Osvaldo Gervasi · Beniamino Murgante · Sanjay Misra · Chiara Garau · Ivan Blečić · David Taniar · Bernady O. Apduhan · Ana Maria A. C. Rocha · Eufemia Tarantino · Carmelo Maria Torre (Eds.)

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Computational Science and Its Applications – ICCSA 2021

21st International Conference
Cagliari, Italy, September 13–16, 2021
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Preface

These 10 volumes (LNCS volumes 12949–12958) consist of the peer-reviewed papers from the 21st International Conference on Computational Science and Its Applications (ICCSA 2021) which took place during September 13–16, 2021. By virtue of the vaccination campaign conducted in various countries around the world, we decided to try a hybrid conference, with some of the delegates attending in person at the University of Cagliari and others attending in virtual mode, reproducing the infrastructure established last year.

This year's edition was a successful continuation of the ICCSA conference series, which was also held as a virtual event in 2020, and previously held in Saint Petersburg, Russia (2019), Melbourne, Australia (2018), Trieste, Italy (2017), Beijing. China (2016), Banff, Canada (2015), Guimaraes, Portugal (2014), Ho Chi Minh City, Vietnam (2013), Salvador, Brazil (2012), Santander, Spain (2011), Fukuoka, Japan (2010), Suwon, South Korea (2009), Perugia, Italy (2008), Kuala Lumpur, Malaysia (2007), Glasgow, UK (2006), Singapore (2005), Assisi, Italy (2004), Montreal, Canada (2003), and (as ICCS) Amsterdam, The Netherlands (2002) and San Francisco, USA (2001).

Computational science is the main pillar of most of the present research on understanding and solving complex problems. It plays a unique role in exploiting innovative ICT technologies and in the development of industrial and commercial applications. The ICCSA conference series provides a venue for researchers and industry practitioners to discuss new ideas, to share complex problems and their solutions, and to shape new trends in computational science.

Apart from the six main conference tracks, ICCSA 2021 also included 52 workshops in various areas of computational sciences, ranging from computational science technologies to specific areas of computational sciences, such as software engineering, security, machine learning and artificial intelligence, blockchain technologies, and applications in many fields. In total, we accepted 494 papers, giving an acceptance rate of 30%, of which 18 papers were short papers and 6 were published open access. We would like to express our appreciation for the workshop chairs and co-chairs for their hard work and dedication.

The success of the ICCSA conference series in general, and of ICCSA 2021 in particular, vitally depends on the support of many people: authors, presenters, participants, keynote speakers, workshop chairs, session chairs, organizing committee members, student volunteers, Program Committee members, advisory committee members, international liaison chairs, reviewers, and others in various roles. We take this opportunity to wholehartedly thank them all.

We also wish to thank Springer for publishing the proceedings, for sponsoring some of the best paper awards, and for their kind assistance and cooperation during the editing process.

We cordially invite you to visit the ICCSA website https://iccsa.org where you can find all the relevant information about this interesting and exciting event.

September 2021

Osvaldo Gervasi
Beniamino Murgante
Sanjay Misra

Welcome Message from the Organizers

COVID-19 has continued to alter our plans for organizing the ICCSA 2021 conference, so although vaccination plans are progressing worldwide, the spread of virus variants still forces us into a period of profound uncertainty. Only a very limited number of participants were able to enjoy the beauty of Sardinia and Cagliari in particular, rediscovering the immense pleasure of meeting again, albeit safely spaced out. The social events, in which we rediscovered the ancient values that abound on this wonderful island and in this city, gave us even more strength and hope for the future. For the management of the virtual part of the conference, we consolidated the methods, organization, and infrastructure of ICCSA 2020.

The technological infrastructure was based on open source software, with the addition of the streaming channels on YouTube. In particular, we used Jitsi (jitsi.org) for videoconferencing, Riot (riot.im) together with Matrix (matrix.org) for chat and ansynchronous communication, and Jibri (github.com/jitsi/jibri) for streaming live sessions to YouTube.

Seven Jitsi servers were set up, one for each parallel session. The participants of the sessions were helped and assisted by eight student volunteers (from the universities of Cagliari, Florence, Perugia, and Bari), who provided technical support and ensured smooth running of the conference proceedings.

The implementation of the software infrastructure and the technical coordination of the volunteers were carried out by Damiano Perri and Marco Simonetti.

Our warmest thanks go to all the student volunteers, to the technical coordinators, and to the development communities of Jitsi, Jibri, Riot, and Matrix, who made their terrific platforms available as open source software.

A big thank you goes to all of the 450 speakers, many of whom showed an enormous collaborative spirit, sometimes participating and presenting at almost prohibitive times of the day, given that the participants of this year's conference came from 58 countries scattered over many time zones of the globe.

Finally, we would like to thank Google for letting us stream all the live events via YouTube. In addition to lightening the load of our Jitsi servers, this allowed us to record the event and to be able to review the most exciting moments of the conference.

Ivan Blečić
Chiara Garau

Organization

ICCSA 2021 was organized by the University of Cagliari (Italy), the University of Perugia (Italy), the University of Basilicata (Italy), Monash University (Australia), Kyushu Sangyo University (Japan), and the University of Minho (Portugal).

