Elderly Walkability Index through GIS: Towards Advanced AI-based Simulation Models*

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Abstract. In the context of progressive urbanization and ageing of the population, the LONGEVICITY project has the objective to study advanced solutions for enhancing the social inclusion of the elderly through walkability. The paper is focused on the application of GIS for the definition of a novel Elderly Walkability Index. This is based of the analysis of a series of geo-referenced data of the City of Milan (Italy) in order to measure: (*i*) the residential density of the elderly inhabitants; (*ii*) the level of pedestrian friendliness of the city in terms of usefulness, comfort and safety. Results allowed to identify the areas of the city where to collect empirical evidences about age-driven pedestrian mobility, for supporting the development of advanced AI-based simulation models.

Keywords: Ageing · Walkability · Pedestrian · GIS · Modeling

1 Introduction

Urbanization is one of the global trends of the 21st Century, which requires institutions to more effectively design and plan the cities to improve the quality of life of the inhabitants. Today, over half of the world's population lives in urban areas and all the regions of the world are expected to urbanize further over the coming decades: by 2030 over 60% of the global population will live in cities and large urban agglomerates [24].

Urbanization shift is occurring globally since 2007, joined to the increasing proportion of elderly in the population. Population aging, due to longevity and a decline in both mortality and fertility rates, is now occurring fastest in high and middle-income countries, being Italy and Japan at the first places experiencing an aging society [23]. World demographic projections show that by 2030 the number of people aged 65 and over will be the 25% of the population. This phenomenon makes the activities of city managers even more difficult, due to rising demand of services and infrastructures for the elderly citizens.

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The World Health Organization [25] has recognized the convergence of aging and urbanization trends, introducing the concept of *Age-friendly Cities*: a framework for urban development encouraging the *active aging* of the population. Many Countries responded through the development of policies supporting pedestrian mobility as a key challenge for encouraging the active inclusion of the elderly citizens (being independent to move about the city determines indeed social participation and access to local community life and services).

Facing this trend, advanced urban planning activities [4] are shifting towards a focus on *walkability* [1], namely how friendly the urban environment is for walking. This is based on developing new strategies for the pedestrianization of urban areas and for guaranteeing the comfort and safety of vulnerable road users while walking (e.g., barrier-free streets, mantainence of sidewalk, visibility of road signs, public places for outdoor activities) [11].

The term walkability refers to those design elements which guarantee the accessibility, comfort and safety of the urban setting for walking [10]. Jeff Speck [20] has recently proposed a *General Theory of Walkability*, which explains the essential elements for evaluating the level of walkability of urban environments (see [12] for a systematic review of the literature), as follows: (*i*) the presence of services within a walkable distance; (*ii*) the level of comfort and safety experienced by people while walking; (*iii*) the attractiveness of the urban areas in terms of architectural design and social context.

As part of the research project "LONGEVICITY: Social Inclusion for the Elderly through Walkability", this work aims at developing innovative strategies to sustain the active aging of the citizens of Milan (Italy), by enhancing pedestrian mobility through walkability. First, the paper to proposes a detailed definition of the criteria, data and methods for the assessment of the level of walkability of urban areas, taking into account the needs of the elderly inhabitants. Then, the paper presents the results of a GIS analysis aimed at identifying the areas of the City of Milan characterized by the highest presence of elderly inhabitants and by the poorest level of walkability. The areas will be exploited to collect empirical evidences about age-driven pedestrian mobility, for supporting the development of advanced AI-based simulation models. The paper concludes with final remarks about results and future works.

1.1 Walkability for the Elderly: Criteria, Data and Methods

As described in previous works alredy presented by the authors [14, 13], the walking behavior of aged pedestrians is strongly conditioned by the progressive decline in the operation of: (*i*) perceptive sensors (e.g., limited perception of light and colors, inability to tune out background noise) and (*ii*) motor-cognitive skills (e.g., reduced range of motion, loss of muscle strength and coordination, changes in posture, diminished attention and reaction time, spatial disorientation). All these bodily changes make elderly people walking slower than adults, and lead to a subjective perception of physical vulnerability and a sense of fragility at the psychological level. According to these considerations, the paper presents a set of walkability assessment criteria specifically focused on the needs of elderly:

