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The 15-Minute City in Porto, Portugal: Accessibility for the elderly

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ABSTRACT

The concept of the 15-Minute City aims to enhance urban accessibility by ensuring that essential services are within a short walking distance. This study evaluates the accessibility of Porto, Portugal, particularly for the elderly, by assessing urban density, permeability, and walkability, with a specific focus on crossings and ramps. A five-step methodology was employed, including spatial analysis using QGIS and Place Syntax Tool, proximity assessments, and an in-situ survey of crossings and ramps in the CHP. The results indicate that while the city of Porto offers a dense and walkable urban environment, significant accessibility challenges remain due to inadequate ramp distribution. The data collection identified 80 crossings, of which only 60 were listed in OpenStreetMap, highlighting data inconsistencies. Additionally, 18 crossings lacked curb ramps, posing mobility barriers for elderly residents. These findings highlight the need of infrastructure improvements to support inclusive urban mobility. The study also proposes an automated method to enhance ramp data collection for broader applications. Addressing these gaps is crucial for achieving the equity and sustainability goals of the 15-Minute City model, ensuring that aging populations can navigate urban spaces safely and efficiently.

1. Introduction

According to Moreno, Allam, Chabaud, Gall, and Pratlong (2021), there are six essential urban social functions to sustain a decent urban life: living, working, commerce, healthcare, education, and entertainment. Service priorities will vary depending on the area, where schools, parks, and healthcare may take precedence in family-oriented areas, while co-working spaces, gyms, and entertainment may be more important in young professional zones.

More recently, in the 1980s and 1990s, through Krier (2009) and especially the foundational publication by Katz, Scully Jr, and Bressi (1994), the New Urbanism movement revisited and updated these ideas. The notion of community is reinforced by pedestrian-scale design and by the importance attributed to public space as a structuring pillar of an intense, multifunctional, neighborhood-based urban life.

Peter Calthorpe's 1993 proposal for Transit-Oriented Development, a mixed-use community located at a reference distance of approximately 400 meters (a quarter of a mile) on foot from a public transport stop, is one of the approaches that gave shape to this movement. Another approach that materialized New Urbanism is that of Andres Duany and Elizabeth Plater-Zyberk for a Traditional Neighbourhood Development, whose ideal dimension is 400 meters from the periphery to the center (Katz et al., 1994).

Ultimately, Moreno's 15-Minute City model builds on these historical principles, focusing on the optimization of district size, proximity to services of general interest, diversity of functions, and prioritizing pedestrian accessibility. In the wake of New Urbanism, the resulting 15-Minute City aims to reverse the trend of modern urbanism, which spatially segmented working and living areas, by ensuring that essential urban functions (such as housing, work, health, education, and leisure) are accessible within a short walk or bike ride, thereby transforming the urban structure into a polycentric one.

In elderly-friendly areas, healthcare, green spaces, and accessible public transport may be the top priorities. The 15-Minute City model

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aims to ensure that residents can access essential services – such as healthcare, education, and recreation – within a 15 min walk or bike ride (Buliung, 2024; Moreno et al., 2021; Teixeira et al., 2024; Tian, Xiao, & Yuan, 2025). These include places for living, shopping, healthcare, education, and entertainment (Dumedah, Iddrisu, Kpevu, Dakurah, & Adams, 2024; Liu, Souter, Wang, & Vollmer, 2019; Moreno et al., 2021). The 15-Minute City model gained renewed focus due to the COVID-19 pandemic-driven shifts. It aims to improve the quality of life by redesigning cities so that residents can reach their daily needs within 15 min on foot, by bicycle, or via public transit. This concept allows citizens to conduct daily activities without excessive travel time, thereby discouraging the use of private vehicles and addressing traffic congestion (Basbas, Campisi, Papas, Trouva, & Tesoriere, 2023).

Thus, by emphasizing walkability and accessibility to daily needs within a short distance, this model promotes a more sustainable urban development (Caselli, Carra, Rossetti, & Zazzi, 2022; Rhoads, Solé-Ribalta, & Borge-Holthoefer, 2022; Shabtay, Navarro, & Thornberg, 2023) addressing sustainable development goals (SDGs), in particular SDG3, good health and well-being, SGD10, reduced inequalities, and SGD11, sustainable cities and communities (World Water Assessment Programme (United Nations), 2015).

The relationship between residential density, land use mix, and street connectivity, basic aspects that define walkability (Vos, Lättman, van der Vlugt, Welsch, & Otsuka, 2023), has a long tradition of empirical evaluation, of a qualitative nature. In situ observation, mapping, and interviews (Gehl & Svarre, 2013) are very useful for getting information about a certain population group, such as the elderly population, which is the focus of this study (Burton & Mitchell, 2006). While chronological age remains a commonly used criterion, it does not always reflect biological or functional age. The UNHCR (2025) defines older adults as those aged 60 and over, whereas WHO (2015), and OECD (2025) use 65 as the benchmark. In Portugal, local urban health and ageing policies reflect this framing. For instance, the Porto City Council's Age-Friendly City Action Plan 2023–2025 (do Porto, 2023) and the Porto Municipal Health Plan (do Porto, 2023) define older adults as individuals aged 65 or above. These documents guide strategic interventions in urban planning, aligned with active and healthy ageing paradigms, and reinforce this age demarcation as central to policy formulation.

Combining this qualitative approach with methodological approaches of a quantitative nature increases the possibility that these more specific contexts can be relatively generalized and therefore increase their impact in terms of scientific knowledge. The use of GIS-based models to assess urban walkability has been the subject of various methodological explorations, considering factors such as walking distances, travel times, and population distribution (Balletto, Ladu, Milesi, & Borruso, 2021; Caselli et al., 2022; Zhang et al., 2023). Some studies have employed computational tools and open-source data to analyze urban services locations and functions (Shabtay et al., 2023), while others have utilized sidewalk network models and percolation theory, which describes how the connectivity of a network changes as nodes or links are added, to optimize service access for vulnerable individuals (Rhoads et al., 2022). Overall, these approaches of distinct nature aim to support urban planners, policymakers, and designers in creating more walkable and accessible neighborhoods (Balletto et al., 2021; Shabtay et al., 2023).

