Elderly and urban services

A GIS support tool to measure pedestrian accessibility

Ph.D. Thesis

Federica Gaglione

Università degli Studi di Napoli Federico II

Dipartimento di Ingegneria Civile, Edile e Ambientale

Università degli Studi di Napoli Federico II

Department of Civil, Architectural and
Environmental Engineering

PhD in Civil Systems Engineering
XXXIII Cycle

Elderly and urban services
A GIS support tool to measure pedestrian accessibility

PhD candidate
Ing. Federica Gaglione

Supervisor
Prof. Arch. Carmela Gargiulo
Co-Supervisor
Dr. Ing. Caitlin Cottrill

scientific book

Federica Gaglione

SUMMARY

1.1 Introduction

In all the Western industrialized countries and in many developing ones, the population ageing index is gradually increasing. It is foreseen that by 2050 one in every five persons throughout the world will be at least 70 years old and that elderly people in 64 countries will represent 30% of the entire population. Scientific and technological advances, combined with economic development, have favoured an increase in life expectancy and consequently a decline in mortality. However, if on one hand longevity is in itself an achievement due to advances in medicine, on the other hand this demographic trend has numerous implications in economic, social security, welfare and urban terms. The United Nations Population Fund predicts that the world population is expected to reach 9.7 billion people in 2050, of which 22% will be over 60 years old and 33% will be living in developed countries. In particular, in some countries, such as China, India and the United States, the number of people aged 60 or older will be over 100 million.

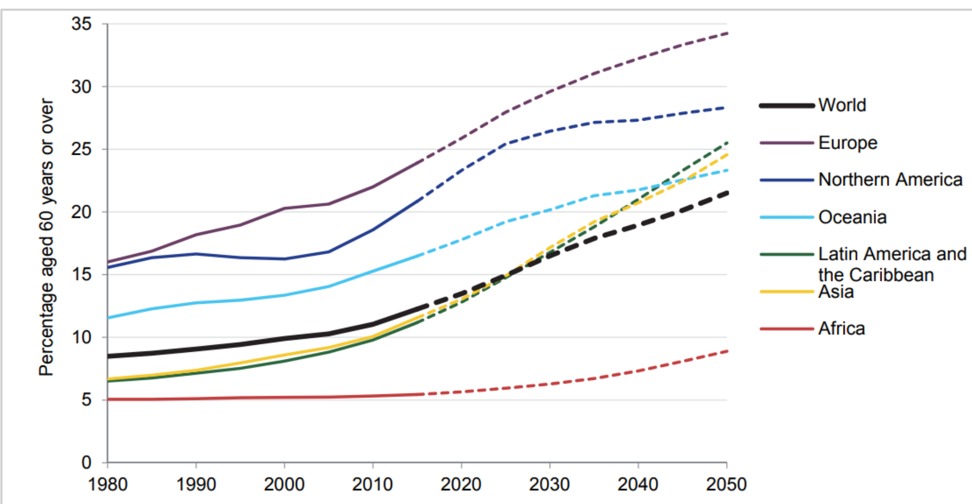


Fig.1 Population growth trend over 65 population
Source: The World Bank

The demographic change taking place poses many challenges of a social, economic, cultural, and urban nature. Since the Second World Assembly on Ageing held in Madrid in 2002, the strengths on which to trigger and develop the International Action Plan for the social integration of elderly people have emerged. The most important of these strengths relate to safeguarding elderly people's health and well-being and fostering an environment favorable to their capacity for initiative. The Plan, like many other subsequent documents, underlies the need for a cultural overturning marked by the recognition of the elderly as a resource and no longer as a problem or an obstacle to the social and economic development of the community and the organization of the urban system, bearing in mind that in Italy, for example, in 2017 life expectancy at 65 has reached 21 years and the related health conditions are expected to improve. Until a few years ago, the elderly were considered as fragile, lonely, marginalized citizens, unable to live independently and have generally been "invisible" in studies and planning instruments that involved the governance of urban transformations. In recent years, a major focus of attention has been paid to the matter in urban development policies, too (OECD, 2015), which should be oriented towards the construction of an urban model aimed at reducing the social exclusion of the elderly. In recent studies and research on the topic the ease of movement within the urban system and, more generally, accessibility to places and services, is identified as a prerequisite for the possibility of including elderly people in the economic and social processes (Glass et al., 2006; Newson & Kemps, 2005). Facilitating elderly people's mobility is a key element in ensuring their commitment to civic and social life, their participation in community activities and in pursuing human interactions that enrich their health, well-being and quality of life (Dickerson et al., 2007). This ongoing demographic trend has triggered a series of changes in the way cities develop, are managed and support the community. The World Health Organization has played a primary role in identifying the key elements necessary to create the conditions for "active aging" long before one reaches old age. The "World report on ageing and health" (World Health Organization, 2015) emphasizes the importance of adapting the built environment to the needs and requirements of older persons, with the aim of replacing outdated policies that primarily consider elderly people as passive subjects, with policies that recognize everyone's right and responsibility to play an active role and participate in community life at every stage of life, including old age. In this context, the WHO Global Network for Age-friendly Cities and Communities is a fundamental reference. It collects and shares experiences from over 250 cities around the world and was established to stimulate and inspire cities and communities to become increasingly age friendly. These primary objectives have evolved over time, and today the aim is to create a model of a city based on the principles of "universal design"; that is, to make public and private spaces of the city accessible to every category of people, regardless of the age, cultural, social, physical and cognitive conditions.

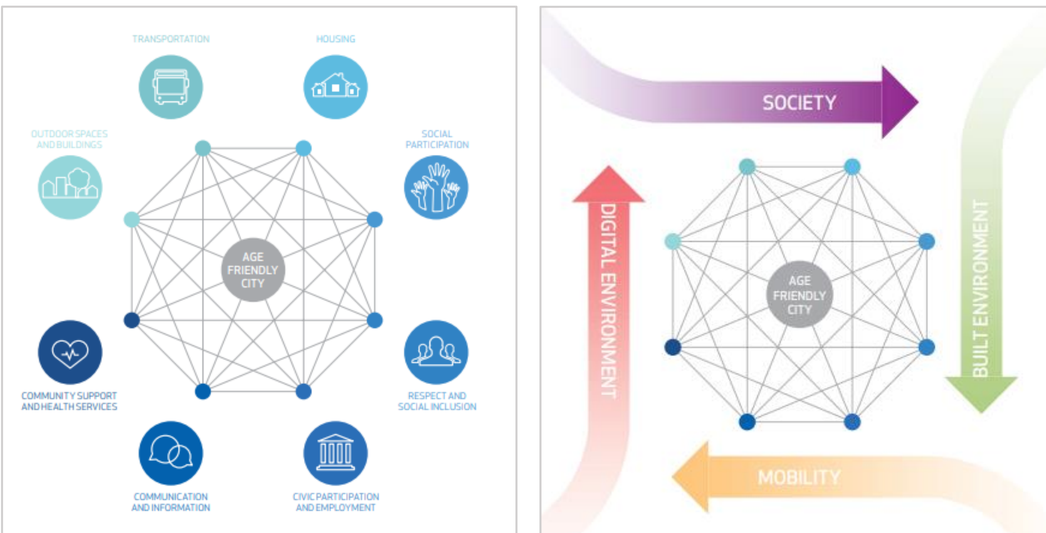


Fig.2 The age friendly city framework

Source: Shaping Ageing Cities (ARUP)

The accessibility envisaged by the Global Network is multidimensional, but much of it rests on the travel opportunities elderly persons can take advantage of within the urban system, according to its physical and functional characteristics (Gargiulo et al., 2018). Urban accessibility can be considered as one of the elements cutting across most of them. In fact, the concept of urban accessibility generally includes the physical characteristics (mobility and open spaces networks), the functional characteristics (services and activities) and the socio-economic characteristics (lifestyles and habits) of an urban system (Papa et al., 2017; Papa, 2018). In the holistic-systemic perspective of the governance of urban transformations, the set of all these components affects the quality of life of individuals and the opportunities for their civic participation and social inclusion. In detail, this study refers to the "urban accessibility" concept according to the holistic-systemic approach of the governance of urban transformations. Urban accessibility can be meant as the possibility of a person with any ability to reach and make use of places and activities of interest without barriers.

1.2 Social inclusion of the elderly in urban areas [1]

Since the early 1980s, a number of initiatives on the ageing issue have been promoted at governance and academic levels, although the "Global Age-Friendly Cities" project launched by the WHO in 2006 is often mentioned as the starting point for age-friendly community development initiatives. In 1982, the UN approved the first Report on the World Assembly on Ageing to encourage dialogue among policy makers, researchers and non-governmental organizations on "the implications of aging of the population for social, economic and urban development" (UN resolution 37/51). From 1991 to 1999 (the latter declared Year of Older Persons), several institutional documents were formulated to provide the main principles of well-being to older people, such as dignity, independence and participation. As a matter of fact, these documents were characterized by a continuous re-definition of terminologies, planning aim priority settings and the need to stress the use of a multidisciplinary approach. If the UN policy recommendations of the 90s were mainly led by gerontological research, at the turn of the new millennium the attention shifted from social, civic and health matters to how to enhance people's quality of life as they age through urban planning (Biggs et al,. 2000; Buffel et al., 2012). This shift occurred for four main reasons: (i) the demographic change related to an increase in the number of people aged 60 and over, which percentage increased from 7.7% in 1950 to 17.8% in 2010 and is expected to rise to 25.1% by 2050 (OECD, 2015); (ii) the urbanization process, as population growth and urbanization are projected to add 2.5 billion people to the world's urban population by

---

[1] This paragraph is contained in the research work of Gargiulo, C., Zucaro, F., & Gaglione, F. (2018). A Set of Variables for the Elderly Accessibility in Urban Areas. *TeMA - Journal of Land Use, Mobility and Environment*, 53-66. https://doi.org/10.6092/1970-9870/6864

2050 (Beard & Petitot, 2010); (iii) the spread of accessibility, sustainability, and universal design concepts referred to in some urban models such as healthy, compact and harmonious city; (iv) the idea to promote retirement communities to make people age in places that effectively meet their needs, also according to WHO principles of an age-friendly city (Evans, 2009; Rioux & Werner, 2011). In particular, the "new" interest in accessibility in cities within urban and transport planning, community design and urban geography disciplines promoted broad research on how the built environment can facilitate relating people, promoting walkability and integrating different land uses (Angelidou, 2017; Batty, 2009; Busi, 2011; Tiboni & Rossetti, 2014). This has encouraged discussion of the need for "appropriate, well-designed places in which people choose to spend time and that provide a place for people to relax, socialize and be part of urban life" (Gehl & Matan, 2009; Meshur, 2016; Papa et al., 2016a). In other words, during the 2000s the questions raised about elder friendly cities started to relate to the mutual interaction between built environment and behavior of the elderly: on one hand, the physical and functional organization of the urban system determines the opportunities to move and participate in the urban life (offer) and, on the other hand, the behaviours and habits of the elder population (demand) require a new configuration of the physical and functional assets of settlement systems. This duality has fueled the debate on how to increase urban accessibility for elderly people, both by referring to the infrastructure network (transport and communication) and the localization of activities of interest (Arentze et al., 2008; Broome et al., 2010; Broom et al., 2012). A large literature has been produced on the key factors that influence travel decisions among people aged 65+ (Ritter et al., 2002; Spinney et al., 2009; Szeto et al., 2017; Wong et al., 2017), while a more recent line of research has focused on how the network of open spaces (built and not built) promotes socialising, participation, and interaction among the elderly and the physiological benefits needed for the maintenance and enhancement of physical health and functioning (Sugiyama & Thompson, 2007; Yuryev et al., 2010). In particular, studies such as Temelová & Slezáková (2014), Yung et al. (2016) and Wen et al. (2018) have investigated elderly preferences about localization, accessibility, infrastructure and facility, maintenance and landscape features of public open spaces, by stressing the need to provide a sense of place that is inclusive and caring for its older users. However, little research has explored the development of forms of city organization to improve the urban accessibility of the elderly, giving particular attention to the mutual influences among the forms of urban organization, the configuration of infrastructural networks and lifestyles. This brief overview highlights the relevance of the topic and constitutes the prelude to the definition of the entire project outlined in the following chapter.

1.3 Aims and objectives of research work

Demographic change raises interesting research questions in the field of urban studies, particularly on the organization of settlement systems. The dual relationship between the organization of the urban system (offer) and the mobility of the population over-65 (as for every city user) has stimulated the scientific debate on how to improve both the accessibility of the elderly to transport and pedestrian networks (Luk and Olszewski, 2003) and services of interest (Guagliardo 2004). The analysis of recent developments on the issue of accessibility to urban places and services for the elderly population develops along two lines of research. A first line of research aimed at investigating issues of improving the access of the elderly population to urban services, intervening on the offer of transport networks to achieve a single service of interest (McGrail & Humphreys, 2014; Lin et al., 2014). A second line of research is on the physical and functional characteristics of the built environment that influence the "walkability" of the elderly at a neighborhood scale (Furukawa & Wang, 2019; Kim et al., 2019; Lee & Park, 2014). Few studies have been involved in the integration of the two approaches by systematizing the pedestrian characteristics that influence the access of the elderly population to the urban services of their interest.

To fill this gap, this study seeks to integrate and overcome the limits of approaches based on accessibility to places and activities, taking into account both the characteristics of the network and the "needs" linked to the behavior of specific segments of the population. Urban accessibility can be understood as the possibility for a person with any capacity to reach and use places and activities of interest without barriers (Gaglione et al., 2019). To this end, the purpose of this research work in the field of urban planning is to develop a decision support tool by developing a methodology to be provided to public administrations to identify critical areas where priority should be given, and how the implementation of certain interventions improves pedestrian accessibility to urban services for the elderly population (Cottrill et al., 2019).

The main research objective is to develop a decision support tool in the GIS environment that has as its central element the classification of the urban fabric in terms of pedestrian accessibility for the elderly to key urban services. This classification is carried out on the basis of the relationships between the behavior of people over 65, in terms of walking speed, the characteristics of the pedestrian network and the offer of urban services. In addition, it identifies the Functional Accessibility Soft Zones (FASZones), or the areas of access to urban services for the population over 65, which represent an innovation of the now outdated concept of the traditional basin and which constitutes an element from which to start to improve the organization and distribution of urban services. The objective of the research, in fact, is to innovate in the disciplinary body of urban planning, from a methodological point of view, traditional urban planning concepts to adapt them to the new socio-cultural needs.

References

Angelidou, M. (2017). Smart city planning and development shortcomings. *TeMA. Journal of Land Use, Mobility and Environment,* 10(1), 77-94. doi:http://dx.doi.org/10.6092/1970-9870/4032

Arentze, T., Timmermans, H., Jorritsma, P., Kalter, M. J. O., & Schoemakers, A. (2008). More gray hair—but for whom? Scenario-based simulations of elderly activity travel patterns in 2020. *Transportation*, 35(5), 613-627. doi:https://doi.org/10.1007/s11116-008-9170-z

Batty, M. (2009). Accessibility: in search of a unified theory. *Environment and Planning B: Planning and Design*, 36, 191-194. doi:https://doi.org/10.1068/b3602ed

Beard, J. R., & Petitot, C. (2010). Ageing and urbanization: can cities be designed to foster active ageing? *Public Health Reviews*, 32(2), 427-450. doi:https://doi.org/10.1007/BF03391610

Biggs, S., Bernard, M, Kingston, P., & Nettleton, H. (2000). Lifestyles of belief: narrative and culture in a retirement community. Ageing & Society, 20(6), 649-672. Retrieved from https://www.researchgate.net/profile/Paul_Kingston/publication/232004739_Lifestyles_of_belief_Narrative_and_culture_in_a_retirement_community/links/542fcf400cf277d58e921782.pdf

Broome, K., Nalder, E., W orrall, L., & Boldy, D. (2010). Age-friendly buses? A comparison of reported barriers and facilitators to bus use for younger and older adults. *Australasian journal on ageing*, 29(1), 33-38. doi:https://doi.org/10.1111/j.1741-6612.2009.00382.x

Broome, K., Worrall, L., Fleming, J., & Boldy, D. (2012). Evaluation of flexible route bus transport for older people. *Transport Policy*, 21, 85-91. doi:https://doi.org/10.1016/j.tranpol.2012.02.005

Buffel, T., Phillipson, C., & Scharf, T. (2012). Ageing in urban environments: Developing 'age-friendly' cities. *Critical Social Policy*, 32(4), 597-617. doi:https://doi.org/10.1177/0261018311430457

Busi, R. (2011). Metodi, tecniche e politiche per la mobilità nella città amica. *TeMA. Journal of Land Use, Mobility and Environment*, 4(2). doi:http://dx.doi.org/10.6092/1970-9870/442

Cottrill, C., Gaglione, F., Gargiulo, C., & Zucaro, F. (2020, August). Defining the characteristics of walking paths to promote an active ageing. In Pedestrians, Urban Spaces and Health: *Proceedings of the XXIV International Conference on Living and Walking in Cities (LWC, September 12-13, 2019, Brescia, Italy) (p. 209)*. CRC Press. ISBN: 978-0-367-46171-3

Dickerson, A. E., Molnar, L. J., Eby, D. W., Adler, G., Bedard, M., Berg-Weger, M., ... & Page, O. (2007). *Transportation and aging*: A research agenda for advancing safe mobility. The Gerontologist, 47(5), 578-590. doi:https://doi.org/10.1093/geront/47.5.578

Evans, S. (2009*). Community and ageing: Maintaining quality of life in housing with care settings. Portland*, US: Policy Press

Furukawa, H., & Wang, Z. (2019, March). A Route Evaluation Method Considering the Subjective Evaluation on Walkability, Safety, and Pleasantness by Elderly Pedestrians. *In International Conference on E-Business and Telecommunications* (pp. 408-416). Springer, Cham. doi: https://doi.org/10.1007/978-3-030-24322-7_51

Gargiulo, C, Zucaro, F., Gaglione, F. (2018), A set of variables for elderly accessibility in urban areas*, TeMA. Journal of Land Use, Mobility and Environmen*t, Special Issue 2, p. 53-66, oct. 2018, ISSN 1970-987 doi: http://dx.doi.org/10.6092/1970-9870/5738

Glass, T. A., De Leon, C. F. M., Bassuk, S. S., & Berkman, L. F. (2006). Social engagement and depressive symptoms in late life: longitudinal findings*. Journal of aging and health*, 18(4), 604-628. doi:https://doi.org/10.1177/0898264306291017

Guagliardo, M.F. (2004). Spatial Accessibility of Primary Care: Concepts, Methods and Challenges. *International Journal of Health Geographics,* 3(3), .doi: https://doi.org/10.1186/1476-072X-3-3

Kim, M. J., Seo, S. H., Seo, A. R., Kim, B. K., Lee, G. Y., Choi, Y. S., ... & Park, K. S. (2019). The Association of Perceived Neighborhood Walkability and Environmental Pollution with Frailty Among Community-dwelling Older Adults in Korean Rural Areas: A Cross-sectional Study. *Journal of Preventive Medicine and Public Health*, 52(6), 405. doi: https://doi.org/10.3961/jpmph.19.166

Lee, H. S., & Park, E. Y. (2014). Comparing the environment for elderly pedestrians among different-sized cities of Gyeonggi province in Korea. *International Journal of Urban Sciences*, 18(1), 76-89. doi: https://doi.org/10.1080/12265934.2013.863449

Lin, T. G., Xia, J. C., Robinson, T. P., Goulias, K. G., Church, R. L., Olaru, D., ... & Han, R. (2014). Spatial analysis of access to and accessibility surrounding train stations: A case study of accessibility for the elderly in Perth, Western Australia*. Journal of Transport Geography*, 39, 111-120. doi: https://doi.org/10.1016/j.jtrangeo.2014.06.022

Luk, J., & Olszewski, P. (2003). Integrated public transport in Singapore and Hong Kong. *Road & Transport Research*, 12(4), 41-51.

McGrail, M. R., & Humphreys, J. S. (2014). Measuring spatial accessibility to primary health care services: Utilising dynamic catchment sizes. *Applied Geography*, 54, 182-188. doi: https://doi.org/10.1016/j.apgeog.2014.08.005

Newson, R. S., & Kemps, E. B. (2005). General lifestyle activities as a predictor of current cognition and cognitive change in older adults: a cross-sectional and longitudinal examination. The *Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, 60(3), P113-P120. doi:https://doi.org/10.1093/geronb/60.3.

OECD. (2015). Ageing in Cities. Paris, F: OECD Publishing. doi:https://doi.org/10.1787/9789264231160-en

Papa, E. (2018). Pianificare per l'accessibilità: misure, applicazioni e barriere. Retrieved from: http://fondazionefeltrinelli.it/app/uploads/2018/05/Ebook__-Mobilita%CC%80-e%CC%80-sviluppo___.pdf

Papa, R., Angiello, G., & Carpentieri, G. (2017). *Integrating Land Use, Transport and Energy Planning*. FedOA Press: Napoli.

Rioux, L., & Werner, C. (2011). Residential satisfaction among aging people living in place. *Journal of environmental psychology*, 31(2), 158-169. doi:https://doi.org/10.1016/j.jenvp.2010.12.001

Ritter, A. S., Straight, A., & Evans, E. L. (2002). Understanding senior transportation: Report and analysis of a survey of consumers age 50. Washington, US: AARP, Public Policy Institute. Retrieved from https://assets.aarp.org/ rgcenter/il/2002_04_transport.pdf

Spinney, J. E., Scott, D. M., & Newbold, K. B. (2009). Transport mobility benefits and quality of life: A time-use perspective of elderly Canadians. *Transport policy*, 16(1), 1-11. doi:https://doi.org/10.1016/j.tranpol.2009.01.002

Sugiyama, T., & Thompson, C. W. (2007). Outdoor environments, activity and the well-being of older people: conceptualising environmental support*. Environment and Planning A*, 39(8), 1943-1960. doi:https://doi.org/ 10.1068/a38226

Szeto, W. Y., Yang, L., Wong, R. C. P., Li, Y. C., & Wong, S. C. (2017). Spatio-temporal travel characteristics of the elderly in an ageing society. *Travel Behaviour and Society*, 9, 10-20. doi:https://doi.org/10.1016/j.tbs.2017.07.005

Temelová, J., & Slezáková, A. (2014). The changing environment and neighbourhood satisfaction in socialist high-rise panel housing estates: The time-comparative perceptions of elderly residents in Prague. *Cities*, 37, 82-91. doi: https://doi.org/10.1016/j.cities.2013.12.002

Tiboni, M., & Rossetti, S. (2012). L'utente debole quale misura dell'attrattività urbana. *TeMA. Journal of Land Use, Mobility and Environment*, 5(3), 91-102. doi:http://dx.doi.org/10.6092/1970-9870/1200

Wen, C., Albert, C., & Von Haaren, C. (2018). The elderly in green spaces: Exploring requirements and preferences concerning nature-based recreation. *Sustainable Cities and Society*, 38, 582-593 doi: https://doi.org/10.1016/j.scs. 2018.01.023

Wong, R. C. P., Szeto, W. Y., Yang, L., Li, Y. C., & Wong, S. C. (2017). Elderly users' level of satisfaction with public transport services in a high-density and transit-oriented city. *Journal of Transport & Health*, 7, 209-217. doi:https:// doi.org/10.1016/j.jth.2017.10.004

Yung, E. H., Conejos, S., & Chan, E. H. (2016). Social needs of the elderly and active aging in public open spaces in urban renewal. *Cities*, 52, 114-122. doi:https://doi.org/10.1016/j.cities.2015.11.022

Yuryev, A., Leppik, L., Tooding, L. M., Sisask, M., Värnik, P., Wu, J., & Värnik, A. (2010). Social inclusion affects elderly suicide mortality*. International Psychogeriatrics*, 22(8), 1337-1343. doi:https://doi.org/10.1017/S1041610210001614

CAPITOLO 2
SCIENTIFIC FRAMEWORK

Elderly population and urban accessibility

2.1 Introduction

In the last twenty years, scientific and technological advances have contributed to an increase in life expectancy and quality of life of elderly.

Only in the last few years urban accessibility for the elderly has become part of urban development policies, which they should be oriented towards the construction of an urban model aimed at reducing the social exclusion of the elderly.

The organization of the urban layout changes due to new social, cultural and economic needs, making it appropriate to improve accessibility to places and services of proximity and of general interest (Guida and Caglioni, 2021; Saha et al., 2021). Recalling what has already been stated by Cass et al. (2005) and by Gargiulo et al. (2019), the increase in the accessibility and usability of spaces, networks and activities by everyone contributes to improving, from a systemic perspective, the relationships between the founding elements of the urban system that determine its functioning.

Accessibility can then be considered as a property of urban settlements that qualifies society, defining the degree of social equity and the quality of life for its inhabitants (Farrington, 2007; Jian et a., 2020).

In this perspective, this chapter is divided into two sub-chapters in which the conceptual framework on the subject is outlined through the main studies of the scientific literature and the tools of the plan. In particular, the state of the art on accessibility studies for the elderly is identified through a review of the main scientific studies on this topic on two different scales, urban and neighborhood. This approach reflects the bi-part focus of existing studies, in order to outline both the approaches and methods used in

development of this issue. It is demonstrated that a research gap exists at the intersection of the scales in terms of accessibility of the elderly to urban areas.
The review of the scientific literature also contributes to the identification of key urban characteristics necessary to make an elderly-friendly city, along with tools such as sustainable urban mobility plans and service plans to identify how public administrations have so far implemented strategies, objectives, and interventions on the issue, as shown in Section 2.3

2.2 Review of literature[2]

The organization of the built environment, and the habits and lifestyles of the users who live in cities, have been discussed by many authors (Borst et al., 2008; Marquet et al., 2017; Papa et al., 2018; Riley et al., 2013). Only in recent years, however, has attention been focused on the "weak" segment of the population (children, the elderly, people with disabilities) in relation to the issue of accessibility in urban areas (Gargiulo et al.2019). The complex relationship between the habits of the elderly and the physical and functional organization of the urban system has stimulated scientific debate on how to improve accessibility to urban places and services. This is particularly important in soft mobility networks, since they constitute the most widespread mode of movement by the elderly and are also the most sustainable for cities (Battara et al., 2018). Ahmad (2019) and Langford et al. (2012) studied the issue of accessibility with an approach aimed at optimizing transport networks to encourage the elderly to reach urban places and services. Bricocoli et al. (2018) and Lee & Park (2014) conducted additional research investigations with an approach aimed at identifying the significant characteristics of the built environment. Such approaches have particular implications for the treatment of urban scale. From a general vantage point, one approach aims at improving access to urban places and services through large transport networks on a territorial scale. A second approach, however, defines the characteristics of the built environment that

[2] This section is contained in the research work of Gaglione F., Cottrill C., Gargiulo C. (2021). Urban services, pedestrian networks and behaviors to measure elderly accessibility. *Transportation research part D: transport and environment*. https://doi.org/10.1016/j.trd.2020.102687

influence the walkability of the elderly on a neighborhood scale.

URBAN SCALE

Studies conducted on the elderly segment of the population at urban scales, within the first line of research, provide essential contributions to the field of spatial accessibility through the use of gravity-based models and contour measures in relation to a single service of interest to the elderly, especially health services, by using a private mode of transport or combining multiple modes of transport (Guagliardo, 2004; Luo & Wang, 2003; Yang et al., 2006; Wang 2012). These studies often develop a new accessibility indicator aimed at measuring specific features, such as the distance and travel time to reach activities of interest. The results show, through the application of GIS tools, the accessibility levels of single categories of urban services defined in terms of time and distances. Findings from these studies may be used to define the critical areas where actions to improve access to the service should be a priority. The ability to reach places and services by using local public transport systems and pedestrian networks contributes to reducing the elderly populations' social exclusion (Currie et al., 2010; Langford et al., 2012; Lucas et al., 2016). In this regard, within the same research line, the efficiency of transport networks is examined and defined through network accessibility measures that consider topological characteristics, such as connectivity in relation to modeled space-time travel requirements of the elderly. More specifically, the travel patterns of the elderly are derived through the use of sample surveys that investigate the lifestyles of the elderly population (including preferences, constraints and current behaviours). This research considers attributes such as travel distance, travel frequency, and travel start time on weekdays and weekends in relation to the spatial characteristics of public transport networks for travel to urban services (Ahmad., 2019; Shao et al., 2019; Szeto et., 2017) with the aim of optimizing travel times in order to establish effective and appropriate public transport policy measures to improve the mobility of the elderly. A corpus of scientific literature has also been produced on the preferences of the elderly towards using a specific means of transport, mostly the bus. In particular, this research segment draws on data on spatial characteristics of the public transport network and accessibility to transport systems (closest bus stop, or whether tram and rail stations are within walking distance), sociodemographic attributes, and the quality of public transport offered (seat availability, travel stability, waiting time for the service) inferred from sampling surveys. The significance of each of the variables is generally examined using linear or multivariate regression models. The results obtained from the different models aim to develop a more complete understanding of the different lifestyles, attitudes, travel behaviors and needs of the elderly and their level of satisfaction with various public transport modes (Broome et al., 2012; Haustein,2012; Kotval 2017; Wong et al.,2017).