- *Usefulness*: urban areas should be designed to guarantee the presence of numerous and diverse public services for the elderly within a walkable distance from their place of residence (e.g., land-use mix; street connectivity; transport services; social and health care service; commercial activities).
- *Comfort*: urban areas should be designed to accommodate the comfort of the elderly while walking (e.g., pavement type; continuity on side-walks; installation of ramps for people with reduced mobility; urban furniture for resting; green areas with trees, benches, tables and fountains).
- *Safety*: urban areas should be designed to guarantee the safety of elderly pedestrians while walking and crossing (e.g., absence of barriers and pothole on side-walks; speed bumpers; traffic lights; illumination systems in proximity of the zebra crossing; legible horizontal and vertical signage).
- *Attractiveness*: urban areas should be designed to have a polycentric structure, with several and distinctive areas of attraction for the elderly inhabitants (e.g., points of interest, amenities, public spaces and events; quality of the architectural streetscape; vitality of the social context).
- *Legibility*: urban areas should be designed to be legible, memorable and navigable, in order to enable the elderly to easily locate themselves and navigate through the city (e.g., roads toponomy; legible road signs; place-based maps for indicating public services).

The assessment of the level of walkability of an urban area for the elderly should comprise the evaluation of different typologies of data: (*i*) *structured data* (e.g., topographical, cadastral, infrastructural and architectural elements of the urban area; census indicators of the socio-demographical characteristics of the inhabitants); (*ii*) *behavioral data* (e.g., analysis of the impact of the spatial features of the area on the actual behaviors of the elderly inhabitants while walking and crossing); (*iii*) *subjective data* (e.g., analysis of the elderly inhabitants' subjective evaluation about the level of walkability of the area).

A wide range of methods have been developed to empirically measure the level of pedestrian friendliness of urban environments, within a multi-disciplinary approach (e.g. urban studies, architecture, urban sociology, environmental psychology, computer science). We propose below a brief description of each method, towards their application for measuring the level of walkability of an urban area for the elderly pedestrians:

- *Geographic Information Systems* (e.g., [3, 22, 27]) can be applied for analyzing structured geo-referred data about the topographical, infrastructural and architectural elements of a urban area and the census indicators of the socio-demographical characteristics of the inhabitants.
- *Field observations* (e.g., [10, 19, 8]) can be applied for annotating the behavior of the elderly while walking and crossing through a determined urban area, to produce a behavioral map by means of manual coding or video tracking analysis.
- *Audit tools* (e.g., [5, 6, 16]) can be applied as self-report scales or questionnaires for collecting qualitative and quantitative data about the elderly subjective perception of the level of pedestrian friendliness of urban areas.

Table 1. The open data analyzed for the assessment of the ERD-Elderly Residential Density, LUE-Level of Usefulness for the Elderly, LCE-Level of Comfort for the Elderly and LSE-Level of Safety for the Elderly of the City of Milan.

Criteria	Indicators	Data	Source	Geo-referenced
ERD	ER	Number of elderly residents per NLI	Geo-portal (2015)	x
		NLI area	Geo-portal (2015)	x
LUE	TS	Subway stations	Geo-portal (2018)	x
		Bus and tram stops	Geo-portal (2018)	x
		Railway stations	Geo-portal (2018)	x
		Bike sharing stations	Geo-portal (2018)	x
	SS	Social and health care services	Geo-portal (2018)	-
		Day time senior centers	City of Milan (2017)	-
		AUSER senior centers	City of Milan (2018)	-
		Multi-functional senior centers	City of Milan (2018)	-
		Social, cultural, recreational centers	City of Milan (2017)	-
		Cultural associations	City of Milan (2018)	-
		Public library	Geo-portal (2018)	-
		Sport facilities	Geo-portal (2018)	-
	CS	Commercial activities	Geo-portal (2018)	-
		Open-air local markets	Geo-portal (2018)	-
		Pharmacies	Geo-portal (2018)	x
		Post offices	City of Milan (2018)	-
LCE	PFA	Only pedestrian areas	Geo-portal (2018)	x
		30 Km/h speed limit areas	Geo-portal (2018)	x
		Limited traffic areas	Geo-portal (2018)	x
		Congestion charge area	Geo-portal (2018)	x
	PCA	Sidewalks and squares	Geo-portal (2018)	x
	UGA	Green areas	Geo-portal (2018)	x
		Woods	Geo-portal (2018)	x
		Plantations	Geo-portal (2018)	x
LSE	PA	Fatal pedestrian accidents	ISTAT (2016)	-
		Non-fatal pedestrian accidents	ISTAT (2016)	-