The 15-Minute City concept is increasingly relevant for urban regeneration efforts, including the reconversion of disused public buildings and maintenance of neighborhood facilities (Balletto et al., 2021), but also of a better fruition of public spaces, function of a more balanced relation between pedestrians and the automobile. The design of the built environment is crucial for walkability, addressed by notions of proximity ("the degree to which complementary land uses (live, work, play) are intermixed and compact") and connectivity ("the directness of the route one can travel between two locations") (Cisneros, Dyer-Chamberlain, & Hickie, 2012), p.149. Road density, the complexity of street networks, and the presence of pedestrian-friendly infrastructure are therefore of extreme influence on how easily people can move around their neighborhoods (Balletto et al., 2021; Bartzokas-Tsiompras & Bakogiannis, 2023; Ulloa-Leon, Correa-Parra, Vergara-Perucich, Cancino-Contreras, & Aguirre-Nuñez, 2023; Vizmpa, Botzoris, Lemonakis, & Galanis, 2023). The presence of sidewalks (Cisneros et al., 2012), and ramps at crossings are key elements of pedestrian infrastructure (Buliung, 2024; Rhoads et al., 2022; Ulloa-Leon et al., 2023; Vizmpa et al., 2023), contributing to urban connectivity by creating a more fluid experience. They not only enable people with mobility challenges to navigate intersections easily (UK Department for Transport, 2021), but also contribute to a more comfortable environment for those using strollers, rolling shopping carts, or luggage. Urban form characteristics such as permeability, density, and functional diversity are essential to creating walkable neighborhoods (Rhoads et al., 2022; Yamu & Frankhauser, 2015).

Permeability, which refers to the ease of traversing the urban layout via different routes, is increased by higher road intersection density, and especially important to elders, as it can enhance their ability to access essential services and maintain social connections (Murgante, Patimisco, & Annunziata, 2024; Ulloa-Leon et al., 2023). Urban density and diversity, related to the concentration of people, infrastructure, buildings and landuse mix within a defined urban area (Moreno et al., 2021; Murgante et al., 2024), affect the distance between essential services and provide the terms for a more equitable access to services for all residents, especially to vulnerable populations such as older adults (Trpković, Milenković, Vujanić, Stanić, & Glavić, 2017; Ulloa-Leon et al., 2023).

The needs of all community members must be considered in urban planning and design (Moreno et al., 2021; Ulloa-Leon et al., 2023; Yamu & Frankhauser, 2015). Safety in urban mobility is one of those shared needs (Vizmpa et al., 2023), one of the six attributes of public space that make up the idea of 'streets for life', along with familiarity, legibility, distinctiveness, accessibility, and comfort (Burton & Mitchell, 2006). The presence of specialized crossings, sidewalks, and other pedestrian-friendly infrastructure can improve the safety of all commuters (Trpković et al., 2017; Ulloa-Leon et al., 2023; Vizmpa et al., 2023), being also the key for accessibility and comfort within public space use. Still, ramps at crossings in the context of the 15-Minute City are not usually explicitly mentioned in the literature, even though they are an important element with an impact on accessibility, safety, comfort, and inclusivity (Blackburn, Zegeer, & Brookshire, 2018; Guida, Carpentieri, & Masoumi, 2022; Trpković et al., 2017). By making it easier for people with mobility limitations to navigate their neighborhoods, ramps support the goal of active transportation for all residents (Balletto et al., 2021; Blackburn et al., 2018; Guida et al., 2022; Moreno et al., 2021).

Pedestrian accidents involving older adults are common, with falls being the most frequent type, often caused by physical obstacles in outdoor settings (Wennberg, Ståhl, & Hydén, 2009). The experience of a fall can lead older individuals to fear falling, prompting them to avoid activities like walking, resulting in negative consequences in physical performance, muscle strength, and changes in their center of gravity (Delbaere, Crombez, Vanderstraeten, Willems, & Cambier, 2004). Fear of moving outdoors increases the risk of developing self-reported difficulties in walking 0.5 km to 2 km (Rantakokko et al., 2009). Reduced walking can lead to a gradual loss of mobility (Rantakokko et al., 2009), which, in turn, may heighten the risk of future falls (Delbaere et al., 2010), thus initiating a harmful cycle that makes outdoor spaces perceived as less accessible and harder to navigate for older pedestrians. More than 50% of older adults report a fear of falling, which significantly negatively impacts their health-related quality of life (da Costa, Pepersack, Godin, Bantuelle, Petit, & Levêque, 2012; Sattler et al., 2025).

Although older adults consider that ramps can be supportive and a facilitator for accessing destinations, they also identify several barriers to their use even when they are available, namely: the existence of curb ramps only on one side of the street, curb ramps that are often blocked or too steep, bumpy textures, debris on curb ramps, slippery curb ramps (Rosenberg, Huang, Simonovich, & Belza, 2012). Depending on their frailty level, there is also diversity in older adults' perceptions concerning their local environment. Those presenting higher frailty perceive their environment as having fewer destinations, street connectivity as being worse, infrastructure for walking and aesthetics as being poorer, and higher levels of crime than less frail older adults, and this can generate maladaptive behaviors detrimental to their health (Martins et al., 2021). The perceived impact on older people of implementing environmental measures such as lower curbs in their residential area was positive, as assessed by Ståhl et al.'s (Ståhl, Horstmann, & Iwarsson, 2013) 5-year longitudinal study. The better individuals perceived health, the higher the overall appreciation of the environmental measures that had been taken. Li, Tian, and Ouyang (2022) revealed that greater street connectivity, a diverse mix of land uses, and closer proximity to transit were linked to better self-reported health, potentially mediated by increased physical activity. In the context of the 15-Minute City, the distance an elder can cover is influenced by walking speed and mobility (Guida et al., 2022; Rhoads et al., 2022). The standard practice considers 15 min as the preferred upper bound for regular walking trips for people with no specific mobility constraints (Alves et al., 2020; Rhoads et al., 2022). However, individual mobility restrictions can significantly reduce the distance a pedestrian can cover in 15 min. To estimate the distance for elders, Guida et al. (2022) suggests 0.8 m/s for the 65–69 age group, 0.7 m/s for the 70–74 age group, and 0.6 m/s for the 75 and older age group. Nonetheless, this is still a general statement once the existence of ramps is usually not mentioned, and it is of the uttermost importance for elders to walkabout and cross streets safely and comfortably.