NEIGHBOURHOOD SCALE

More recent research on the issue has focused on elderly pedestrians' accessibility to urban areas at a neighborhood scale by examining how to reorganize open and unopened spaces to encourage "active aging". In particular, these studies have highlighted the physical and natural characteristics of the built environment that influence the "walkability" of the elderly at a neighborhood scale (Colclough, 2009; Kim et al., 2014; Lee & Park, 2014). If walking is the "easiest" way of getting around the city, the study of the relationships between the pedestrian behavior of the elderly and the local urban environment is highly complex. Abley (2005) tried to define the characteristics of a network suitable for walkability: connected, pedestrian friendly, visible, convenient and comfortable streets. Then, Saelens and Handy (2008) investigated the urban features correlated with walking inclination at a neighbourhood scale and their findings were framed by Cervero et al. (2010) who identified six components of walkability, which are density, diversity, design, distance, destination and demand management. The scientific debate inherent in the study of walkability of the elderly at a neighborhood scale questions physical characteristics (related to the geometry and characteristics of the road network such as sidewalk width and street crossings), environmental considerations (related to elements of urban furniture such as lighting and benches) and functional characteristics (related to the location of urban services) in determining the safety and attractiveness of a pedestrian path during the walking experience, with the aim of gaining insights into urban design strategies that can improve pedestrian satisfaction (Chen et al.,2019; Gharaveis, 2020). Walkability can be defined as "the extent to which the built environment is conducive to walking on"

(Liao et al., 2020). The purpose of walking and people's perceptions of urban space play a key role in the willingness to walk (Brown, 2007; Chu, 2017; Evans, 2009; Stafford and Baldwin, 2017). For instance, some built environment features can facilitate or restrain walking (e.g. shading, road network slope) and the localization of activities influence the daily life routine trips (e.g. home-market; home-recreation service). Many studies have been developed on a micro scale, looking at neighborhood areas where there is a lower tendency of the elderly to walk (due to their health) and the complexity of the relevant built environment (e.g. pedestrian crossings, traffic lights, presence of ramps, state of sidewalk paving, vehicle traffic volumes, etc.). These studies have often aimed to deduce perceptions of built environment characteristics and how they impact upon the choice of a pedestrian path for the elderly to reach urban services with consideration of temporal availability of walking deduced through the use of questionnaires. Multivariate statistical techniques, such as multicriteria analysis and regression models, are used to identify the significance of each of the variables in order to improve pedestrian accessibility in terms of practicability, safety and attractiveness of the pedestrian paths, and the collection and localization of the characteristics is carried out using GIS tools (Bivina & Parida, 2019; Joo & Kim, 2011; Li et al., 2015). Furthermore, studies in the GIS environment have developed qualitative or quantitative walkability indicators (Loo & Lam 2012; Loh et al., 2019; Manaugh & El-Geneidy, 2011), which, combined with the location of urban services, aim to define the walkability levels of the area under study for the elderly and provide insight into the prioritization of interventions. The qualitative indicators developed at the same time underline a difficulty in finding such accurate data as there are no specific databases on each of the characteristics of the built environment. The methods used in these studies define the pedestrian score on a predefined scale of values, constituting the synthetic indicator of each pedestrian path in relation to proximity services, providing information on the characteristics of comfort, safety and usability of pedestrians (Loo, & Lam, 2012; Manaugh & El-Geneidy, 2011). The quantitative pedestrian indicators used in the scientific field are based on two approaches, one "place-based" which aims to measure the levels of pedestrian traffic based on the presence of local services (Kuzmyak et.al, 2006; Grasser et.al, 2013) and another "network-based", as they aimed to measure accessibility to the nearby service by focusing on the characteristics of the pedestrian network and identifying the best routes for users. Both research approaches aggregate different variables by developing a composite index of pedestrianism that helps to measure various dimensions of the built environment. Most of the walkability indicators consider characteristics relating to connectivity, land use and the presence of services since the location and distribution of services and places influence the choice of possible pedestrian paths. From the above, we see that previous research and studies show a gap regarding accessibility to urban areas for the elderly population. The studies conducted within the first line of research have contributed to defining the levels of accessibility to specific urban services on a territorial scale. Accessibility levels express general time and distance-based access to urban services, but do not take into account the more fine-grained characteristics of the urban environment. Studies by Gharaveis (2020) and Kim et al. (2014) developed on a neighborhood scale, on the other hand, aim to identify characteristics of the built environment that may affect the elderly population's weighted walking time to reach urban neighborhood services. However, few studies have dealt with integrating the two different approaches on the topic. In this perspective, the thesis work aims to define a methodology that addresses this gap by defining a new measure of pedestrian accessibility on the pedestrian network built starting from the weight of each feature of the pedestrian network (identified through an Analytic Hierarchy Process (AHP) analysis) and behaviours in terms of walking speed. The measure of pedestrian accessibility on the network relates to the travel time of the elderly according to their ability to travel the network in terms of walking speed, which is added to an average time weighted on the characteristics of the built environment. The accessibility measure developed on the pedestrian network graph aims to integrate and overcome the research gap highlighted on the issue of the accessibility of the elderly to the two different scales. As urban-scale studies have focused on measuring the accessibility of transport networks considering the topological characteristics of the network, such as connectivity and the relative preferences of the elderly. The studies at the neighborhood scale aim to develop quantitative indicators of walkability considering the characteristics of the built environment linked to the safety of the elderly and the amenity of the urban context in relation to the temporal availability of the elderly to walk. Neither of the two different approaches to the topic, however, considered the average walking time of the elderly weighted on the weights of the physical characteristics and the urban context of the pedestrian paths in relation to the distribution and location of urban services at the quarter scale to provide support for the prioritization of interventions. The pedestrian accessibility measure here defines levels of pedestrian accessibility to urban services through joint consideration of built environment characteristics, the preferences, and behaviors of elderly pedestrians in the network, and locations of activities of interest at a neighborhood scale. Furthermore, this work methodologically aims to redefine a traditional concept of urban planning such as catchment areas through Functional Accessibility Soft Zones (FASzones), which represent an innovation of the now outdated concept of the traditional catchment area and which can constitute an element on which to base the reorganization of urban services to better respond to the renewed needs of the population.

2.3 Urban features and planning tools for an elderly friendly city[3]

The senior population segment has rarely been considered within urban development policies, despite the spread of the age-friendly approach. Policies and strategies to regulate the urban system should be promoted to meet the needs and requirements of this segment of the population, making the city more accessible, safe and inclusive through the organization of spaces and mobility networks. In this first part, the body of research and evidence on this topic was examined, to identify the main urban characteristics necessary to favour age-friendly environments / communities as well as the cognitive framework on urban governance tools. There were two criteria for selecting the instruments that regulate urban transformations: those adopted in the last ten years and those relating to the Italian provincial capitals. The cognitive framework on research and studies, which refer to different subject areas, has shown that urban accessibility is mainly studied both in terms of organization of the displacement networks and in relation

[3] This section is contained in the research work of Gargiulo, C., Zucaro, F., & Gaglione, F. (2018). A Set of Variables for the Elderly Accessibility in Urban Areas. *TeMA - Journal of Land Use, Mobility and Environment*, 53-66. https://doi.org/10.6092/1970-9870/6864

to widespread behaviours and health conditions. In fact, according to Buffel et al. (2012) "physical environments have a significant impact upon all age groups but especially for those reliant on their immediate locality for support and assistance". More specifically, the studies refer to three main areas of research: (i) studies on upgrading transport supply to improve the displacement of the elderly (Alsnih & Hensher, 2003; Haustein, 2012; Morency et al., 2011; Scheiner, 2006; Shoval et al., 2010; Wong et al.,2017); (ii) studies relating to the redevelopment of open spaces (built and not built), to encourage the participation and social aggregation of the elderly (Bowling & Dieppe, 2005; Gehl et al., 2006; Buffel et al., 2012; Scharlach & Lehning, 2013; Toepoel, 2013); iii) studies on the positive incidence of soft mobility on the reduction of diseases affecting the elderly (Macniven et al., 2014; Maisel, 2016; Moran et al., 2014; Pan et al., 2009; Stewart et al., 2001; Van Cauwenberg et al., 2016).

The study of scientific literature, in the first part of this research work, contributed to identifying the key urban features that constitute an elder-friendly city:

- Perception of the speed and volume of traffic;
- Neighbourhood aesthetics (e.g., foliage, attractive buildings and scenery, absence of litter);
- Satisfaction with the ease and pleasantness of neighbourhoods;
- Overall safety;
- General functionality of the neighbourhood (e.g., traffic condition, street lighting at night, unattended dogs and safety from crime);
- Walkability, pedestrian safety and attractive routes;
- Local park and natural environments nearby.

Some features, such as the aesthetics of the neighbourhood, the presence of pedestrian paths and local parks, are meant to make the movement of the elderly easier and enjoyable; other features, such as street lighting and traffic perception, significantly affect their sense of security and their participation in social activities.

In addition to the study of the scientific literature, the cognitive framework on the planning tools, in this phase was useful to understand how the decision-makers had dealt with the issue and what the proposals of the different urban contexts are currently. In detail, the Sustainable Urban Mobility Plans (SUMP) and Service Plans proved to be the only ones particularly sensitive to the issue of improving urban accessibility for the elderly. Several Italian provincial capitals, such as Milan, Parma and Turin, have paid particular attention to the issue starting from the core objectives of the plan: equity, security, social inclusion and everyone's right to access the city without barriers. Starting from these objectives, strategies and actions have been developed in order to improve urban accessibility for the elderly through:

– The increase in soft mobility facilities;
– The improvement of street lighting;
– Improving safety at traffic intersections;
– Reducing obstacles on sidewalks.

It is worth noting that the 100 Station Plan of Naples pays particular attention to the issue of improving accessibility (specially to rail network stations) through the integration of urban transformation governance and transport planning, although this plan was developed over 10 years ago (2001). In particular, this plan identifies the catchment area of the railway stations, according to the geometric, morphologic and functional characteristics that influence the pedestrian accessibility (Papa & Trifiletti, 2010). The Service Plans of the cities of Lodi and Bari make use of the radii of influence of some services for the elderly population in urban areas, such as:

– ASL (Local Health Service) = 500m;
– Pharmacies= 500m;
– Clubhouses for the elderly= 200m.

The values of the radii of influence provided by the Service Plans above mentioned are, actually, the theoretical quantities from which to start to define the relative catchment areas. From the study of the relevant scientific literature on the issue of accessibility to urban places and services for the elderly population and from the planning tools, it emerges that this problem has still been addressed in a marginal way. This means that the same tools are not able to respond effectively to the needs of these users, as administrators, professionals and technicians of the territory have not produced proposals such as to improve the structure and organization of the urban system for this type of users.

2.4 Gaps about urban accessibility for elderly

From the cognitive framework of the scientific literature and the Italian urban governance tools, this research work identified two main gaps about the issue of urban accessibility of elderly. First, elder people rarely feature in urban policies though governance tools aimed at efficiently satisfying their specific needs, despite the growth of the "age-friendly approach". Our review confirms Uhlenberg (2009) and MacLeod et al.'s (2016) considerations about the fact that planning documents barely mention elder people's needs. They are usually mentioned in terms of numbers, but the analyses rarely result in concrete proposals and measures. In particular, this issue within urban planning tools has been discussed less intensely than other plans such as the urban mobility ones (in general). According to Buffel et al. (2012), "in this context, elderly people illustrate many of the tensions running through urban change". Second, to deal with this ageing challenge occurring in a shifting economic and global ecological context (EEA, 2013) it can be assumed that a city needs a physical and functional reorganization. On one hand, both public transport and soft mobility networks should be redesigned in order to increase the attractiveness of the city and the elderly well-being by allowing better accessibility to urban open and built spaces and to activities. On the other hand, a proper mix of functions and accessibility to the same places for different social and generational groups guarantee that the built space will contribute to the social equilibrium of a society. Intervening on both these two elements means improving urban accessibility for all ageing groups, by making built spaces livable and accessible to every category of people, including persons with disabilities in line with the principles of universal design, which aim at a model city accessible to all categories of users (UN, 2006; Tiboni & Rossetti, 2012). In particular, the issue related to the most suitable localization and distribution of activities of interest for the elderly is still lacking within the scientific debate. Few studies have addressed the issue of how the "spreading" of local and welfare facilities for the elderly can contribute to increased urban accessibility levels. The research work is based, in fact, on the consideration that improving urban accessibility requires the adoption of a holistic-systemic approach. It means putting in relation activities already developed in the territory, transport networks and open spaces (built and not built), and user needs through the development of a methodology. In detail, the development of the methodology aims to systematize the characteristics of the functional subsystem (urban neighborhood services), physical (characteristics of the pedestrian network) pedestrianism of the elderly and their needs with the aim of classifying urban areas using data reasonably easily accessible and the elderly population served by each single service. Considering the above, our paper suggests that decision makers and urban planners should adopt an integrated approach to plan ageing cities, as this challenge can be seen as an opportunity to increase the city's sustainability, attractiveness, and competitiveness in the areas of land use, transport, welfare services and social cohesion.

References

Abley, S. (2005). Walkability Scoping Paper. Christchurch, New Zealand.

Ahmad, Z., Batool, Z., & Starkey, P. (2019). Understanding mobility characteristics and needs of older persons in urban Pakistan with respect to use of public transport and self-driving. *Journal of Transport Geography*, 74, 181-190. doi: https://doi.org/10.1016/j.jtrangeo.2018.11.015

Alsnih, R., & Hensher, D. A. (2003). The mobility and accessibility expectations of seniors in an aging population. *Transportation Research Part A: Policy and Practice*, 37(10), 903-916. doi:https://doi.org/10.1016/S0965- 8564(03)00073-9

Battarra, R. Zucaro, F., Tremiterra, MR (2018) Smart Mobility and Elderly People. Can ICT Make the City more accessible for everybody? *TeMA. Journal of Land Use, Mobility and Environment*, Special Issue 2, oct. 2018, ISSN 1970-987.doi: https://doi.org/10.6092/1970-9870/5768

Bivina, G. R., & Parida, M. (2019). Prioritizing pedestrian needs using a multi-criteria decision approach for a sustainable built environment in the Indian context. *Environment, Development and Sustainability*, 1-22. doi: https://doi.org/10.1007/s10668-019-00381-w

Borst, H. C., Miedema, H. M., de Vries, S. I., Graham, J. M., & van Dongen, J. E. (2008). Relationships between street characteristics and perceived attractiveness for walking reported by elderly people. *Journal of Environmental Psychology*, 28(4), 353-361. doi: https://doi.org/10.1016/j.jenvp.2008.02.010

Bowling, A., & Dieppe, P. (2005). What is successful ageing and who should define it? Bmj, 331(7531), 1548-1551. doi:https://doi.org/10.1136/bmj.331.7531.1548

Bricocoli, M. Bouwer, Aleid E., Gargiulo, C (2018), Editorial Preface: Elderly Mobility, *TeMA. Journal of Land Use, Mobility and Environment,* Special Issue 2, p. 3-8, oct. 2018. ISSN 1970-9870.doi: http://dx.doi.org/10.6092/1970-9870/5868

Broome K., Worrall L., Fleming J. & Boldy, D. (2012). Evaluation of flexible route bus transport for older people. *Transport Policy*, 21, 85-91. doi: https://doi.org/10.1016/j.tranpol.2012.02.005

Brown, B. B., Werner, C. M., Amburgey, J. W., & Szalay, C. (2007). Walkable route perceptions and physical features: converging evidence for en route walking experiences. *Environment and behavior*, 39(1), 34-61. doi: https://doi.org/10.1177/0013916506295569

Buffel, T., Phillipson, C., & Scharf, T. (2012). Ageing in urban environments: Developing 'age-friendly' cities. *Critical Social Policy*, 32(4), 597-617. doi:https://doi.org/10.1177/0261018311430457

Cass, N., Shove, E. and Urry, J. 2005. Social exclusion, mobility and access. The Sociological Review. 53(3): 539–555. https://doi.org/10.1111/j.1467-954X.2005.00565.x

Cheng, L., Chen, X., Yang, S., Cao, Z., De Vos, J., & Witlox, F. (2019). Active travel for active ageing in China: The role of built environment. *Journal of transport geography*, 76, 142-152. doi: https://doi.org/10.1016/j.jtrangeo.2019.03.010

Chu, N. S. (2017). Walkability and Accessibility: Users' Perspectives of a Planned Neighborhood. Thesis dissertation. Retrieved from: https://dc.uwm.edu/etd/1455/

Colclough, J. G. (2009). Modelling Pedestrian Accessibility Using GIS Techniques to Assess Development Sustainability. *In European Transport Conference*

Currie, G., Richardson, T., Smyth, P., Vella-Brodrick, D., Hine, J., Lucas, K., ... & Stanley, J. (2010). Investigating links between transport disadvantage, social exclusion and well-being in Melbourne–Updated results. *Research in transportation economics*, 29(1), 287-295. doi: https://doi.org/10.1016/j.retrec.2010.07.036

EEA. (2013). Cities in transition: challenges and opportunities for the elderly. Retrieved from https://www.eea.europa.eu/articles/a-europe-to-thrive-in/cities-in-transition-leaflet

EEA. (2013). Cities in transition: challenges and opportunities for the elderly. Retrieved from https://www.eea.europa.eu/articles/a-europe-to-thrive-in/cities-in-transition-leaflet

Evans, G. (2009). Accessibility, urban design and the whole journey environment. Built environment, 35(3), 366-385. doi: http://dx.doi.org/10.2148/benv.35.3.366

Farrington, J. (2007). The New Narrative of Accessibility: Its Potential Contribution to Discourses in (Transport) Geography. Transport Geography, 15(5), 319– 30. https://doi.org/10.1016/j.jtrangeo.2006.11.007

Gargiulo, C., Zucaro F. & Gaglione, F. (2019), Improving accessibility to urban services for over 65: a GIS-supported method, in C. Gargiulo & C. Zoppi (Eds.), Planning, nature and ecosystem services (pp. 839-850). Naples: *FedOAPress*. ISBN: 978-88-6887-054-6, doi: 10.6093/978-88-6887-054-6

Gehl, J., Kaefer, L. J., & Reigstad, S. (2006). Close encounters with buildings. *Urban design international*, 11(1), 29-47. doi:https://doi.org/ 10.1057/palgrave.udi.9000162

Gharaveis, A. (2020). A systematic framework for understanding environmental design influences on physical activity in the elderly population. *Facilities*. doi: https://doi.org/10.1108/F-08-2018-0094

Guagliardo, M.F. (2004). Spatial accessibility of primary care: concepts, methods and challenges. International *Journal of Health Geographics*, 3. doi: https://doi.org/10.1186/1476-072X-3-3

Guida, C., & Caglioni, M. (2020). Urban accessibility: the paradox, the paradigms and the measures. A scientific review. TeMA-Journal of Land Use, Mobility and Environment, 13(2), 149-168.

Grasser, G., Van Dyck, D., Titze, S., Stronegger, W.: Objectively measured walkability and active transport and weight-related outcomes in adults: a systematic review. *International Journal of Public Health*, 58, 615-625 (2013). https://doi.org/10.1007/s00038-012-0435-0

Haustein, S. (2012). Mobility behavior of the elderly: an attitude-based segmentation approach for a heterogeneous target group. *Transportation*, 39(6), 1079-1103. doi: https://doi.org/10.1007/s11116-011-9380-7

Jian, I. Y., Luo, J., & Chan, E. H. (2020). Spatial justice in public open space planning: Accessibility and inclusivity. Habitat International, 97, 102122. https://doi.org/10.1016/j.habitatint.2020.102122

Joo, Y. J., & Kim, S. H. (2011). A new route guidance method considering pedestrian level of service using multi-criteria decision making technique. *한국공간정보학회지*, 19(1), 83-91.

Kim, S., Park, S., & Lee, J. S. (2014). Meso-or micro-scale? Environmental factors influencing pedestrian satisfaction. *Transportation Research Part D: Transport and Environment*, 30, 10-20. doi: https://doi.org/10.1016/j.trd.2014.05.005

Kotval, K. Z. (2017). Transit accessibility for older adults in the Greater Lansing, Michigan region, *Quality in Ageing and Older Adults*, 18(3), 175-187. doi: https://doi.org/10.1108/QAOA-08-2016-0032

Kuzmyak, J. R., Baber, C., & Savory, D. (2006). Use of walk opportunities index to quantify local accessibility. *Transportation Research Record*, 1977(1), 145-153. https://doi.org/10.1177/0361198106197700117

Langford, M., Higgs, G., & Fry, R. (2012). Using floating catchment analysis (FCA) techniques to examine intra-urban variations in accessibility to public transport opportunities: the example of Cardiff, Wales. *Journal of Transport Geography*, 25, 1-14. doi: https://doi.org/10.1016/j.jtrangeo.2012.06.014

Lee, H. S., & Park, E. Y. (2014). Comparing the environment for elderly pedestrians among different-sized cities of Gyeonggi province in Korea. International Journal of Urban Sciences, 18(1), 76-89. doi: https://doi.org/10.1080/12265934.2013.863449

Li, F., Fisher, K. J., Brownson, R. C., & Bosworth, M. (2005). Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. *Journal of Epidemiology & Community Health*, 59(7), 558-564. doi: http://dx.doi.org/10.1136/jech.2004.028399

Liao, B., EW van den Berg, P., van Wesemael, P. J., & A Arentze, T. (2020). How Does Walkability Change Behavior? A Comparison between Different Age Groups in the Netherlands. *International Journal of Environmental Research and Public Health*, 17(2), 540.

Loh, V. H., Rachele, J. N., Brown, W. J., Ghani, F., Washington, S., & Turrell, G. (2019). The potential for walkability to narrow neighborhood socioeconomic inequalities in physical function: A case study of middle-aged to older adults in Brisbane, Australia. *Health & pl*ace, 56, 99-105. doi: https://doi.org/10.1016/j.healthplace.2019.01.020

Loo, B. P., & Lam, W. W. Y. (2012). Geographic accessibility around health care facilities for elderly residents in Hong Kong: A microscale walkability assessment*. Environment and Planning B: Planning and Design*, 39(4), 629-646. doi: https://doi.org/10.1068/b36146

Lucas, K., Van Wee, B., and Maat, K., 2016. A method to evaluate equitable accessibility. *Transportation*, 43, 473–490. doi:https://doi.org/10.1007/s11116-015-9585-2

Luo, W., & Wang, F. (2003). Measures of spatial accessibility to health care in a GIS environment: synthesis and a case study in the Chicago region. *Environment and Planning B: Planning and Design*, 30(6), 865-884. doi:https://doi.org/10.1068/b29120

MacLeod, S., Musich, S., Hawkins, K., Alsgaard, K., & Wicker, E. R. (2016). The impact of resilience among older adults. *Geriatric Nursing*, 37(4), 266-272. doi:https://doi.org/10.1016/j.gerinurse.2016.02.014

Macniven, R., Pye, V., Merom, D., Milat, A., Monger, C., Bauman, A., & van der Ploeg, H. (2014). Barriers and enablers to physical activity among older Australians who want to increase their physical activity levels. *Journal of physical activity and health*, 11(7), 1420-1429. doi:https://doi.org/10.1123/jpah.2012-0096

Maisel, J. L. (2016). Impact of older adults' neighborhood perceptions on walking behavior. *Journal of aging and physical activity*, 24(2), 247-255. doi:https://doi.org/10.1123/japa.2014-0278

Manaugh, K., & El-Geneidy, A. (2011). Validating walkability indices: How do different households respond to the walkability of their neighborhood? *Transportation research part D: transport and environment*, 16(4), 309-315. doi: https://doi.org/10.1016/j.trd.2011.01.009

Marquet, O., Hipp, J. A., & Miralles-Guasch, C. (2017). Neighborhood walkability and active ageing: a difference in differences assessment of active transportation over ten years. *Journal of Transport & Health*, 7, 190-201. doi: https://doi.org/10.1016/j.jth.2017.09.006

Moran, M., Van Cauwenberg, J., Hercky-Linnewiel, R., Cerin, E., Deforche, B., & Plaut, P. (2014). Understanding the relationships between the physical environment and physical activity in older adults: a systematic review of qualitative studies*. International journal of behavioral nutrition and physical activity*, 11(1), 79. doi:https://doi.org/10.1186/1479- 5868-11-79

Morency, C., Paez, A., Roorda, M. J., Mercado, R., & Farber, S. (2011). Distance traveled in three Canadian cities: Spatial analysis from the perspective of vulnerable population segments. *Journal of Transport Geography*, 19(1), 39-50. doi:https://doi.org/10.1016/j.jtrangeo.2009.09.013

Pan, S. Y., Cameron, C., DesMeules, M., Morrison, H., Craig, C. L., & Jiang, X. (2009). Individual, social, environmental, and physical environmental correlates with physical activity among Canadians: a cross-sectional study. *BMC public health*, 9(1), 21. doi:https://doi.org/10.1186/1471-2458-9-21

Papa R., Fistola R., Gargiulo C. (2018) (eds) Smart Planning: Sustainability and Mobility in the Age of Change. Green Energy and Technology. *Springer*, Cham, ISSN 1865-3537 Green Energy and Technology book series

Papa, E., & Trifiletti, E. G. (2010). Il sistema della mobilità: la cura del ferro. In R. Papa (Ed.), Napoli 2011: città in trasformazione (pp. 78–165). Naples, IT: Mondadori Electa.

Piano dei servizi (Piano Governo del Territorio ai sensi della LR 12/2005). Retrivied from: http://www.comune.lodi.it/flex/cm/pages/ServeBLOB.php/L/IT/IDPagina/1469

Piano urbanistico generale (indirizzi del PUG/ strutturale). Piano dei Servizi di Bari. Retrivied from: http://www.comune.manfredonia.fg.it/urbanistica/n016allegato.pdf

Piano Urbano per la Mobilità Sostenibile (PUMS) Comune di Parma (marzo.2017). Retrivied from: http://www.simpla-project.eu/media/82192/parma_sump.pdf

Piano Urbano per la Mobilità Sostenibile (PUMS) Comune di Torino (marzo.2017). Retrivied from: http://geoportale.comune.torino.it/web/sites/default/files/mediafiles/pums_all1_relazione_3.pdf

Piano Urbano per la Mobilità Sostenibile (PUMS) della Città metropolitana di Milano (giugno.2017). Retrivied from: http://download.comune.milano.it/24_03_2015/Documento%20di%20Piano%20febbraio%202015%20(1427206289866).pdf

Riley, D. L., Mark, A. E., Kristjansson, E., Sawada, M. C., & Reid, R. D. (2013). Neighborhood walkability and physical activity among family members of people with heart disease who participated in a randomized controlled trial of a behavioral risk reduction intervention. *Health & place*, 21, 148-155. doi: https://doi.org/10.1016/j.healthplace.2013.01.010

Saelens, B. E., & Handy, S. L. (2008). Built environment correlates of walking: a review. Medicine and science in sports and exercise, 40(7 Suppl), S550. doi: https://doi.org/ 10.1249/MSS.0b013e31817c67a4

Saha, M., Chauhan, D., Patil, S., Kangas, R., Heer, J., & Froehlich, J. E. (2021). Urban Accessibility as a Socio-Political Problem: A Multi-Stakeholder Analysis. Proceedings of the ACM on Human-Computer Interaction, 4(CSCW3), 1-26.

Scharlach, A. E., & Lehning, A. J. (2013). Ageing-friendly communities and social inclusion in the United States of America. *Ageing & Society*, 33(1), 110-136. doi:https://doi.org/10.1017/S0144686X12000578

Scheiner, J. (2006). Does the car make elderly people happy and mobile? Settlement structures, car availability and leisure mobility of the elderly. European *Journal of Transport and Infrastructure Research*, 6(2), 151-172. Retrieved from http://www.ejtir.tbm.tudelft.nl/ISSUES/2006_02/pdf/2006_02_03.pdf

Shao, F., Sui, Y., Yu, X., & Sun, R. (2019). Spatial-temporal travel patterns of elderly people–A comparative study based on buses usage in Qingdao, China. *Journal of Transport Geography*, 76, 178-190. doi: https://doi.org/10.1016/j.jtrangeo.2019.04.001

Shoval, N., Auslander, G., Cohen-Shalom, K., Isaacson, M., Landau, R., & Heinik, J. (2010). What can we learn about the mobility of the elderly in the GPS era? *Journal of Trans*port *Geography*, 18(5), 603-612. doi:https://doi.org/ 10.1016/j.jtrangeo.2010.03.012

Stafford, L., & Baldwin, C. (2017). Planning Walkable Neighborhoods. *Journal of Planning Literature*, 33(1), 17–30. doi:10.1177/0885412217704649

Stewart, A. L., Verboncoeur, C. J., McLellan, B. Y., Gillis, D. E., Rush, S., Mills, K. M., ... & Bortz, W. M. (2001). Physical activity outcomes of CHAMPS II: a physical activity promotion program for older adults. *The Journals of Gerontology Series A: Biological Sciences and Medical Sciences*, 56(8), M465-M470. doi:https://doi.org/10.1093/gerona/56.8.M465

Szeto, W. Y., Yang, L., Wong, R. C. P., Li, Y. C., & Wong, S. C. (2017). Spatio-temporal travel characteristics of the elderly in an ageing society. *Travel Behaviour and Society*, 9, 10-20. doi: https://doi.org/10.1016/j.tbs.2017.07.005

Tiboni, M., & Rossetti, S. (2012). L'utente debole quale misura dell'attrattività urbana*. TeMA*. *Journal of Land Use, Mobility and Environment*, 5(3), 91-102. doi:http://dx.doi.org/10.6092/1970-9870/1200

Toepoel, V. (2013). Ageing, leisure, and social connectedness: how could leisure help reduce social isolation of older people?. *Social indicators research*, 113(1), 355-372. doi:https://doi.org/10.1007/s11205-012-0097-6

Uhlenberg, P. (Ed.). (2009*). International handbook of population aging* (Vol. 1). Berlin, De: Springer Science & Business Media.

United Nations (UN). (2006). Convention on the rights of persons with disabilities. Retrieved from http://www.un.org/disabilities/documents/convention/convoptprot-e.pdf

Van Cauwenberg, J., Van Holle, V., De Bourdeaudhuij, I., Van Dyck, D., & Deforche, B. (2016). Neighborhood walkability and health outcomes among older adults: The mediating role of physical activity. *Health & place*, 37, 16-25. doi: https://doi.org/10.1016/j.healthplace.2015.11.003

Wang, F. (2012). Measurement, optimization, and impact of health care accessibility: a methodological review. *Annals of the Association of American Geographers*, 102(5), 1104-1112. doi: https://doi.org/10.1080/00045608.2012.657146

Wong, R. C. P., Szeto, W. Y., Yang, L., Li, Y. C., & Wong, S. C. (2017). Elderly users' level of satisfaction with public transport services in a high-density and transit-oriented city*. Journal of Transport & Health*, 7, 209-217. doi:https:// doi.org/10.1016/j.jth.2017.10.0

CAPITOLO 3
RESEARCH METHODOLOGY

3.1 Methodology articulation

In this third chapter of the thesis work, the entire methodology developed for the research project is outlined. More specifically, the method aims to support the development of policies and practices for the governance of urban and territorial transformations aimed at improving pedestrian accessibility to urban services for the elderly, in order to increase the quality of life of the elderly population and allow them to play an active role in the life of the community. The methodology of this work, supported by an extensive study of the scientific literature, also aims to integrate and overcome the research gap on the issue and to improve the approaches developed so far as can also be seen in Chapter 2. In more detail, the methodology in this chapter is spread over two sections. The first section outlines the methodological phases to innovate, from a methodological point of view, the traditional "tools of the trade" of urban planning to adapt them to the new socio-cultural needs, and in particular to the definition of Functional Accessibility Soft zones, which represent an innovation of the now outdated concept of the traditional catchment area and which can constitute an element on which to base the reorganization of urban services to better respond to the renewed needs of the population. The Functional Accessibility Soft zones identify the portions of the municipal territory that can actually be reached by the elderly population. The second section aims to overcome the gaps that emerge in the research by proposing a methodology aimed at defining a new measure of pedestrian accessibility on the pedestrian network built starting from the weight of each characteristic of the pedestrian network (identified through an Analytic Hierarchy Process analysis (AHP)) and the behavior of the elderly in terms of walking speed. The pedestrian accessibility measure defines the levels of pedestrian accessibility to urban services through the joint consideration of the characteristics of the built environment, the preferences and behaviors of elderly pedestrians in the network and the offer of urban services on a neighborhood scale. The methodological approach used allows quantification of the definition of the levels of accessibility to the various types of urban services. The accessibility levels also identify the critical areas that require priority interventions and the areas where it is possible to increase the levels of pedestrian accessibility to urban services. The methodologies outlined in the two sections allow us to define both in the first section, at a theoretical level, the elderly population actually served due to the distribution and location of urban services in the area and in the second section, also taking into account their availability to walking on foot to reach an urban service that has the characteristics of an urban context and of safety that can be defined in the various urban contexts. The perimeter of urban areas is a support tool for decision makers to identify where and how to intervene and to define a panel of urban planning strategies and actions in order to make the city accessible, safe, inclusive and active.

3.2 Definition of the Functional Accessibility Soft Zones [4](FASZones)

As regards the objective of the work aimed at improving accessibility to urban services of interest for the elderly, this section describes the steps of the first segment of research that allowed identification of the FASZones for each service category that we considered of interest for people aged over 65, classified in three different age-ranges: 65-69; 70-74; >75. The population groups were chosen in accordance with the indications of the National Statistical Institute, which deals with general population censuses and which identifies the elderly in the same three categories. The proposed methodology is divided into four phases.