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Geographical Analysis, Urban Modeling, Spatial Statistics (GEOG-AND-MOD 2021)

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12th International Symposium on Software Quality (ISSQ 2021)

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10th International Workshop on Collective, Massive and Evolutionary Systems (IWCES 2021)

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Urban Accessibility and Social Equity in Covid-19 Era: A Spatial Analysis in Two Neighbourhoods of the City of Naples

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Abstract. The academic debate has been turn the attention on pedestrian accessibility to urban services, as walking allow to solve several issues ranging from social and health problems also accentuated by the ongoing pandemic. The innovation in geospatial field has encouraged the development of accessibility and walkability measures and indicators oriented to measure the main physical and functional characteristics of the built environment related to the accessibility of urban services at the neighbourhood scale. According to these premises, this research work, aimed at improving pedestrian accessibility and guaranteeing equal access to neighbourhood-scale services, proposes a seven-steps GIS method based on an Accessibility Indicator that integrates the main aspects of walkability indexes relating to connectivity, sense of security, geometry and amenity of urban built environment. This Accessibility Indicator defines the areas of easy accessibility to the local essential services, by referring to two different maximum distances: the first relates to the distance of 700 m defined in the literature as the distance that a user is willing to walk to use a neighborhood service and the second relates to the regulatory restrictions adopted in the most difficult periods of the pandemic (500 m).

Keywords: Social equity · Urban accessibility · Covid-19

1 Trends and Research Perspectives of Walkability

1.1 Walking as Opportunity to Improve the Urban Quality

The World Health Organization in the Action Plan for the prevention and control of communicable diseases 2013–2020 invites governments and local decision makers to promote active mobility (walking and cycling) in local government policies to help reduce various health diseases such as obesity, diabetes, etc. and therefore favour healthier lifestyles and behaviors [1]. Some authors investigated the link between urban mobility

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habits and health conditions and found that the odds of obesity increase by 6% for each additional hour spent in a car and conversely decline by 4,8% for each additional km walked per [2]. The economic burden of this situation has been estimated to be around 80.4 billion euro per year for Europe and 400 million dollars per year for USA, due to the costs related to the healthcare system [3] and [4]. This cost could be avoided if all segments of population were to achieve an average of 20 min per day of simple and inexpensive activities such as walking [3]. Until before the pandemic in Italy fewer and fewer people choose to move using a means of transport other than the car to go to the workplace but, at the same time, the number of journeys on foot and by bicycle was increasing: the distances on foot increased by more than 5%, while the bike doubles (and more) its share while still occupying a small segment of the modal distribution of urban journeys (2.7%) [5]. This slow growth occurred in the period 2017–2018 and had a remarkably raised during and post lockdown conditions, as the Covid-19 made walking and cycling even more appealing. In fact, sidewalks are open spaces where pedestrians can usually avoid crowding and keep a safe distance of at least 1 m. Nonetheless, these trends seem not to fully correspond to the results expected from the implementation of strategies and actions that for 15 years have been referring to the Smart City paradigm and more recently to the Age Friendly City model. If on the one hand through the Smart Mobility approach the technological solutions and innovations can encourage people to walk by supporting them in planning the paths and overcoming immaterial barriers, [6, 7] and [8], on the other hand the diffusion of the principles of Universal Design favour re-organising the physical and functional structure of urban systems, in order to increase urban accessibility to the main urban services, mainly by walking, for all population segments [9–11] and [12]. Therefore, the aims of smartness and improvement of the urban accessibility both of open spaces (built and not) and activities, involves increasing the walkability. Recently a few policy options to promote active mobility in urban areas have been proposed by different government institutions. The UN Agenda 2030 for Sustainable Development [13] has claimed how in the transition to a low-carbon society a radical modal shift towards soft mobility is required to reach most goals, in particular the ones related to well-being (goal n. 3), urban sustainability (goal n. 11) and climate (goal n. 13). In 2020, the UN and the WHO highlighted how cities must adapt to the new health crisis such as the Covid-19 by increasing the quality of urban spaces and the accessibility options to reach the primary services such as food and health [14].

According to what has just been described, it results that local decision makers intend to adapt and reorganize built and open spaces according to the renewed needs of pedestrian accessibility to essential urban places and services that reveal to be more pressing during a pandemic crisis. In this perspective, this study aims to support local policymakers in improving pedestrian accessibility and guaranteeing equal access to neighbourhood-scale services.

The paper is structure as follows: the two next sub-sections provide the scientific framework of walkability issue and the review of its main indexes respectively; Sect. 2 illustrates the methodology developed in GIS environment; Sect. 3 discusses the results for two municipalities of the city of Naples; Sect. 4 draws the conclusions by providing causes of reflections.