While the 15-Minute City concept has gained significant attention in urban planning research, most studies focus on walkability, land-use diversity, and access to essential services, often overlooking the role of specific pedestrian infrastructure elements. In particular, there is a noticeable lack of research on the presence and distribution of ramps at street crossings and their impact on accessibility within the 15-Minute City framework. Studies assessing urban mobility for vulnerable populations, including the elderly, typically emphasize sidewalk conditions and intersection density but rarely consider the availability of ramps as a critical factor in ensuring safe and inclusive mobility. This gap in the literature limits our understanding of how cities can accommodate individuals with reduced mobility, an essential aspect of equitable urban design. By examining ramp distribution in Porto's historic center (CHP), this study seeks to address this research gap and highlight the need for ramp-inclusive planning in achieving truly accessible 15-Minute Cities.

The city of Porto, in Portugal, is characterized for land use mix density, street permeability, and walkability to urban services within the 15-Minute City context for the elderly population. The accessibility assessment to the urban services for this population group was twofold, on the one hand, in general terms, by applying this notion to the city of Porto, and, on the other hand, more specifically by studying this attribute in CHP based on more detailed evaluation of parameters related to ramps.

As a starting point for our analysis, since there are no consistent data regarding ramps in OpenStreetMap, this project team manually and exhaustively mapped crossings and ramps in the CHP. As part of the ACAMAI project, a preliminary AI object-based detection approach was introduced to automate the mapping of city accessibility constraints, including the identification of curb ramps at crossings (Moita et al., 2024). Although still under development, this approach is expected to provide automated mechanisms for identifying and mapping curb ramps in the future, therefore supporting more exhaustive accessibility assessments. Once fully implemented, the ACAMAI approach will enable the extension of this solution beyond the historic center, facilitating a city-wide evaluation of accessibility conditions and contributing to data-driven urban planning for inclusive mobility.

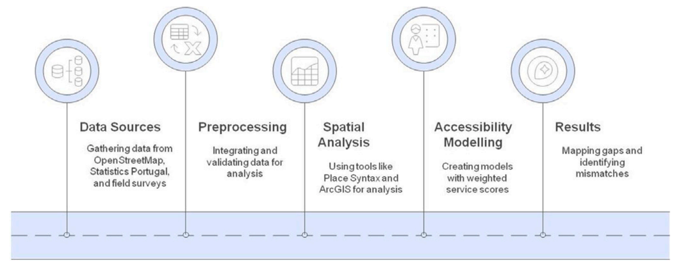


Fig. 1. Flowchart of methodological steps.

Despite the growing adoption of the 15-Minute City concept, limited research has explored the specific challenges elderly residents face, particularly in terms of crossings and ramp accessibility. This study aims to bridge that gap by analyzing Porto's walkability for older adults. The study reveals that while Porto is generally walkable, inadequate ramp distribution presents significant mobility challenges for the elderly, identifying discrepancies in open-source mapping data and proposing AI-based solutions for improved data collection. Ultimately, the paper advocates for infrastructure improvements and inclusive urban planning that prioritize the needs of aging populations to achieve equitable and sustainable city environments.

The remainder of this paper is structured as follows: Section 2 outlines the data sources and presents the five-step methodology employed to assess accessibility in Porto, with a particular focus on elderly residents. Section 3 discusses the results obtained through spatial analysis, proximity evaluation, walkability and permeability assessment, and the in situ survey of pedestrian infrastructure in the CHP. In Section 4, the main findings are summarized, and strategic recommendations are proposed to promote inclusive mobility aligned with the 15-Minute City framework. Section 5 concludes with a discussion of the study's limitations and points to future research directions.

2. Data and methods

The study follows a five-step approach: (1) evaluate the number of urban services within a 15 min walking distance from the centroid of a census block; (2) assess the proximity of urban services; (3) examine permeability within a 15 min walking distance from the centroid of a census block; (4) analyze walkability for the elderly population within a 15 min walking distance; and (5) evaluate the impact of ramp characteristics on the accessibility to urban services within the 15-Minute City for the elderly. A flow chart outlines the methodological steps of our study (Fig. 1)

2.1. Study site

This study was developed for the city of Porto, Portugal, at census block scale (Fig. 2), focusing in more detail the CHP. This smaller area, which is classified as a UNESCO World Heritage Site for its "Outstanding Universal Value", is especially challenging to assess the real (effective) conditions of the pedestrian movement due to its hilly topography, narrow and winding streets, mixed-use buildings, and diversely shaped squares. Nevertheless, the city (CHP) layout, though hilly in some areas, promotes short commutes and active transportation, with key urban services: living, working, commerce, healthcare, education and entertainment.

With a total of 231,800 residents in the last census of 2021, Porto's population decrease of 2.4% mimics the 2% decrease in Portugal from 2011 to 2021. Nonetheless, there was an increase of almost 3% in

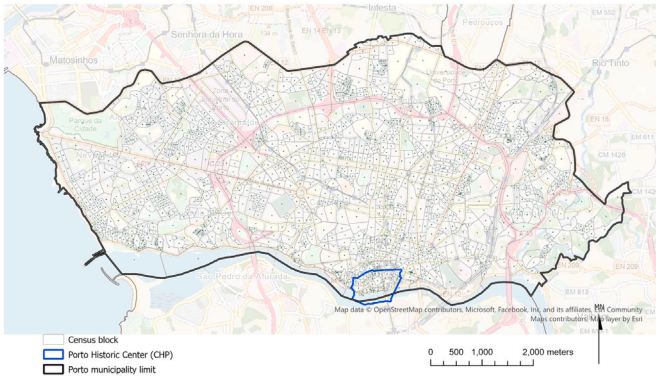


Fig. 2. Study location and CHP, 2025.