[4] This paragraph is contained in the research work of Gargiulo C., Zucaro F., & Gaglione F. (2019). Improving accessibility to urban services for over 65: A gis-supported method. *In International Conference on Innovation and Urban and Regional Planning INPUT aCAdemy 2019* (pp. 971-982). https://doi.org/ 10.6093/978-88-6887-054-6

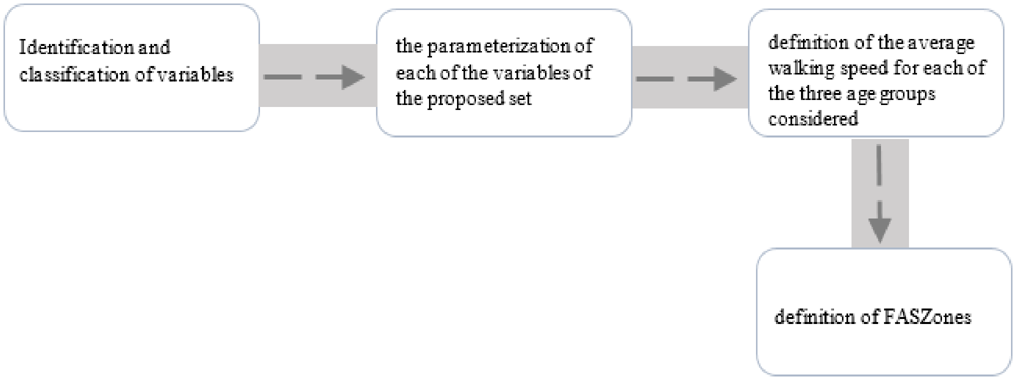


Fig.3 Phases of methodology FASZones

The first phase concerned the identification of the classified variables, adopting a holistic-systemic approach, in the four subsystems which make up the urban system.

- Socio-economic subsystem, behavior and habits of the elderly

- Environmental subsystem, of the context characteristics

- Physical subsystem, of pedestrian spaces and canals

- Functional subsystem, of urban activities and services.

The selected variables are recognized in the literature as significant using statistical techniques, in particular regression models. Table 1 shows the weights that were found to be significant from the use of the various statistical techniques employed in relation to the four characteristics of the urban system. In addition to the characteristics identified as significant in the literature, others relevant to the objectives of the research work have been introduced.

Tab.1 Variable set from scientific literature studies

VARIABLE	**WEIGHT**	**PAPER**	**METHODS**
	Socio-economic subsystem		
Population over 65 divided into three groups (60-70, 70-80,> 80)	p=- 0.25 p < 0.001 p= 0.37	Wong, et al (2018). Hawkesworth, et al (2018). Morency, et al (2011).	non-linear regression model (probit model) Linear regression model multivariate regression model
Population divided by gender	p= - 0.27 p= 0.578 p= - 0.02	Wong, et al. (2018). Haustein, S. (2012).	non-linear regression model (probit model)

		Schwanen et al (2001).	multivariate regression model / Cluster analysis linear regression model
Degree of education	p=0.273 p=0.41-0.38 p=0.06-0.10	Haustein, S. (2012). Scheiner, J. (2006). Schwanen, et al (2001).	multivariate regression model / Cluster analysis logistic regression models linear regression model
State of occupation	p=0.4 p=0.09 p=(0.15-0.45) p=0.05	Wong, et al (2018). Haustein, S. (2012). Morency, et al (2011). Schwanen, et al (2001).	non-linear regression model (probit model) multivariate regression model / Cluster analysis multivariate regression model linear regression model
Income	p=1.9 p=0.29 p=0.15-0.17 p= 0.37-0.50	Wong, et al (2018). Hawkesworth, et al (2018). Haustein, S. (2012). Scheiner, J. (2006).	non-linear regression model (probit model) linear regression model multivariate regression model / Cluster analysis logistic regression models
Car ownership	p=0.27-0.71 p=0.46 p=0.03	Haustein, S. (2012). Morency, et al (2011). Schwanen, et al (2001).	multivariate regression model / Cluster analysis multivariate regression models Linear regression model
Old age index			
Health state			
Environmental subsystem			
Orography (elevation)			
Slope of road network			
Physical subsystem			
Presence of protected pedestrian paths (sidewalks)	p=0.16 p<0.001 p=0.01	Joseph (2014) Nyunt et al. (2015) Adkins et al. (2012)	Gradual binary logistic regression multivariate regression model OLS regression model
Pedestrian network connectivity	p<0.01	Adkins et al. (2012)	OLS regression model
Quality of the flooring	p=0.01 p=0.66 p=0.712	Adkins et al. (2012) Joseph (2014) Gòmez et al. (2010)	OLS regression model Stepwise binary logistic regression Multivariate regression model
Presence of pedestrian crossing	p=0.16 p=0.01	H.C. Borst et al. (2008) F. Li et al. (2004)	multivariate linear regression model Multivariate regression model

Width of protected pedestrian paths (pavements)			
Presence of pedestrian signs	p<0.01	Adkins et al. (2012)	OLS regression model
Presence of road crossings with signs (traffic lights)	p=0.05 p<0.01 p<0.001	F. Li et al. (2004), Adkins et al. (2012), Nyunt et al. (2015)	multivariate regression model OLS regression model multivariate regression model
Volume of vehicular traffic	p=0.19 p=0.088	H.C. Borst et al. (2008) Gòmez et al. (2010)	multivariate linear regression model multivariate regression model
Noise pollution	p=0.005	Parra et al. (2010)	linear regression model
Street lighting	p=0.35	Salvador et al. (2010).	linear regression model
Lighting density			
Presence of escalators and elevators			
Presence of green areas	p=0.13 p=0.05, p=0.04, p=0.195, p=0.06	H.C. Borst et al. (2008), F. Li et al. (2004), Adkins et al. (2012), Parra et al. (2010), Nyunt et al. (2015)	multivariate linear regression model multivariate regression model OLS regression model linear regression model multivariate regression model
Presence of open spaces	p=0.05, p=0.11	F. Li et al. (2004), Joseph (2014)	multivariate regression model Stepwise binary logistic regression
Presence of rest areas (benches)	p=0.07	H.C. Borst et al. (2008)	multivariate linear regression model
	Functional subsystem		
Pharmacies			
Polydiagnostic Center			
Post office			
Municipal Office			
Bank			
Library			
Churches			
Cinema			

Sports Center			
Supermarket			
Shops and services	p=0.72	Hawkesworth, et al (2018)	Multivariate regression model
Density of green areas	p=0.67	Hawkesworth, et al (2018)	Multivariate regression model

Phase two involved the parameterization of each of the variables of the proposed set, aimed at obtaining the measurement of urban characteristics useful for defining strategies and interventions to improve pedestrian accessibility to urban areas for the elderly. This operation is an innovative element compared to other research, as these use mostly qualitative data obtained from sample surveys such as questionnaires. From Tab. 2 it is possible to note that, if the quantification of the variables of the socio-economic subsystem is detectable by databases of institutes that deal with statistical analysis concerning the population, for the environmental subsystem the quantitative data have been obtained through spatial analysis in the GIS environment and for the functional subsystem from the service plans (Bari and Lodi service plans) for each service of local interest.

Tab.2 Influence rays of the main urban services

VARIABLE	**MEASURE**	**SOURCE**
	Socio-economic subsystem	
Population over 65 divided into three groups (65-69, 70-74, > 75)	Ab.	ISTAT
	Environmental subsystem	
Slope	m	GIS
	Functional subsystem	
Pharmacies	R.i.= 500 m	Services plan Bari – Services plan Lodi
Polydiagnostic Center	R.i.= 560 m	L. De Falco,1977 Manual of the architect, II edition
Cinema	R.i.= 515 m	L. De Falco,1977 Manual of the architect, II edition
Library	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition
Church	R.i.= 480 m	L. De Falco,1977 Manual of the architect, II edition
Bank	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition

Post Office	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition
Municipal Office	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition
Supermarket	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition
Sport center	R.i.= 500 m	L. De Falco,1977 Manual of the architect, II edition

To define the sections of the municipal area that an elderly person can travel to reach a specific service, the ability of the elderly person (walking speed), the topological characteristics of the pedestrian network in relation to the urban services of interest to him have been studied. to define travel times and distances that can be reached for this segment of the population with the logic described in the third and fourth phase of this work. The third phase involved the definition of the average walking speed for each of the three age groups considered. Other studies (Colclough, 2009; Scaglioni-Solano & Aragón-Vargas, 2015) have been considered; however, given the characteristics considered, such as the orography of the territory which varies from territory to territory, the walking speeds determined here appear most relevant. To this end, the study of the scientific literature made it possible to consider useful, for the purposes of this work, the research carried out by Weber (2016) who determined these values on the basis of the main socio-economic characteristics and health status of the elderly population.

More in detail, the values identified are the following:

- For the population group aged 65-69 the average walking speed is equal to 0.81 m /s.

- For the population group aged 70-74 the average walking speed is equal to 0.69 m /s.

- For the population group aged over 75, the average walking speed is 0.60 m /s.

Starting from the average speeds, in the fourth phase the influence radii for each type of service considered were identified, which represent the maximum distances that a generic user is willing to travel on foot to reach a specific service (Tab.3), starting from influence rays that have been identified by the study of the governance tools of urban transformations, in particular the Service Plans (in particular Lodi and Bari) and Urban Plans of Sustainable Mobility. The areas of influence for the three segments of the elderly population were first defined. The area of influence identifies the area of access to the urban service with the limit of considering the isotropic territory, therefore, a territory that has the same morphological characteristics in all its parts and that can be travelled equally in all its directions without considering the actual characteristics of the pedestrian network. To this end, phase 4 has been structured as follows:

- Calculation of the average travel time (for any type of user) for each range of influence (distance to be covered on foot) of the services considered;

- Redefinition of the different radii of influence of each type of service (maximum distance that can be covered on foot), measured according to the different speeds of each age group and assuming the average travel time already identified as constant; as can be seen from table 3 and fig. 4.

Fig.4 Ideogram rays of influence on the elderly populations

Tab.3 Influence rays of services of interest for the three older population segments

Population	Services	Time (MIN)	Influence rays (M)
	Functional subsystem (services of local interest)		
65-69 70-74 >75	Pharmacies	6	292 248 216
65-69 70-74 >75	Polydiagnostic Center	7	340 290 252

65-69	Cinema	6	292
70-74			248
>75			216
65-69	Library	7	340
70-74			290
>75			252
65-69	Church	6	292
70-74			248
>75			216
65-69	Bank	6	292
70-74			248
>75			216
65-69	Municipal Office	6	292
70-74			248
>75			216
65-69	Post office	6	292
70-74			248
>75			216
65-69	Supermarket	6	292
70-74			248
>75			216
65-69	Sport center	7	340
70-74			290
>75			252

- Identification of the area of influence of each service, that is, the theoretical area in which the users of that service reside This procedure, however, has the limit of considering the territory as isotropic. The areas of influence thus obtained, in fact, do not represent the areas in which the users of a specific service actually reside, since they do not take into account the morphology of the territory and the presence of actually practicable paths as can be seen from fig. 5.

Fig.5 Ideograms area of influence on the elderly population

To identify the viable paths, a procedure was used in a GIS environment which made it possible to define the pedestrian network that the elderly can use to access the services. More specifically, the pedestrian graph has been associated with both the average travel speeds and the slope inferred from the Digital Elevation Model which constitutes an obstacle for the elderly in arriving at an urban service. Functional Accessibility Soft zones (FASZones) have been defined using a tool from the Network Analyst in GIS, that is, the sections of the municipal area that can actually be reached by the elderly population, redefining the traditional concept of catchment area to meet the new needs of the population.

3.3 The measure of pedestrian accessibility to urban services

3.3.1 Pedestrian routes suitable for the elderly[5]

This section describes the steps of the second research segment, aimed at classifying urban areas according to the levels of pedestrian accessibility to key services and also according to the behavior of the elderly (based on the average walking speed) developed a five-step methodology.

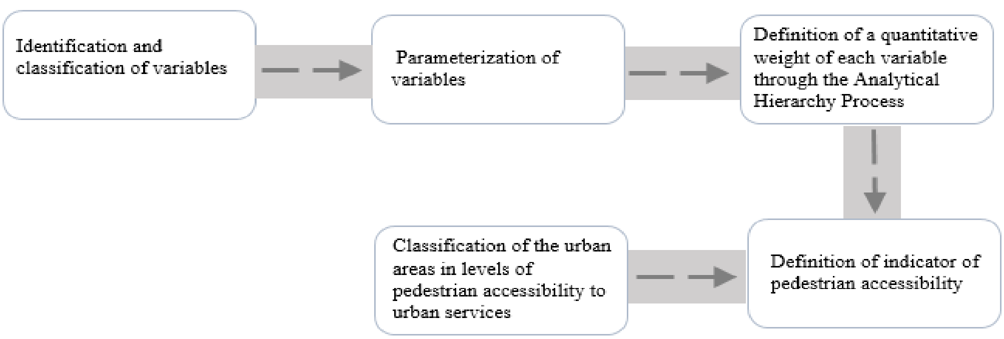


Fig.6 Phases of methodology

The first phase of the study concerned the definition of pedestrian paths suitable for the elderly (Cottrill et al., 2019). The variables were classified according to the following three categories:

[5] Part of this paragraph is contained in the research work of Cottrill, C., Gaglione, F., Gargiulo, C., & Zucaro, F. (2020, September). Defining the characteristics of walking paths to promote an active ageing. In Pedestrians, Urban Spaces and Health: *Proceedings of the XXIV International Conference on Living and Walking in Cities. CRC Press.* ISBN: 978-0-367-46171-3

- physical characteristics that refer to the geometry and quality of the pedestrian paths, such as the slope and the state of the pavement.
- characteristics of the pedestrian paths and of the surrounding context, such as to perceive support, protection and a sense of safety in walking to places and services, for example the density of lighting and presence of escalators; and
- characteristics of the urban context that refer to the attractiveness of a pedestrian path, for example the presence of green areas or panoramic points.

On the basis of the scientific literature, the most significant variables were identified following Multiple-criteria decision analysis (MCDA) as shown in Table 4 (Moon et al., 2016; Wey & Chiu, 2013). The relative importance of each of the variables was quantified, taking into consideration their relation to walkability through the use of multi-criteria analysis. For example, Joo and Kim (2011) and Moon et al (2016) found that the quality of the pavement (e.g. the material used) and the absence of steps are among the main factors encouraging walking. Wang et al (2016) and Bivina et al. (2019) identified security (relating to the perception of the built environment), safety (linked to the presence of barriers such as crossings) and comfort (e.g. presence of benches) as the main characteristics that encourage the walkability of the elderly. Sayyadi and Awasthi (2013), Lee and Park (2014) and Bivina and Parida (2019) found that the presence of services (e.g. green areas) and open spaces and cleanliness occupy the lowest level of the hierarchical list of characteristics of urban accessibility. In addition, other variables relevant to the research objectives have been introduced with respect to these studies. More specifically, the width of the sidewalks was considered under physical characteristics; in characteristics linked to the sense of safety, the lighting density has been included; and in characteristics of the urban context, the presence of panoramic points and non-main roads has been identified. The choice to exclude main roads is linked to the fact that high vehicle travel speeds on these roads and resulting noise pollution make pedestrian movements of the elderly unsafe and unpleasant. Table 4 shows the set of variables that most influence the urban accessibility of the elderly, according to the results of the previous studies on urban accessibility and the walkability of the elderly. In detail, table 4 reports the MCDA weights obtained from the studies of the scientific literature providing a useful comparison for the use of the same analysis whose methodological phases are described below. It is also useful to specify that with respect to the whole set of thoughtful variables, the density of public lighting is the only one linked to the context, defined as the number of light poles compared to the length of the arcs of the pedestrian network.

Tab.4 Characteristics of the pedestrian network

ID	Variable	Measure	Source	References	MCDA weight
Physical characteristics					
1	Slope of the links of the road network	>5%=0 <5%=1	GIS	Joo &Kim, 2011 Moon et al., 2016	0.131 0.195
2	Sidewalk width	<1,5 m=0 >1,5m=1	Google Maps	Joo &Kim, 2011 Moon et al., 2016	0.050
3	State of pavement of the sidewalk	0=poor good=1	Google Maps	Joo &Kim, 2011 Moon et al., 2016	0.150 0.190
Characteristics related to the sense of safety					
4a	Lighting density	<0,056=0 >0,056=1	GIS	Lee & Park, 2014	0.045
4b	Vehicle traffic volume	>17,5 m=0 <9 m=1	GIS		
5	Presence of escalators	No=0 Yes=1	Google Maps	Moon et al., 2016	0.268
6	Presence of bench	No=0 Yes =1	Google Maps	Lee & Park, 2014	0.040
Urban context characteristics					
7	Presence of green areas	No=0 Yes =1	Google Maps	Joo &Kim, 2011 Moon et al., 2016 Bivina & Parida, 2019 Sayyadi & Awasthi, 2013	0.104 0.028 0.020
8	Presence of panoramic points	No=0 Yes =1	Google Maps	Lee & Park, 2014 Sayyadi & Awasthi, 2013	0.066 0.119
9	Non-main roads	No=0 Yes =1	Google Maps	Bivina & Parida, 2019 Wey et al., 2013	0.097 0.207

The second phase of the study concerned the parameterization of each variable of the proposed set. In particular, some variables related to the physical characteristics of a pedestrian path, such as the slope and width of the pavement, are measured on a quantitative scale. To convert these characteristics to a dichotomous scale, conditions favorable to an elderly person along the route have been defined (for example, slope <5%, pavement width >1.5 m, as well as the "difficult" factors that an elderly person may encounter along the route). To define the latter, we consulted documents such as the Highway Code (Legislative Decree of April 30, 1992, no. 285), which regulates the circulation of vehicles and pedestrians on the road. These showed that slopes >5% and pavement widths <1.5m present an architectural barrier for users who walk in the city, in particular for vulnerable groups of the population. For characteristics related to the sense of safety, lighting density and volumes of vehicular traffic were considered. For lighting density, the favorable/unfavorable criteria for the elderly along a pedestrian path were defined based on the number of light poles along the length of the arc in the GIS environment using the natural breaks method. For the volume of vehicular traffic, the criteria have been established on the basis of the type of road and its width as governed by the Ministry of Infrastructure and Transport (MIT) 11/05/2001 (Publication of the regulation on the G.U. n. 3 of 04/01/2002 Functional and geometric standards for the construction of roads). Other variables are measured on a qualitative scale (presence/absence). It is worth noting that the state of the pavement has been defined by means of a direct survey on the territory where the arcs of the network present, for example, a rough pavement, cracks, or discontinuity of the material. The set of variables has been associated in the GIS environment with each arc of the pedestrian graph.

3.3.2 Techniques for defining data weights Analytic Hierarchy Process (AHP)

To take a quantitative weight of each of the variables considered and to understand the relationships between each of the variables examined, in phase three a multi-criteria analysis activity was undertaken, using the Analytic Hierarchy Process (AHP). The choice to consider this method was made for two reasons: (i) the first is that the set of variables examined included quantitative variables such as the slope, the width of the sidewalk, the density of illumination and the volume of vehicular traffic and variable qualities such as urban green space and benches measured according to their presence / absence. The entire set of variables was measured both quantitatively and qualitatively, which did not allow us to use a regression model to help define a weight for each of the variables of the pedestrian network, favoring a multi-criteria analysis; (ii) the second is that a multicriteria analysis such as AHP allows, not only to attribute a quantitative weight to each of the variables examined or a ranking, but also to identify the relationship between the variables through a pairwise comparison between them.

The AHP, developed by the mathematician Thomas L. Saaty (1980), is a method that is based on pairwise comparisons of options to derive the weight of one variable compared to the others, and is able to convert qualitative data into numerical values, which is useful for classifying each alternative on a numerical basis, constituting the statistical technique akin to the set of variables proposed.

The AHP phases are defined as follows:

- Establish the pairwise comparison matrix, defined in linear algebra as the eigenvector matrix. This matrix has the characteristic of being a square matrix (n*n), symmetrical and diagonal.
- Define the AHP pairwise comparison by assigning judgments on a scale defined by decision makers (or experts). The definition of the verbal judgments took place using the Delphi method. The Delphi method is used when "there is an incomplete knowledge of a problem or phenomenon" (Skulmoski et al., 2007) and consists in involving a panel of experts, such as academics, researchers and technicians of the area who have different skills and knowledge on the subject. According to Delbecq et al. (1975) and Rowe (1994) a heterogeneous panel, characterized by experts with different perspectives on the problem, produces proportionally higher results and more acceptable solutions than homogeneous groups. The experts were selected through the Horizon2020 European projects platform. Starting from the list of projects financed on this issue, project managers who could define the panel of experts were first identified. From the reading of each project related to the theme of this research, three categories of experts were selected, namely academics and researchers, professionals and

technicians of the territory with experience in public administration and, in particular, in the urban planning sector. The academics and researchers were selected in relation to the high number of scientific publications about mobility, in particular pedestrian mobility and on urban accessibility for vulnerable groups of the population. The professionals and technicians of the area were selected based on their curriculum. In particular, the technicians of the territory based also on the roles assumed in the public administration such as the drafting of urban plans for sustainable mobility, initiatives and strategies implemented on a local scale focused on urban mobility while the professionals based on their experience and the work carried out in the field of pedestrian mobility. The choice to consider several categories with different competencies and knowledge was made to have the most complete opinions on the subject. Each member of the panel, described in Section 4.3 below, was asked to respond to a questionnaire identifying the influence of each individual characteristic for each group of variables examined and on the choices of a pedestrian path by the elderly population to whom about 80% answered. Their reported judgments were then transposed on a scale of values of 1 to 9 (Saaty, 1980) as in Tab.5.

Tab.5 Conversion of Verbal Values to Numerical Values in the AHP method

Value	**Interpretation**
1	Measure *i* and Measure *j* have equal influence
3	Measure *i* has slightly more influence than Measure *j*
5	Measure *i* has more influence than Measure *j*
7	Measure *i* has strongly more influence than Measure *j*
9	Measure *i* has absolutely more influence than Measure *j*
2,4,6,8	Intermediate values can be applied between the above judgements
1/3	Measure *i* has slightly less influence than Measure *j*
1/5	Measure *i* has less influence than Measure *j*
1/7	Measure *i* has strongly less influence than Measure *j*
1/9	Measure *i* has absolutely less influence than Measure *j*
½, ¼, etc.	Intermediate values can be applied between the above judgements

(Saaty, 1980)

For each row *i* with respect to column *j* of the matrix, a score is attributed on a previously illustrated scale; conversely, the score of the decision of row *j* with respect to column *i* will be equal to its reciprocal. The result of the comparison is the dominance coefficient *aij*, which represents the estimate of the dominance of the element *i* over the element *j*. Following the initial score determination, we next:

- Normalize the values of the matrix (defined as the eigenvector matrix) so as to calculate the weight of each variable as the average of each row *i* of the matrix. These weights define the priorities of the individual variables.
- Calculate the weighted average of each variable (on the weights defined in the previous point), which is useful for estimating the weight of each variable on the judgment attributed by multiplying each column *j* of the matrix of the comparison in pairs by the weight relative to that column.
- Verify the consistency or inconsistency of the assessments assigned by calculating the consistency index and the consistency ratio of the matrix. The consistency of the matrix is useful for checking whether the judgments provided by the experts within the comparison matrix are consistent with the assessments made.

The consistency index is expressed by the following formula

$$CI= (\lambda_{max} - n)/ (n-1)$$

where λ_{max} constitutes the maximum eigenvalue of the matrix, in turn calculated as the ratio between the weighted average of each variable and the weight of each variable and n is the dimension of the matrix. This index constitutes the indispensable premise for calculating the coherence ratio of the matrix expressed as:

$$\text{Consistency ratio (CR)} = CI / RI$$

where RI is equal to the random consistency index defined by Saaty (1980) based on the size of the matrix (Tab.6).

Tab.6 Values of RI in the AHP Method

RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49
n	1	2	3	4	5	6	7	8	9	10

To consider the coherent judgements within the pairwise comparison matrix, CR <0.1 (10%) is placed as a constraint (Saaty: 2012). If this CR exceeds one conventionally set equal to 10% of the R.I. value, it is necessary to review the judgements in the pairwise comparison matrix to identify the cause of the inconsistency and correct it.

The weights deducted from the AHP have been associated with the arcs of the pedestrian network in the GIS environment. Each weight was associated with both the "difficult" factors that the elderly person encounters along the route to access services, for example a poor state of the pavement or high volume of vehicular traffic, and those that constitute architectural barriers for elderly (such as slope >5% or width of the sidewalk <1.5m), while simultaneously giving a reward to the arcs of the network that have characteristics suitable for the elderly.

The next step was the Sensitivity analysis allowed to evaluate the effect of changes in weights of the input values and the assumptions on final outputs (Tsai et al., 2010; Sayyadi & Awasthi, 2012).

In fact, the AHP analysis ranking is heavily dependent on the weights associated with the main criteria. Therefore, a small change in the weights of the criteria have a significant impact on the final classification of the variables.

3.3.3 Sensitivity analysis to validate the weights

According to Balusa and Gorai (2019), «Sensitivity analysis is an essential component of AHP decision-making models […] as it provides information about an alteration in the ranking of the alternatives». Nevertheless, urban accessibility studies mostly referred to this type of analysis as a further work phase to be done. To date, it seems that only Sayyadi & Awasthi (2012) developed it to support decision-making process in locating pedestrian zones. Thus, the present work efforts to measure the consistency in defining the most relevant characteristics of suitable urban paths for the elderly in different conditions. To this end, 20 experiments were conducted with the criterion of varying by increasing the weights of the variables that had a minority role and majority variables were decreased in order to verify whether the variation of these weights completely altered the ordering of the variables obtained from the use of AHP (Table 4). Finally, the findings achieved by AHP method and confirmed by Sensitivity analysis were integrated with spatial analysis, as according to Chandio et al. (2013), «the GIS is a powerful tool in spatial modelling which involves many spatial decision problems providing alternative scenarios in the context of maps».

3.3.4 Construction of index accessibility pedestrian network

The definition of weights with AHP was the starting point in phase four for the development of the accessibility measure. More specifically, the measurement of pedestrian accessibility on the network relates the controls of the elderly in terms of ability to walk every single arc of the network with the weight of the individual characteristics of the pedestrian network, defined in the previous phase.

More specifically, the accessibility index outlined on the pedestrian network graph is as follows:

$$Accessibility\ Pedestrian\ Network = T_{ij} + \sum_{ij}^{n=1} \left(M_{ij}\ x\ T_{ij} \right)$$

where:

T_{ij} is the average walking time of the elderly person from node *i* to node *j* of the pedestrian graph

$\sum_{ij}^{n=1}(M_{ij})$ is the sum of the weights of each characteristic of the pedestrian network from node *i* to node *j*

$\sum_{ij}^{n=1}(M_{ij}\ x\ T_{ij})$ is the average time weighted on the weights of the variables from node *i* to node *j*.

The new accessibility measure defined on the pedestrian network graph is given by two parameters. The first parameter is the average walking time for the elderly, calculated as the ratio between the lengths of the individual arcs of the pedestrian network and the walking speed. In turn, the walking speed of the elderly person was inferred from the study of the scientific literature, in particular of the research carried out by Weber (2016) which determined these values based on the main socio-economic characteristics of the elderly population as expressed in paragraph 3.2.

The second parameter is the weighted average time determined as the product between the average walking time by the elderly person for the weights of the individual characteristics of the pedestrian network inferred from the AHP in phase three of the methodology and associated with the pedestrian network.

The pedestrian accessibility index defines an average time on each pedestrian route based on the effective ability of the elderly person to walk on each arc of the network. At the same time, an average time is weighted based on the characteristics of each pedestrian path. The weighted average time increases if the pedestrian paths have more "difficult" factors, for example inadequate pavement conditions or high slopes compared to favorable conditions; therefore, the elderly person uses a higher "cost" in terms of time in the arcs of the network that are not suitable for their needs. The logic is to create a synthetic indicator from the behaviour of the elderly on each arc of the pedestrian network with the physical characteristics, safety and urban context in order to define accessibility on the pedestrian graph in relation to the possibility of a person with any ability to reach and use places and activities of interest in relation to the characteristics of the built environment. The development of this indicator inserts an element of originality in the scientific reference framework, as it tries to integrate and overcome gaps in approaches identified in Chapter 2. Previous studies that have developed accessibility indicators on the network describe it as a function of the topological characteristics of the network (network connectivity) in order to delineate the travel times in relation to the preferences and lifestyles of the elderly, but do not take into account the characteristics of the built environment along the network (Bono & Gutiérrez, 2011; Weiping & Chi, 2011). By contrast, other studies on accessibility to urban places and services have measured characteristics such as time or distance to define levels of accessibility in reaching an urban service. These studies, however, have not taken into account the "needs" variable linked to the behaviour of specific segments of the population but only to their preferences derived from sample surveys. Recent walkability studies have defined synthetic indicators of qualitative or quantitative "walkability" (Svensson, 2009; Loh et al., 2019), but generally do not include weights of the characteristics of the network and built environment when determining the temporal ability of the elderly to walk to urban services; rather, only their willingness to walk. The originality of this work is to relate physical and safety characteristics and the built environment with the actual capacity in terms of walking speed to access urban services through a synthetic quantitative pedestrian accessibility indicator that integrates and exceeds existing approaches and methods in the scientific reference framework. In phase five of the methodology, we use the defined times on each arc of the pedestrian network and the distribution and location of key types of service for the elderly segment of the population to classify urban areas in terms of pedestrian accessibility to urban services, using a network analysis tool in the GIS environment. Pedestrian access levels are defined through isochrones, which define the areas covered by urban services that are reachable within a given time interval by the different age categories identified. More specifically, urban areas have been classified into three specific time intervals (5, 10, and 15 minutes) (Lovett et al., 2002; Weber & Kwan 2002) by each urban service. The classification of urban areas in terms of pedestrian accessibility to urban services is an indispensable premise for the construction of a tool to support the public decision maker in undertaking interventions (linear, punctual and areas) on portions of municipal territory, to improve the quality of life of the elderly population.[6]

References

Adkins, A., Dill, J., Luhr, G., & Neal, M. (2012). Unpacking walkability: Testing the influence of urban design features on perceptions of walking environment attractiveness. *Journal of Urban Design*, 17(4), 499-510. doi: https://doi.org/10.1080/13574809.2012.706365

Balusa, B. C., & Gorai, A. K. (2019). Sensitivity analysis of fuzzy-analytic hierarchical process (FAHP) decision-making model in selection of underground metal mining method. *Journal of Sustainable Mining*, 18(1), 8-17. doi:https://doi.org/10.1016/j.jsm.2018.10.003

Bivina, G. R., Gupta, A., & Parida, M. (2019). Influence of microscale environmental factors on perceived walk accessibility to metro stations. *Transportation Research Part D: Transport and Environment*, 67, 142–155. doi: https://doi.org/10.1016/j.trd.2018.11.007

Bono, F., & Gutiérrez, E. (2011). A network-based analysis of the impact of structural damage on urban accessibility following a disaster: the case of the seismically damaged Port Au Prince and Carrefour urban road networks. *Journal of Transport Geography*, 19(6), 1443-1455. doi: https://doi.org/10.1016/j.jtrangeo.2011.08.002

Borst, H. C., Miedema, H. M., de Vries, S. I., Graham, J. M., & van Dongen, J. E. (2008). Relationships between street characteristics and perceived attractiveness for walking reported by elderly people. *Journal of Environmental Psychology*, 28(4), 353-361.

[6] Paragraphs 3.3.2 and 3.3.4 is contained in the research work of Gaglione F., Cottrill C., Gargiulo C. (2021). Urban services, pedestrian networks and behaviors to measure elderly accessibility. *Transportation research part D: transport and environment.* https://doi.org/10.1016/j.trd.2020.102687

Chandio, I.A., Matori, A.N.B., WanYusof, K.B. & al. (2013). GIS-based analytic hierarchy process as a multicriteria decision analysis instrument: a review. Arabian *Journal of Geosciences*, 6(8), 3059-3066.