1.2 Walkability and Urban Built Environment

Walking is currently an intense topic of discussion in academic debate, as researchers have been focusing on it as a mean to solve a variety of issues from social ills and health problems relating to global warming and air pollution. Measuring the friendliness of the urban settlements to the pedestrian users commits the scientific community in identifying the urban characteristics that influence walking behaviours. In fact, urban settlement features can perform both as facilitators and impediments to walkability, that can be defined as "the extent to which the built environment supports and encourages walking by providing for pedestrian comfort and safety, connecting people with varied destinations within a reasonable amount of time and effort, and offering visual interest in journeys throughout the network" [15]. Cervero and Kockelman [16] before and Ewing and Cervero [17] after, suggested the five main features of the built environment influencing walkability: the greater buildings Density and better accessibility to public transport are accompanied by a smaller amount of kilometres travelled (shorter Distances); in the same way, the greater Diversity in Land Uses and in the mix of functions (Destination accessibility) is accompanied by a greater level of pedestrianization of the spaces (Design) and therefore a more limited use of motorized vehicles. These famous "5Ds" have been linked to basic or neighbourhood services to highlight the importance of their proximity for social inclusion and access opportunities. Promoting pedestrian accessibility can make urban societies more inclusive by allowing easier access to relevant services even for people with limited mobility. Several authors found that quality and attractiveness of a neighbourhood were strongly related to walkability levels [18] and [19] and this correlation depends also on the socio-economic conditions of the community. For instance, gentrification processes and associated displacement of disadvantaged groups worsen social inequity of those who could potentially benefit the most from highly walkable urban environments. The disadvantaged are likely to include socially vulnerable groups such the elderly, minorities, and those with low education and/or low-skill occupations that have limited resources and are often mobility-restricted [20] and [21]. Furthermore, if the Covid-19 era increased the need of walking, it also exposed the spatial inequalities in moving through the different urban districts. The innovation in geospatial technology field, such as the Geographical Information Systems (GIS), has enabled the development of walkability measures. Some studies used a "place-based" approach, as their main aim was measuring the walkability levels of territorial unit like census tracts or catchment areas by reason of the presence of local services (i.e. green areas, recreational activities, health assistance) [22]. Other works employs "network-based" approach, as they aimed at measuring the accessibility to nearby service by focusing on the features of pedestrian network and on the identification of the best paths for users [23]. Both the lines of research aggregate different variables and indicators into a walkability index helping to measure various dimensions of built environment that cannot be captured completely by individual indicators alone [24].

1.3 Reviewing Walkability Indexes

According to Vale et al. [25] approximately 80 or more walkability indexes have been developed from different perspectives such as urban studies, public health and transport planning, to measure the pedestrian friendliness at neighbourhood and city levels.

Among all these indexes, this work takes into consideration the nine most consolidated and wide used ones by providing a compared reading of them: Walkshed, Neighbourhood Destination Accessibility Index (NDAI), Moveability Index, Pedshed, Walk Opportunity Index, Walk Score®, Walkability Index (WI), Pedestrian Environment Index (PEI) and Pedestrian Index of the Environment (PIE). They were selected after an extensive literature review and all of them can represent a level-headed overview of the current main methods for measuring walkability. According to the method described in the next section, the review of the walkability indexes was a preliminary and necessary step to develop the method described in the next section, as it allowed defining the features of walkability to take into consideration and the most suitable way to measure them. Data collection, methods and spatial level of analysis represented the key aspects of the review supplied.