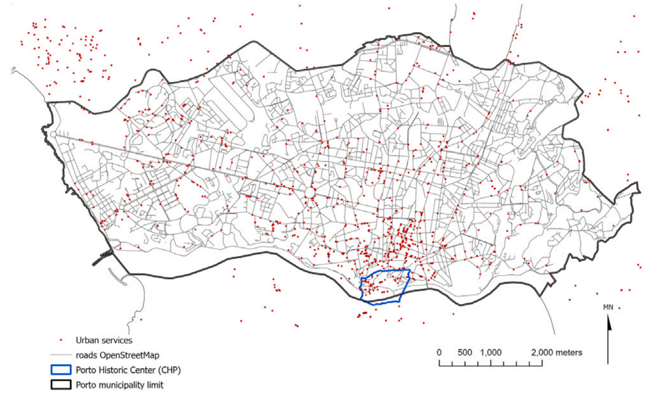


Fig. 3. OpenStreetMap urban services and roads - city of Porto, Portugal.

the population above 65 years of age in the city of Porto, reflecting the continuous increase of the aging index of 184.9 elders (population above 65 years of age for each 100 young people - 0 to 14 years of age) in 2021 (Instituto Nacional de Estatística, 2023).

2.2. Urban services

The urban services categories selected to include in this study were based on Moreno's concept of the 15-Minute City (Moreno et al., 2021), and discussed in other works (Liu et al., 2019; Murgante et al., 2024; Yamu & Frankhauser, 2015; Zhang et al., 2023) , assessing the physical accessibility to amenities, assuming their potential utility to elderly residents, not their current operational status. The presence and proximity of services are used as proxies for potential access, with emphasis placed on the infrastructural conditions.

The AR function calculates the sum of all amenities that can be reached via a network within a user-defined radius, but contrasts with other widely used location-based accessibility methods, like Gravity-Based Methods, or Floating Catchment Area models, which balance the simplicity of counting reachable destinations with the sophistication of considering the utility of those destinations. The Attraction Reach metric captures the density and diversity of urban functions, but does not explicitly incorporate the competition for services or the perceived attractiveness/quality of amenities, relying primarily on location and proximity.

The location of the urban services was obtained from the OpenStreetMap dataset (OpenStreetMap contributors, 2024), as were roads and streets. OpenStreetMap (OSM) was used as the primary data source due to its open-access nature, extensive geographic coverage, and ability to integrate with GIS-based spatial analysis tools. Despite its known limitations, such as data inconsistencies and missing attributes for pedestrian infrastructure, OSM remains a valuable resource for urban accessibility studies, providing a foundation for further validation through field surveys. The urban services that were included in each category are presented in Table 1, and their spatial distribution along with streets and roads in Fig. 3.

Based on the previous experience of other studies on European cities (Murgante et al., 2024; Rhoads et al., 2022; Teixeira et al., 2024), Chilean cities (Ulloa-Leon et al., 2023), and Asian cities (Liu et al., 2019; Tian et al., 2025), it is key to work with different levels of hierarchy in urban services (Table 1), as these must account for the various forms of mobility that take place in the city. The weight the urban services represent on the individuals should be based on the neighborhood type features, being either family-oriented areas (schools, parks, and healthcare get higher weight), or young professional zones (co-working spaces, gyms, and entertainment take priority), or elderly-friendly areas, where healthcare, financial stability, mobility, and social well-being rank higher. The explored categories include healthcare – access to doctors, pharmacies, and medical facilities is the top concern for older adults; financial services – reliable banking, pension services, and financial assistance help ensure economic security; recreational activities – social engagement, physical exercise, and hobbies contribute to mental and physical well-being; institutional (public services) – access to government services, social programs, and community centers helps maintain independence; education – lifelong learning opportunities, workshops, and senior education programs enhance cognitive health; cultural facilities – museums, theaters, and cultural events offer social and intellectual enrichment; retail activities - proximity to stores for groceries and daily essentials is important for convenience; civil defense – emergency preparedness and safety measures provide peace of mind; craft Stores – while beneficial for hobbies, they are generally lower in priority compared to essential services. The relative importance of the urban services categories was based on the weights (Table 2) proposed by Murgante et al. (2024) and adapted to the elderly population (Padeiro et al., 2022; Ulloa-Leon et al., 2023).

Table 1
Urban services per service category.

Service category	Urban Services (amenities in OpenStreetMap)
Civil Defense	Police
Craft Stores	Marketplace
Cultural Facilities	Cinema, Theater
Education	Schools, Kindergarten, Universities
Financial Services	Bank
Healthcare	Healthcare facilities, Pharmacy
Institutional, Public Services	Post office, Library
Recreational Activities	Leisure park, Place of worship, Sports
Retail Activities	Convenience stores, Supermarket

Table 2
Urban services weights per service category.

Service category	Weight	Weight (Elders)
Civil Defence	0.0182	0.05
Craft Stores	0.0182	0.03
Cultural Facilities	0.0331	0.08
Education	0.2935	0.10
Financial Services	0.1372	0.15
Healthcare	0.1372	0.30
Institutional, Public Services	0.1372	0.10
Recreational Activities	0.0617	0.12
Retail Activities	0.1372	0.07
Consistency ratio	0.0265	0.00

The QGIS geographic information system software version 3.34 (Prizren) (QGIS Development Team, 2024) and the PST Place Syntax plugin (Chalmers School of Architecture (SMoG), 2024) were used to quantify proximity, permeability, walkability and active mobility. The graph-based PST Place Syntax Tool, a spatial analysis software, evaluates urban configurations based on space syntax principles (how spaces are arranged and interrelated, focusing on the structure of street networks, buildings, and public spaces). The Attraction Reach (AR) tool supports the assessment of centrality or spatial segregation. Provided the AR assessment for each service category (Table 1), the level of service coverage index was calculated by the sum of the product of the average AR for a service category and respective weight (elders) (Table 2), adapted from Murgante et al. (2024).