- *Web applications* (e.g., [7, 22]) can be applied for asking the elderly to rate the level of walkability of an urban area by means of mobile applications. Actually, *RateMyStreet*[3], *Walk Score*[4] and *Walkanomics*[5] are the most popular web applications for walkability assessment.
- *Social media data* (e.g., [18, 17, 2]) can be applied for achieving a bottom-up characterization of the level of walkability of urban areas, directly based on the geo-referred contents generated by the elderly users on social media.
- *Computer-based simulations* (e.g., [15, 28, 9]) can be applied for providing optimized architectural solutions for managing urban areas, thanks to the possibility to simulate elderly pedestrian dynamics and to test alternative conditions and courses of action.

2 Methodology

The proposed GIS analysis was based on a series of structured open data of the City of Milan, focused on: (*i*) the residential density of the elderly inhabitants; (*ii*) the level of usefulness (accessibility to transport, social and commercial

[3] Retrieved from: `https://goo.gl/dXC4TL`
[4] Retrieved from: `https://goo.gl/QzEBNu`
[5] Retrieved from: `https://goo.gl/Wj2Amy`

services within a walkable distance); (*iii*) the level of comfort (accessibility of pedestrian-friendly areas and urban green areas within a walkable distance); (*iv*) level of safety (possibility for the elderly to do not be exposed to pedestrian-car accidents). We did not analyzed the level of attractiveness and legibility of the city, due to the difficulty to collect geo-referenced data about these criteria.

The analysis was performed by means of the software ESRI ArcMap 10.5 and series of open data (see Tab. 1) retrieved from: Geo-portal of the City of Milan[6]; website of the City of Milan[7]; ISTAT-Italian National Institute of Statistics[8]. Part of the data were not geo-referred with latitude-longitude coordinates, so they have been coded by using the tool Geoplaner[9].

The total area of the City of Milan (about 182 km^2) is divided in No. 9 Municipalities, which have the prerogative to decentralize the government of the city. According to the local Territorial Administration Plan[10] (2016), Municipalities are subdivided in No. 88 Neighborhoods or NLI-Nuclei of Local Identity: a system of areas connected by means of mobility infrastructures and services, and characterized by urban vitality, distinctive features, historical heritage, but also by ongoing renovation projects. Thus, NLI have been considered as the most appropriate spatial units for the proposed GIS analysis, in terms of historical peculiarity, granularity, average area (about 2 Km^2).

The retrieved open data were used to design a series of multi-layers maps the City of Milan, considering the territorial boundaries of the above described NLI. This was aimed at estimating the spatial distribution of each data set among the NLI. Then, we defined a novel EWI-Elderly Walkability Index through the weighted summation of the considered indicators (see Tab. 1), to identify the NLI characterized by the highest residential density of elderly inhabitants and by the poorest levels of usefulness, comfort and safety for the elderly.

3 Results

3.1 Elderly Residential Density

To estimate the residential density of the elderly population of the City of Milan, we analyzed a series of geo-referenced data set focused on the demographic characteristics of the inhabitants (e.g., age, gender, NLI of residence) among its No. 88 NLI. Data were retrieved from the Geo-portal of the City of Milan, on the basis of the national census executed in 2015 by ISTAT (see Tab. 1).

Data analysis shows that in 2015 the number of citizens with an age equal or more than 65 years old (about 324,300 people) was equal to the 24% of the total population of the City of Milan (about 1,351,500) (see Fig. 1/a). Then, we calculated the ratio between the number of elderly residents among the NLI (i.e.

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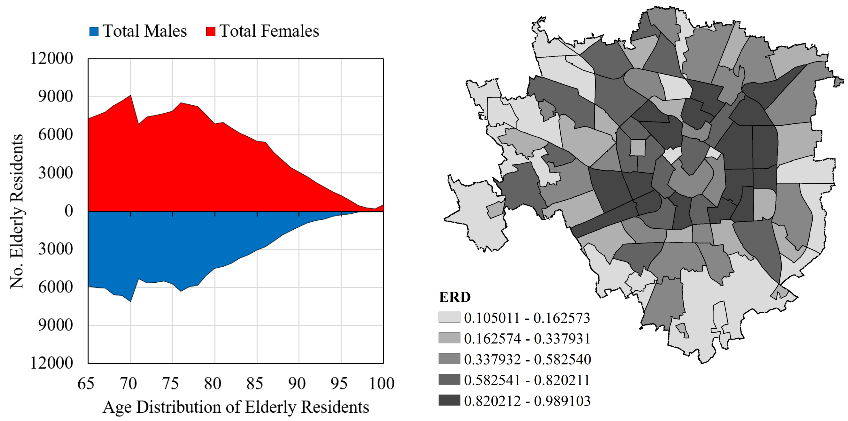