In 2006 Frank et al. [26] lead the foundations for the development of walkability methods oriented to capture the influence of urban form on walkability. Frank et al. [26] and [27] developed the Walkability Index that integrates land-use mix, connectivity, and residential density. Their values are first measured in a network buffer around each participant's residence and then normalized (z-score) by assigning a double weight to the connectivity of the street network as the higher density of intersections, the easier of travel to destinations is. These normalized variables are combined to calculate the WI [27] that has been used in numerous studies related to travel behavior too, by defining different ranges of weights for the three components of the index. As the WI was developed in USA where cities are characterized by lower population density, degree of land-use mix, and connectivity than European cities, Grasser et al. [28] adapted Frank's Walkability Index adapting it to them: population density, household density, an entropy index for land-use mix and three-way intersection density were considered and weighted in a different way. As far as the use of the kernel density method is concerned and regarding the concentration of recreational facilities or playgrounds, the Moveability Index differs from the WI whose inspiration took from. In fact, the aim of Moveability Index was to measure opportunities for physical activity of children in urban areas [29] and [30]. Walkability Index inspired the development of another index taken into consideration that is Walk Score. It rates the proximity of daily life activities to specific addresses in USA, Canada, Australia, and New Zealand. Walk Score® measure is based on an algorithm that calculates the points according to the distance of an origin to each category of urban opportunities within 30 min on foot. Distances are transformed in 0–100 "amenity scores" through a polynomial distance decay function. If the closest facility in a category is within 0.4 km, the maximum number of points is assigned and no points are allocated to facilities further away than 1.6 km. Further elements such as weather and crime allow to calculate the add-on scores. All the scores are first weighted and then summed to the final Walk Score® on a 0–100 scale. This commercial web-tool is used by users mainly to assess their home-buying decisions and by researchers to measure built environment characteristics in transport and health research. Nevertheless, the complete algorithm is proprietary and some aspects of the methodology remain unavailable, many researchers agree that the Walk Score® metric is an overall measure of walkability that does not take into account the aspects of space design and street furniture that can influence the quality and the choice pf a path, such as the width of a sidewalk, the presence of obstacles to the walk, or the visual quality of the space [31] and [32]. Some of these aspects related to the street layout, together with safety and sidewalk connectivity, are considered in the Pedshed index that is based on walking catchment approach as it measures the area accessible through the street network within a defined Euclidean distance. In addition to Walk Score that has a calculation procedure proprietary, also Walkshed index works through a DecisionTree® Avencia's geographic planning and prioritization software that scores a location based on the quantity and diversity of amenities within a 1-mile radius. Walkshed allows users to customize the weight of the variables according to their preferences, to calculate the walkability of Philadelphia neighborhoods to reach shops, stops and other services. Like the previous, the Walk Opportunities Index (WOI) developed by Kuzmyak et al. [33] mainly refer to residential density, mix of functions and completeness of pedestrian network. The WOI calculates the walking distance to each opportunity in 0.25-mile buffers. Distance, size and importance of each destination determine WOI weight. Instead of summing the values of the variables composing the index, the Pedestrian Environment Index (PEI), multiplying each of them to avoid influences between components and that the final value can be zero because of one single component. The PEI formula requires data that are mostly available publicly, such as population density, land use, buildings, street network features [34]. The Pedestrian Index of the Environment (PIE) differ from this last index and from the others for the more elaborated procedure to calculate it. PIE variables, referring to the 5 D's of urban form, are calculated through the kernel density method to consider the decreasing impact of urban features on walking behavior as distance increases [35]. The variables are then weighed by using a single-variable binary logit models and their sum is normalized on a 20–100 scale. The last index is the neighborhood destination accessibility index (NDAI) whose final score was calculated by summing the eight weighted domain scores (education, transport, recreation, social and cultural, food retail, financial, health, and other retail), obtaining a value between 0 and 31, with a higher score representing better walking access to services and amenities [36]. To provide an effective and worthy representation of the outputs of the compared review of the walkability indexes taken into account a radar diagram was elaborated (Fig. 1). Pedshed and PEI count more built environment characteristics than the other indexes, by requiring a wider set of data to be collected. Thus, can be explained by considering that data gathering phase can reveal onerous for the calculation of an indicator, as it depends on the accessibility and availability of databases available for the study area [37] and [38]. However, the measurement of the susceptibility of the built environment to be walked cannot take place without working at a level of detail that is as accurate as possible, compatibly with the resources available. Features related to connectivity, land use and presence of amenities are shared by most walkability indexes, as the localization and distribution of services and places influence the choice of possible walking paths [39]. Moving to the methodological aspects, except of the Walkshed index, the others use compensatory methods by summing (unless PEI) and standardizing characteristics of the built environment related to the 5Ds. All the indexes' outputs refer to an area and Walkscore, Walkshed and Moveability refer to a deeper level of detail by referring to sub-sections of streets or to pixels.

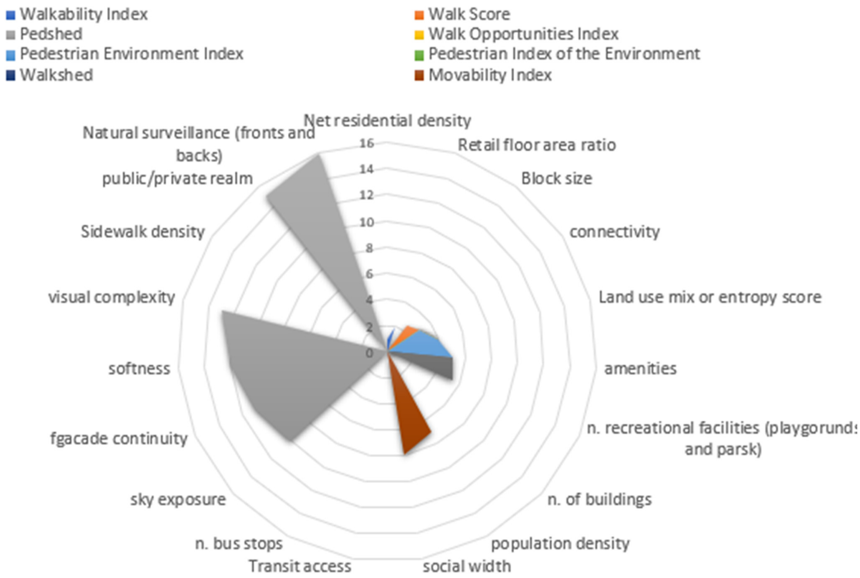

Fig. 1. Main characteristics of the nine walkability indexes (authors' elaboration).

2 Methodology

The renewed needs for pedestrian accessibility to urban places and services, also resulting from the pandemic crisis, constitute the starting point to rethink the physical and functional organization of urban systems.