Colclough, J. G. (2009). Modelling Pedestrian Accessibility Using GIS Techniques to Assess Development Sustainability. In European Transport Conference. Retrivied from: http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.684.903&rep=rep1&type=pdf

Cottrill, C., Gaglione, F., Gargiulo, C., & Zucaro, F. (2020, August). Defining the characteristics of walking paths to promote an active ageing. In Pedestrians, Urban Spaces and Health: *Proceedings of the XXIV International Conference on Living and Walking in Cities (LWC, September 12-13, 2019, Brescia, Italy) (p. 209).* CRC Press. ISBN: 978-0-367-46171-3

Delbecq, A.L., Van de Ven, A.H. & Gustafson, D. (1975). Group Techniques for Program Planning; a guide to nominal group and Delphi processes. Glenview IL, Scott Foresman and Company. ISBN 0-673-07591-5

Gómez, L. F., Parra, D. C., Buchner, D., Brownson, R. C., Sarmiento, O. L., Pinzón, J. D., ... & Lobelo, F. (2010). Built environment attributes and walking patterns among the elderly population in Bogotá. *American journal of preventive medicine*, 38(6), 592-599. doi: https://doi.org/10.1016/j.amepre.2010.02.005

Hawkesworth, S., Silverwood, R. J., Armstrong, B., Pliakas, T., Nanchalal, K., Jefferis, B. J., ... & Casas, J. P. (2018). Investigating associations between the built environment and physical activity among older people in 20 UK towns. *J Epidemiol Community Health*, 72(2), 121-131. doi: http://dx.doi.org/10.1136/jech-2017-209440

Joe Weber & Mei-Po Kwan (2002) Bringing Time Back In: A Study on the Influence of Travel Time Variations and Facility Opening Hours on Individual Accessibility, *The Professional Geographer*, 54:2, 226-240. doi: https://doi.org/10.1111/0033-0124.00328

Joo, Y. J., & Kim, S. H. (2011). A new route guidance method considering pedestrian level of service using multi-criteria decision making technique. *Spatial Information Research*, 19(1), 83-91.

Joseph, A., & Zimring, C. (2007). Where active older adults walk: Understanding the factors related to path choice for walking among active retirement community residents. *Environment and Behavior*, 39(1), 75-105. doi:https://doi.org/10.1177/0013916506295572

Lee, H. S., & Park, E. Y. (2014). Comparing the environment for elderly pedestrians among different-sized cities of Gyeonggi province in Korea*. International Journal of Urban Sciences*, 18(1), 76-89. doi: https://doi.org/10.1080/12265934.2013.863449

Li, F., Fisher, K. J., Brownson, R. C., & Bosworth, M. (2005). Multilevel modelling of built environment characteristics related to neighbourhood walking activity in older adults. *Journal of Epidemiology & Community Health*, 59(7), 558-564.

Loh, V. H., Rachele, J. N., Brown, W. J., Ghani, F., Washington, S., & Turrell, G. (2019). The potential for walkability to narrow neighborhood socioeconomic inequalities in physical function: A case study of middle-aged to older adults in Brisbane, Australia. *Health & place*, 56, 99-105. doi: https://doi.org/10.1016/j.healthplace.2019.01.020

Lovett, A., Haynes, R., Sünnenberg, G., & Gale, S. (2002). Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. *Social science & medicine,* 55(1), 97-111. doi: https://doi.org/10.1016/S0277-9536(01)00212-X

Moon, M., Lee, Y., Yu, K., & Kim, J. (2016). Optimized Path Finding Algorithm for Walking Convenience of the People with Reduced Mobility. *Journal of the Korean Society of Surveying*, Geodesy, Photogrammetry and Cartography, 34(3), 273-282. ISSN: 1598-4850

Morency, C., Paez, A., Roorda, M. J., Mercado, R., & Farber, S. (2011). Distance traveled in three Canadian cities: Spatial analysis from the perspective of vulnerable population segments. *Journal of Transport Geography*, 19(1), 39-50. doi:https://doi.org/10.1016/j.jtrangeo.2009.09.013

Nyunt, M. S. Z., Shuvo, F. K., Eng, J. Y., Yap, K. B., Scherer, S., Hee, L. M., ... & Ng, T. P. (2015). Objective and subjective measures of neighborhood environment (NE): relationships with transportation physical activity among older persons. *International journal of behavioral nutrition and physical activity*, 12(1), 108

Parra, D. C., Gomez, L. F., Sarmiento, O. L., Buchner, D., Brownson, R., Schimd, T., ... & Lobelo, F. (2010). Perceived and objective neighborhood environment attributes and health related quality of life among the elderly in Bogota, Colombia. *Social Science & Medicine*, 70(7), 1070-1076. doi: https://doi.org/10.1016/j.socscimed.2009.12.024

Rowe, W.R. (1994). Understanding Uncertainty. Risk Analysis, 14(5), 743-750. doi: https://onlinelibrary.wiley.com/doi/abs/10.1111/j.1539-6924.1994.tb00284.x

Saaty, T. L. (1980*). The Analytic Hierarchy Process* Mcgraw Hill, New York. AGRICULTURAL ECONOMICS REVIEW, 70.

Saaty, T. L., & Vargas, L. G. (2012). *Models, methods, concepts & applications of the analytic hierarchy process* (Vol. 175). Springer Science & Business Media. ISBN 978-1-4614-3597-6

Salvador, E.P., Reis, R.S. & Florindo, A.A. Practice of walking and its association with perceived environment among elderly Brazilians living in a region of low socioeconomic level. *Int J Behav Nutr Phys Act* **7,** 67 (2010). https://doi.org/10.1186/1479-5868-7-67

Sayyadi, G., & Awasthi, A. (2012). AHP-based approach for location planning of pedestrian zones: Application in Montréal, Canada. *Journal of transportation engineering*, 139(2), 239–246. doi: https://doi.org/10.1061/(ASCE)TE.1943-5436.0000493

Scaglioni-Solano, P., & Aragón-Vargas, L. F. (2015). Age-related differences when walking downhill on different sloped terrains. *Gait & posture*, *41*(1), 153-158. doi: https://doi.org/10.1016/j.gaitpost.2014.09.022

Scheiner, J. (2006). Does the car make elderly people happy and mobile? Settlement structures, car availability and leisure mobility of the elderly. European Journal of Transport and Infrastructure Research, 6(2), 151-172. Retrieved from http://www.ejtir.tbm.tudelft.nl/ISSUES/2006_02/pdf/2006_02_03.pd

Schwanen, T., & Páez, A. (2010). The mobility of older people: an introduction. *Journal of Transport Geography*, 18(5), 591–595. doi: https://doi.org/10.1016/j.jtrangeo.2010.06.001

Skulmoski, G.J., Hartman, F.T., Krahn, J. (2007). The Delphi method for graduate research. The *Journal of Information Technology Education*, 6(1), 1-21. doi: https://doi.org/10.28945/199

Svensson, J. (2009, November). Accessibility in the urban environment for citizens with impairments: using gis to map and measure accessibility in Swedish cities. *In Proceedings of the 24th International Cartographic Conference,* Santiago, Chile (pp. 15-21).

Tsai, H. Y., Chang, C. W., & Lin, H. L. (2010). Fuzzy hierarchy sensitive with Delphi method to evaluate hospital organization performance. Expert Systems with Applications, 37(8), 5533-5541. doi: https://doi.org/10.1016/j.eswa.2010.02.099

Wang, Y., Chau, C. K., Ng, W. Y., & Leung, T. M. (2016). A review on the effects of physical built environment attributes on enhancing walking and cycling activity levels within residential neighborhoods. *Cities*, 50, 1–15. doi: https://doi.org/10.1016/j.cities.2015.08.004

Weber, D. (2016). Differences in physical aging measured by walking speed: evidence from the English Longitudinal Study of Ageing. *BMC geriatrics*, 16(1), 31. Doi: https://doi.org/10.1186/s12877-016-0201-x

Weiping, H., & Chi, W. (2011). Urban road network accessibility evaluation method based on GIS spatial analysis techniques

Wey, W. M., & Chiu, Y. H. (2013). Assessing the walkability of pedestrian environment under the transit-oriented development. *Habitat International*, 38, 106-118. doi: https://doi.org/10.1016/j.habitatint.2012.05.004

Wong, R. C. P., Szeto, W. Y., Yang, L., Li, Y. C., & Wong, S. C. (2017). Elderly users' level of satisfaction with public transport services in a high-density and transit-oriented city. *Journal of Transport & Health*, 7, 209-217. doi:https:// doi.org/10.1016/j.jth.2017.10.004

CAPITOLO 4

RESULTS AND DISCUSSION NAPLES AND ABERDEEN PEDESTRIAN PATHS

4.1 Articulation of experimentation

This section describes the procedure for implementing and applying the GIS-based tool. In order to verify the methodology described in section 3.3 (second research segment) and develop the GIS-based tool, the first step was the selection of a study area for the implementation of the tool. In particular, the study area was chosen as the city of Naples, in particular the V municipality (Italy) and the city of Aberdeen (Scotland). The comparison between the two cities with strongly different urban characteristics constituted an interesting test bed for the implementation of the tool. Furthermore, direct knowledge of the two cities allowed verification of the results obtained from the application of the GIS-based tool. After the selection of the study area, the input data for the implementation of the tool were collected. In particular, according to the methodology, the GIS-based tool was developed in three stages. In the first phase, urban characteristics were implemented to the pedestrian network graph and the relative weights defined. Subsequently, the pedestrian accessibility index was built in relation to the behaviour of the elderly and the pedestrian urban characteristics by implementing the creation of the pedestrian network. Finally, the pedestrian accessibility index and the location of urban services for the elderly population at the neighbourhood scale were useful in classifying urban areas in levels of pedestrian accessibility to services. For each phase the results obtained were described and discussed in a specific way. Section 4.1 is structured as follows: Section 4.2 describes the city of Naples and the city of Aberdeen. Section 4.3 illustrates the main results obtained from the definition of the weights of the pedestrian network characteristics and data association in GIS.

Section 4.4 the validation of the weights through the sensitivity analysis while section 4.5 The discussion of the results obtained from the pedestrian paths [7]

4.2 Two cities in comparison: Naples and Aberdeen

The organization of the built environment, and the habits and lifestyles of the users who live in cities, have been discussed by many authors (Borst et al., 2008; Marquet et al., 2017; Papa et al., 2018; Riley et al., 2013). Only in recent years, however, has attention been focused on the "weak" segment of the population (children, the elderly, people with disabilities) in relation to the issue of accessibility in urban areas (Gargiulo et al.2019). In this perspective, the described methodology has been tested in two different urban areas: Naples, Italy and Aberdeen, Scotland. In particular, the area selected in Naples includes the two districts of Vomero and Arenella, while the Aberdeen area includes multiple districts. More specifically, more districts of Aberdeen have been chosen than the two districts of Naples to compare two districts of approximately equal population of the elderly. In addition, the choice of the districts is motivated by the profound morphological, settlement and functional differences that characterise them. In more detail, the municipalities of Vomero and Arenella are both characterized by an older demographic structure, in which percentage of the population over 60 is higher than any other municipality of Naples, equal to 34.3% (City of Naples, 2016). The ageing index, which is the synthetic indicator of the degree of population ageing (the ratio of the population aged 65 and over and the number of people younger than 15), is above 100. In particular, in 2010 this indicator amounted to 188.8% and the value rose up to 210.2% in 2016, with a growth of 21.4%, the latter percentage being higher than any other municipality of Naples (City of Naples, 2016). Moreover, the Vomero district is characterised by a compact and planned fabric, made on a unitary design. In practice, this neighbourhood is designed with a checkerboard pattern, much like the areas of Piazza Vanvitelli and Medaglie d'Oro. The Arenella district, on the other hand, is of a more recent formation than the Vomero district and includes areas such as those related

[7] Part of this paragraph is contained in the research work of Gaglione F., Cottrill C., Gargiulo C. (2021). Urban services, pedestrian networks and behaviors to measure elderly accessibility. *Transportation research part D: transport and environment*. https://doi.org/10.1016/j.trd.2020.102687

to the Rione Alto district, adjacent to the hospital area, the Policlinico and via Domenico Fontana (Fig.7). These areas are characterised by an unplanned fabric, in which the building process began as a consequence of the building saturation of the nearby Vomero district. The hilly orographic conformation of the Neapolitan area (from 150 to 375 m above sea level) influences the choice of spaces and services for the elderly, thus representing an important element in defining strategies and policies aimed at improving accessibility to urban services for the elderly population.

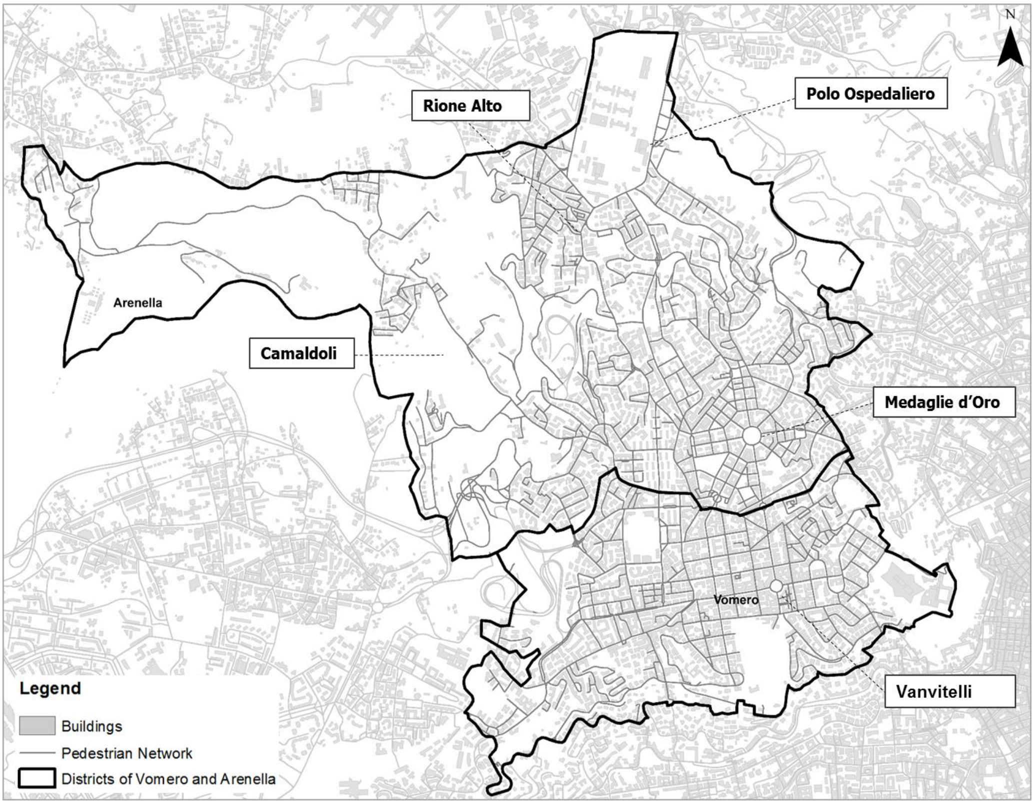


Fig.7 Vomero and Arenella districts in the city of Naples

The districts of the city of Aberdeen are characterized by a demographic structure where 35% of the population is over 65. Moreover, the development of the city of Aberdeen is largely due to its orographic conformation. The presence of the two rivers, the Dee in the south and the Don in the north, on the one hand constituted a natural communication route from the coast to the fertile hinterland and, on the other, precious shelters for navigation on the rugged north-east coast of Scotland. Furthermore, the crossing of these two rivers has conditioned the urban development of the city. Until the mid-18th century, the landform had been "Aberdeen's chief urban planner" (Dennison et al., 2002: p. 33). In detail, for Aberdeen, both the neighborhood of Old Aberdeen and newer areas within Aberdeen (which comprises a number of neighborhoods, as seen in Fig.8) were investigated.

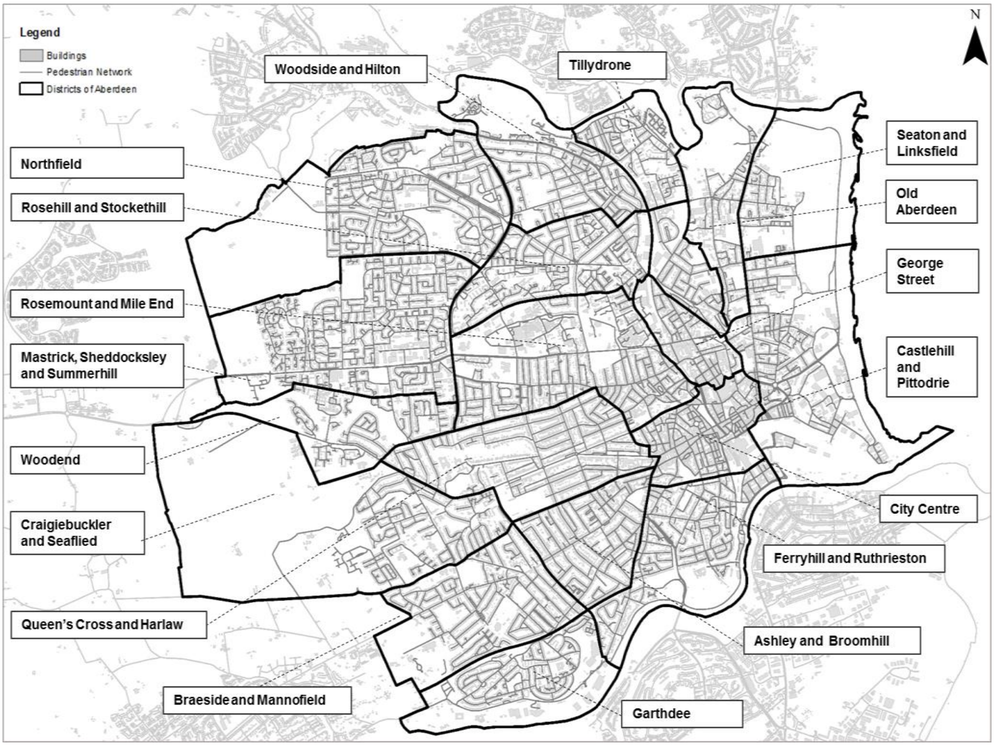


Fig.8 districts of Aberdeen

Old Aberdeen is the historical part of the city, characterized by dense and compact development in which road links were created to facilitate movement both within Old Aberdeen and into neighboring areas. Instead, the new parts of the city of Aberdeen have experienced a different development (Wyness; 1972, Adams; 1978). The urban model can be thought of in terms of three main levels of intervention and development. The first is the medieval, and mainly organic, model. In this case, the roads are rarely straight and most of them wind their way to find the easiest paths and the lowest inclines. The second, characterized by long straight streets, is the series of important Georgian (and later Victorian) interventions and developments of the second half of the 18th and 19th centuries. The third, not represented in the above plan show twentieth-century interventions. This period of development was mainly about meeting new needs such as mass car ownership and the need for efficient traffic circulation, and growth in office size. Newer parts of Aberdeen have been subject to redevelopment since the 1970s. In Aberdeen, the proximity to the port has given rise to redevelopment processes favoring the presence of greater urban services (Fig.8).

4.3 Ranking of pedestrian characteristics

The application mainly concerned the definition of pedestrian paths suitable for the elderly. The set of variables outlined has been associated, in the GIS environment, with each arc of the pedestrian graph of the Vomero and Arenella districts and of the districts of Aberdeen. For the attribution of a quantitative weight to each of the characteristics of the pedestrian network, an AHP multicriteria analysis was carried out after the application of the Delphi method. The results obtained are reported below of the Delphi survey for the two different territorial contexts. In detail, the Delphi study was conducted with an international panel of 150 experts, made up of academics and researchers on the subject and professionals and technical experts operating in the public administration with experience on the issue of urban accessibility. The platform of the European Horizon 2020 project was used to select stakeholders. In turn, the project managers of each project were identified, and the panel of experts selected. In detail, 90 academics were identified, including researchers and professors, comprising half Italian and half non-Italian respondents, as the opinions to be found are in two territorial contexts (Italian and European). Furthermore, as regards academics and researchers, the selection was also conducted starting from the literature review to select the main experts of the scientific debate on the subject. 35 experts as technicians working in public administrations and 25 professionals with expertise in pedestrian mobility were selected, always divided between Italians and Europeans. The questionnaire, conceived through Google Survey, is found entirely as annex A at the end of the volume. Subsequently, all experts were asked to fill in an electronic questionnaire which was disseminated via e-mail. In the end, 120 experts (about 80% of the panel contacted) filled out the survey. In detail, all 90 selected academics responded to the survey, along with 15 additional experts including local technicians and professionals, for a total of 120 respondents. Experts have identified for both contexts the importance of the physical characteristics linked to the sense of safety as the most relevant aspects that influence urban walkability for the elderly, and it was not surprising as they depend on where the over 65 can walk the Delphi method. For the Neapolitan context, the slopes and the presence of lifts/elevators obtained the two highest scores (respectively 68.2% and 63.6%) due to the orographic characteristics of the two districts of Naples, followed by the width of the sidewalk (60%) and pavement quality (59%).Among the characteristics of the urban context, the presence of non-main roads (54.4%) and the absence of green areas (48%) shows that open spaces that are not built are recognized as a key element for the attractiveness of a walkable path also combined with illumination density (Hillsdon et al., 2006; Tribby et al., 2016). On the other hand, the panoramic points obtained a lower score with a score of 22.7% and the presence of benches with 30%. Benches scored higher than viewpoints as a safe element for the elderly during their walking experience. For the territorial context of Aberdeen, the experts gave a higher judgment to the physical characteristics of a pedestrian path such as width of the sidewalk (62.5%) and quality of the pavement (87.5%), below the importance of characteristics related to the sense of safety and protection of the elderly along the walking experience of the elderly. In detail, the volume of vehicular traffic of 50% combined with the presence of escalators and elevators, highlights that the pedestrian safety characteristics perceived by the elderly are secondary only to the physical characteristics of the paths. The presence of travel options along non-main roads was recognized as the first significant urban element for walkability (48%), after the presence of green areas, which constitutes an element of attractiveness and pleasure in walking along a pedestrian path (45%). The slope (25%) had a lower score due to the morphological and orographic characteristics of the city of Aberdeen in conjunction with the presence of benches (22%). It should be specified that it was possible to detect the lighting density only for the Neapolitan context and that for the city of Aberdeen the volume of vehicular traffic was considered between the variables. The results obtained from the questionnaires defined the relevance of each of the variables examined through the attribution of a judgment, as can be seen, by the experts for the two territorial contexts examined. The relevance of each of these variables was transposed into a quantitative value on the scale of values attributed by Saaty, 1980, as shown in Table 5. The phases in which the method is divided have been carried out using computer software (Super Decision Version 3.2) aimed at executing AHP. The results obtained for the districts of Naples and Aberdeen relating to the overall weights of the characteristics of the pedestrian network are shown below. Tables 7 to 16 outline the outputs for the two territorial contexts of Naples and Aberdeen, as described below:

- Tables 7-8 show the outputs obtained for the two territorial contexts of the pairwise comparison between the variables. Such tables have the characteristic of being symmetrical and diagonal. With respect to the main diagonal on the right of the table, in each row *i* with respect to column *j* of the matrix the scores on a scale from 1 to 9 are reported by the AHP experts. These scores constitute the transposition of the verbal judgment assigned by the experts through the questionnaire into a numerical value. On the left, vice versa, the decision values of row *j* with respect to column *i* equal to their reciprocal have been inferred. The comparison between the two tables highlights the differences between the two case studies. For the Neapolitan context the importance of characteristics such as the slope, the width of the sidewalk as it is evident from the assignment of the judgments with respect to furnishing characteristics. For the context of Aberdeen, the importance of characteristics such as the state of the pavement or the volume of vehicular traffic emerges with respect to urban furniture characteristics.

Table 7 Pairwise Comparison of set of variables on the city of Naples

Row *i* \ Column *j*	**1**	**2**	**3**	**4a**	**5**	**6**	**7**	**8**	**9**
1	**1.00**	3.00	4.00	4.00	1.00	5.00	6.00	7.00	4.00
2	0.33	**1.00**	3.00	4.00	1.00	4.00	5.00	6.00	3.00
3	0.25	0.33	**1.00**	3.00	0.25	3.00	4.00	5.00	3.00
4a	0.33	0.25	0.33	**1.00**	0.20	4.00	3.00	5.00	0.33
5	1.00	1.00	4.00	5.00	**1.00**	4.00	4.00	5.00	3.00
6	0.20	0.25	0.33	0.25	0.25	**1.00**	3.00	4.00	0.33
7	0.17	0.20	0.25	0.33	0.25	0.33	**1.00**	4.00	0.20
8	0.14	0.17	0.20	0.20	0.20	0.25	0.25	**1.00**	0.20
9	0.25	0.33	0.33	3.03	0.33	3.03	5.00	5.00	**1.00**
	3.68	6.53	13.45	20.81	4.48	24.61	31.25	42.00	15.06

Note: The values from 1 to 9 present in the tables correspond to the individual characteristics of the pedestrian network in line with table

Table 8 Pairwise Comparison of set of variables on the city of Aberdeen

Row *i* \ Column *j*	**1**	**2**	**3**	**4b**	**5**	**6**	**7**	**8**	**9**
1	**1.00**	0.25	0.25	0.25	1.00	3.00	4.00	6.00	2.00
2	4.00	**1.00**	4.00	3.00	5.00	4.00	5.00	7.00	4.00
3	4.00	0.25	**1.00**	3.00	4.00	4.00	5.00	7.00	3.00
4b	0.25	0.33	0.33	**1.00**	3.00	4.00	5.00	7.00	1.00
5	1.00	0.20	0.25	0.33	**1.00**	3.00	4.00	6.00	2.00
6	0.33	0.25	0.25	0.25	0.33	**1.00**	4.00	5.00	0.25
7	0.25	0.20	0.20	0.20	0.25	0.25	**1.00**	4.00	0.20
8	0.17	0.14	0.14	0.14	0.17	0.20	0.25	**1.00**	0.14
9	0.50	0.25	0.33	1.00	0.50	4.00	5.00	7.14	**1.00**
	11.50	2.88	6.76	9.18	15.25	23.45	33.25	50.14	13.59

Note: The values from 1 to 9 present in the tables correspond to the individual characteristics of the pedestrian network in line with table 4

- Tables 9-10 highlight the normalisation process of the matrix so that the sum of the elements is equal to 1 and defines in the last column of the tables the option weight vector, or the priorities relating to the individual variables. The outputs obtained from the option weight vector were inferred as the average of each row of the normalised pairwise comparison tables.

Table 9 Normalized set of variables and weights on the city of Naples

Row *i* | Column *j*	**1**	**2**	**3**	**4a**	**5**	**6**	**7**	**8**	**9**	**Option Weight Vector**
1	0.27	0.46	0.30	0.19	0.22	0.20	0.19	0.17	0.27	0.25
2	0.09	0.15	0.22	0.19	0.22	0,16	0.16	0.14	0.20	0.17
3	0.07	0.05	0.07	0.14	0.06	0.12	0.13	0.12	0.20	0.11
4a	0.09	0.04	0.02	0.05	0.04	0.16	0.10	0.12	0.02	0.07
5	0.27	0.15	0.30	0.24	0.22	0.16	0.13	0.12	0.20	0.20
6	0.05	0.04	0.02	0.01	0.06	0.04	0.10	0.10	0.02	0.05
7	0.05	0.03	0.02	0.02	0.06	0.01	0.03	0.10	0.01	0.04
8	0.04	0.03	0.01	0.01	0.04	0.01	0.01	0.02	0.013	0.02
9	0.07	0.05	0.02	0.15	0.07	0.12	0.16	0.12	0.07	0.09
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Table 10 Normalized set of variables and weights on the city of Aberdeen

Row i \ Column j	1	2	3	4b	5	6	7	8	9	Option Weight Vector
1	0.09	0.09	0.037	0.03	0.07	0.13	0.12	0.12	0.15	0.09
2	0.35	0.35	0.592	0.33	0.33	0.17	0.15	0.14	0.29	0.30
3	0.35	0.09	0.15	0.33	0.26	0.17	0.15	0.14	0.22	0.21
4b	0.02	0.12	0.05	0.11	0.20	0.17	0.15	0.14	0.07	0.11
5	0.09	0.07	0.04	0.04	0.07	0.13	0.12	0.12	0.15	0.09
6	0.03	0.09	0.04	0.03	0.02	0.04	0.12	0.10	0.02	0.05
7	0.02	0.07	0.03	0.02	0.02	0.01	0.03	0.08	0.01	0.03
8	0.01	0.05	0.02	0.02	0.01	0.01	0.01	0.02	0.010	0.02
9	0.04	0.09	0.05	0.11	0.03	0.17	0.15	0.14	0.07	0.10
	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	

Once the priority vector has been defined, it is important to understand if the matrix of the pairwise comparisons is consistent or not, that is, we try to "measure" whether the subjective judgments of the decision maker attributed to each comparison are consistent or not. To check the consistency of the matrix it is necessary to perform some intermediate steps as described in the following tables.

- Tables 11-12 how the influence of the judgement attributed by the decision maker for the weight vector option, which was defined for each judgement element by multiplying each column *j* of the pairwise comparison table 7-8 for the weight relative to that column, with the aim of defining a weighted sum value.

Table 11 Weighted average of the variables on the city of Naples

Row *i* \ Column *j*	1	2	3	4a	5	6	7	8	9	Weighted Sum Value
1	0.25	0.52	0.43	0.29	0.20	0.24	0.21	0.15	0.37	2.66
2	0.08	0.17	0.32	0.29	0.20	0.20	0.18	0.13	0.28	2.00
3	0.06	0.06	0.11	0.22	0.05	0.15	0.14	0.10	0.28	1.20
4a	0.08	0.04	0.04	0.07	0.04	0.20	0.11	0.10	0.03	0.71
5	0.25	0.17	0.43	0.36	0.20	0.20	0.14	0.10	0.28	2.10
6	0.05	0.04	0.04	0.02	0.05	0.05	0.11	0.08	0.03	0.50
7	0.04	0.03	0.03	0.02	0.05	0.02	0.04	0.08	0.02	0.30
8	0.04	0.03	0.02	0.01	0.04	0.01	0.036	0.02	0.02	0.23
9	0.06	0.06	0.04	0.22	0.07	0.15	0.009	0.10	0.09	0.79

Table 12 Weighted average of the variables on the city of Aberdeen

Row *i* Column *j*	**1**	**2**	**3**	**4b**	**5**	**6**	**7**	**8**	**9**	**Weighted Sum Value**
1	0.09	0.07	0.05	0.03	0.09	0.16	0.13	0.11	0.19	0.92
2	0.36	0.30	0.82	0.34	0.45	0.21	0.16	0.12	0.38	3.00
3	0.36	0.07	0.21	0.34	0.36	0.21	0.16	0.12	0.29	2.10
4b	0.02	0.10	0.07	0.11	0.27	0.21	0.16	0.12	0.10	1.17
5	0.09	0.06	0.05	0.04	0.09	0.16	0.13	0.11	0.19	0.90
6	0.03	0.07	0.05	0.03	0.03	0.05	0.13	0.09	0.02	0.50
7	0.02	0.06	0.04	0.02	0.02	0.01	0.03	0.07	0.02	0.30
8	0.02	0.04	0.03	0.02	0.02	0.01	0.033	0.02	0.01	0.19
9	0.05	0.07	0.07	0.11	0.05	0.21	0.008	0.13	0.10	0.79

The definition of the weighted sum value for both the two territorial contexts is preparatory to the definition of the maximum eigenvalue of the matrix λ_{max} and is given by the average of the ratios between the weighted averages and the relative percentage weights.

- Tables 13-14 demonstrate the relationship between the defined weighted sum value and option weight vector for each variable. The average value of this ratio defines the maximum eigenvalue of the matrix, which is useful in turn for defining its maturity index to verify the consistency of the judgements attributed in relation to the number of variables, finally to define the consistency ratio of the matrix itself.