(a) Elderly population (b) ERD

Fig. 1. (a) The demographic characteristics of the elderly citizens of the City of Milan in 2015, considering population size, age distribution and gender. (b) The ERD-Elderly Residential Density of the No. 88 NLI of the City of Milan (quintile frequency distribution of standardized values).

ER-Elderly Residents) and the area of each NLI (Km^2). Results were normalized (z values in a range between 0 and 1) in order to more easily compare data among the NLI. The map presented in Figure 1/b highlights in dark shade the NLI characterized by the highest ERD value ($z \geq 0.820212$, quintile frequency distribution of standardized values), which corresponds to more than No. 4530 elderly residents per Km^2.

3.2 Level of Usefulness for the Elderly

To estimate the LUE-Level of Usefulness for the Elderly of the City of Milan, data analysis was based on the localization of those services specifically tailored to accommodate the needs of the elderly, and on the calculation of their spatial distribution among the NLI. The objective was to estimate the possibility for the elderly residents of each NLI to reach various public services within a walkable distance from their place of residence. Data were retrieved from the Geo-portal of the City of Milan and from the website of the City of Milan (see Tab. 1).

We firstly focused on the localization of TS-Transport Services, which guarantee the autonomous mobility of the elderly through the city by using public transports. This comprehends the localization of: subway stations; bus and tram stops; railway stations (which serve as local transport service within the City of Milan); bike-sharing stations.

Then, we localized those SS-Social Services specifically tailored to guarantee the social inclusion of the elderly within their NLI of residence, focusing on: social and health care services for the elderly; day time senior centers; multi-functional aggregation senior centers; social, cultural and recreational senior centers; cultural associations; public library and sport facilities.

Eventually, we localized those CS-Commercial Services which allow the elderly to access goods and products within a walkable distance from their place of residence, focusing on: medium and high sized commercial activities (shops of more than 250 m^2); open-air local markets; pharmacies; post offices.

The analysis was based on calculation of the density distribution of TS, SS and CS among the NLI (see Fig. 5 in Appendix), considering the area of each NLI (Km^2). The estimation of the LUE-Level of Usefulness for the Elderly was based on the ratio between the summation of TS per Km^2, SS per Km^2 and CS per Km^2 present in each NLI, and the number of ER-Elderly Residents per Km^2 of each NIL. The summation has been weighted by means of constant parameters to accentuate the impact of the density distribution of SS on LUE, compared to TS and CS (see Eq. 1):

$$LUE_{NLI} = \frac{K_{TS} \cdot |TS_{NLI}| + K_{SS} \cdot |SS_{NLI}| + K_{CS} \cdot |CS_{NLI}|}{|ER_{NLI}|} \tag{1}$$

Results were normalized (z values in a range between 0 and 1) to more easily compare data among the NLI. The map presented in Figure 2/a shows the NLI characterized the lowest LUE-Level of Usefulness for the Elderly ($z \leq 0.237956$, quintile frequency distribution), which corresponds to the poorest density distribution of TS (in average No. 22 TS per Km^2), SS (in average No. 7 SS per Km^2) and CS (in average No. 3 CS per Km^2), considering also the number of elderly residents of the NLI (in average No. 1971 ER per Km^2).

3.3 Level of Comfort for the Elderly

To estimate the LCE-Level of Comfort for the Elderly of the City of Milan, data analysis was based on the localization of those facilities specifically designed to accommodate the needs of the elderly while walking through the city, and on the calculation of their spatial distribution among the NLI. The objective was to estimate the possibility for the elderly to benefit from pedestrian-friendly road infrastructures within a walkable distance from their place of residence. Data were retrieved from the Geo-Portal of the City of Milan and from the website of the City of Milan (see Tab. 1).