In this perspective, this study aims to support local policymakers in improving pedestrian accessibility and guaranteeing equal access to neighborhood-scale services through a GIS-based method integrating the main characteristics of indexes of walkability. Nine indexes were considered to identify and measure in a quali-quantitative way numerous physical features of the pedestrian network and the built environment that influence the accessibility of urban services. The main goal is the measurement of pedestrian accessibility to services which are essential during pandemics, according to the restrictive distance imposed by national regulations too. These two central aspects related to Covid-19 were considered due to the assumption that the new Covid-19 Virus Variants and the still-uncertain ways of transmission require to ensure equal access to urban activities and places to all population segments. Besides, the organization of the urban system affects the accessibility and the use of services and urban spaces, as well as their localization and distribution. Therefore, they are key elements to avoid further forms of inequality and marginalization in those parts of the city which, due to their socio-economic level and quality of life, are normally disadvantaged compared to others and whose gap tends to worsen in times of crisis such as the pandemic.

The study is in continuity with previous works by the authors who, adopting a systemic approach that integrates the pedestrian network, the demand and supply of services, aimed at improving pedestrian accessibility by the elderly to services, also through the definition of optimal pedestrian paths that facilitate the achievement of services by the elderly.

In this perspective, during the research work presented in these pages, aimed at improving pedestrian accessibility to urban services, especially at the neighborhood scale, a six-phase method in a GIS environment was developed. The first phase consisted of measuring pedestrian accessibility to services identified as essential in the Covid-19 lockdown period or identifying areas equipped with necessary services that can be easily reached on foot by the inhabitants of those areas.

To this end, the significant characteristics of the urban system have been selected such as: (i) the geomorphological characteristics and those relating to safety, amenities and pleasantness of both the pedestrian network and the urban fabric, (ii) the socio-economic characteristics of the population, (iii) the location of services. Furthermore, reference was taken at two different distances: the first relates to the distance of 700 m, defined in the literature as the distance a user is willing to travel on foot to use a neighborhood service, while the second relates to regulatory restrictions adopted in the most difficult periods of the pandemic in Italy (500 m). With this in mind, 19 variables have been identified to measure pedestrian accessibility which also include those relating to the walkability indicators derived from the review which refer to the topological and geometric aspects of the network (connectivity) and the supply of proximity services (Table 1).

Table 1. The characteristics of urban system useful to measure pedestrian accessibility.

ID	Variable	Measure	Source
Socio-economic characteristics			
1	Population divided by age groups (30–39;40–49;50–59;60–69; +70)	Inhabitant	ISTAT
2	Population density	Inhabitant	ISTAT
Characteristics of the pedestrian network and the built environment			
3	Network connectivity	n°/m	GIS
4	Slope of the network link	$> 5\% = 0 < 5\% = 1$	GIS
5	Sidewalk width	$< 1{,}5$ m $= 0 > 1{,}5$ m $= 1$	Google maps
6	State of the flooring	0 = poor good = 1	Google maps
7	Crossroad	No = 0 Yes = 1	Google maps
8	Traffic light intersection	No = 0 Yes = 1	Google maps
9	Speed of vehicular traffic	> max 50 km/h = 0 < 30 km/h = 0	Openstreet map

(*continued*)

Table 1. (*continued*)

ID	Variable	Measure	Source
10	Volume of vehicular traffic	$> 17{,}5$ m $= 0 < 9$ m $= 1$	GIS
11	Presence of benches	No = 0 Yes = 1	Google maps
12	Presence of shaded paths	No = 0 Yes = 1	Google maps
13	Noise pollution	< 55 dBA $= 0 > 55$ dBA $= 1$	Acoustic zoning plan
Functional characteristics			
14	Pharmacies	n°	Google my maps
15	Banks	n°	Google my maps
16	Post office	n°	Google my maps
17	Neighborhood food	n°	Google my maps
18	Supermarket	n°	Google my maps
19	Neighborhood green	n°	Google my maps

The second phase concerned the parameterization and geolocation of the variables.

The socio-economic and functional variables were parameterized using the ISTAT database and the Google Mymaps platform, respectively.

The variables, relating to both the characteristics of the pedestrian network and the built urban environment, were detected through direct surveys in the study area. They were parameterized afterward concerning a qualitative scale, through the presence/absence, or by identifying threshold values (based on regulatory or planning documents), explaining conditions that are favorable (or not) to the practicability of each arch of the pedestrian network. In other words, in the first case for the definition of the state of the pavement, for example, pedestrian paths with pavement in a poor state of maintenance were defined as "poor"; in the second case, the speed of vehicular traffic, the Highway Code was consulted, since in Article 142 it governs the maximum speeds on each type of road permitted for traffic safety and protection of human life by identifying the roads passable even by pedestrians with speeds below < 30 km/h. Similarly, for the variable linked to noise pollution, the reference values of the decibels were taken from the acoustic zoning plan of the Municipality of Naples. The coexistence of qualitative and quantitative variables made it necessary, in phase three, to normalize the values. Normalization was also useful to calculate the sum of the walk score scores for each arc of the pedestrian network from generic node i to node j, on a scale from 1 to 13 due to the characteristics of the routes and the urban context considered. The choice of this method is due to the different nature of the considered variables, which do not allow to objectively define a differential "weight" without the use of statistical methods and local surveys as was performed in the authors' previous works [40].