To analyze the spatial distqribution of accessibility for elderly residents in the 15 min city framework, the Getis–Ord Gi* hot spot analysis (Getis & Ord, 1992) in ArcGIS Pro was performed. This method helps in understanding patterns in accessibility, resource distribution, and other urban factors relevant to the 15 min city framework. It identifies statistically significant clusters of high and low values, allowing to pinpoint areas with concentrated accessibility advantages or deficiencies. The input dataset included key service categories essential for older adults (Table 2 and Fig. 3). The analysis produced a Z-score and *P*-value for each spatial unit, where high positive Z-scores indicate clusters (areas with significant high values), low negative Z-scores indicate cold spots (areas with statistically significant low values), and areas with no significant clusters. The results were visualized using a choropleth map to highlight spatial inequalities, guiding policy recommendations for improving senior-friendly urban infrastructure.

2.2.1. Proximity

The Attraction Reach function in the PST Place Syntax plugin evaluates the sum of all urban services from a set of attraction objects that can be reached via a network within a defined radius. The AR function from the Place Syntax Tool (PST) is used as a core methodological component to assess accessibility within the 15 min city framework, with specific attention to elderly populations. Rather than identifying only the closest service, the AR function calculates the total number of reachable destinations within a defined walking distance, thereby capturing the density and diversity of available urban functions (Chalmers School of Architecture (SMoG), 2024). This approach uses origin points (e.g., census block centroids), destination layers (e.g., healthcare, commerce), and a pedestrian street network to produce a more realistic assessment of spatial accessibility. The AR function is based on network-based walking paths rather than Euclidean distances, reflecting actual travel routes through complex urban forms such as those found in CHP, an area characterized by steep terrain and narrow, winding streets. The incorporation of the 800-meter walking distance threshold, adapted for older adults, is based on a reduced average walking speed (3.2 km/h), to ensure that the 15 min limit reflects the demographic's realistic mobility constraints.

The urban services under study are the ones presented in Table 1. The attraction object was selected to be the centroid of the census block (Fig. 2). The network was compiled using GIS Tools (Caselli et al., 2022; Zhang et al., 2023), from the OpenStreetMap database (Fig. 3). The distance mode was set for walking distance, which reflects the metric distance of the shortest walking path connecting two points (census block centroid to urban service) following the segment lines. The distance was set at 800 m, assuming that an elderly person would walk at a pace of 3.2 km/h. This threshold reflects a realistic walking range for elderly individuals within a 15 min time frame, based on empirical studies of reduced walking speeds associated with ageing. Specifically, we now reference studies indicating that many older pedestrians are unable to cross streets or cover distances at average adult walking speeds, and that speeds as low as 0.6–0.8 m/s are more representative of the 65+ age group. These findings support the use of a conservative threshold like 800 m to ensure that the 15 min accessibility window remains inclusive (Alves et al., 2020; Asher, Aresu, Falaschetti, & Mindell, 2012; Chalmers School of Architecture (SMoG), 2024; Trpković et al., 2017).

2.2.2. Permeability

Permeability is an indicator of both walkability and connectivity, which depends on the density of intersections (New South Wales Government, 2025), where higher intersection density tends to more walkable and connected environments (Rodrigue, 2024). Intersections with more road links show greater connectivity. Density of intersections (number of intersections per km^2) was assessed for each census block by the ratio of the number of intersections within an 800 m walking distance (approximately 15 min) to the total number of intersections in a circular area with an 800 m radius. The intersections were obtained from the OpenStreetMap dataset (OpenStreetMap contributors, 2024), and the PST Place Syntax plugin (Chalmers School of Architecture (SMoG), 2024).

2.2.3. Walkability and active mobility

Even though the OpenStreeMap dataset on crossings includes attributes to assess accessibility (e.g., kerb=lowered/raised/flush, or ramp=yes), most crossings do not have these characteristics validated for the city of Porto. For example, 99% of the crossings within the municipality of Porto do not have information on wheelchair accessibility, and 94% do not have information on kerb characteristics.

Ramps at crosswalks are considered important for people with reduced mobility, allowing them to safely transition between the sidewalk and the road. *In situ* exhaustive data collection on the characteristics of the road crossings and ramps was carried out in the CHP (Fig. 2) on all streets, locating the crossings, the number of ramps per crossing, and restrictions on mobility.

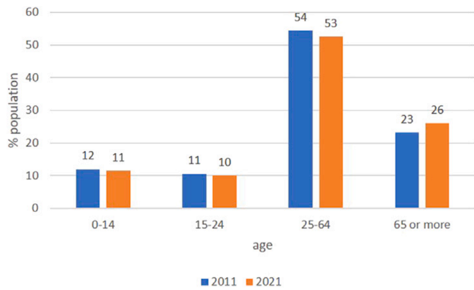
3. Results and discussion

3.1. Population profile

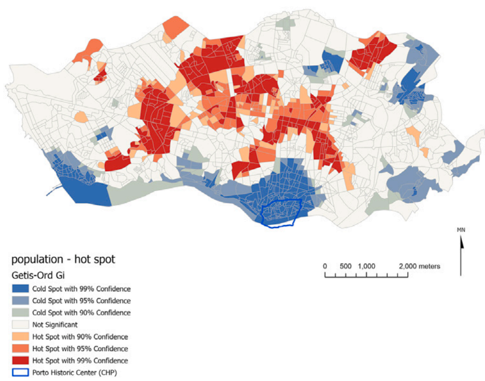
Data from the Statistics Portugal (Instituto Nacional de Estatística, 2023) shows that there is a prevalence of 26% of population above 65 years of age (Fig. 4a). Elderly population is not evenly distributed (Fig. 4c–d), as certain areas show a higher number of elder residents, and others lower number of elder residents (Fig. 4b–c). The darker red regions represent clusters of areas with a higher number of elder residents (Fig. 4b), which do not follow the pattern for the percentage of elders (Fig. 4d), suggesting that some areas are populated with older individuals, although not significantly populated (e.g., CHP).