We focused on the localization of: (*i*) PFA-Pedestrian Friendly Areas (Km^2), comprising pedestrian areas restricted to vehicular traffic, urban areas with vehicle speed limit to 30 km/h, limited traffic areas to vehicular traffic and congestion charge areas; (*ii*) PCA-Pedestrian Circulation Areas (Km^2), comprising sidewalks and squares; (*iii*) UGA-Urban Green Areas (Km^2), comprising parks, public garden, private courtyards, woods, and plantations areas.

The analysis was based on the calculation of density distribution of PFA, PCA and UGA among the NLI (see Fig. 6 in Appendix), considering the area of each NLI (Km^2). The estimation of the LCE-Level of Comfort for the Elderly was based on the ratio between the summation of the PFA per Km^2, PCA per Km^2 and UGA per Km^2 present in each NLI, and the number of ER-Elderly Residents per Km^2 of each NLI. The summation has been weighted to accentuate the impact of the density distribution of PFA on the overall LCE, compared to PCA and UGA (see Eq. 2):

$$LCE_{NLI} = \frac{K_{PFA} \cdot |PFA_{NLI}| + K_{PCA} \cdot |PCA_{NLI}| + K_{UGA} \cdot |UGA_{NLI}|}{|ER_{NLI}|} \quad (2)$$

Results were normalized (z values in a range between 0 and 1) to more easily compare data among the NLI. The map presented in Figure 2/b shows the NLI characterized the lowest LUE-Level of Comfort for the Elderly ($z \leq 0.364242$, quintile frequency distribution), which corresponds to the poorest density distribution of PFA (in average 0.017 Km^2 of PFA per Km^2), PCA (in average 0.069 Km^2 of PFA per Km^2) and UGA (in average 0.271 Km^2 of PFA per Km^2), considering also the number of elderly residents of the NLI (in average No. 4264 ER per Km^2).

3.4 Level of Safety for the Elderly

To estimate the LSE-Level of Safety for the Elderly, data analysis was based on the localization of the pedestrian-car accidents occurred in the City of Milan, and on the calculation of their spatial distribution among the NLI. The objective was to estimate the possibility for the elderly to benefit from safe road infrastructures within their place of residence. Data were retrieved from the ISTAT-Italian National Institute of Statics in 2016, on the basis of the data gathered by local authorities during that year (see Tab. 1).

As highlighted by the WHO [26], pedestrians are some of the most vulnerable road users, with a percentage of fatalities corresponding to 22% of the total victims due to road accidents (1.2 million people). Although the data presented in 2015 by the Italian Minister of Infrastructures and Transport[11] showed a significant reduction of the phenomenon at a national level (-45% of fatal pedestrian accidents in the period 2001-2015), the number of pedestrian-car accidents occurred in the City of Milan in 2016 is still alarming: No. 16 fatal accidents and No. 1346 non-fatal accidents. Moreover, the 25% of the total number of road accidents occurred in the City of Milan in 2016 involved elderly pedestrians (No. 11 fatal accidents and No. 336 non-fatal accidents with elderly pedestrians).

We focused on the localization of PA-Pedestrian Accidents, comprising fatal and non-fatal pedestrian-car accidents. The analysis was based on the calculation of density distribution of PA among the NLI (see Fig. 7 in Appendix), considering the area of each NLI (Km^2). The estimation of the LSE-Level of Safety for the Elderly was based on the ratio between PA per Km^2 and the number of ER-Elderly Residents per Km^2 of each NLI (see Eq. 2):

[11] Retrieved from: `https://goo.gl/VdCg9f`

$$LSE_{NLI} = 1 - \frac{|PA_{NLI}|}{|ER_{NLI}|} \quad (3)$$

Results were normalized (z values in a range between 0 and 1) to more easily compare data among the NLI. The map presented in Figure 2/c shows the NLI characterized the lowest LSE-Level of Safety for the Elderly ($z \leq 0.267516$, quintile frequency distribution), which corresponds to the highest density distribution of PA (in average No. 15 PA per Km^2), considering also the number of elderly residents of the NLI (in average No. 2198 ER per Km^2).