Based on the walk scores obtained and the reading of the walkability indicators, the following accessibility indicator was developed in phase four:

$$\text{Accessibility Index} = \mathrm{D_{ij}} + \left(\mathrm{D_{ij}} \times \sum\nolimits_{ij}^{1} W_{ij}\right) \tag{1}$$

where:

$\mathrm{D_{ij}}$ is the distance of each arc of the pedestrian network that can be traveled from node i to node j;

$(\sum_{ij}^{1} W_{ij})$ the relevance of the weight of each characteristic of the pedestrian network from node i to node j.

The indicators outlined within the literature review take into account the characteristics relating to connectivity, land use and the presence of services and the relative distances from them. Distance, size and relevance of each destination determine its weight by assigning a pedestrian score for the achievement of urban services.

Compared to the indicators reported in the review, the indicator developed in this study takes into account not only the characteristics of the pedestrian network linked to its connectivity but also those relating to its geometry, the sense of safety perceived by users and the context of the urban area of reference, components considered essential in defining the degree of usability of the routes and the level of accessibility to neighborhood services. More specifically, the proposed Accessibility indicator relates the distance to be traveled to reach a certain service on each arc of the pedestrian network with the weighted average of its characteristics, on a scale of values from 0 to 1.

In phase five, on the basis of the distances that a user can or is willing to travel, respectively in times of pandemics and not, urban areas have been classified in terms of pedestrian accessibility to essential services through the use of a Network Analysis tool in GIS environment. Starting from the services present within the study area and defined the areas accessible to them, it was possible to identify the number of users served [32]. In phase six, in relation to these two distances, the population served in five age groups (30–39, 40–49, 50–59,60–69, +70) was calculated to understand if there is social equity between different areas of the same city and between the different age groups of the population.

3 Results

The proposed methodology was tested in the V and VIII Municipalities of Naples that have profound differences in terms of the socio-economic, settlement, geomorphological and functional characteristics, although characterized by the same number of inhabitants. More in detail, the V municipality is characterized by central districts that developed between the nineteenth and twentieth centuries (Vomero) or by ancient small villages that have succumbed to the intense settlement expansion of the 60s–70s of the last century (Arenella), endowed with the functional characteristics of the city center; the VIII instead includes peripheral districts, which once represented the rich and fertile Neapolitan agricultural reservoir but which, the myopic expansion policy (Scampia) or the spontaneous and uncontrolled expansion (Chiaiano and Piscinola) of the last 50 years, have relegated to areas substantial economic, social and settlement discomfort leaving them deprived of both essential and general services that constitute the basic elements on which to build the "community effect". Figure 2 shows two examples of the application of the Indicator to two categories of different services: healthcare (pharmacies) and economic (post offices) in the two different periods considered. As can be seen, both types of services have a consistent diffusion in the 5th municipality and consequently the areas served by these cover ordinarily almost the entire territory of the Municipality. On the other hand, the situation in the VIII municipality is different since the conditions of discomfort and poor accessibility are perceptible due to the reduced number of equipment, the consequent scarce extension of the areas ordinarily served, to be further reduced in periods of restriction. Furthermore, in the VIII Municipality, the situation is further aggravated considering that the areas identified by the Accessibility Index must be built by contemplating not only the elements considered above but also the conditions of the pedestrian network, which in this part of the city is lacking in safety, comfort, and amenities (Fig. 2).

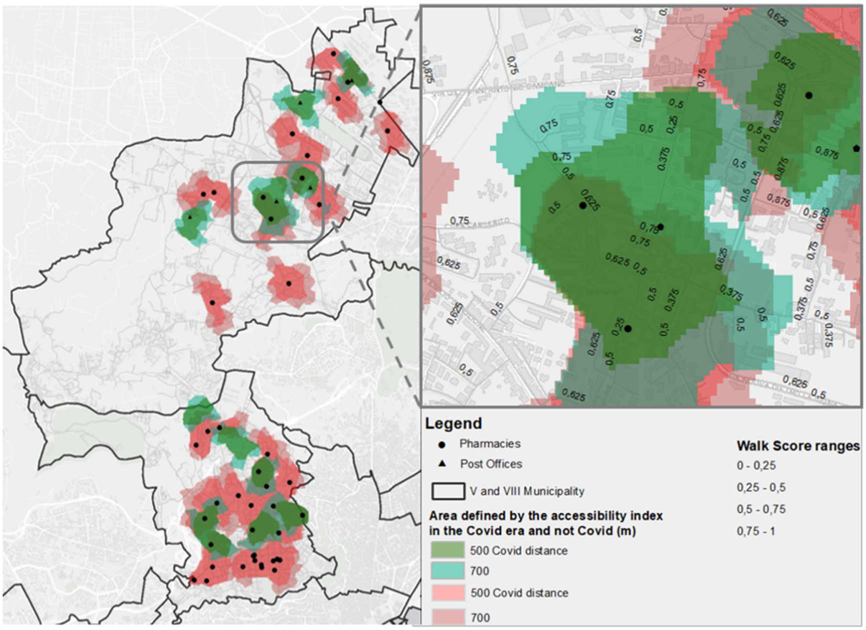

Fig. 2. Accessibility Index results and walk scores of pedestrian network links for the V and VIII municipalities of City of Naples (authors' elaboration).

