the effective implementation of the FMC in UOPG 5 depends on stronger coordination between municipal land-use planning and sustainable mobility policies. Proximity alone is insufficient if it is not supported by high-quality transport systems that ensure equitable access across neighbourhoods and facilitate inter-municipal connectivity. Coordination across planning levels is particularly relevant in municipalities such as Matosinhos, where daily life frequently extends beyond administrative boundaries.

The Municipality of Matosinhos has taken an important first step by recognising the relevance of habitat quality in its Municipal Housing Charter, particularly in its emphasis on access to services, infrastructure, and transport networks. However, this strategic acknowledgement must be translated into more concrete and operational measures, especially in the field of mobility. Reducing dependence on private vehicles will require targeted investments in public transport coverage and reliability, improved conditions for walking and cycling, and better integration between different modes of transport.

5. CONCLUSION

This dissertation explored proximity-centred accessibility through the lens of the FMC framework, applying it to the context of UOPG 5. The FMC model envisions compact, polycentric, mixed-use neighbourhoods where essential services are reachable within a 15-minute walk or bike ride. It promotes proximity over long-distance mobility, aiming to reduce car dependency, cut greenhouse gas emissions, and encourage healthier, more active lifestyles.

The framework employed in this dissertation aimed to provide a comprehensive diagnosis of service accessibility and functional diversity within UOPG 5, aligning with the diagnostic approach proposed by Guzman et al. (2024). The analysis combined an objective assessment, through spatial analysis, with a subjective evaluation conducted via a questionnaire survey to assess the applicability of the FMC model in the study area. Three analytical dimensions were developed: an Accessibility Index, which assessed the spatial distribution of facilities and infrastructure; a questionnaire of Individual Preferences, which identified residents' perceived importance of different categories of amenities; and a Diversity Index, which measured the variety and balance of land uses within the area.

The research objectives proposed are closely aligned with these components. Objective 1 - identify the existing distribution of infrastructure in UOPG 5 - was addressed through the Accessibility Index. Objective 2 - understand the individual preferences of the local community concerning the relative importance of different amenities within walking distance - was achieved through the questionnaire on individual preferences. Objective 3 - assess the degree of alignment between the current spatial configuration of infrastructure, community preferences, and the principles of the FMC framework – was operationalised through the Diversity Index.

With regard to Objective 1, results show that the Services category displays the highest mean accessibility, largely due to the abundance of hairdressers and beauty shops, cafés and restaurants. Conversely, the Recreation category presents the lowest accessibility scores, reflecting a limited supply of destinations within walking distance.

Objective 2 revealed a notable gap between objective and perceived accessibility. While the questionnaire responses often validated the spatial data, discrepancies emerged. In some cases, areas with moderate or even high diversity scores were still perceived as lacking by residents. This suggests that factors such as service quality, reliability and affordability play a critical role in shaping lived experiences of accessibility. The importance of integrating qualitative insights into spatial models is clear: only through this combination can we achieve a more holistic understanding of urban functionality.

The analysis for Objective 3 revealed a clear spatial divide. Higher diversity scores clustered, particularly around Senhora da Hora and Padrão da Légua where mixed-use development and local commerce are more prevalent. Conversely, lower diversity scores appeared in mono-functional residential neighbourhoods. These results suggest a continued reliance on car-based mobility in underserved areas, where residents may lack walkable access to daily services.

Beyond these spatial patterns, the results prompt critical reflection on the methodology used. The Diversity Index offers a useful overview of functional diversity, but it is built on assumptions that may oversimplify complex realities. Treating all POI equally, regardless of function or scale, can distort the actual accessibility and diversity experience. For instance, equating a metro station with a bus stop, or a hospital with a dental clinic, fails to account for significant differences in service impact. Future models should explore differentiated weighting and incorporate service-specific characteristics to improve accuracy, as defends Ulloa-Leon et al. (2023).

The results also have implications for local planning. Although the CMM has acknowledged the importance of habitat quality in its Charter, more concrete action is needed. This dissertation contributes to that effort by highlighting gaps in proximity-based access and offering evidence to support a shift from mobility-centred planning to a more localised, proximity-centred model in UOPG 5.

The study also faced limitations, most notably the low response rate to the FMC-focused questionnaire. A more robust sample would allow for deeper insights into residents' preferences and perceptions, which is an aspect that can be strengthened in future research.

Future research should also incorporate the Walkability Index and calculate the FMC Index, comparing them with the Diversity Index developed here. It would also be valuable to examine the difference between objective proximity and perceived proximity, especially considering how the relative importance of POIs can vary across individuals and contexts. The ranking of service categories in the questionnaire suggests a preference gradient but does not quantify the strength of preference. Understanding how much more a person values healthcare over recreation, for instance, could significantly inform weighting schemes in future models.

Moreover, although the FMC model is intended to function at the neighbourhood level, its effectiveness also depends heavily on connectivity between neighbourhoods. This remains a core challenge in UOPG 5, where even areas with relatively high internal diversity can feel disconnected from the broader urban fabric. Addressing this challenge requires a more integrated approach to spatial planning, one that considers both internal diversity and inter-neighbourhood links.

Looking forward, the methodology developed in this dissertation presents a scalable and adaptable tool for evaluating functional diversity across urban contexts. It can be replicated in other UOPGs or metropolitan areas, with adjustments tailored to local planning priorities and data availability. Crossing demographic data with individual preferences would also allow for equity-based analysis, helping to determine how accessibility varies by age, income, or other social factors. Additionally, given that each methodology faces limitations, it would be interesting to review how different frameworks assess the degree of applicability of the FMC model within UOPG 5.

In conclusion, this dissertation contributes to the growing body of work advocating for proximity-based urbanism. While UOPG 5 demonstrates some progress in central areas,

substantial gaps remain in achieving the balanced, inclusive accessibility envisioned by the FMC framework. By identifying these disparities and offering a replicable assessment tool, this study supports evidence-based planning and calls for more intentional efforts to foster spatial equity, reduce car dependency, and create resilient, liveable urban environments.

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7. ANNEXES

Annexes can be found here.