3.5 Elderly Walkability Index

The last analysis was aimed at identifying the NLI of the City of Milan characterized by the highest residential density of elderly inhabitants and the poorest levels of usefulness, comfort and safety for the elderly pedestrians. To estimate the EWI-Elderly Walkability Index, data analysis was based on the summation of the achieved results about LUE, LCE and LSE. The summation has been weighted to accentuate the impact of the density distribution of LSE on the overall EWI, compared to LUE and LCE (see Eq. 2):

$$EWI_{NLI} = K_{LUE} \cdot |LUE_{NLI}| + K_{LCE} \cdot |LCE_{NLI}| + K_{LSE} \cdot |LSE_{NLI}| \quad (4)$$

Results were normalized (z values in a range between 0 and 1) to more easily compare data among the NLI. The map presented in Figure 2/d shows the NLI characterized the lowest EWI-Elderly Walkability Index ($z \leq 0.182536$, quintile frequency distribution). Average results about NLI quintile frequency distribution among ERD, LUE, LCE, LSE and EWI are presented in Figure 3.

4 Conclusions and Future Works

In the context of global progressive urbanization and ageing of the population, the LONGEVICITY project studies the cities of the future as characterized by the growing presence of long-lived and active citizens and by the need to design technologically advanced services and infrastructures to enhance sustainable mobility strategies. The project is be carried out by an international consortium (University of Milano-Bicocca, Politecnico di Milano, The University of Tokyo, AUSER Volontariato Lombardia) and is based on a strongly cross-disciplinary approach, integrating skills, methodologies and tools ranging from Social Sciences, Design of Services, Artificial Intelligence and Complex Systems Science.

In particular, the LONGEVICITY project aims at supporting the social inclusion and active aging of the population in urban settings by enhancing their pedestrian mobility through walkability. To this end, the project is based on

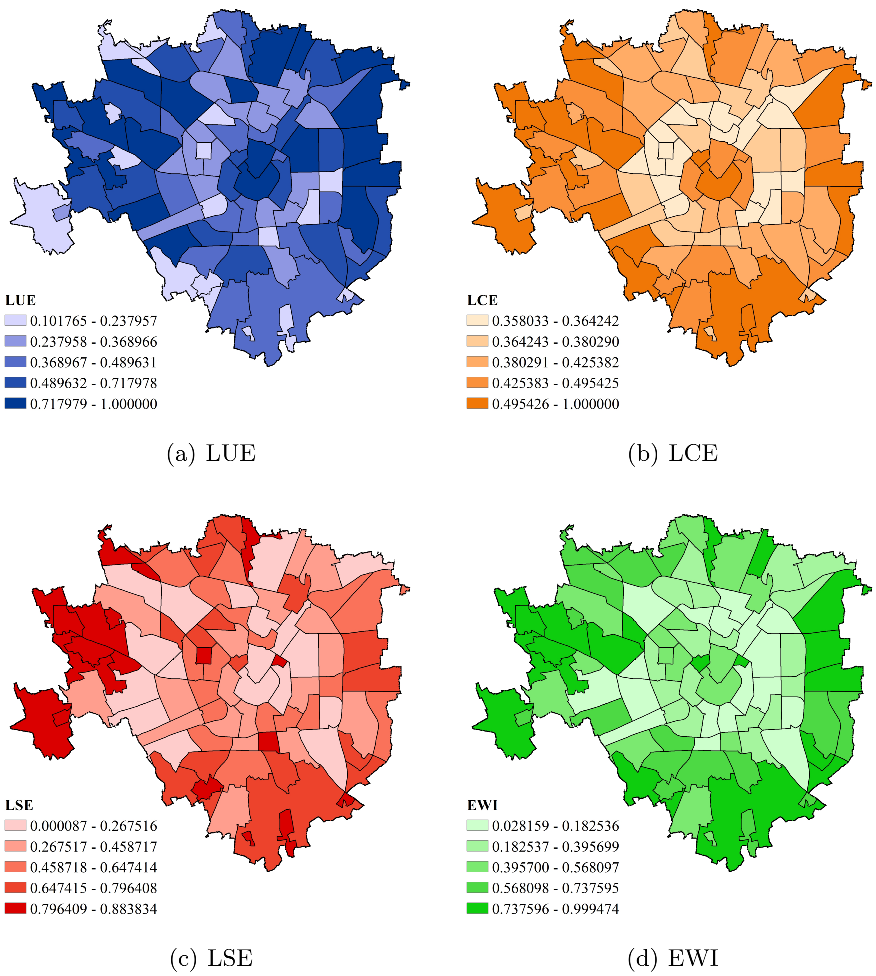
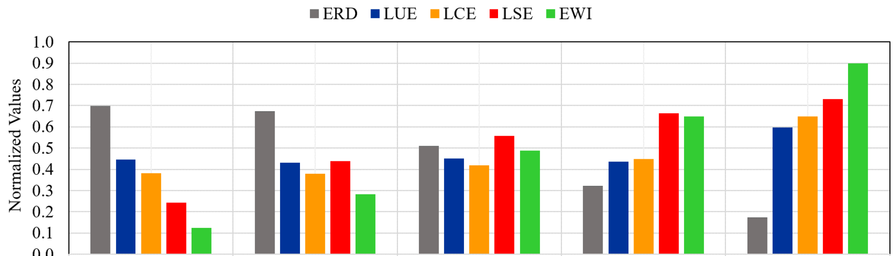