The Index applied to the two Municipalities show the distribution of services and their accessibility, highlights the gap that differentiates the two study areas which is not only physical, functional and organizational (as already mentioned at the beginning of this paragraph) but also refers to services accessibility.

In detail, the Vomero district, characterized by a high population density and a hilly orographic conformation, has a compact urban fabric designed on a rather orderly and regular design, with a strong presence of commercial activities and a good endowment

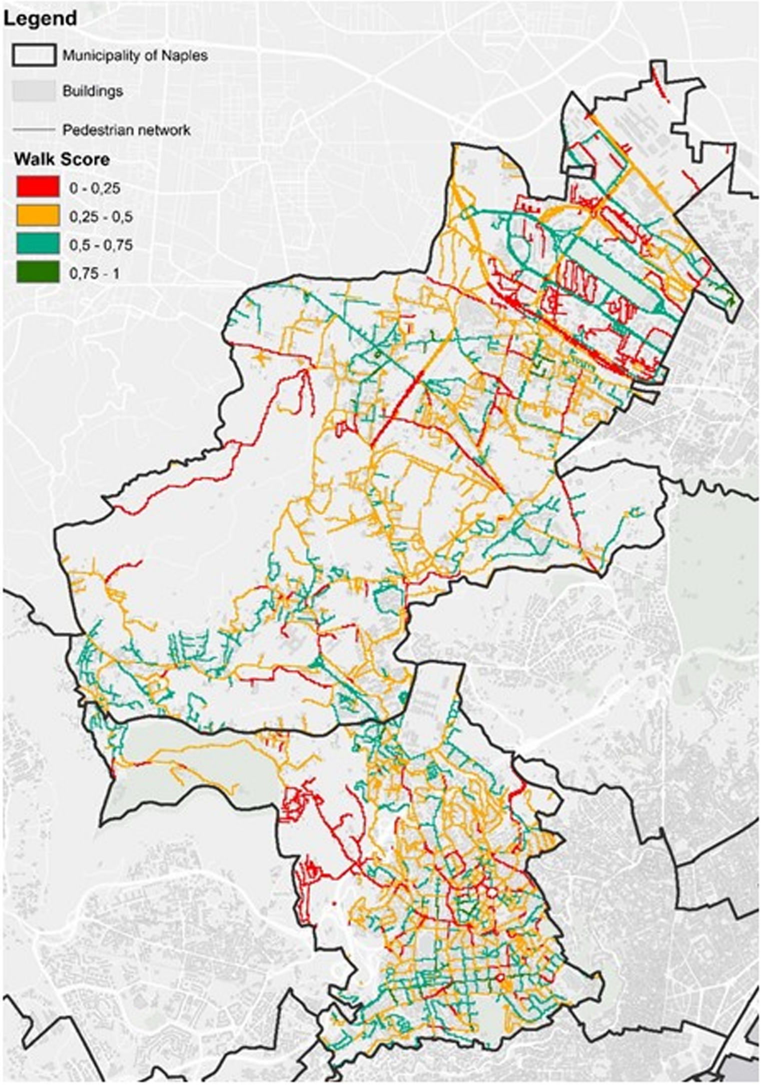

Fig. 3. Classification of pedestrian network according to Walk Score calculated (authors' elaboration).

and a variety of neighborhood services and general services, especially in some areas such as those adjacent to Piazza Vanvitelli, Piazza Bernini and Piazza Medaglie d'Oro. The Arenella district, on the other hand, is more recent than the Vomero district and includes areas such as that of the Rione Alto, adjacent to the hospital area, the Policlinico and via Domenico Fontana, characterized by an unplanned fabric that has extended as a consequence of the building saturation of the Vomero.

The districts of Chiaiano, Piscinola and Scampia are, on the other hand, peripheral districts of the city of Naples whose urban fabric, partly planned, is characterized by blocks of economic and popular housing and the absence of services, even assistance ones, in which the low-income population, low schooling and early parenting found their place. A fair amount of functional mix can be identified in the area next to the Ciro Esposito Park in Scampia and the area adjacent to the Chiaiano and Pisci-nola-Scampia underground line 1. Regarding Fig. 2, it is worth noting that in both the Municipalities there are areas characterized by a total lack of essential services, such as, for example, the portion of municipal territory close to the administrative limit between the two municipalities. This is the hilly area of the Camaldoli in the 5th municipality and the area next to the Cotugno hospital, Via Comunale Guantai and Via Vicinale Margherita in the 8th municipality. The resident population in this macro-area, disadvantaged in terms of the supply of essential services compared to the remaining parts of the two Municipalities, also has limited opportunities for moving on foot, due to the lack of pedestrian routes, especially -all in the Camaldoli area (5th municipality) (Fig. 3). The extreme difficulty of accessing the urban services on foot will certainly have made life even more complicated during the pandemic period for the residents of this area. The restrictive measures imposed during the pandemic period have established the possibility of reaching only the services close to homes. In particular, most of the regions (e.g. Friuli Venezia Giulia) have identified 500 m as the maximum distance that can be traveled to reach the essential services present in the area adjacent to the residences. In accordance with this value, the population served in five age groups was calculated (30–39, 40–49, 50–59.60–69, +70), for both municipalities under study, all of the areas identified by the proposed Accessibility Indicator. For health-related services (pharmacies) the results (Fig. 4) show that vulnerable groups of the population such as the 60–69 and the over 70 are better served in the 5th municipality, with a percentage equal to 35% compared to the other groups of the population. This figure is also due to a greater concentration of this service in the more consolidated urban fabric areas. For the V municipality (Fig. 5), on the other hand, a social marginalization of vulnerable groups of the population emerges (60–69; +70), served only for 12% compared to 26% of the other population groups. For the economic services (banks and post offices) of the 5th municipality, an almost uniform distribution of about 11% is seen for banks, while for post offices it is about 6%, however, constituting a very low rate of the population of the entire municipality. The rates drop further for the VIII municipality, with a percentage for banks equal to 3% and post offices equal to 5% for the population groups considered.