Table 13 Definition of weighted sum value/option weight vector for variables on the city of Naples

Variables	**Weighted Sum Value**	**Option Weight Vector**	**Weighted Sum Value/Option Weight Vector**
1	2.66	0.25	11.00
2	1.84	0.17	11.00
3	1.16	0.11	11.00
4a	0.71	0.07	10.00
5	2.13	0.20	11.00
6	0.47	0.05	10.00
7	0.33	0.04	9.00
8	0.23	0.02	11.00
9	0.79	0.09	9.00

Note: λmax = Average (Weighted Sum Value/Option Weight) =10; Consistency Index (C.I.) = (λmax – n) / (n-1); where n=number of compared options (measures) = 9; Consistency Index (C.I.) = 0,139; Consistency Ratio = C.I. / Random Index (R.I.) = 0,096<0.1 matrix consistency OK

Table 14 Definition of weighted sum value/option weight vector for variables on the city of Aberdeen

Variable	Weighted Sum Value	Option Weight Vector	Weighted Sum Value/Option Weight Vector
1	0.92	0.09	10.00
2	3.16	0.30	11.00
3	2.13	0.21	10.00
4b	1.17	0.11	10.00
5	0.92	0.09	10.00
6	0.51	0.05	10.00
7	0.30	0.03	9.00
8	0.19	0.02	11.00
9	0.79	0.10	8.00

Note: λmax = Average (Weighted Sum Value/Option Weight) =10; Consistency Index (C.I.) = (λmax – n) / (n-1); where n=number of compared options (measures) = 9; Consistency Index (C.I.) = 0, 12; Consistency Ratio = C.I. / Random Index (R.I.) =0,0832<0.1 matrix consistency OK

The coherence and congruence of the matrix of the pairwise comparison has been validated. This allows us to confirm the results obtained by the Option Weight Vector, or to define the weight of each of the variables considered and the relative priority ranking for each of the two territorial contexts.

- Tables 15-16 summarize the weights inferred for each single variable examined and the relative weight in percentage terms.

Table 15 Weights of variables on the city of Naples

Variables	Option Weight Vector	Option Weight Vector (%)	Option Local Weight Vector
1	0.25	25%	0.67
2	0.17	17%	0.61
3	0.11	11%	0.10
4a	0.07	7%	0.25
5	0.20	20%	0.68
6	0.05	5%	0.07
7	0.04	4%	0.28
8	0.02	2%	0.10
9	0.09	9%	0.62

Table 16 Weighted average of the variables on the city of Aberdeen

Variable	Option Weight Vector	Option Weight Vector (%)	Option Local Weight Vector
1	0.09	9%	0.27
2	0.30	30%	0.61
3	0.21	21%	0.12
4b	0.11	11%	0.50
5	0.09	9%	0.12
6	0.05	5%	0.38
7	0.03	3%	0.23
8	0.02	2%	0.10
9	0.10	10%	0.67

4.4 Ranking validation results of pedestrian paths

To ensure the reliability of the final weights of the input values (the AHP scores), sets of sensitivity analyzes have been developed for the two territorial contexts. In detail, 20 sensitivity analysis experiments were conducted. In the first 10 experiments, the variables tested included the group of characteristics linked to the sense of security and urban context that have assumed a minority value. The weights were increased from time to time by 10% up to an increase of 60%. In contrast, for the variables that have assumed a majority value, the weights have been decreased by less than 10% up to a decrease of 60%. The most significant scenarios have been reported where the weight increase was equal to 50% for characteristics such as "green areas", "presence of panoramic points" and "bench" for both territorial contexts. The scenarios of significant decrease of the variables have been reported, which also in this case was equal to 50% for characteristics such as "sidewalk width"; " state of pavement" and "Non-main roads" for the Neapolitan context. Instead, for Aberdeen, not only the quality of the pavement was reduced, but also the volume of vehicular traffic and the presence of furniture for stairs and elevators. In addition, these experiments were defined considering the rank of the AHP scores, where it is possible to identify three groups of variables, whose distances (between one group and another) are well defined (Table.17). The "viability street" cluster has such high weights (compared to the others, over 20%) that these values would remain the same size even if they vary; the second and third groups, respectively called "comfort" and "amenity."

Table 17 Cluster of pedestrian paths Naples and Aberdeen

<table>
<tr><th>Variables</th><th>AHP weights Naples</th><th>Cluster</th><th>Variables</th><th>AHP weights Aberdeen</th><th>Cluster</th></tr>
<tr><td>Slope of the road network</td><td>25%</td><td rowspan="3">Viability Street Cluster</td><td>Sidewalk width</td><td>30%</td><td rowspan="2">Viability Street Cluster</td></tr>
<tr><td>Presence of escalators</td><td>20%</td><td>State of pavement of the sidewalk</td><td>21%</td></tr>
<tr><td>Sidewalk width</td><td>17%</td><td>Vehicle traffic volume</td><td>11%</td><td rowspan="4">Comfort Cluster</td></tr>
<tr><td>State of pavement of the sidewalk</td><td>11%</td><td rowspan="3">Comfort Cluster</td><td>Presence of escalators</td><td>9%</td></tr>
<tr><td>Non-main roads</td><td>9%</td><td>Slope of the road network</td><td>9%</td></tr>
<tr><td>Lighting density</td><td>7%</td><td>Non-main roads</td><td>10%</td></tr>
</table>

Presence of bench	5%	Amenity Cluster	Presence of bench	5%	Amenity Cluster
Presence of green areas	4%		Presence of green areas	3%	
Presence of panoramic points	2%		Presence of panoramic points	2%	

Figures 9 to 12 report the results of the sensitivity analysis of the 6 tests showing that they do not differ much from the AHP rank. Observing these orders due to such changes, the first type of variable is relatively insensitive to the variation of weights compared to the other groups where the variation of the weight does not differ from the initial value. The histograms on Naples and Aberdeen, or the related scenarios, show that the modification of the weights is relatively insensitive and confirms the robustness of the order of the variables obtained in Naples and Aberdeen by using the AHP model.

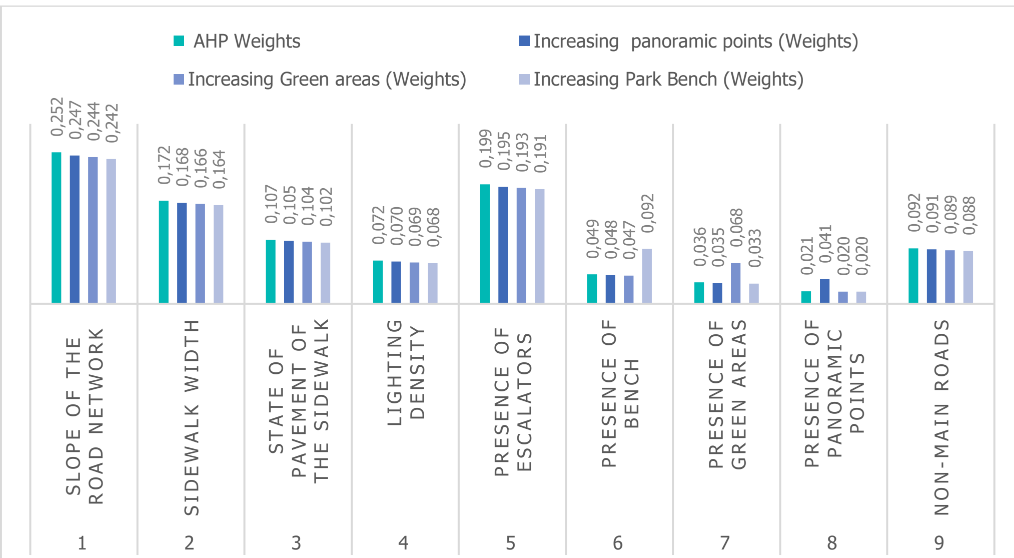


Fig.9 sensitivity analysis- scenarios increasing Naples

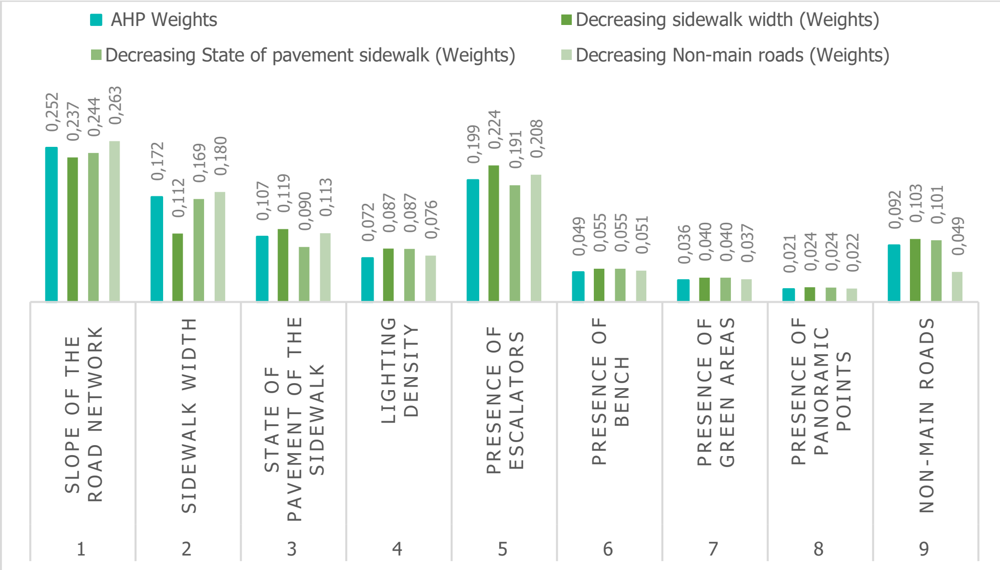


Fig.10 sensitivity analysis- scenarios decreasing Naples

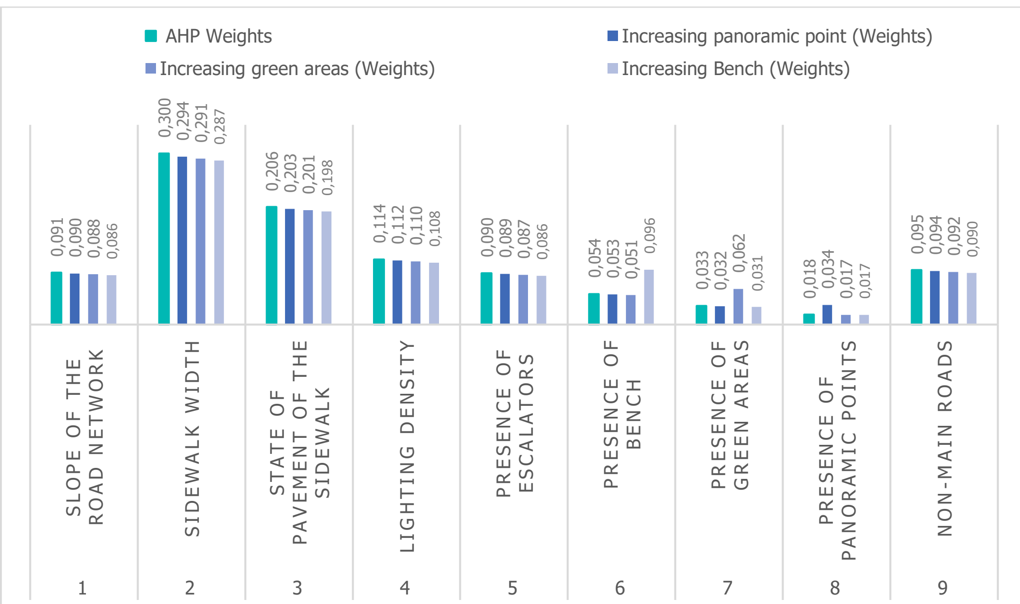


Fig.11 sensitivity analysis- scenarios increasing Aberdeen

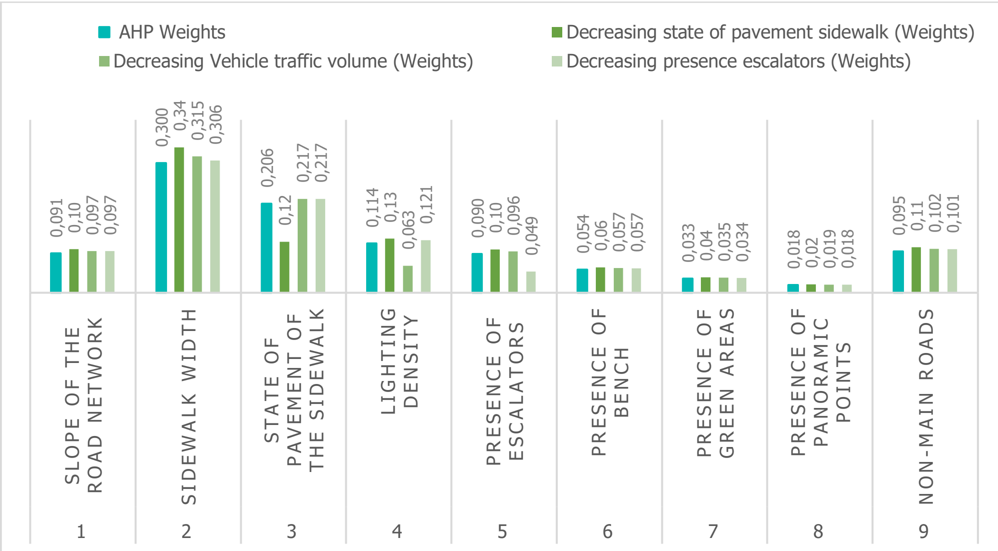


Fig.12 sensitivity analysis- scenarios decreasing Aberdeen

4.5 Discussion pedestrian paths

The weights obtained by the AHP (in table 15-16) for the two territorial contexts first highlight the importance of physical characteristics such as the width of the sidewalk, the quality of the pavement and therefore the practicability of a pedestrian path and possible obstacles which can limit accessibility to urban services. Secondly, the importance of safety features related to protection from various risks during the walking experience were considered, including street lighting, the volume of vehicular traffic and the presence of escalators for both Naples and Aberdeen. Finally, the importance of the urban context characteristics linked to the pleasantness and attractiveness of the pedestrian path, given, for example, by the presence of urban furniture that improves the degree of comfort of the path. The results obtained from the application also allow one to: (i) *Identify the portions of the pedestrian network in which to intervene:* Interventions may be recommended primarily based on the weights defined by the AHP to improve both the individual characteristics considered and the overall usability and attractiveness (Fig.13). In particular, in the application to the Neapolitan context, it can be noted that the routes in the area of Piazza Vanvitelli and Piazza Medaglie d'Oro are suitable for the elderly, while in the area of Rione Alto and the area of Camaldoli the routes present barriers and obstacles. In Aberdeen, by contrast, all pedestrian paths are suitable for the elderly (Fig.13). These results, in part, are due to the morphological differences of the two cities examined: Naples has a hilly territory while Aberdeen is generally flat (with the exception of the area between the port and the main city centre). For example, Naples demonstrates a higher presence of topographical slopes that may impede the elderly traveler; however, while it exhibits a more sloping territory than the city of Aberdeen, at the same time it also contains a pedestrian network more suitable for the elderly than Aberdeen in terms of network characteristics. (ii) *Identify the "optimal" paths that possess all the qualities (characteristics) considered*: For Naples and Aberdeen the colored areas (green) shown in Figures 23 and 24 are the optimal routes based on individual characteristics in their current state, while those remaining are pedestrian paths that need additional development of the tested characteristics to improve their suitability.

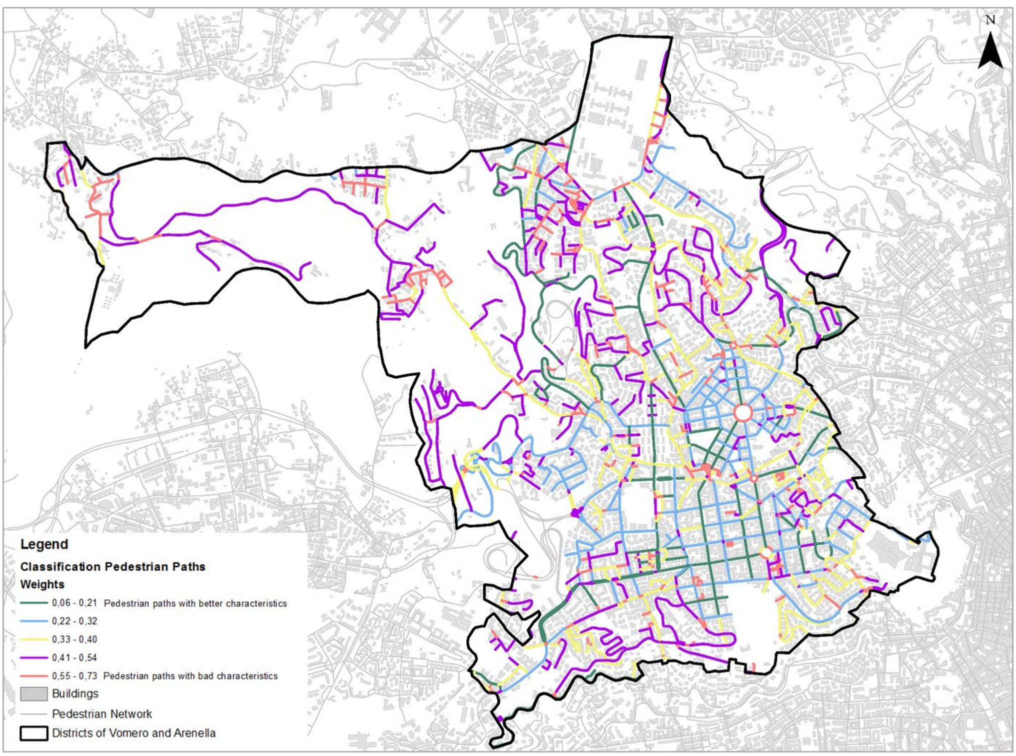


Fig.13 Pedestrian paths classified according to the weights of the characteristics considered for Naples.

As shown in Fig. 14, given the significant differences between the two contexts examined, Aberdeen presents a better predisposition of the routes from the point of view of the physical characteristics compared to Naples.

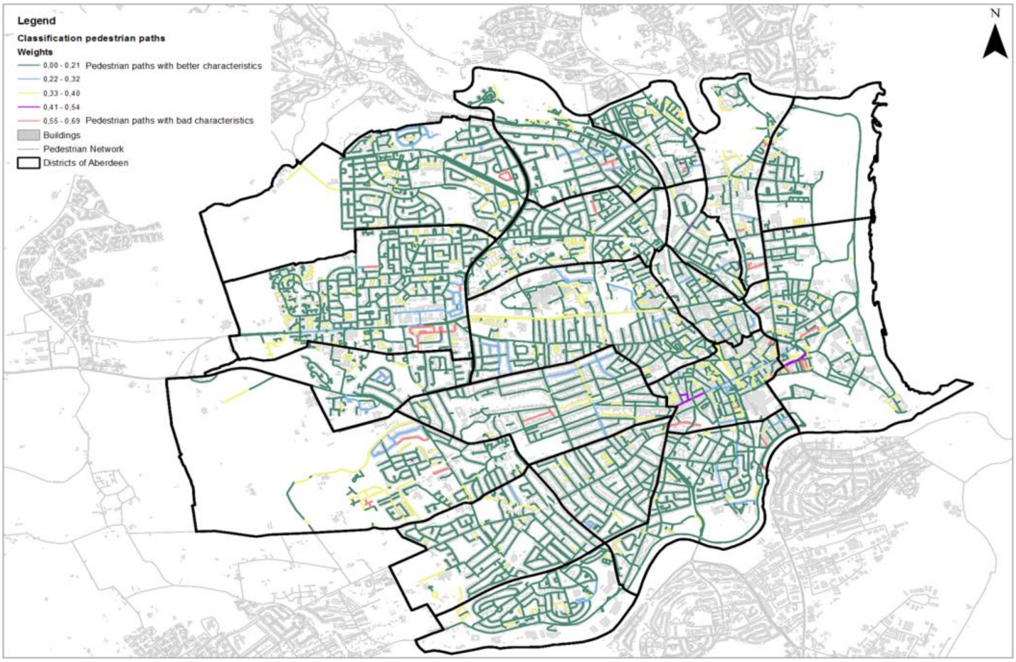


Fig.14 Pedestrian paths classified according to the weights of the characteristics considered for Aberdeen.

References

Adams, I. H. (1978). *The making of urban Scotland*. McGill-Queen's Press-MQUP.

Hillsdon, M., Panter, J., Foster, C., and Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. *Public Health*, 120, 1127–1132. doi: 10.1016/j.puhe.2006.10.007

Tribby, C. P., Miller, H. J., Brown, B. B., Werner, C. M., & Smith, K. R. (2016). Assessing built environment walkability using activity-space summary measures. *Journal of transport and land use*, 9(1), 187. doi: https://dx.doi.org/10.5198%2Fjtlu.2015.625

Adams, I. H. (1978). The making of urban Scotland. McGill-Queen's Press-MQUP.

Borst, H. C., Miedema, H. M., de Vries, S. I., Graham, J. M., & van Dongen, J. E. (2008). Relationships between street characteristics and perceived attractiveness for walking reported by elderly people. Journal of Environmental Psychology, 28(4), 353-361. doi: https://doi.org/10.1016/j.jenvp.2008.02.010

Dennison, E. P., Simpson, A. T., & Simpson, G. G. (1800). The growth of two towns. Dennison, EP, Ditchburn, D., and Lynch, M., Aberdeen before, 13-43.

Gargiulo, C., Zucaro F. & Gaglione, F. (2019), Improving accessibility to urban services for over 65: a GIS-supported method, in C. Gargiulo & C. Zoppi (Eds.), Planning, nature and ecosystem services (pp. 839-850). Naples: FedOAPress. ISBN: 978-88-6887-054-6, doi: 10.6093/978-88-6887-054-6

Hillsdon, M., Panter, J., Foster, C., and Jones, A. (2006). The relationship between access and quality of urban green space with population physical activity. Public Health, 120, 1127–1132. doi: 10.1016/j.puhe.2006.10.007

Marquet, O., Hipp, J. A., & Miralles-Guasch, C. (2017). Neighborhood walkability and active ageing: a difference in differences assessment of active transportation over ten years. Journal of Transport & Health, 7, 190-201. doi: https://doi.org/10.1016/j.jth.2017.09.006

Papa R., Fistola R., Gargiulo C. (2018) (eds) Smart Planning: Sustainability and Mobility in the Age of Change. Green Energy and Technology. Springer, Cham, ISSN 1865-3537 Green Energy and Technology book series

Riley, D. L., Mark, A. E., Kristjansson, E., Sawada, M. C., & Reid, R. D. (2013). Neighborhood walkability and physical activity among family members of people with heart disease who participated in a randomized controlled trial of a behavioral risk reduction intervention. Health & place, 21, 148-155. doi: https://doi.org/10.1016/j.healthplace.2013.01.010

Tribby, C. P., Miller, H. J., Brown, B. B., Werner, C. M., & Smith, K. R. (2016). Assessing built environment walkability using activity-space summary measures. Journal of transport and land use, 9(1), 187. doi: https://dx.doi.org/10.5198%2Fjtlu.2015.625

Wyness, F. (1965). City by the Grey North Sea: Aberdeen. Alex. P Reid.

CAPITOLO 5

RESULTS AND DISCUSSION NAPLES AND ABERDEEN

5.1 Results of measure pedestrian accessibility in levels

In accordance with the previous section, the definition of the weights of single variables on each arc of the pedestrian network was the starting point for determining the measure of pedestrian accessibility expressed in terms of time associated with the graph of the pedestrian network of the fifth municipality of Naples and Aberdeen. The travel times defined on the basis of the walking speed of the elderly, together with the weight of the characteristics shown on the pedestrian graph and the distribution and location of services, were the inputs to classify the areas of the municipal territory (through the use of a tool network analysis) in three classes (one for each of the three-time intervals of 5, 10 and 15 minutes). With this in mind, the results obtained show that the areas in which it is possible to reach the different services in established time intervals (5 minutes' yellow, 10 minutes green and 15 minutes red) change by reason of the characteristics of the pedestrian network.

5.2 Discussion of measure pedestrian accessibility

In reference to the outputs obtained from the measurement of pedestrian accessibility in relation to the distribution and location of the different types of services of interest to the elderly, the results show that health services (pharmacies, poly-diagnostic centres) are homogeneously distributed and located in those portions of the urban fabric characterized by a unified and planned design, such as in the area bordering the Vomero district and in the area close to the Pascale hospital centre (Arenella district) (fig.15).

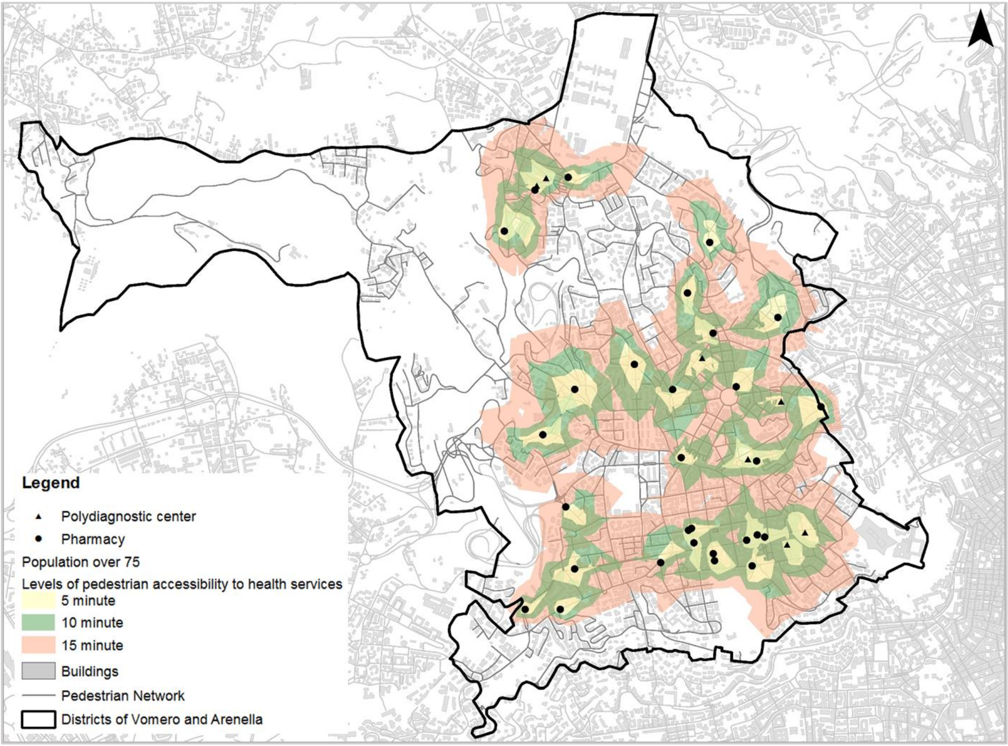


Fig.15 Classification of urban areas in levels of pedestrian accessibility to health services for Naples

At the same time, the results present a network of pedestrian paths suitable for the elderly in the Vomero district compared to the area next to the hospital center and with access to the service in a time interval of 10 minutes. On the other hand, accessibility to health services is lacking in the areas adjacent to the Cardarelli hospital and in the Camaldoli area, where the pedestrian network is not suitable for the elderly.

For Aberdeen, the offer of health services is widespread in the neighbourhoods of Craigiebuck and Seafield, Queen's Cross and Harlaw, Woodend and Rosemount and Mile End, but access to the service can be reached by the elderly in most districts in 15 minutes, despite the elderly-friendly features of the entire pedestrian network throughout the study area.

In some cases, health services are centred along main streets at the borders of districts, which is reflected in longer walking times seen in district centres and on the outskirts of the city (fig.16).

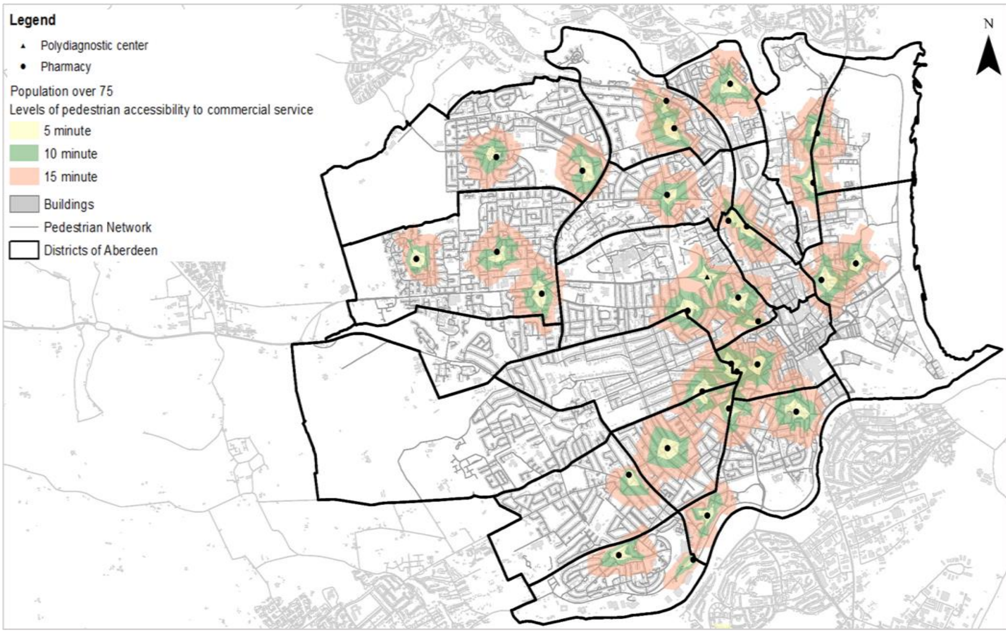


Fig.16 Classification of urban areas in levels of pedestrian accessibility to health services for Aberdeen

Turning to financial services (banks, post offices and municipal offices), the areas served are concentrated in most of the Vomero and Arenella districts with suitable and accessible routes for the elderly in Piazza Medaglie d'Oro and Vanvitelli in a time interval of 10 minutes. In the Rione Alto area, access to the service can be reached in a longer time due to a pedestrian network that does not meet the needs of the elderly. Moreover, for the Camaldoli area there is a total absence of this type of service, while the area of the Rione Alto demonstrates longer times of access to services. In the Camandoli area, not only the pedestrian paths do not meet certain requirements for the elderly but at the same time there is a total absence of such services (fig.17). By contrast, in Aberdeen the areas served by this type of activity are more concentrated in districts, such as the City Center and George Street, which have undergone redevelopment processes due to their adjacency to the port. This is similarly seen in the district of Old Aberdeen, which constitutes the oldest urban fabric of the city of Aberdeen, and in the neighborhoods adjacent to it such as Woodside and Hilton, Tillydrone, Queen's Cross and Harlaw. In the remaining districts, the absence of service or this type of service may be noted within a 10-minute walk of the elderly population (fig.18).