Fig. 2. The maps show the results of the GIS analysis, focusing on: (a) LUE-Level of Usefulness for the Elderly, (b) LCE-Level of Comfort for the Elderly, (c) LSE-Level of Safety for the Elderly and (d) EWI-Elderly Walkability Index of the No. 88 NLI of the City of Milan (quintile frequency distribution of standardized values).

methodological and computational tools aimed at assessing the level of pedestrian friendliness of urban areas, and at achieving advanced solutions focused on the needs and perceptions of senior citizens with respect to infrastructures and mobility services in the City of Milan (Italy).

In this context, the current work was aimed at presenting a systematic review of the contributions present in the literature about the criteria, data and methods for the assessment of the level of walkability of urban environments, focusing of the specific needs of the elderly pedestrians. Then, the paper proposed the



	Lowest Quintile	Second Quintile	Third Quintile	Fourth Quintile	Highest Quintile
ERD	0.699091	0.674078	0.511677	0.322348	0.174559
LUE	0.446440	0.430420	0.450992	0.436476	0.596731
LCE	0.381231	0.379847	0.417826	0.449741	0.649832
LSE	0.242206	0.438000	0.557014	0.663949	0.730345
EWI	0.124787	0.282069	0.489130	0.648167	0.899926

Fig. 3. Average results of NLI quintile frequency distribution of standardized values about: ERD-Edlerly Residential Density; LUE-Level of Usefulness for the Elderly; LCE-Level of Comfort for the Elderly; LSE-Level of Safety for the Elderly; EWI-Elderly Walkability Index.

definition of a novel EWI-Elderly Walkability Index, based on the the application of GIS-Geographic Information Systems for the analysis of a series of structured and geo-referenced data on the City of Milan.

Results are focused on the residential density of the elderly inhabitants and on the level of pedestrian friendliness of the city in terms of usefulness, comfort and safety for the elderly pedestrians. The objective of the research was to identify the Neighborhoods or NLI of the City of Milan characterized by the poorest level of walkability and by the highest presence of elderly residents.

In line with the research plan of the project, the presented multi-layer map of the City of Milan represents a preliminary step aiming at identifying the NLI where to execute a series of outdoor and indoor activities participated by a large sample of elderly inhabitants of the area (e.g., walking groups, participatory design activities). On the basis of the achieved results, we identified the Neighborhood "Padova" (see Fig. 4) as one of the most critical area of the City of Milan in terms of usefulness, comfort and safety for the elderly pedestrians (about No. 5189 ER per Km^2; EWI = 0.318198). The identified NLI will be object of further investigations through audit tools, questionnaires, field observations, mobile applications, controlled experiments and computer-based simulations.

Future works will be focused on the integration between GIS and AI-based techniques [21] for the analysis and clustering of geo-referenced data about urban pedestrian mobility. In particular, one of the ongoing work is focused on the development of a mobile application to collect geo-referenced information about the walking behavior of the elderly citizens participating the project.

This is aimed at executing a bottom-up assessment of the level of walkability of the City of Milan (Italy) by means of three main functionalities of the application: (*i*) tracking tool, to collect quantitative data about the daily walking