Finally, compared to commercial services (supermarket and grocery stores), in the 5th municipality, the over 70s are better served within a radius of 500 m, with a percentage equal to 13% and 12% compared to other groups of the population, who can more easily travel a greater distance. The scenario is completely opposite for the VIII Municipality where the most disadvantaged groups of the population are those of the 60–69 and over 70. Among the overall population served by all the services considered, a substantial disparity emerges between the two Municipalities. For the V, about 50% of the population is served within 500 m (except for the age group 30–39 minors equal to about 40%). In the VIII municipality, 27% of the population aged between 30 and 59 is served within 500 m, while the percentage drops to 22% for the over 60s.

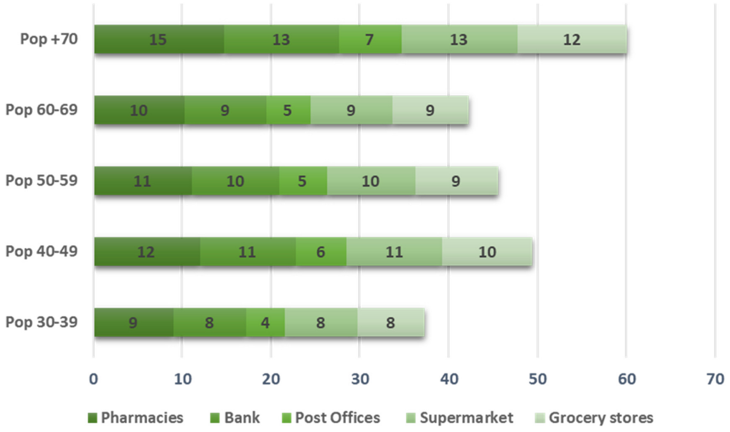

Fig. 4. Percentage of segments of population accessing to services within the V municipality of Naples.

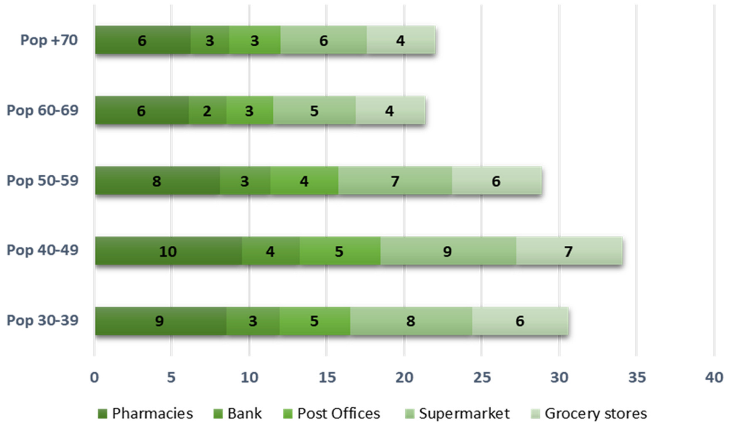

Fig. 5. Percentage of segments of population accessing to services within the VIII municipality of Naples.

4 Conclusions

The results just outlined underline how the measure of pedestrian accessibility can efficiently support local decision-makers in localizing, distributing and integrating urban services, by improving the walking network quality. In particular, the physic and functional organization of the urban system should be equity-oriented towards all the population segments, according to the different socio-economic backgrounds. In line with age-friendly city principles, local decision-makers should guarantee equally accessible urban services to all citizens, independently from their social, economic and physical conditions, to avoid "states of crisis" of the urban system when subjected to external agents like pandemics.

Urban accessibility can therefore be a tool to increase social equity even in peripheral neighborhoods, more socially disadvantaged and characterized by physical and functional marginality, where there is little accessibility to the resources and opportunities that a city can offer.

This consideration is also consistent with EU cohesion policy (2014) which recommends planners and policymakers to use the "lens of social equity" to change old development strategies and write new ones to make urban systems more inclusive, resilient and sustainable provide accessible and connected jobs, health care and recreation.

Nevertheless, it is worth mentioning some limits of this study. Firstly, for the measurement of the Accessibility Index the distances related to stops of public transport and the cycling mobility could be added, also to take into account the spread of micro-mobility consequent to post pandemic period. To this aim, the set of variables could be increased by regarding further proximity services and other characteristics of the multimodal network.

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