3.2. Urban services

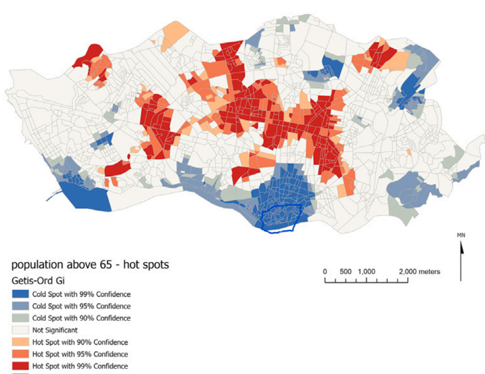
The Getis/Ord Gi* analysis of the urban services assessed in this study (Table 2) for the city of Porto, shows a cluster around the CHP, and cold spots in the periphery of the city (Fig. 5). The central area, shown in red, has the highest concentration of urban services, while the peripheral blue regions have the least. The light gray areas represent non significant intermediary levels of urban services. Comparing this to the elderly population distribution (Fig. 4), there seems to be a mismatch — many areas with a high elderly population have lower access to urban services. This suggests a potential challenge in ensuring accessibility to essential services like healthcare, transportation, and social support for older residents living in areas with fewer urban facilities. The observed mismatch between elderly population density and urban service accessibility in Porto's Historic Center can be explained by a combination of spatial, historical, and infrastructural factors. Research by Brandão Alves et al. (Alves, Cruz, Rother, & Strunk, 2021) demonstrates that a significant proportion of pedestrian pathways in the UNESCO-designated center feature steep slopes, over 5% gradient on 23% of the network, which severely limits walkability for older adults, even though it remains their primary residential area. Additionally, the medieval urban morphology – narrow, winding, and uneven streets – further exacerbates physical barriers to mobility, discouraging the provision or retention of essential services near elderly clusters.



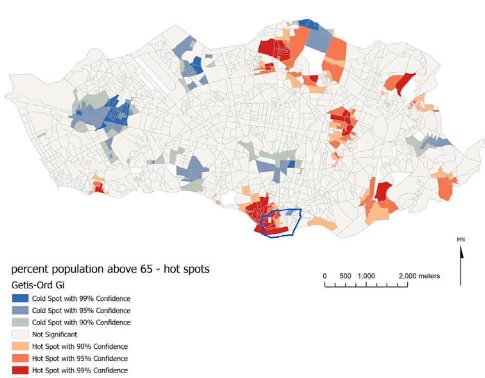
(a)



(b)

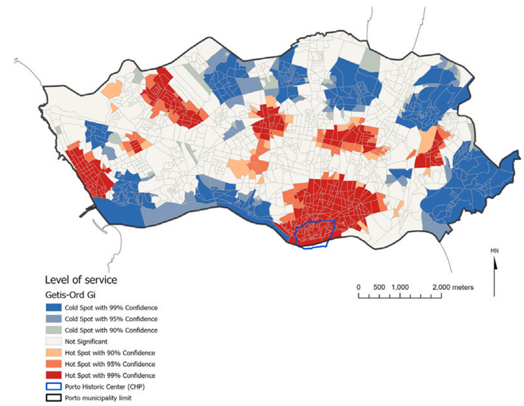


(c)

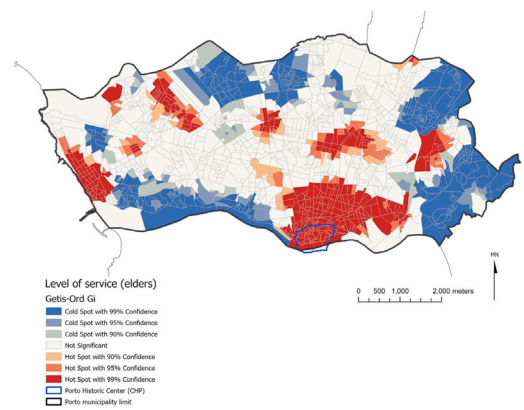


(d)

Fig. 4. Population profile of Porto, Portugal from the 2011 and 2021 Census database: (**a**) population evolution 2011–2021 (**b**) spatial concentration of population above 65 (hot-spot); (**c**) spatial concentration of population (hot-spot); (**d**) spatial percentage of population above 65 (hot-spot).



(a)



(b)

Fig. 5. CHP, 2025: (**a**) level of service by census block; (**b**)level of service by census block of population above 65 years of age.

Furthermore, urban revitalization in the Historic Center has recently focused on tourism and commercial redevelopment, including the conversion of residential units into short-stay tourist accommodations, often displacing traditional services or limiting their expansion. Together, these topographical and socio-economic dynamics help explain why high concentrations of older residents do not necessarily coincide with adequate proximity to urban services, underscoring the need for equity-driven urban planning that takes into account terrain constraints and demographic-specific service needs. Addressing these disparities would require improving public services and infrastructure in elderly-dense areas to ensure their well-being and quality of life (Logan et al., 2022; Merlo, Johansson, Nilson, & Chapman, 2025).

Clustering of the number of intersections within 800 m walking distance reveals distinct spatial patterns across Porto (Fig. 6). Areas clustered in red highlight a higher concentration of junctions and pedestrian crossings within the walking distance, typically aligning with more central and densely populated by urban services (Fig. 6). In contrast, the clusters represented in blue show varying degrees of intersection density, suggesting a gradation of walkability and connectivity in the peripheral area of the municipality, away from the CHP.