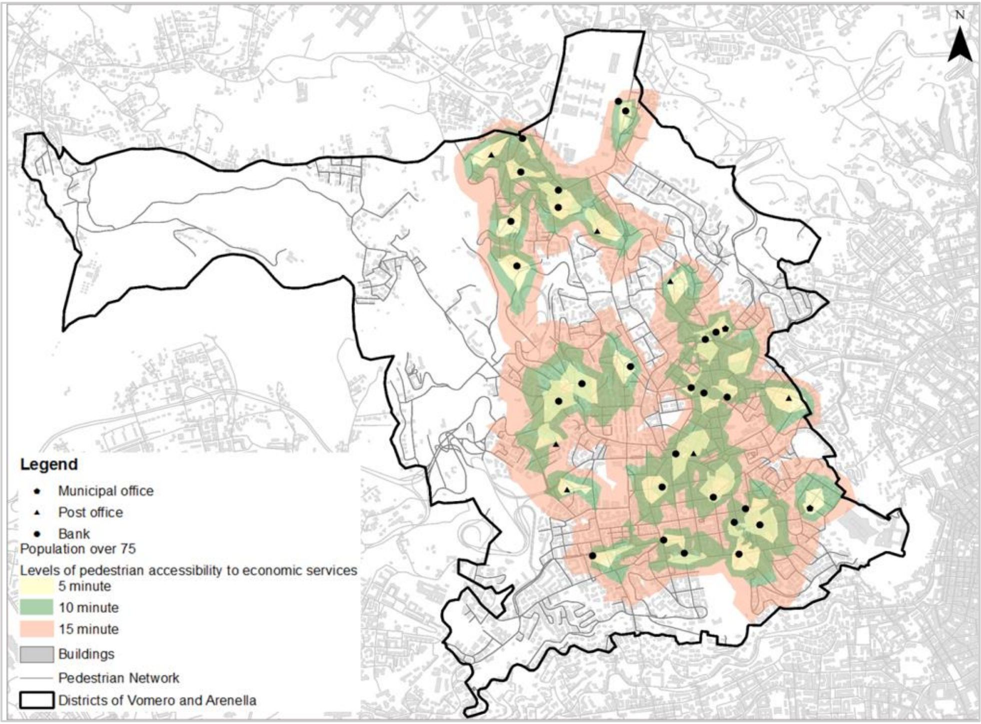


Fig.17 Classification of urban areas in levels of pedestrian accessibility to economic services for Naples

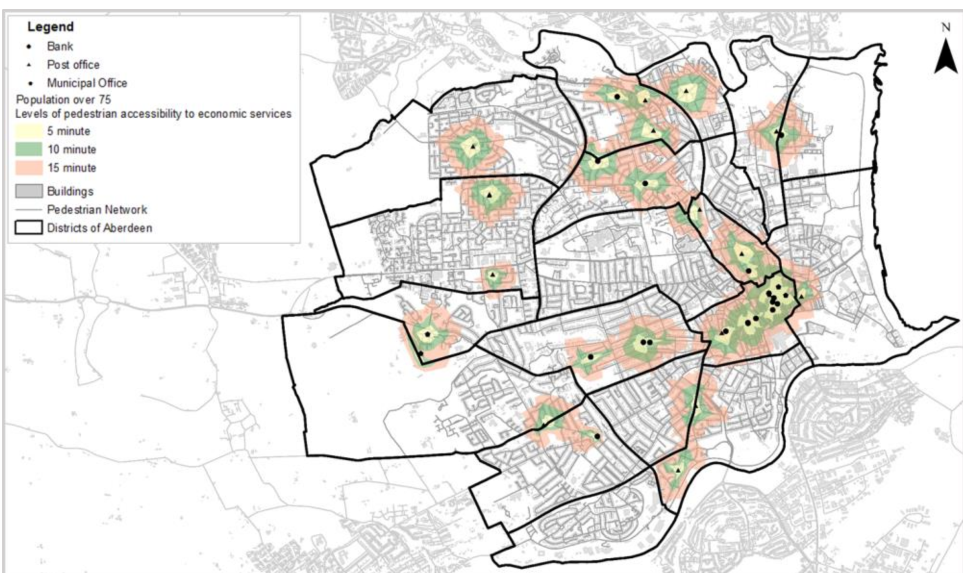


Fig.18 Classification of urban areas in levels of pedestrian accessibility to economic services for Aberdeen

If the study areas of the Vomero and Arenella districts are generally characterized by medium-high accessibility to health and financial services, those of Aberdeen have better accessibility to health services than financial services. In the Vomero and Arenella districts, cultural services are concentrated almost exclusively in the area between Piazza Medaglie d'Oro and Vanvitelli with a greater prevalence of the urban service of the churches than the other two services examined due to the historical-artistic identity of the city of Naples. It is evident from the map that the times are in 15 minutes, even if the network of pedestrian paths largely responds to certain characteristics for the elderly, their distribution and location are not easily accessible to this segment of the population (fig. 19). In the districts of Aberdeen there is a widespread presence of this type of activity, in particular the urban service of churches. As in Naples, there is widespread presence of churches that outline the historical and artistic characteristics of the place, and with access times to the service in 10 minutes in most of the districts considered, moreover the network of pedestrian paths responds well to the needs and requirements of the over-75 population. Cultural services such as libraries and cinemas appear to be present only in some parts of the city, but at the same time it is a service that the elderly prefer less than churches (fig. 20).

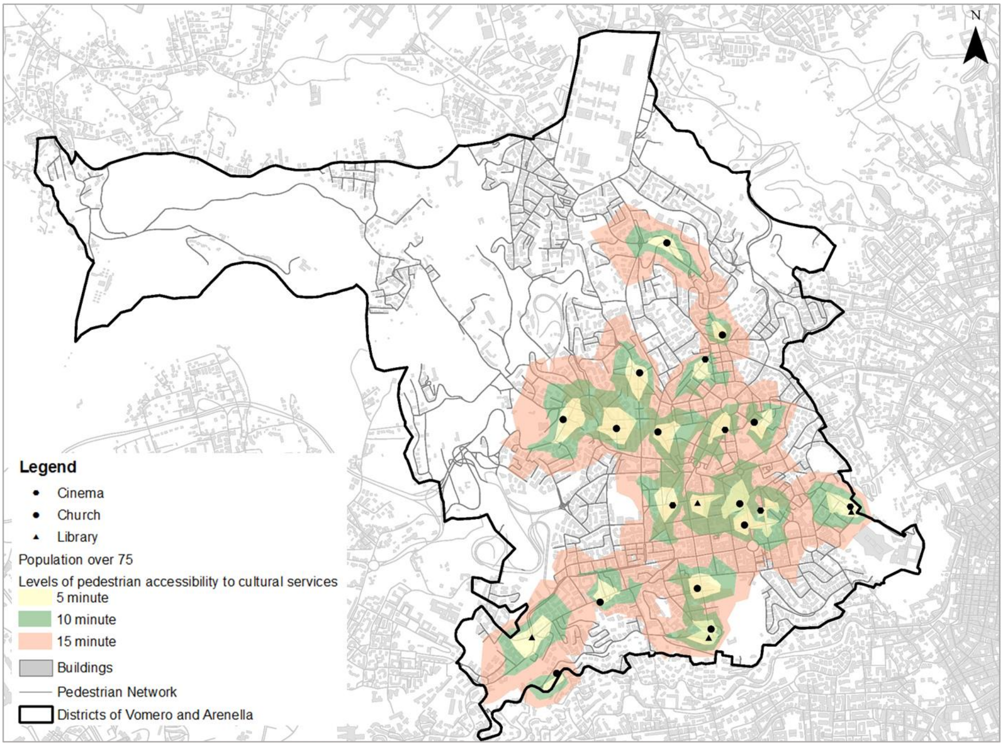


Fig.19 Classification of urban areas in levels of pedestrian accessibility to cultural services for Naples

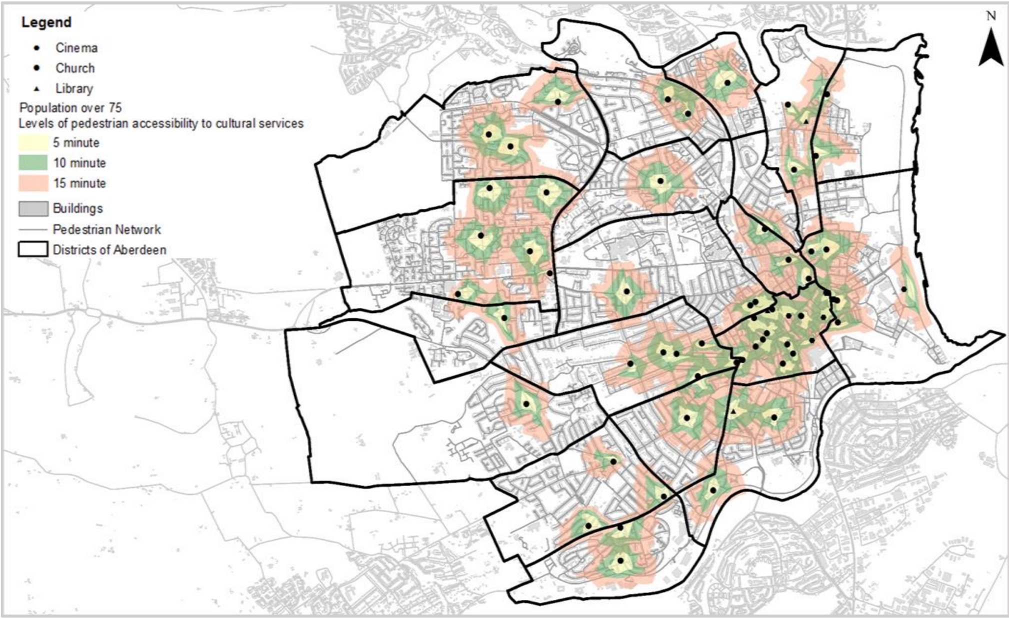


Fig.20 Classification of urban areas in levels of pedestrian accessibility to cultural services for Aberdeen

For both study areas examined, there is a lack of leisure services (such as sports centers). In detail, a concentration of this service can be seen only in some areas of the two districts considered. The area between Piazza Vanvitelli and via Luca Giordano shows the presence of a pedestrian network that can be used for the elderly. In the area adjacent to the hospital and via Domenico Fontana and in the eastern area of the Arenella district, this service is not easily accessible for the elderly due to the presence of barriers and obstacles along the pedestrian paths (fig.21). For Aberdeen, access to recreational services is seen only in a few districts of the city, catering to the needs of only 15% of the population.

In detail, the presence in the most consolidated areas of the city and in the neighboring districts such as Old Aberdeen, Woodside, and Hilton and George street is evident, as well as in more recently formed areas such as City Center, Ashley and Broomhill and Garthdee. In the other districts, however, these services are not present.

The map shows that this service is located on the borders of the various districts and along the main roads (fig.22).

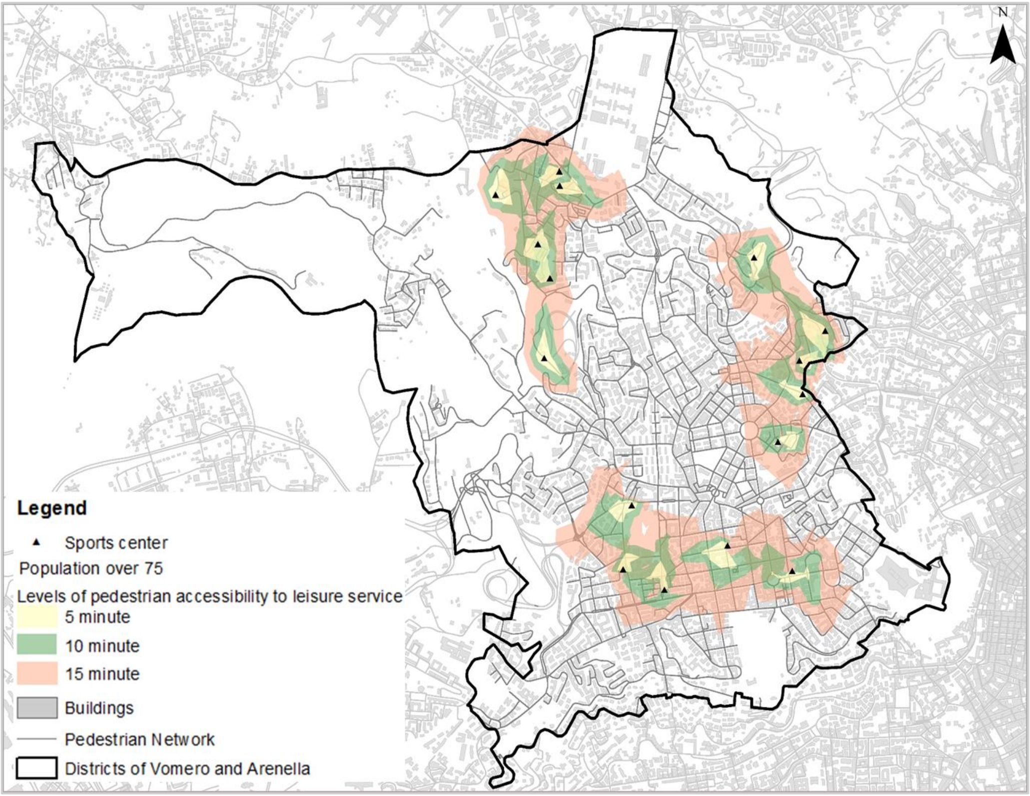


Fig.21 Classification of urban areas in levels of pedestrian accessibility to leisure services for Naples

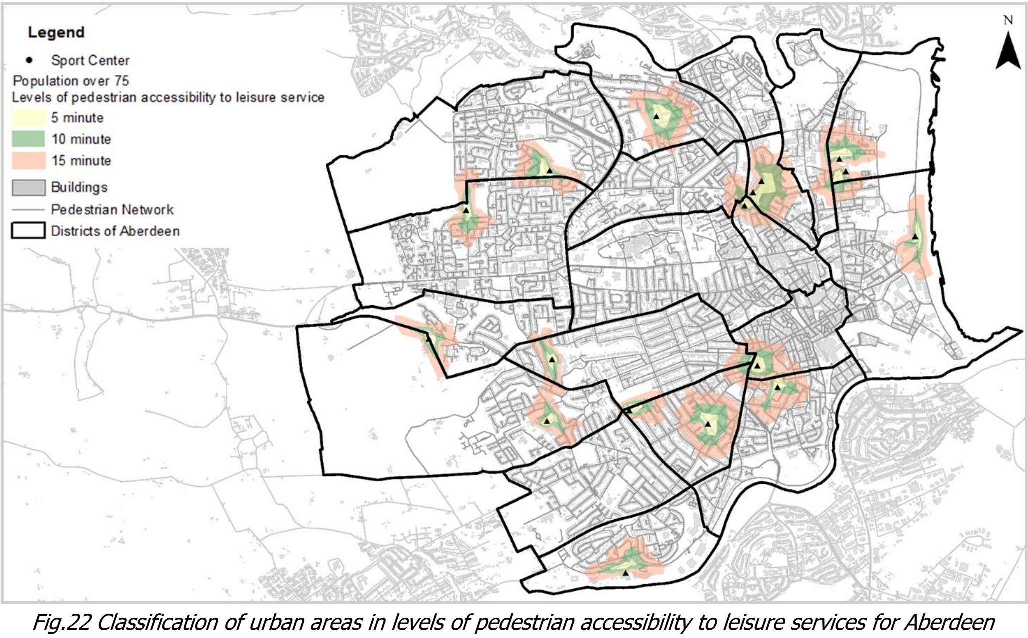


Fig.22 Classification of urban areas in levels of pedestrian accessibility to leisure services for Aberdeen

Accessibility to commercial services (such as supermarkets) is limited to the adjacent area of the Vomero and Arenella districts, with the difference that in the Vomero district the network of pedestrian paths is more suitable for the elderly than the pedestrian network of the Arenella district. This difference can be seen within the map that the same time interval, for example 5 minutes, satisfies a greater demand for the elderly population than the areas adjacent to the hospital and east of the Arenella district (fig.23).

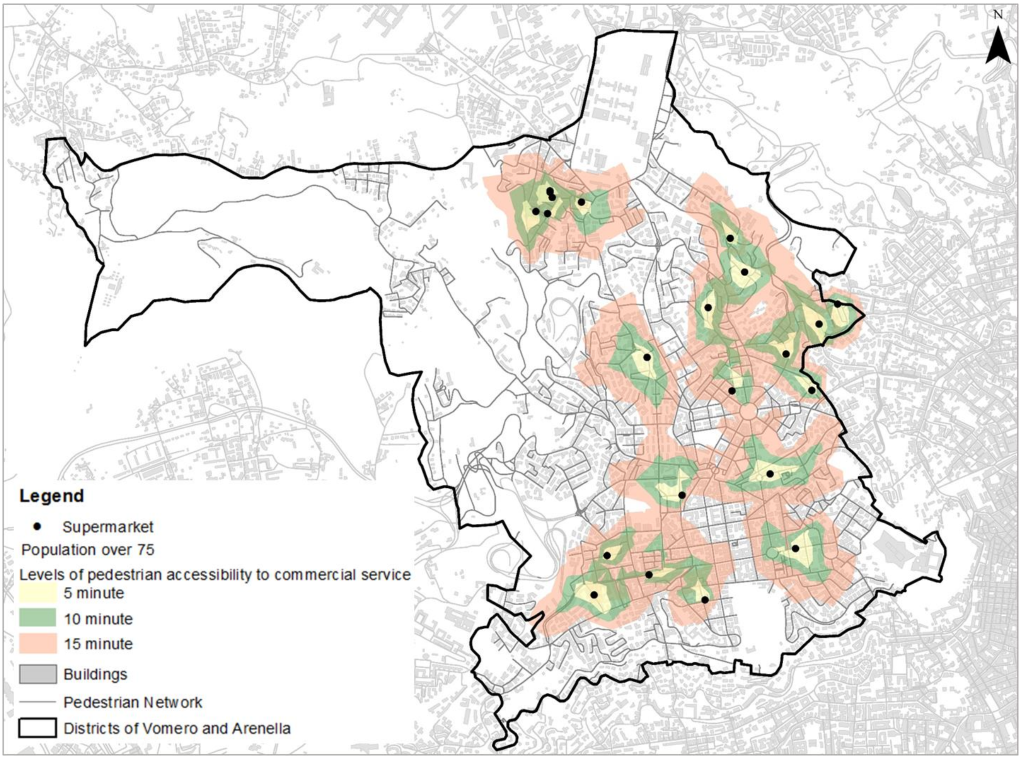


Fig.23 Classification of urban areas in levels of pedestrian accessibility to commercial services for Naples

In Aberdeen, the distribution of these services appears to be homogeneous in the study area, with access times generally of 5 and 10 minutes in both the newly formed and more established areas of the city.

Only in some districts, such as Ferryhill and Queen's Cross and Harwlaw, is the service lacking, constituting purely residential areas involving the use of other modes of travel to achieve this service such as local public transport (fig.24).

Fig.24 Classification of urban areas in levels of pedestrian accessibility to commercial services for Aberdeen

In the results obtained for the two territorial contexts and for the different types of urban services, we can identify some "hot spots" of functional accessibility. For the fifth municipality of Naples there is high accessibility in the portion of urban fabric integrated between Medaglie d'Oro and Vanvitelli, in correlation also to an adequate pedestrian network, and in the more recently developed areas of via Francesco Solimena and Rione Alto, but with a pedestrian network that does not respond to characteristics suitable for the elderly. The same applies to the city of Aberdeen, where there is a greater offer of services in the areas of the city Centre and George Street following the 1970s redevelopment due to the proximity to the port. The concentration of the elderly in areas characterized by high accessibility is reflective of the importance of such characteristics for older urban residents. This finding, in turn, offers a valuable contribution to practices in urban planning and the consideration of the values of residents. In fact, the functional offer is diversified in these areas by accessibility advantages offered, due to the availability of multiple options, while in newly formed areas it has led to "uneven" access to services both for the Neapolitan context and for the city of Aberdeen. Furthermore, the results obtained from the classification of urban areas in the different levels of accessibility for each service, made it possible to define the population over 75 served.

The over 75 population served by each accessibility level (5.10 and 15 minutes) was calculated in absolute value, allowing us to define the average value of the over 75 population served. In turn, this average value was compared with the total population present in the districts under study in order to understand in percentage terms the population served based on the location of the service and the ability to travel on foot. In detail, the cards 18 and 19 show the results obtained for each territorial context under study.

The definition of pedestrian accessibility levels to urban services are consistent with the population served in the various urban partitions. It emerges from the results of Tab 18-19 that for urban services related to health such as pharmacies, economic such as banks and commercial such as supermarkets, in Naples the servicing population is greater than 50% while for Aberdeen it is slightly lower at 40%, confirming the high diffusion of the services that can be reached within the district by walking.

Table 18 Population served to urban services in Naples

	Urban services	5 minute	10 minute	15 minute	Population served over 75 total (%)
1	Pharmacies	7195	10760	13828	68
2	Polydiagnostic Center	1761	3820	5712	24
3	Bank	2944	7941	11784	50
4	Post office	2346	4282	6785	27
5	Municipal Office	306	880	2008	6
6	Cinema	520	1639	4527	10
7	Church	3885	6007	9881	38
8	Library	858	1639	3353	10
9	Sport Center	2000	3200	6400	20
10	Supermarket	5573	8782	12256	56

Around 20% of essential urban services are served for the elderly, such as post offices, municipal offices and polydiagnostic centers. Even for the polydiagnostic centers in Aberdeen, only 2% of the elderly population is served. As regards cultural services, both Naples and Aberdeen have a population served of around 40%; the high diffusion of this service is due to the historical and cultural characteristics that the two cities have experienced. On the other hand, for services related to free time for the elderly such as cinemas, bookstores and sports centers, the population is served with a percentage of 10%, demonstrating that only some neighborhoods are privileged by these services that can be reached on foot, requiring the elderly to choose to travel by means other than walking to reach these services, for example local public transport.

Table 19 Population served to urban services in Aberdeen

	Urban services	5 minute	10 minute	15 minute	Population served over 75 total (%)
1	Pharmacies	7867	17678	29326	34
2	Polydiagnostic Center	239	267	717	2
3	Bank	3582	6788	14372	43
4	Post office	3704	8400	16003	16
5	Municipal Office	1388	2000	2574	13
6	Cinema	303	699	1622	1
7	Churches	10940	22504	34503	44
8	Library	978	2476	4943	5
9	Sport Center	3120	7689	14620	15
10	Supermarket	12586	16386	20385	32

5.2 Conclusions

The entire research work aims to define a tool to support decision makers in the development of policies aimed at improving pedestrian accessibility to urban services, in order to increase the quality of life of the elderly population and allow them to play an active role in the life of the community. The results obtained are both methodological and operational. The methodological results of this work aim to integrate and overcome the demonstrated research gap in terms of scale, and to enhance approaches on the issue of accessibility to urban areas for the elderly. This is realized by relating the behaviour of the elderly in terms of walking speed and the characteristics of the physical pedestrian network to the characteristics of safety and the urban context through a new measure of pedestrian accessibility combined with the offer of urban services. The methodological approach used allows quantification of the definition of the levels of accessibility to the different types of urban services.

The operational results, obtained by using innovative research tools, show the portions of the municipal area where intervention is needed, and how to intervene most effectively. The accessibility levels also identify the critical areas that require priority interventions and the areas where it is possible to increase the levels of pedestrian accessibility to urban services. For example, the urban areas characterised by a lack of accessibility to urban services require both "prompt" interventions, related to a better distribution and localisation of services, and "areal" interventions, linked to the urban context. By contrast, urban areas with a high supply of service areas but with pedestrian barriers and obstacles require "linear" interventions to improve the walking experience of the elderly. Therefore, integrated actions should be taken on both the functional and physical subsystems to improve and increase accessibility to urban areas for the elderly and reduce their social exclusion.[8]

The description of the entire support tool in the GIS environment aimed at decision maker and the precise definition of the different types of intervention that are developed according to the population served, the accessibility levels of each intervention are the development of the chapter 6.

[8] Part of this paragraph is contained in the research work of Gaglione F., Cottrill C., Gargiulo C. (2021). Urban services, pedestrian networks and behaviors to measure elderly accessibility. *Transportation research part D: transport and environment.* https://doi.org/10.1016/j.trd.2020.102687

CAPITOLO 6
GUIDELINES DECISION MAKERS

6.1 Introduction

“We are living in the information age; we are part of the information society ". With these words, Stillwell et al. (1999) introduce their contribution on the relationship between geographic information systems and planning, underlining the importance of geographic information in developing an adequate knowledge of the world that surrounds us, reducing uncertainty and supporting decision-making processes.

The value of information, and in particular geographical information, is in fact evident for disciplines characterized by a strong spatial connotation and the governance of urban transformations. The study of urban phenomena is a scientific field that is largely based in the cognitive phase on the study of the "measurement" of physical entities such as transport, functional entities such as urban services and on the spatial analysis of such phenomena. Urban studies are combined with the possibilities and potentials offered by software based on geographic information systems (Laurini, 2001; Murgante, 2008).

From the point of view of local science, it is possible to define GIS as: "the set of methods, techniques and procedures typical of cognitive sciences, information and communication, which, considering GIS as an environment for the development of knowledge, the definition of decision support tools in the governance of socio-territorial processes " (Chuvieco, 2007).

In this perspective, the entire volume had the purpose of developing a decision support tool in the GIS environment aimed at defining a method for classifying urban areas by pedestrian accessibility levels. This method is applicable to any territorial context that needs to measure pedestrian accessibility to urban services and to identify how to intervene in the municipal area. In detail, the aims of the support tool defined in this research work are twofold. On one hand, it aims to outline the entire procedure in GIS aimed at professionals and technicians in the area who want to conduct pedestrian accessibility analysis on their own territories as outlined in sub-chapter 6.2. On the other hand, it proposes in sub-chapter 6.3 to define an abacus of interventions for local decision makers aimed at improving pedestrian accessibility to urban services to be implemented within the plan tools in relation to the criticalities present in the territory that emerged from the GIS analysis.

6.2 The procedures for the realization of the tools

This sub-chapter outlines the support tool for local technicians of the entire methodology of the research work developed through the ArcGIS software. The ArcGIS software can perform spatial analysis operations that are also useful for measuring accessibility to urban areas for the elderly population and quantifying the variation in space and time of the impacts that have developed. More specifically, this sub-chapter outlines the entire support process for local technicians for possible accessibility analysis of municipal areas, illustrating the entire model set up in a GIS environment.

In particular, the model is divided into three main activities carried out to develop the entire methodology in GIS.

- creation of the data geodatabase - Development of a relational data database (Geodatabase), usable in the GIS environment and which contains all the alphanumeric and spatial data necessary to contain the entire dataset considered on the subject

-application of geoprocessing and numerical computation operations that define the sequence and related analytical workflows

- Construction of the Model Builder - Development of the entire model of the GIS methodology capable of sequentially executing all the geoprocessing operations on the alphanumeric and spatial data collected.

The Model Builder is an ArcGIS application that allows for design, simulation and analysis of analytical workflow models, which can be made up of a sequence of components capable of performing geoprocessing and numerical calculation operations. This application allows the programming of workflows using a visual programming language through the creation of diagrams that contain the sequence of operations envisaged as it was developed in this work. This tool uses a Python type programming language developed in GIS software and which is also used for the creation of additional components for carrying out certain operations.

To quantify accessibility to urban services for the elderly, it was necessary to identify a set of parameters in shapefile format and alpha-numeric data. The shapefile constitutes the vector format, to be found, in which some of the characteristics that make up the feature classes are associated with this shape. In addition, some shapes have been associated with additional urban features that will be illustrated from time to time in detail.

First, the parameters that can be found through the use of data freely accessible (open data) to public administrations, technicians and scholars who are involved in studying these urban phenomena have been selected. The choice of these parameters to be used for the quantitative analysis was based on previous experience gained in other recent scientific and technical studies, which used these variables to highlight from a quantitative point of view the accessibility to urban services for the various population groups (Akhavan & Vecchio, 2018; Pinto & Sufineyestani, 2018).

The variables found in shapefile format and useful for the socio-anthropic subsystem were the census sections and the alphanumeric data relating to the demography of the municipal area. With regard to the functional subsystem, 10 essential urban services were found for the elderly population, divided into health services (pharmacies and multi-diagnostic centres), economic services (municipal offices, post offices and banks), cultural services (churches, bookshops and cinemas), leisure services (sports centres) and very low commercial services (supermarkets).

Table 20 illustrates the useful data formats and the institutional sources from where it is possible to find such data by dividing them by the two territorial contexts considered for this thesis work.

For the physical subsystem, the graph of the pedestrian network was found. The first activity carried out was to relate the entire set of variables described above or the spatial vector data with the alpha-numeric data through the creation of a geodatabase capable of containing all the input data or the entire set of variables such as can be seen in Fig. 25 and that in the GIS programming functions, they are outlined in blue

Table 20 Model parameter for mapping urban accessibility

Model parameter	**Data format**	**Source Italy**	**Source United Kindom**
Census section	Shapefile	Italian Institute of Statistics (ISTAT)	Consumer Data Research Centre (CDRC)
Population divided by age	Table	Italian Institute of Statistics (ISTAT)	Consumer Data Research Centre (CDRC)
Buildings	Shapefile	National geoportal	Digimap
Pedestrian network	Shapefile	Open street maps	Digimap
Pharmacies	Kml	Google my maps	Google my maps
Polidiagnostic center	Kml	Google my maps	Digimap
Bank	Kml	Google my maps	Google my maps
Municipal office	Kml	Google my maps	Google my maps
Post office	Kml	Google my maps	Google my maps
Cinema	Kml	Google my maps	Google my maps
Church	Kml	Google my maps	Digimap
Libraries	Kml	Google my maps	Google my maps
Supermarkets	Kml	Google my maps	Google my maps

Having defined the starting geodatabase, the second activity was that concerning the application of the geoprocessing and number of calculating operations that defined the sequence and the related analytical workflows. In detail, the first two workflows were carried out for the socio-economic and physical subsystem. For the socio-economic subsystem, i.e. the census sections, the alphanumeric data relating to the total population and the population divided by age group for each section of the census have been associated. The operation of associating the population data to the census sections took place through a join operation. Subsequently, a new field was created within the table of attributes and the population density as the ratio between the total populations was calculated within the same field in order to classify the municipal area in terms of population aged over 75 in relation to their dwellings (built shapefile).

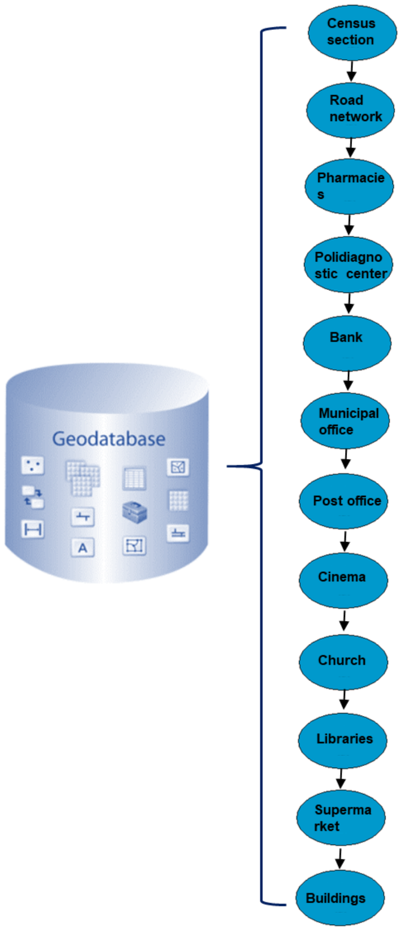


Fig.25 Definition of the geodatabase

For the physical subsystem relating to the road network graph, the first operation was to carry out topological corrections. The topological corrections were carried out through three operations: (i) right click on the road network feature class; (ii) click on the new window that appears; (iii) add topological rules, obtaining as output a new file of the road network corrected topologically. Once the topological corrections have been made, the slope of each arc of the pedestrian network has been associated with the graph of the pedestrian network. The slope at each arc of the network was obtained from the digital elevation model (also known as DEM, from the English Digital Elevation Model), which represents the distribution of the shares of a territory in digital format. Starting from the level curves of the territory to define the spatial distribution of the level curves on the territory, it was used as a geoprocessing operation in detail gostatistical Analyst tools, interpolation IDW. Through ArcGis functions present in the ArcToolbox of 3D Analyst Tools, in particular the Functional Surface, interpolate shape, these dimensions to the shapefile of the road network were associated. In addition, an extra field was added to the graph of the road network to which, as well as the slope, the walking speed of the population over 75, derived from the study of the reference scientific literature, was included. Knowing the walking speed of the population over 75, a new field was calculated; that is, the average walking time on each network arc for the population over 75 by comparing the length of each network arc that is defined in the shapefile (shapelength) with the walking speed. Furthermore, 9 other fields were added to the pedestrian network graph that form the entire set of characteristics of the pedestrian network in line with table 4. Table 21 shows the set of pedestrian variables with the related format and source found, which are always contained within the geotabase.