The spatial clustering of intersections indicates that central areas in Porto benefit from higher permeability, while peripheral neighborhoods face greater connectivity challenges. This supports prior research emphasizing that intersection density is a key determinant of walkability (Guzman, Oviedo, & Cantillo-Garcia, 2024; Rodrigue, 2024; Vizmpa et al., 2023). However, our findings bring with new insights by showing that even in high-density areas, the absence of essential pedestrian infrastructure – such as ramps – can limit walkability for

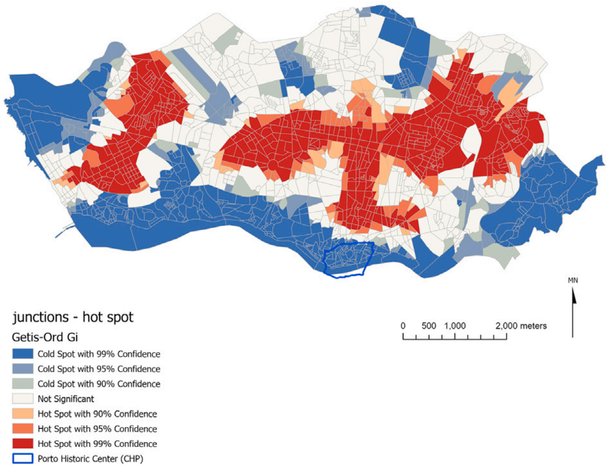


Fig. 6. Spatial clustering of intersections within 800 m walking distance per census block.

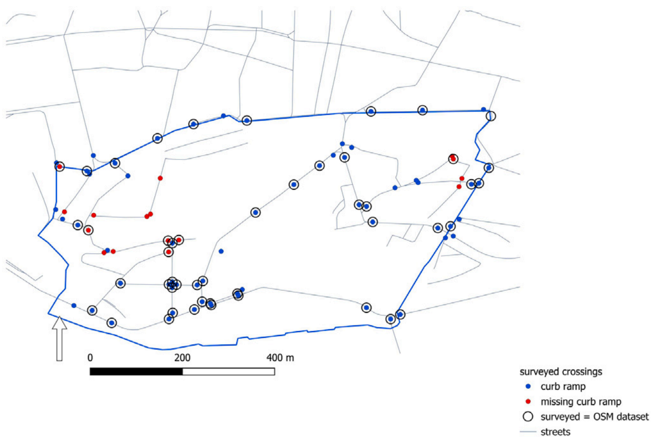


Fig. 7. OpenStreetMap and surveyed ramps at crossings in the CHP, 2025.

elderly individuals, an aspect often overlooked in standard walkability assessments.

The existence of ramps in pedestrian crossings is crucial for ensuring walkability, particularly for individuals with reduced mobility. In the exhaustive *in situ* survey conducted in the CHP, 80 crossings were identified, providing a more complete representation of pedestrian infrastructure than the OpenStreetMap dataset, which lists only 60 crossings (Fig. 8). Notably, only 48 crossings from the data collection are coincident with those in OpenStreetMap, suggesting significant gaps in the dataset (Fig. 7). This discrepancy highlights the limitations of crowd-sourced mapping efforts, where pedestrian infrastructure, such as ramps, may be under-reported or outdated. Furthermore, even when crossings are mapped, the presence or absence of ramps is not always consistently documented, limiting the dataset's usability for urban accessibility studies.

The presence of curb ramps at pedestrian crossings plays a vital role in enabling mobility, particularly for elderly individuals who may have difficulty navigating curbs. From the 80 crossings identified in the CHP, 18 of these lacked curb ramps. The absence of ramps creates physical barriers that limit the independence of elderly residents, forcing them to take longer, less direct routes or avoid certain areas altogether. This contradicts the fundamental principles of the 15-Minute City, which aims to promote equitable access to urban spaces (Noworól, Kopyciński, Hałat, Salamon, & Hołuj, 2022). Without fully accessible pedestrian infrastructure, the city risks excluding a significant portion of its population from safe and efficient mobility.

Fig. 8. Example of surveyed and OpenStreetMap crossings locations.

Our findings reveal that 22% of surveyed crossings lacked curb ramps, significantly impacting mobility for elderly residents. This aligns with previous studies emphasizing the importance of pedestrian infrastructure for walkability (Burton & Mitchell, 2006; Ulloa-Leon et al., 2023), yet highlights a critical gap in how urban accessibility is assessed. While research on the 15-Minute City has extensively covered sidewalk connectivity and intersection density (Balletto et al., 2021; Rhoads et al., 2022), the role of ramps remains underexplored, underscoring the need for more inclusive planning approaches. Without these, seniors face isolation and limited access to healthcare, social activities, and daily essentials, contradicting the principles of the 15-Minute City.

The mismatch between elderly population distribution and urban service availability suggests that certain areas with high concentrations of older residents lack sufficient access to essential services. This echoes findings by Murgante et al. (2024), Padeiro et al. (2022), who stress that urban service proximity alone does not ensure accessibility, particularly for vulnerable populations. Our study extends this discussion by demonstrating how missing pedestrian infrastructure, such as ramps, exacerbates mobility barriers, reinforcing spatial inequalities in service access.

To align with the 15-Minute City model, urban planners must prioritize the retrofitting of crossings with accessible ramps, ensuring that all residents, regardless of age or ability, can navigate their environment with ease. Addressing these gaps would not only enhance mobility but also contribute to fostering a more inclusive and age-friendly city. Addressing these limitations is essential for creating inclusive urban environments that support the mobility of all individuals.

Porto, Portugal's second-largest city, presents a compelling case for the 15-Minute City concept, with its compact urban fabric and historic neighborhoods. Its walkable streets, traditional mixed-use buildings, and proximity of essential services create an environment where residents can access work, education, commerce, and leisure within a short distance. The city's ongoing efforts to enhance cycling infrastructure, pedestrian zones, and public transit further align with the principles of sustainability and urban resilience. However, challenges such as steep topography and rising tourism-driven gentrification highlight the need for inclusive planning to ensure accessibility for all residents (Caselli, Carra, Rossetti, & Zazzi, 2021; Caselli et al., 2022; Perez & Fusco, 2024).

The absence of adequate infrastructure, particularly curb ramps, at pedestrian crossings creates physical barriers that can exacerbate the fear of falling and moving outdoors, prompting older individuals to avoid walking or take longer, less direct routes, which ultimately contributes to a gradual loss of mobility and heightens the risk of future falls, and contradicts the fundamental principles of the 15-Minute City, which aims to promote equitable access to urban services (Logan et al., 2022; Moreno et al., 2021). While prior studies have highlighted the potential of the 15-Minute City for fostering active mobility and sustainable urban development (Shabtay et al., 2023; Teixeira et al., 2024), our study underscores that without adequate pedestrian infrastructure, these benefits may not be fully realized for aging populations. This suggests that future applications of the 15-Minute City model must integrate a more detailed accessibility assessment to ensure inclusive mobility solutions.

4. Summary and conclusions

This study assessed the accessibility of Porto, Portugal, for elderly residents within the framework of the 15-Minute City, focusing on the availability of ramps at pedestrian crossings. The findings highlight several key challenges:

- a significant 22% of crossings lacked curb ramps, creating mobility barriers for elderly individuals and those with reduced mobility;
- there is a mismatch between elderly population distribution and urban service availability, with many areas having a high concentration of older residents but poor accessibility to essential services;
- while central areas of Porto demonstrate high walkability due to intersection density, the absence of proper pedestrian infrastructure – particularly ramps – limits mobility and connectivity, even in well-connected neighborhoods;
- OpenStreetMap data on pedestrian crossings showed notable inconsistencies, with only 48 of the 80 surveyed crossings matching OpenStreetMap records, thus highlighting gaps in publicly available urban accessibility data.

To address these challenges and ensure equitable urban mobility, we propose

- retrofitting crossings with accessible ramps, and prioritizing the installation of curb ramps at all pedestrian crossings, particularly in areas with high elderly populations;
- enhance urban accessibility data collection and incorporate AI-based automated mapping tools (such as the ACAMAI project) to improve accessibility assessment and ramp identification;
- ensure that pedestrian infrastructure, including crossings and ramps, is explicitly considered in urban mobility and land-use planning policies, and walkability models include ramp availability as a core metric for assessing accessibility, particularly for vulnerable populations;
- strengthen collaboration between urban planners, accessibility advocates, and technology platforms, like OpenStreetMap, to improve data accuracy and inclusivity;
- implement pilot programs in historic areas, such as Porto's UNESCO World Heritage Center, to test and refine pedestrian-friendly mobility solutions.

While older adults often view certain environmental improvements, such as the installation of lower curbs in their neighborhoods, positively, these interventions do not necessarily translate into a reduced perception of difficulty when walking or into increased outdoor activity. For urban planning strategies like the 15 min city to meaningfully enhance the lives of older residents, it is insufficient to rely solely on automated tools that quantify accessibility, connectivity, or spatial integration. A more impactful approach requires the active and continuous involvement of older adults throughout the planning and implementation process. Recognizing their lived experience and capacity for civic participation is essential. A truly age-inclusive community is one that not only accommodates but also listens to and learns from its older citizens. They are best positioned to identify which services matter most, which areas require better accessibility and mobility, and how existing urban interventions have helped (or hindered) their quality of life. Their participation ensures that measures are not only appropriate and cost-effective but also socially sustainable. Moreover, cities must commit to ongoing reflection and adaptation, continually assessing and improving how well their infrastructure, policies, and services meet the diverse needs and abilities of older adults.

By addressing these infrastructure gaps, Porto and other cities adopting the 15-Minute City model, can create more inclusive, age-friendly urban environments that enable safe, independent, and equitable mobility for all residents, which align with sustainable urban development goals, particularly SDG3 on Good Health and Well-Being, SDG10 on Reduced Inequalities, and SDG11 on Sustainable Cities and Communities.

5. Limitations of the study

A key limitation of this study is its reliance on physical distance as the sole proxy for accessibility within the 15 min city framework, particularly concerning older adults. While spatial proximity captures geographic closeness, it neglects critical factors such as competition for services (i.e., the supply–demand balance), differences in the attractiveness and quality of amenities, and the effects of distance decay, which assumes uniform mobility and travel behavior. These oversights are especially problematic for older populations, whose mobility is shaped by slower walking speeds, reduced physical capacity, and greater sensitivity to environmental and temporal constraints. It should also integrate subjective data obtained through questionnaires or qualitative methods to better capture the perception of accessibility. This approach can provide a more nuanced understanding of accessibility, particularly for older adults, whose mobility is often influenced by non-physical factors such as the subjective feeling of safety while crossing the street, the fear of falling, and the perceived effort of walking. It could also leverage emerging mobility big data sources such as smart transit cards, location-based services, bike-sharing systems, GPS, and mobile signal data (Fang, Liu, & Kwan, 2025; Wei, Kan, Kwan, Liu, Su, & Chen, 2024; Willberg, Järv, Väisänen, & Toivonen, 2021) to provide more nuanced insights into real-world travel patterns. Nonetheless, such datasets may exclude individuals with limited digital access or usage, potentially introducing bias in assessing amenity accessibility for aging populations within the 15 min city paradigm.

CRediT authorship contribution statement

Maria Simas Guerreiro: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Maria Alzira Pimenta Dinis:** Writing – review & editing, Writing – original draft, Project administration, Investigation, Funding acquisition. **Sara Sucena:** Writing – review & editing, Writing – original draft, Conceptualization. **Isabel Silva:** Writing – review & editing. **Madalena Pereira:** Writing – original draft, Data curation. **Diogo Ferreira:** Data curation. **Rui S. Moreira:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis, Conceptualization.

Declaration of Generative AI and AI-assisted technologies in the writing process

During the preparation of this work, the authors used ChatGPT (OpenAI) to enhance the clarity of writing and proofread the manuscript. After using this service, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

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Data availability

Data will be made available on request.

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