Table 21 Set of variables pedestrian's paths

Model parameter	Data format	Source Italy	Source United Kindom
Slope of the links of the road network	Shapefile	GIS	GIS
Sidewalk width	Shapefile	Google maps	Google maps
State of pavement of the sidewalk	Shapefile	Google maps	Google maps
Lighting density	Shapefile	Google maps/GIS	Google maps/GIS
Vehicle traffic volume	Shapefile	Google maps	Google maps
Presence of escalators	Shapefile	Google maps	Google maps
Presence of bench	Shapefile	Google maps	Google maps
Presence of green areas	Shapefile	Google maps	Google maps
Presence of panoramic points	Shapefile	Google maps	Google maps
Non-main roads	Shapefile	Google maps	Google maps

For each of these nine fields, another nine fields were associated, relating to the weight of each of the characteristics taken into consideration, taken from the Super Decisions computer software, which is aimed at performing AHP. In particular, the sequences of all the geoprocessing operations on alphanumeric and spatial data constitute the first of the construction of the model builder as can be seen from Fig.26 below.

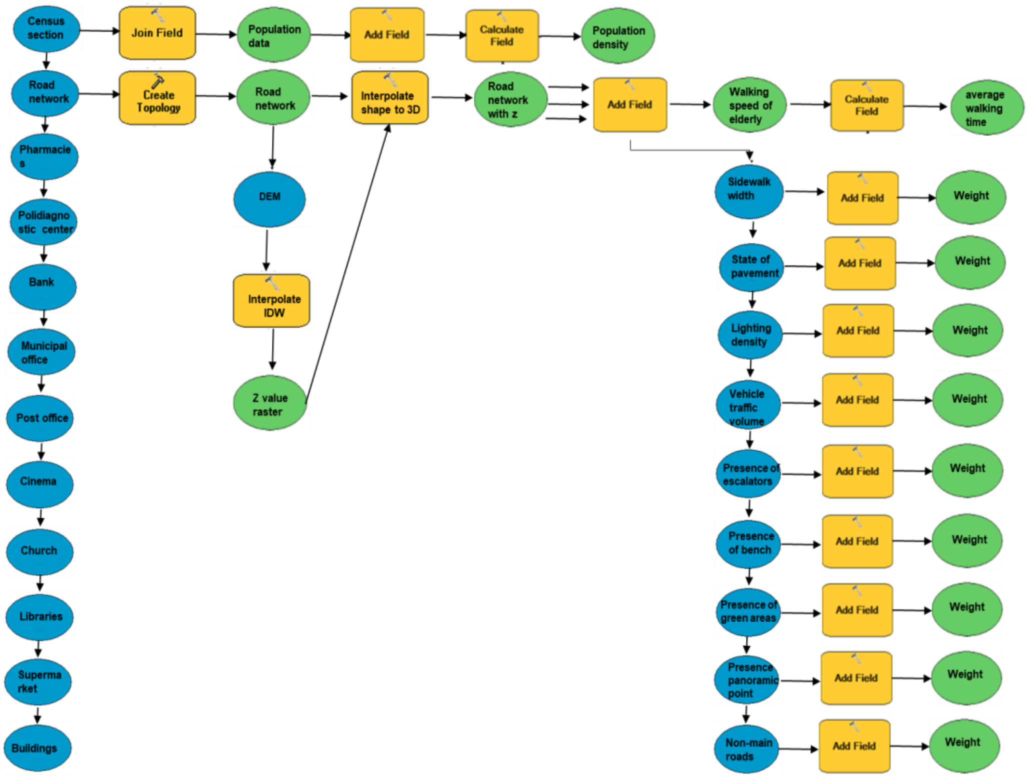


Fig.26 The first part of Model Builder

The next step was to add a further field to the table of attributes of the pedestrian graph by calculating the sum of the weights of each network arc by classifying the "age-friendly" network arcs and the network arcs that need interventions along the routes. Besides, a new field was calculated thanks to the sum of the weights, or the average time on each network arc, based on the elderly's ability in terms of walking speed. The sum of the average time weighted with the average travel time of the elderly on each network span define a new field on the pedestrian network, or the accessibility pedestrian network index. The accessibility pedestrian network index is the indispensable premise for the creation of the road graph network through the geoprocessing operation called new network dataset by imposing the times defined by the setting of the indicator as impedance to the network graph. Once the graph of the road network was created, it was possible to define the pedestrian accessibility levels for each individual urban service and the service areas through a command of the Network Analyst called new service area. Within the service area, the imposed impedance was 5, 10 and 15 minutes from each individual service considered. The intervals were taken from the studies of the scientific reference literature (Lovett et al., 2002). The sequences of all the geoprocessing operations and numerical calculations constitute the second part of the construction of the model builder, as shown in Fig 27 below.

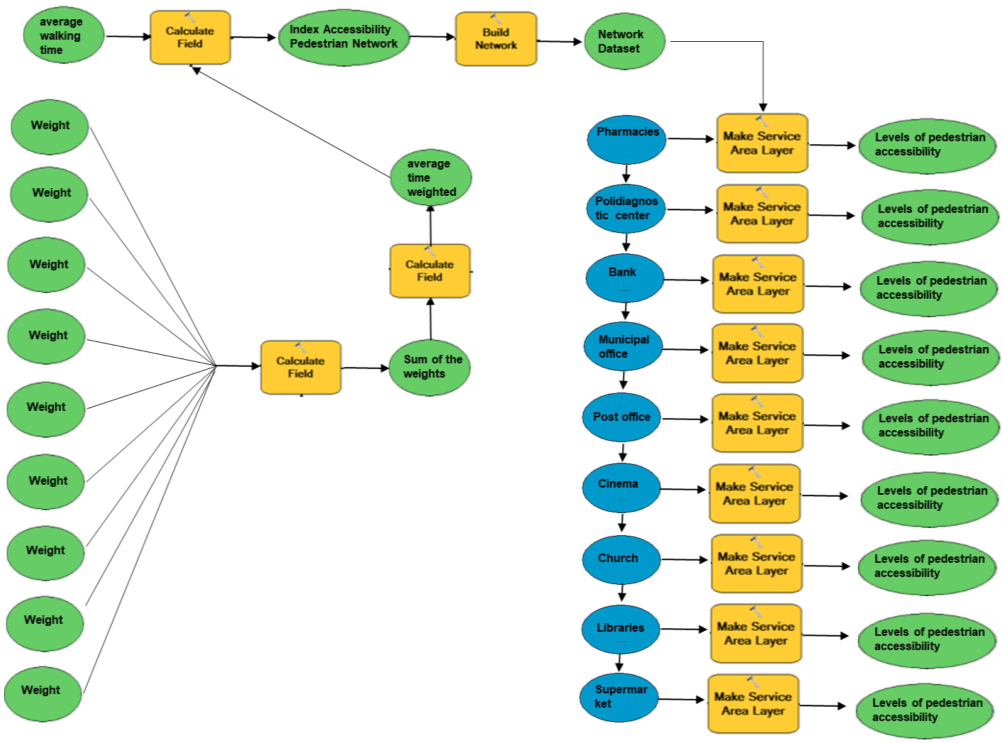


Fig.27 The second part of Model Builder

The union of the first and second part of the model builder constitutes the entire procedure that the technicians of the area can use for the analysis of pedestrian accessibility to urban services for the elderly population.

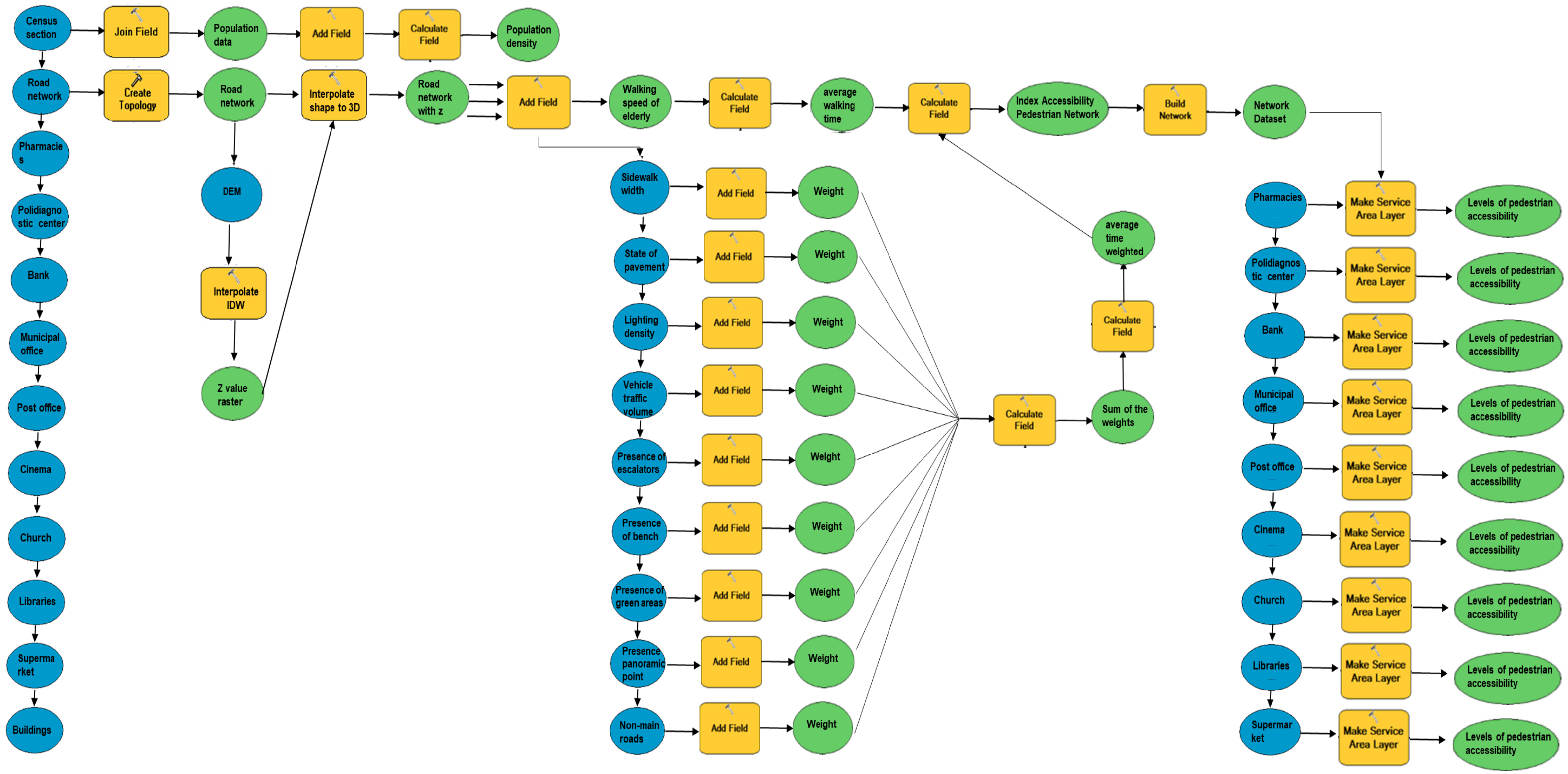


Fig.28 The Model Builder of accessibility pedestrian to urban services for elderly

6.3 Support Tool to decision makers

The support tool in the GIS environment aims to support public administrations in the choices of interventions aimed at increasing pedestrian accessibility for over 65s in order to contribute to the improvement of their quality of life.

The interventions are also useful for the implementation and adaptation of both regulatory instruments (national and regional) and technical and administrative tools (e.g. Urban Plans, Traffic Plan, Sustainable Urban Mobility Plan, etc.) at the urban scale and/or neighbourhoods to better integrate the principles of pedestrian urban accessibility and universal design in the governance processes of urban and territorial transformations. The interventions are divided into three categories: (i) linear interventions that refer to the characteristics of the pedestrian paths; (ii) specific interventions that refer to both the location and distribution of urban services; and (iii) aerial interventions linked to the urban context and on how improve the urban quality of neighbourhoods. Bearing this in mind, the following interventions have been defined in relation to the main objectives that can be pursued to favour the soft movements of this segment of the population:

- Improvement of pedestrian paths during the walking experience, allowing the elderly to encounter favourable factors in walking around the neighbourhoods
- Improvement of safety perceived by users so that the elderly perceives support and protection in walking
- Improvement of urban quality such as the presence of green areas along the open spaces of the city and the pedestrian paths that favour the attractiveness of a path by the elderly
- Improvement of the use of services through new forms of organization of urban services such as the differentiation of access to services for different groups of the population

The various interventions that are concrete solutions for improving pedestrian accessibility and which have proven successful in different urban contexts are articulated from these objectives (Table 22). For some interventions, a summary sheet was proposed that describes the type of built urban environment in which the proposed solution was implemented and the description of the type of intervention (annex B of the volume).

Tab 22 Matrix of interventions for the improvement of pedestrian accessibility

	Interventions	**ID**
Improvement of pedestrian paths	Use of drainage materials for pavements	PP1
	Use of drainage materials for pedestrian crossings	PP2
	Use of drainage materials for open spaces	PP3
	Improvement of horizontal and vertical signs relating to the identification of cycle and pedestrian paths	PP4
	Increase in the presence of elevators to improve pedestrian accessibility to rail line stations	PP5
	Increase sidewalk width	PP6
	Identification and signaling of pleasant and comfortable paths characterized, for example, by the greater presence of rows of trees	PP7
	Identification and signaling of pleasant and comfortable paths that allow you to reach, for example, "green and blue spaces"	PP8
Improvement of safety perceived by users	Increased pedestrian crossing time	SP1
	Signaling of traffic lights at which, in order to cross, the elderly can ask other pedestrians or the traders present in the immediate vicinity for help	SP2
	Pedi bus: to reach recreational activities	SP3
	Promotion of car sharing / carpooling services to facilitate travel along steep roads	SP4
	Street lighting improvement also through "smart lighting" systems	SP5
Improvement of urban quality	Increased presence of benches in open spaces. In particular, the benches can be designed in such a way as to have both a higher seat that facilitates standing up and a support that the elderly can grasp to get up	QU1
	Increase in the presence of benches along the shady paths, near commercial activities that are highly attractive to the elderly. In particular, the benches can be designed in such a way as to have both a higher seat that facilitates standing up and a support that the elderly can grasp to get up	QU2
	Increase in rows of trees along pedestrian paths, especially those characterized by the presence of highly attractive services for the elderly	QU3
	Creation of "green and blue spaces" to encourage pedestrian travel and aggregation	QU4
	Installation of signs, vertical or horizontal, aimed at illustrating the habits and the relationship that the inhabitants have with their community of belonging	QU5
	Establishment of "Living streets" in which the street is converted into an urban space to encourage social aggregation.	QU6
Improvement of the use of services	New forms of organization of services, such as, for example, different opening hours for the elderly of the services of greater interest (ASL, post office)	US1

	Increase in the location and distribution of the main urban services, due to the presence of pedestrian paths suitable for the elderly	US2
	Identification and reporting of urban services to which the elderly have priority of access and use, such as pharmacies	US3
	Establishment of on-call accompanying services to make trips longer than the willingness to walk of the elderly	US4

The interventions were identified through a reading of international case studies in which local administrations are committed to building age-friendly cities, intervening both on a neighbourhood scale and in the entire municipal area. In order to identify effective interventions to ensure the usability of the pedestrian network and of the activities and services of interest to the elderly, a review of international best practices was carried out, that is, of those experiences and initiatives that have proved successful for the elderly. The review identified development of a city accessible to the over 65s and other vulnerable segments of the population to study and examine the best practices implemented on the issue. These virtuous cities, with respect to the research theme, which take into account the strategy outlined by the World Health Organization to promote Age-friendly Cities and Communities, are committed to promoting urban transformation interventions that allow "aging in place", that is, to allow the elderly to actively participate in the life of their own community. Table 23 shows the 23 case studies of Italian and European cities that have implemented strategies and interventions aimed at improving pedestrian accessibility for the elderly to urban services at both the urban and neighbourhood scale. These 23 case studies have been chosen because they constitute the most recent reports and consolidated planning tools in urban planning practice, constituting useful ideas to guide the choices of the public decision-maker.

Tab 23 Best practice age-friendly

Case studies	**Source**
Manchester	Age-Friendly Seating & Sense of Place (2015)
Viborg	Accessibility in an Historical Setting (2013)
Lyon	Personnes âgées: des citoyens à part entière (2010)

Philadelphia	Ralston Center project (2017)
Seattle	University of Washington project led by the Taskar Center for Accessible Technology (2016)
Sydney	Urban Forestry Strategy (2013)
Singapore	Project of the Land Transport Authority (LTA) organization (2014)
New York City	Safe streets for seniors (2008)
Akita	Improvement of winter road services (2014)
Kent	Kent Design Guide (2005)
Hamilton	Hamilton's Plan for an Age-Friendly City (2014)
London	Plan of Transport for London, TfL (2013)
Yokohama	Yokohama Healthy Family (2016)
Copenaghen	Plan of Copenaghen City (2004)
Peterborough	Age friendly Peterborough (2017)
Tokyo	Aging Tokyo (2017)
Baltimore	Falls Prevention Strategy for Older Adults (2018)
Udine	Udine Sta Bene in Strada (2019)
Empoli	Progetto Atlante 65+ "Rete servizi per gli anziani" (2020)
Bologna	Segnali di vita (2014)
Bassano del Grappa	PEBA – Piano per l'Eliminazione delle Barriere Architettoniche (2019)
Imperia	Iniziativa del Comune (2017)
Emilia-Romagna	Campagna di educazione alla sicurezza stradale (2013)

For each intervention, the indirect benefits obtained from the implementation of that Intervention were also defined and which concern further aspects related to the improvement of the quality of life of both the elderly and the entire urban population, such as, for example, the increase in comfort, thermal, social inclusion, energy, etc. also given the multidisciplinary nature of the argument. Furthermore, the integration in the various governance tools of urban and territorial transformations are also identified and the consequent application of the Actions and Interventions is facilitated by the "matrix", specially formulated, which allows the relation of governance tools with the general objectives, and to also taking into account the main stakeholders involved (Tab. 24). The general orientations can be defined not only to the various scales of governance of urban transformations, but also through several instruments belonging to the same scale. In other words, the same objective and the corresponding Interventions can be declined at different scales and with different tools, through actions with different contents and which can be integrated with each other.

Tab 24 Matrix of relations with plan tools

	Interventions	**Indirect benefits**	**governance tools**	**Stakeholder**
Improvement of pedestrian paths	PP1	Urban drainage improvement - Urban heat island mitigation	PUMS Urban sustainable mobility plan	
	PP2	Urban drainage improvement - Urban heat island mitigation	PUMS Urban sustainable mobility plan	
	PP3	Urban drainage improvement - Urban heat island mitigation	PUMS Urban sustainable mobility plan	
	PP4	Improvement of safety perceived by pedestrian users	Traffic Plan	
	PP5	Improvement of safety perceived by pedestrian users	PUMS Urban sustainable mobility plan	
	PP6	Improvement of safety perceived by pedestrian users	PUMS Urban sustainable mobility plan	
	PP7	Improvement of urban quality	Traffic Plan	City associations -
	PP8	Improvement of urban quality	Traffic Plan	City associations -
Improvement of safety perceived by users	SP1		Traffic Plan	
	SP2	Reduction of social exclusion	-	Citizen Associations - Traders' Associations
	SP3	Reduction of social exclusion	-	City associations

	SP4		PUMS Urban sustainable mobility plan	Vehicle transport service companies
	SP5	Improvement of urban quality		Companies ICT
Improvement of urban quality	QU1		-	City associations
	QU2		-	Citizen Associations - Traders' Associations
	QU3	Urban drainage improvement - Urban heat island reduction	Municipal urban plan - Green plan	
	QU4	Improvement of health conditions	-	
	QU5	Reduction of social exclusion	-	City associations
	QU6	Reduction of social exclusion	-	City associations
Improvement of the use of services	US1		Service plan	
	US2			
	US3		-	Citizen Associations - Traders' Associations
	US4	Reduction of social exclusion	PUMS Urban sustainable mobility plan	City associations - Digital companies - Local public transport companies

By way of example, the interventions proposed on two areas studied in this research work are reported: Naples and Aberdeen. In particular, the areas chosen, based on the results obtained by the GIS tool, are those that present the greatest criticality for the elderly – in particular, for Naples the Rione Alto area, and for Aberdeen the Rosemount and Mile End neighbourhoods. Starting from these critical areas, summary sheets of the types of needed intervention are outlined and how these interventions improve levels of accessibility, highlighting the comparison between before and after the intervention.

An illustrative title shows a critical area of the Neapolitan urban context and a critical area of Aberdeen. In detail, it was selected in the districts of Vomero and Arenella in the Rione Alto area. The area of the Rione Alto is a newly formed area born after the building expansion of the area of Vanvitelli and Medaglie d'oro, which has a well-planned urban area. Figure 29 shows an integrated reading between the classification of pedestrian network and pedestrian accessibility levels to one of the services considered, which supermarkets are.

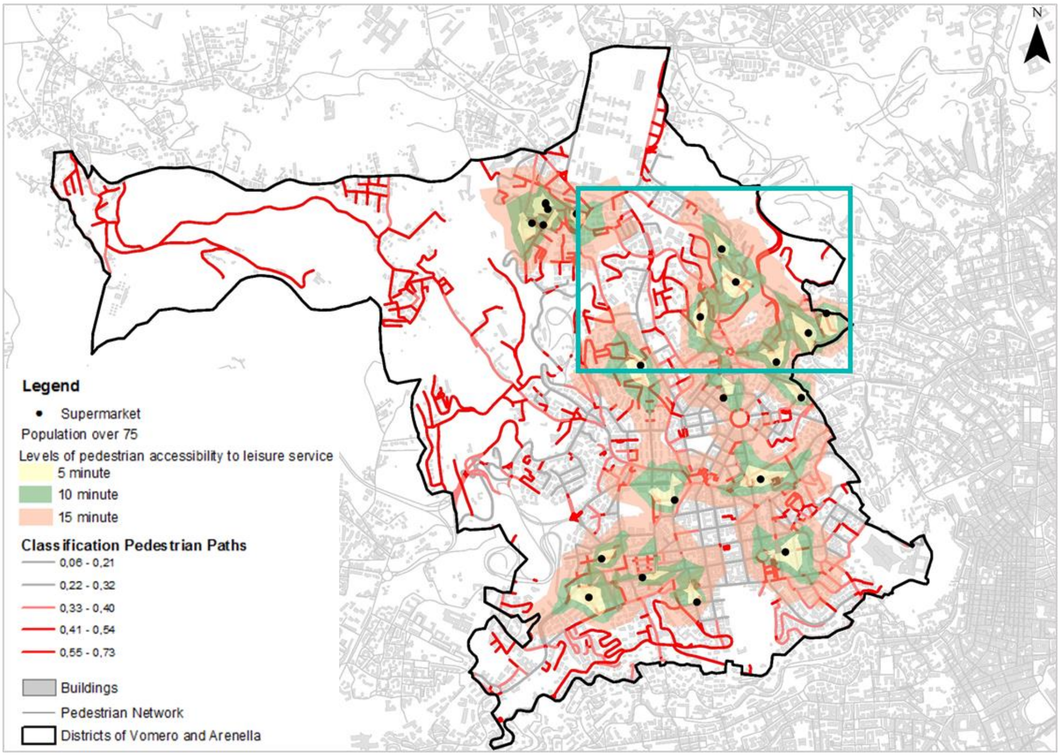


Fig.29 Critical area of the Rione Alto Pre-intervention scenario

The integrated reading between the classification of the pedestrian network defined on the basis of the weights derived from the AHP and the levels of pedestrian accessibility to urban services are useful for understanding the necessary interventions for the purpose of improving and increasing accessibility to urban areas. In the specific case considered, the intervention is aimed at the practicability of the adjacent routes to reach the urban service, since the activity appears to be widespread in the two districts. In detail, the shortcomings on the pedestrian paths can be seen both from the point of view of physical characteristics, such as the width of the sidewalks and the state of the pavements, and of safety, such as the presence of benches. Below is the sheet for the three interventions on the pedestrian paths, and how in other cities these interventions have been implemented.

	Improvement of pedestrian paths
Intervention	Use of drainage materials for pavements
Form	PP1
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Neighborhood
Location	Established city
IMPLEMENTATION	
Indirect benefits	Urban drainage improvement - Urban heat island mitigation
Territory governance tools	PUMS
Stakeholders to be involved	
Intersection with other actions and interventions	PP2 – PP3 – PP7 Location and size of sidewalks

DESCRIPTION

The use of draining pavements for the refurbishment or construction of new sidewalks facilitates the removal of rainwater in the surface layers of the subsoil, thus making them less slippery and facilitating their walkability by vulnerable users such as the elderly.

CASE STUDY

Safely enjoy the outdoors
Philadelphia, USA
Federation Housing
More information availability at:
https://www.federationhousing.org/

	Improvement of safety perceived by users
Intervention	Street lighting improvement also through smart lighting systems
Form	SP5
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Neighborhood
Location	Established city
IMPLEMENTATION	
Indirect benefits	
Territory governance tools	Traffic plan
Stakeholders to be involved	Local authorities
Intersection with other actions and interventions	

DESCRIPTION

In recent years, the hours of movement and opening of economic activities have extended to night hours, with cities increasingly living at night. To overcome the problems that pedestrians encounter in the hours of darkness - such as safety and visibility - the installation of public lighting systems can effectively improve the usability of urban spaces.

CASE STUDY

Low-Energy Interactive Public Light Sculpture
Rotterdam, Netherlands
Studio Roosegaarde for CBK Rotterdam et al.

More information availability at:
https://www.studioroosegaarde.net/project/dune

	Improvement of urban quality
Intervention	Increased presence of benches in open spaces
Form	QU1
GENERAL INFO	
Type of intervention	Areal
Territorial scale	Neighbourhood
Location	Established city
IMPLEMENTATION	
Indirect benefits	Reduction of social exclusion
Territory governance tools	-
Stakeholders to be involved	City associations
Intersection with other actions and interventions	QU1 – QU3 – PP9 Localization of built open spaces
DESCRIPTION	

The improvement of street furniture can facilitate the pedestrian movements of the elderly, as it provides them with some of the comforts useful for refreshment and affects the perception of the built environment in which they move, making it more pleasant and welcoming. In particular, it is possible to equip the open spaces built with benches characterized by a higher seat that facilitates standing up and a support that the elderly can grab to get up, thus also favoring social aggregation.

CASE STUDY

Comfort streets
Philadelphia, USA
Ralston Center Organization

More information availability at:
https://www.metdra.de/en/street-furniture/benches/senior-citizens-benches/

Urban Core initiative
Madrid, Spain

More information availability at:
https://www.theguardian.com/cities/2014/sep/26/madrid-plans-citycentre-.

The implementation of these interventions would entail a different accessibility to supermarkets, improving it above all for the elderly. To confirm this, fig. 30 shows how pedestrian accessibility to the activity varies when these characteristics are present in pedestrian paths.

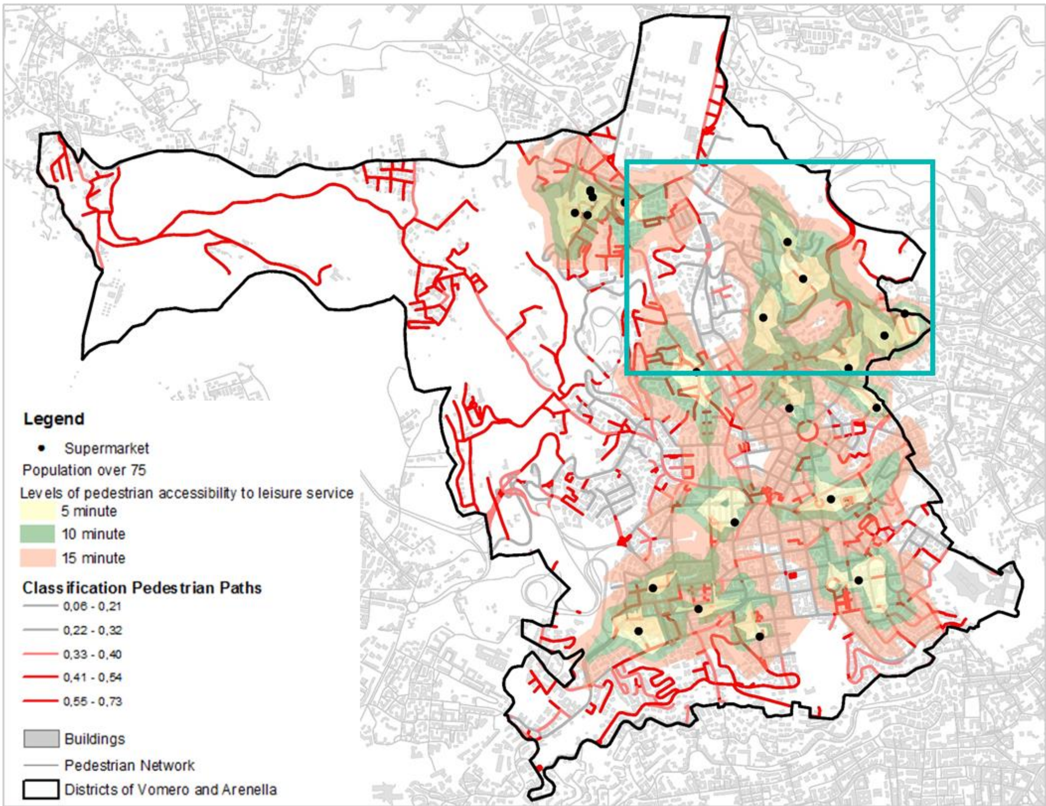


Fig.30 Critical area of the Rione Alto Post-intervention scenario

The map shows that the variation in the weights on the individual network arcs due to the implementation of the interventions entails an increase in the portions of the municipal territory that have the possibility of accessing the service in relation to the defined levels of pedestrian accessibility. The elderly can arrive not only in shorter times, but also with greater safety and usability. The implementation of certain interventions favours a greater demand of the elderly population in terms of number of inhabitants.

The implementation of these interventions has favoured the implementation of the practicability for the achievement of the urban service, leading to an increase in accessibility in relation to the levels defined as well as the Neapolitan territory.

As far as Aberdeen is concerned fig. 31 shows the characteristics of the pedestrian network which are widely adequate for the elderly to travel around on foot. Only some arcs require interventions aimed at improving their pedestrian accessibility to urban services. Here, The Rosemount and Mile End district was considered for the achievement of the same urban service considered for Naples. In these areas the interventions that favour the improvement of access to the service are identified, enclosed as for Naples in summary sheets. In detail, the sheets are aimed at the state of the pavement and the severe lack of benches in Aberdeen, with paths obscured by the characteristic green scenery of the city.

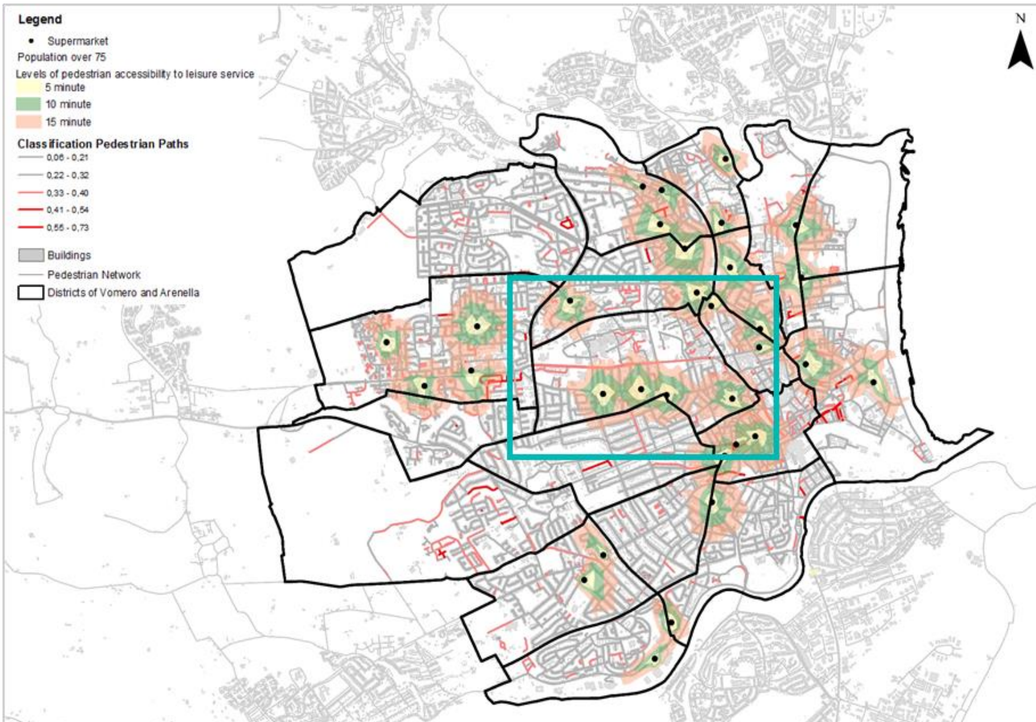


Fig.31 Critical area of Rosemount and Mile End Pre-intervention scenario

	Improvement of pedestrian paths
Intervention	Use of drainage materials for open spaces
Form	PP3
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Neighborhood
Location	Established city
IMPLEMENTATION	
Indirect benefits	Urban drainage improvement - Urban heat island mitigation
Territory governance tools	PUMS
Stakeholders to be involved	
Intersection with other actions and interventions	PP1 – PP2 – PP7 Location and surface of built open spaces
DESCRIPTION	

The use of draining pavements for the reconstruction or construction of built open spaces facilitates the removal of rainwater in the surface layers of the subsoil, thus making them less slippery and facilitating their accessibility by vulnerable users such as the elderly.

CASE STUDY

Safely enjoy the outdoors
Philadelphia, USA
Federation Housing

More information availability at:
https://www.federationhousing.org/

Pervious Pavement Projects
Portland, USA
Portland Municipality and Nonprofit organization Depave

More information availability at:
https://www.portlandoregon.gov/bes/article/77074

	Improvement of urban quality
Intervention	Increase in the presence of benches along the paths shaded by greenery, in the vicinity of commercial activities that are highly attractive for the elderly
Form	QU2
GENERAL INFO	
Type of intervention	Areal
Territorial scale	Neighborhood
Location	Established city
IMPLEMENTATION	
Indirect benefits	Associazioni cittadine
Territory governance tools	
Stakeholders to be involved	
Intersection with other actions and interventions	QU1 – PP7
DESCRIPTION	

The improvement of street furniture can facilitate the pedestrian movements of the elderly, as it provides them with some of the comforts useful for dining and affects the perception of the built environment in which they move, making it more pleasant and welcoming. By integrating this type of action with others aimed at improving the overall quality of the urban environment, it is therefore possible to increase the participation of over 65s in the life of their community. In particular, it is possible to equip the open spaces built with benches characterized by a higher seat that facilitates standing up and a support that the elderly can grab to get up, thus also favoring social aggregation.

CASE STUDY

Comfort streets
Philadelphia, USA
Ralston Center Organization

More information availability at:
https://www.metdra.de/en/street-furniture/benches/senior-citizens-benches/

Urban Core initiative
Madrid, Spain

More information availability at:
https://www.theguardian.com/cities/2014/sep/26/madrid-plans-citycentre-.

The implementation of these interventions has favoured the implementation of the practicability for the achievement of the urban service leading to an increase in accessibility in relation to the levels defined as well in the Neapolitan territory.

Fig.32 Critical area of the Rosemount and Mile End Post-intervention scenario

From fig. 32 it can be seen that some districts of the city of Aberdeen show a total absence of urban service, as also outlined in the discussion of the results on the measure of pedestrian accessibility, while other districts of the city, for example the City centre, present a concentration of urban services. The city of Aberdeen largely relies on urban services enclosed within large shopping centres located in certain points of the city, not by favouring a type of pedestrian mobility for the elderly, but by imposing a further mode of movement such as local public transport or use of private vehicles, especially when our cities affected by COVID-19 require us to limit our movements in daily life (Zecca et.al,2020). Public decision makers should implement interventions aimed at a better distribution and localization of services as required, as can also be seen from table 20

6.4 Conclusions

The elderly population has been considered fragile, alone, marginalized, unable to live independently and generally "invisible" in studies and planning tools that involved the governance of urban changes. If the components of an age-friendly city are well defined in the studies of the scientific literature (Gargiulo et al., 2018), in governance tools of urban transformation the definition and implementation of strategies and actions for more vulnerable groups are not yet well defined. Policy makers and planners should take an integrated approach to planning aging cities, as this challenge can be seen as an opportunity to increase city sustainability, attractiveness and competitiveness in the fields of land use, transport, welfare services and social cohesion.

The research theme appears to be in line with current EU policies. The European Horizon 2020 project called INCLUSION addresses a series of challenges related to accessibility in urban areas. In particular, the report by Cottrill et al. highlights the complex mobility needs of people, especially vulnerable groups of the population, and the need to define the role of new forms of transport and travel solutions. The main purpose of this work is precisely to allow the elderly to age actively by optimizing some physical and environmental characteristics to make them easily accessible to the elderly, thus favouring their travel and preventing the social exclusion (Komise, 2009; Walker and Maltby 2012). Considering the city as a whole and adopting an integrated view of users, available services and their accessibility could help "address physical and social disparities and meet the needs of all groups in the community" (Plouffe et al., 2018). This holistic approach has characterized the development of the proposed methodology which, through the localization of the offer of urban services by the over 65s, combined with the physical characteristics of the urban system that influence the choice of a route (e.g. presence of sidewalks), aims to define: (i) the network of pedestrian paths suitable for the elderly to reach the main services of interest, and (ii) the priority areas where to intervene based on the levels of pedestrian accessibility to urban services. Bearing this in mind, this research work introduces innovations from a methodological point of view. First, a methodology is introduced aimed at quantifying the levels of pedestrian accessibility to urban areas. Secondly, it aims to integrate and overcome the strong research gap on the topic of urban accessibility through the development of a composite

index that takes into account the behaviour of the elderly in terms of walking speed, characteristics of the physical pedestrian network, characteristics security and urban context and offer of urban services. The development of this indicator constituted an element of originality within the scientific reference framework as studies on accessibility to places and activities on an urban scale define new accessibility indicators with an approach to measure time or distance for achieve an urban service without taking into account the urban and context characteristics. The studies at the neighbourhood scale have considered urban characteristics in their studies, but only defining their rankings or setting qualitative indicators given the difficulty in finding such precise quantitative data as (width of the sidewalk, benches) on the different neighbourhoods.
A further innovation of this research work was the desire to combine the use of statistical techniques such as AHP with the GIS tool. Today their real and functional integration represents a research frontier not yet strongly consolidated in the scientific debate (Mandal & Mondal, 2019) for the definition and analysis of the complexity of urban phenomena. Furthermore, the use of GIS allows the implementation of a tool capable of providing detailed information locally. From a technical point of view, using the Model Builder to implement the tool is an important advantage. In fact, thanks to it, the tool can be exported to the Python programming language. Since Python is an open-source language, the tool script can be used to eventually develop a new spatial analysis application, including all the methodological procedures described here, even outside the field of GIS. Furthermore, also thanks to the availability of large sources of institutional data (Open Street Maps, Google maps), the tool could be easily applied in other urban contexts, not only Italian but also European as can be seen from the application of this research work. A further research innovation was the definition of a panel of interventions to be provided to decision makers since the elderly are not mentioned and considered several times in the plan tools. The interventions can be inserted within the plan tools and implemented according to the planning of the interventions of the public administrations. The proposed panel, aimed at improving the urban accessibility of the elderly, can bring indirect benefits to other challenges that cities have to face such as energy, climate change given the multidisciplinary nature of the issue. Although the proposed work has introduced several research innovations, it

is important to point out that some improvements can be made for the final version of the tool. First of all, on the choice of the variables considered due to the availability of the data and, above all, to the lack of specific datasets at local level. The development of the pedestrian accessibility indicator can take into account a variable set of pedestrian characteristics that is certainly wider and on the offer of urban services not to consider only their distribution and location.

In summary, the methodology developed within this research work can be further strengthened both for the characteristics of the pedestrian network and for the indicator of pedestrian accessibility to urban services. As regards the characteristics of the pedestrian network, the set of variables can be expanded through a direct survey on the territory of such precise data as pedestrian crossings, traffic light crossings, and presence of pedestrian signs. On the other hand, the pedestrian accessibility indicator can be improved by taking into account on the one hand a wider set of characteristics of the pedestrian network in order to carry out a more complete survey of the built environment, but at the same time of preferences and behaviours travel of the elderly inferred through direct GPS monitoring of the elderly. The study undertaken here has focused on variables constructed from data that is generally widely available to urban planners; however, the additional activities indicated above, though requiring more intensive data collection activities, would potentially add additional robustness to the application.

References

Accessibility in an Historical Setting (2013). Retrieved from https://historicengland.org.uk/images-books/publications/easy-access-to-historic-buildings/heag010-easy-access-to-historic-buildings/

Age friendly Peterborough (2017). Retrieved from: https://extranet.who.int/agefriendlyworld/network/peterborough-region/

Age-Friendly Seating & Sense of Place (2015). Retrieved from: file:///C:/Users/Federica/Downloads/Age_Friendly_Seating_and_Sense_of_Place.pdf

Aging Tokyo (2017). Retrieved from: https://www.aging2.com/tokyo/

Akhavan, M., & Vecchio, G. (2018). Mobility and Accessibility of the Ageing Society. Defining Profiles of the Elderly Population and Neighbourhood. *TeMA-Journal of Land Use, Mobility and Environment*, 9-22. doi: https://doi.org/10.6092/1970-9870/5757

Campagna di educazione alla sicurezza stradale (2013). Retrieved from https://mit.gov.it/documentazione/sulla-buona-strada-2013-campagna-di-comunicazione-sulla-sicurezza-stradale

Chuvieco, E., Aguado, I., Yebra, M., Nieto, H., Salas, J., Martín, M. P., ... & De La Riva, J. (2010). Development of a framework for fire risk assessment using remote sensing and geographic information system technologies. *Ecological Modelling*, *221*(1), 46-58. doi: https://doi.org/10.1016/j.ecolmodel.2008.11.017

Falls Prevention Strategy for Older Adults (2018). Retrieved from: https://www.who.int/ageing/publications/Falls_prevention7March.pdf

Gargiulo, C., Zucaro, F., & Gaglione, F. (2018). A Set of Variables for the Elderly Accessibility in Urban Areas. *TeMA - Journal of Land Use, Mobility and Environment*, 53-66. https://doi.org/10.6092/1970-9870/5738

Hamilton's Plan for an Age-Friendly City (2014). Retrieved from: https://www.hamilton.ca/city-initiatives/strategies-actions/age-friendly-hamilton

Horizon 2020-Inclusion. Retrivied from: http://h2020-inclusion.eu/fileadmin/user_upload/Documents/Deliverables/INCLUSION_D1.2_Review_and_classification_of_prioritized_area_types_and_user_groups_and_identification_of_challenges_and_gaps_v10_Pending_EU_Approval.pdf

Improvement of winter road services (2014). Retrivied from:https://www.ifmeworld.org/HigherLogic/System/DownloadDocumentFile.ashx?DocumentFileKey=2d5ada92-615b-c237-5d01-453cdad7a3e1

Iniziativa del Comune (2017). Retrieved from http://www.comune.treviso.it/iniziativa-ecoincentivi-comunali-anno-2017-interventi-finalizzati-promuovere-risparmio-energetico-la-riduzione-co2-promuovere-lo-sviluppo-mobilita-sostenibile/

Kent Design Guide (2005). Retrieved from: https://www.kent.gov.uk/about-the-council/strategies-and-policies/regeneration-policies/kent-design-guide

Komise, E. (2009). Dealing with the impact of an ageing population in the EU (2009 Ageing Report)[online]. Retrieved from: http://eur-lex.europa.eu/LexUriServ/LexUriServ.

Laurini, R. (2002). Information systems for urban planning: a hypermedia cooperative approach. CRC Press

Lovett, A., Haynes, R., Sünnenberg, G., & Gale, S. (2002). Car travel time and accessibility by bus to general practitioner services: a study using patient registers and GIS. *Social science & medicine,* 55(1), 97-111. doi: https://doi.org/10.1016/S0277-9536(01)00212-X

Mandal, S., & Mondal, S. (2019). Logistic Regression (LR) Model and Landslide Susceptibility: A RS and GIS-Based Approach. In Statistical Approaches for Landslide Susceptibility Assessment and Prediction (pp. 107-121). Springer, Cham.

Murgante, B. (Ed.). (2008). L'informazione geografica a supporto della pianificazione territoriale. Franco Angeli

PEBA – Piano per l'Eliminazione delle Barriere Architettoniche (2019). Retrieved from https://www.padovanet.it/informazione/peba-piano-di-eliminazione-delle-barriere-architettoniche

Personnes âgées: des citoyens à part entière (2010).Retrieved from: https://lyon.eelv.fr/fiche-pratique-fiche-pratique-personnes-agees-des-citoyens-a-part-entiere/

Pinto, F., & Sufineyestani, M. (2018). Key Characteristics of an Age Friendly Neighbouhood. *TeMA - Journal of Land Use, Mobility and Environment*, 117-132. doi: https://doi.org/10.6092/1970-9870/5754

Plan of Copenhagen City (2004). Retrieved from: http://depts.washington.edu/open2100/Resources/1_OpenSpaceSystems/Open_Space_Systems/copenhagen.pdf

Plan of Trasport for London, TfL (2013). Retrieved from: https://tfl.gov.uk/

Plouffe, L., Kalache, A., & Voelcker, I. (2016). A critical review of the WHO age-friendly cities methodology and its implementation. In T. Moulaert and S. Garon (Eds.), A*ge-friendly cities and communities in international comparison* (pp. 19-36). Cham, CH: Springer. doi: https://doi.org/10.1007/978-3-319-24031-2_2

Progetto Atlante 65+"Rete servizi per gli anziani" (2020) Retrieved from:https://www.empoli.gov.it/avviso/avviso-pubblico-progetto-rete-dei-servizi-gli-anziani-atlante-65

Project of the Land Transport Authority (LTA) organization (2014). Retrieved from:https://www.lta.gov.sg/content/ltagov/en.html

Ralston Center project (2017). Retrivied from:https://ralstoncenter.org/wp-content/uploads/2018/07/Ralston-Center-2017-Annual-Report.pdf

Safe streets for seniors (2008). Retrivied from: https://www1.nyc.gov/html/dot/html/pedestrians/safeseniors.shtml

Segnali di vita (2014). Retrieved from: https://mobilita.regione.emilia-romagna.it/osservatorio/approfondimenti/multimedia/foto/segnali-di-vita-gli-eventi-nelle-citta-dellemilia-romagna

Stillwell, J., Geertman, S., & Openshaw, S. (Eds.). (1999). Geographical Information and Planning. Springer Science & Business Media

Udine Sta Bene in Strada (2019). Retrieved from: https://www.comune.udine.it/files/tematiche/salute-sociale-welfare/citta-sane/sito20/udinestabeneinstrada.pdf

University of Washington project led by the Taskar Center for Accessible Technology (2016).Retrivied from:https://tcat.cs.washington.edu/

Urban Forestry Strategy (2013).Retrivied from: https://www.cityofsydney.nsw.gov.au/strategies-action-plans/urban-forest-strategy

Walker, A., & Maltby, T. (2012). Active ageing: A strategic policy solution to demographic ageing in the European Union. I*nternational Journal of Social Welfare*, 21, 117-130. doi:https://doi.org/10.1111/j.1468-2397.2012.00871.x

Yokohama Healthy Family (2016). Retrieved from: http://doc.future-city.jp/pdf/forum/2016_06/04_04_koibuchi_en.pdf

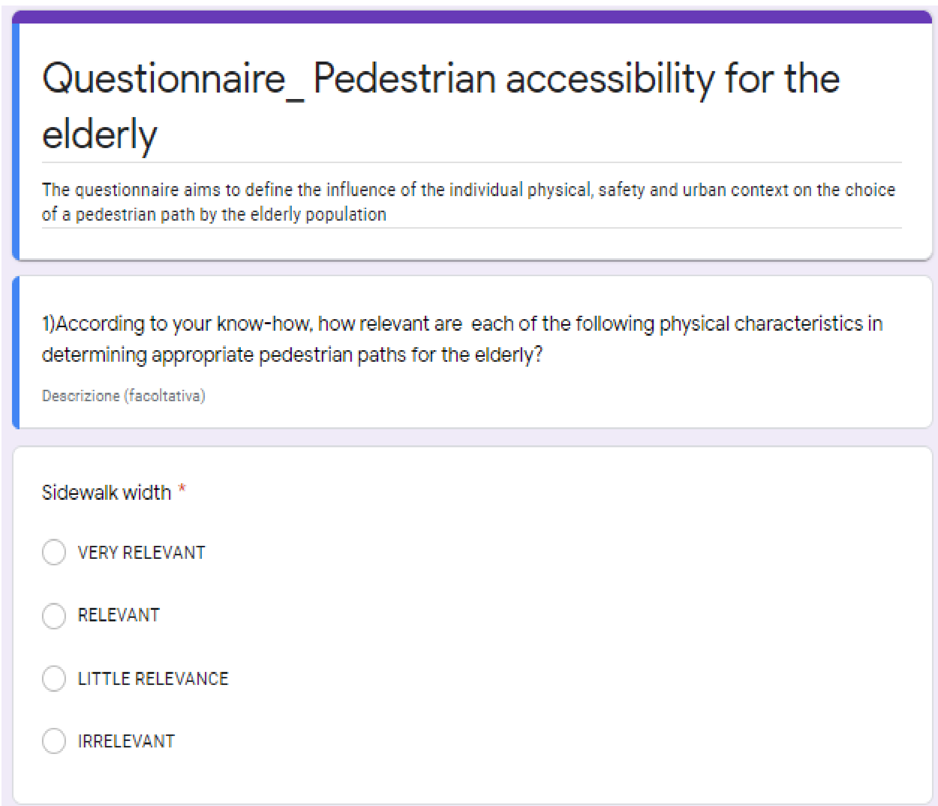
Zecca, C., Gaglione, F., Laing, R., & Gargiulo, C. (2020). Pedestrian routes and accessibility to urban services: an urban rhythmic analysis on people's behaviour before and during the Covid-19. *TeMA: journal of land use, mobility and environment*, *13*(2). doi: https://doi.org/10.6092/1970-9870/7051

FIGURE

TABLE

Annex A Google Survey

The questionnaire, developed through Google Survey as in fig. A1, included 7 questions. It was presented to experts from the period February-September 2020. It was preceded by a brief description of our research objectives. We also explained that the questionnaire mentioned a series of urban characteristics to be considered in order to assess both the influence of each of the characteristics of the pedestrian paths and the travel behaviour of the elderly. In the questionnaire, the experts were asked to evaluate each of the characteristics through a verbal judgment divided into four classes and in other cases into three classes.


Questionnaire_ Pedestrian accessibility for the elderly

The questionnaire aims to define the influence of the individual physical, safety and urban context on the choice of a pedestrian path by the elderly population

1)According to your know-how, how relevant are each of the following physical characteristics in determining appropriate pedestrian paths for the elderly?

Descrizione (facoltativa)

Sidewalk width *

VERY RELEVANT

RELEVANT

LITTLE RELEVANCE

IRRELEVANT

2) According to your know-how, how relevant are each of the following characteristics related to the sense of security when determining appropriate pedestrian paths for the elderly?

Descrizione (facoltativa)

Street lighting *

- VERY RELEVANT
- RELEVANT
- LITTLE RELEVANCE
- IRRELEVANT

3) According to your know-how, how relevant are each of the following urban context characteristics in determining appropriate pedestrian paths for the elderly?

Descrizione (facoltativa)

Presence of green areas *

- VERY RELEVANT
- RELEVANT
- LITTLE RELEVANCE
- IRRELEVANT

4) According to your know-how, how relevant is the presence of a green area to the choice of a pedestrian path , even in the absence of characteristics identified in the previous points?

- VERY RELEVANT
- RELEVANT
- IRRELEVANT

5) According to your know-how, how relevant is the presence of a panoramic point to the choice of a pedestrian path for the elderly, even in the absence of all the features listed in points 1 to 4? *

- VERY RELEVANT
- RELEVANT
- IRRELEVANT

Fig. A1. Screenshot of the survey

Annex B Interventions

	Improvement of pedestrian paths
Intervention	Use of drainage materials for pedestrian crossings
Form	PP2
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	Urban drainage improvement - Urban heat island mitigation
Territory governance tools	PUMS
Stakeholders to be involved	
Intersection with other actions and interventions	PP1 – PP3 Location of road intersections
DESCRIPTION	

The use of draining pavements for the reconstruction or construction of crossings makes it possible to facilitate the removal of rainwater in the surface layers of the subsoil, thus making them less slippery and facilitating their practicability by vulnerable users such as the elderly.

CASE STUDY

Permeability Guide
Dublino, Irlanda
Dublino County Council

More information availability at:
https://www.nationaltransport.ie/wp-content/uploads/2011/

Pedestrian toolkit
Long Beach, USA
Long Beach Municipality

More information availability at:
http://longbeach.gov/globalassets/lbds/media-library/documents/orphans/dt-and-tod/downtown-long-beach-pedestrian-plan_chapter-4_06152016-reduced

	Improvement of pedestrian paths
Intervention	Improvement of horizontal and vertical signs relating to protected crossings and the identification of cycle-pedestrian paths
Form	PP4
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	
Territory governance tools	Traffic plan
Stakeholders to be involved	Local authorities - Transport companies
Intersection with other actions and interventions	
DESCRIPTION	

The speed of movement of pedestrians is lower than other modes of travel, these users also need to use the shortest route to reach a destination. By installing the appropriate signage, it is possible to support pedestrians by increasing their ease of movement in the public space, also reducing the dependence on digital navigation devices such as mobile phones that greatly help pedestrians to identify the shortest path. In addition, the installation of appropriate luminous signs can also affect the improvement of traffic and road safety.

CASE STUDY

Talking Street Sign Navigation Concept Copenhagen, Denmark. What the Phonics for public use.

More information availability at:
https://termcoord.eu/2014/05/wtph-phonics/

	Improvement of safety perceived by users
Intervention	Signaling of traffic lights at which, in order to cross, the elderly can ask for help to cross to other pedestrians or to the traders present in the immediate vicinity
Form	SP2
GENERAL INFO	
Type of intervention	Linear
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	Reduction of social exclusion
Territory governance tools	PUMS
Stakeholders to be involved	City associations
Intersection with other actions and interventions	SP1 -
DESCRIPTION	

Road intersections that are difficult for the elderly to cross (due to physical characteristics, due to the presence of intense vehicular flows, etc.) can be equipped with special vertical signs that encourage other pedestrians and the owners of commercial activities located nearby, to help those over 65 in making the move within the intersection.

CASE STUDY

Human streets
San Francisco, USA
Human streets organization

More information availability at:
https://humanstreets.org/seniors-and-people-with-disabilities-demand-more-time-to-cross-the-street-df64f3bb72fe

	Improvement of urban quality
Intervention	Increase in the presence of benches along the shady paths, near commercial activities that are highly attractive to the elderly
Form	QU2
GENERAL INFO	
Type of intervention	Aereal
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	Citizen associations - Traders' associations
Territory governance tools	-
Stakeholders to be involved	Local public transport companies
Intersection with	QU1 – PP8
other actions and interventions	Localization of commercial activities

DESCRIPTION

The improvement of street furniture can facilitate the pedestrian movements of the elderly, as it provides them with some of the comforts useful for refreshment and affects the perception of the built environment in which they move, making it more pleasant and welcoming. By integrating this type of action with others aimed at improving the overall quality of the urban environment, it is therefore possible to increase the participation of over 65s in the life of their community. In particular, it is possible to equip the open spaces built with benches characterized by a higher seat that facilitates standing up and a support that the elderly can grab to get up, thus also favoring social aggregation.

CASE STUDY

Comfort streets
Philadelphia, USA
Ralston Center Organization

More information availability at:
https://www.metdra.de/en/street-furniture/benches/senior-citizens-benches/

	Improvement of urban quality
Intervention	Individuazione e segnalazione di percorsi di stimolazione cognitiva per l'invecchiamento in salute (*health and active ageing*)
Form	QU5
GENERAL INFO	
Type of intervention	Aereal
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	Improvement of health conditions
Territory governance tools	-
Stakeholders to be involved	
Intersection with	QU6
other actions and interventions	-

DESCRIPTION

It involves creating a series of cognitive stimulation paths for the healthy aging of the elderly population, whose contents include informative and playful moments aimed at keeping cognitive functions active, both for the positive effects that their maintenance entails, both as response to fears of mental decay that worry the elderly.

CASE STUDY

Portland Memory Garden
Portland, USA

More information availability at:
http://www.portlandmemorygarden.org/

	Improvement of urban quality
Intervention	Establishment of Living streets in which the street is converted into an urban space to encourage social aggregation.
Form	QU6
GENERAL INFO	
Type of intervention	Aereal
Territorial scale	Metropolitan area
Location	Established city
IMPLEMENTATION	
Indirect benefits	Reduction of social exclusion
Territory governance tools	-
Stakeholders to be involved	City associations
Intersection with	PP8- QU3
other actions and interventions	-

DESCRIPTION

The "green" transformation of local streets characterized by the mere presence of residences can encourage participation, inclusion, and social aggregation within the community to which the elderly belongs. In practice, the parking areas and the roadway area are transformed into urban gardens, areas for carrying out recreational and outdoor sports activities, green areas whose maintenance is entrusted to residents.

CASE STUDY

Living Street
Ghent, Belgio
Consiglio Comunale

More information availability at:
https://www.igpdecaux.it/blog/out-of-home-design/arredo-urbano-belgio-living-street/

PERSONAL BIBLIOGRAPHY

Gargiulo, C., Zucaro, F., & Gaglione, F. (2018). A Set of Variables for the Elderly Accessibility in Urban Areas. *TeMA - Journal of Land Use, Mobility and Environment*, 53-66. https://doi.org/10.6092/1970-9870/5738

Gargiulo C., Zucaro F., & Gaglione F. (2019). Improving accessibility to urban services for over 65: A gis-supported method. In International Conference on Innovation and Urban and Regional Planning INPUT aCAdemy 2019 (pp. 971-982). FedOA Press doi: https://doi.org/10.6093/978-88-6887-054-6

Cottrill, C., Gaglione, F., Gargiulo, C., & Zucaro, F. (2020, September). Defining the characteristics of walking paths to promote an active ageing. In Pedestrians, Urban Spaces and Health: *Proceedings of the XXIV International Conference on Living and Walking in Cities (LWC, September 12-13, 2019, Brescia, Italy) (p. 209). CRC Press*. ISBN 978-0-367-46171-3

Gaglione, F., Gargiulo, C., & Zucaro, F. (2019). Elders' quality of life. A method to optimize pedestrian accessibility to urban services. *TeMA - Journal of Land Use, Mobility and Environment*, 12(3), 295-312. doi: https://doi.org/10.6092/1970-9870/6272

Gargiulo, C., Gaglione, F., Guida, C., Papa, R., Zucaro, F., & Carpentieri, G. (2020). The role of the urban settlement system in the spread of Covid-19 pandemic. The Italian case. *TeMA - Journal of Land Use, Mobility and Environment*, 189-212. https://doi.org/10.6092/1970-9870/6864

Zecca, C., Gaglione, F., Laing, R., & Gargiulo, C. (2020). Pedestrian routes and accessibility to urban services: An urban rhythmic analysis on people's behaviour before and during the Covid-19. *TeMA - Journal of Land Use, Mobility and Environment*, *13*(2), 241-256. doi: https://doi.org/10.6092/1970-9870/7051

Gaglione F., Cottrill C., Gargiulo C. (2021). Urban services, pedestrian networks and behaviours to measure elderly accessibility. *Transportation research part D: transport and environment*. https://doi.org/10.1016/j.trd.2020.102687

Gargiulo C., Gaglione F., Zucaro F. (2021) Spatial Accessibility: Integrating Fuzzy AHP and GIS Techniques to Improve Elderly Walkability. In: La Rosa D., Privitera R. (eds) Innovation in Urban and Regional Planning. INPUT 2021. *Lecture Notes in Civil Engineering*, vol 146. *Springer, Cham*. https://doi.org/10.1007/978-3-030-68824-0_65

Gargiulo, C., Gaglione, F., & Zucaro, F. (2021, September). Urban Accessibility and Social Equity in Covid-19 Era: A Spatial Analysis in Two Neighbourhoods of the City of Naples*. In International Conference on Computational Science and Its Applications* (pp. 509-524). Springer, Cham. https://doi.org/10.1007/978-3-030-87016-4_37

In all the countries of the industrialized West and in many developing countries, the population aging index is gradually increasing and it is expected that in 2050 one in five people in the world will be over 70 years old and that 64 countries will have a population older than 30% of the entire population. The relationship between the organization of the pedestrian network and the location and distribution of urban activities are important elements for improving accessibility to urban places and services of interest to the elderly. Many scholars are engaged in research aimed at improving the characteristics of the pedestrian network and the characteristics of the built environment that influence the "walkability" at the neighbourhood scale or improving the accessibility in reaching a specific urban service through the transport networks of transport. In this perspective, the purpose of the thesis work is the development of a decision support tool in a GIS environment to classify urban areas according to the levels of pedestrian accessibility for the elderly to urban services. Accessibility levels are defined through the measurement of accessibility built starting from the weight of each characteristic of the pedestrian network (identified through the analysis of the Analytic Hierarchy Process (AHP)), from the behaviour of the elderly especially in terms of speed and time distance for the different age groups of the elderly population. The application of the thesis work took place in two territorial contexts: Naples, Italy and Aberdeen, Scotland. The results obtained provide suggestions to local decision makers in the choice of interventions and their priorities to be implemented at the neighbourhood scale to improve the quality of life of the elderly and on the other provide a technical-operational contribution to measure pedestrian accessibility to urban services in other territorial contexts in the GIS environment.

Federica Gaglione, engineer, graduated with honours in Building Engineering at the University of Naples Federico II. In 2018 she was the winner with a scholarship of the competition for admission to the PhD in Civil Systems Engineering within the governance of urban and territorial transformations. From August to December 2019, she served as a Visiting Researcher at the University of Aberdeen (UK) undertaking a significant amount of research regarding pedestrian accessibility for older persons.