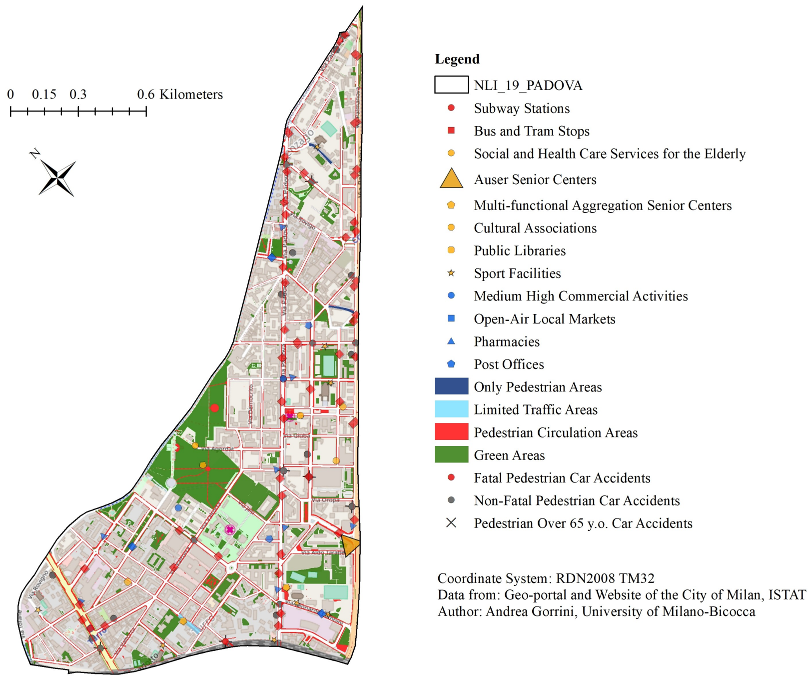


Fig. 4. The localization of TS-Transport Services, SS-Social Services, CS-Commercial Services, PFA-Pedestrian Friendly Areas, PCA-Pedestrian Circulation Areas, UGA-Urban Green Areas and PA-Pedestrian accidents within the territorial boundaries of the NLI "Padova" of the City of Milan.

behaviors of participants (e.g., trajectories, speed, walking pace); (*ii*) audit tool, to collect the subjective evaluations of the elderly about the level of walkability of a specific area; (*iii*) spatial transcript tool, to design augmented maps of urban areas, by integrating geo-referenced and multimedia annotations of the elderly users. The above described results will be exploited to support the development of advanced AI-based simulation models [9], aiming at incorporating both vehicular and pedestrian dynamics for the evaluation of alternative layouts and traffic management solutions considering age-driven pedestrian mobility.

According to the SUMP-Sustainable Urban Mobility Plan of the City of Milan[12] (2017), the presented results could be of notable interest for those public institutions involved in the design of sustainable mobility strategies. The results achieved through the proposed EWI are able, in fact, to highlight the NLI of the city which require to be more effectively managed in order to support pedestrian mobility, with particular reference to the needs of the elderly. This could motivate, for example, strategic investments to optimize the provision of transport

[12] Retrieved from: `https://goo.gl/ZPUdAC`

and social services among the NLI or to design age-friendly areas where people can enjoy walking and gathering in comfort. In conclusion, the presented results are potentially relevant to complement studies on outdoor ambient assisted environments, to evaluate future transportation scenarios in Smart Cities.

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Appendix

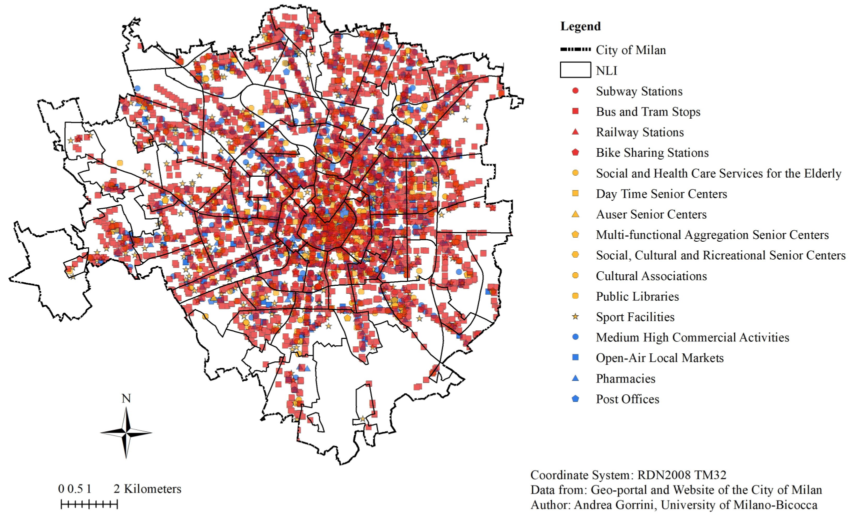

Fig. 5. The localization of TS-Transport Services, SS-Social Services and CS-Commercial Services among the NLI of the City of Milan.

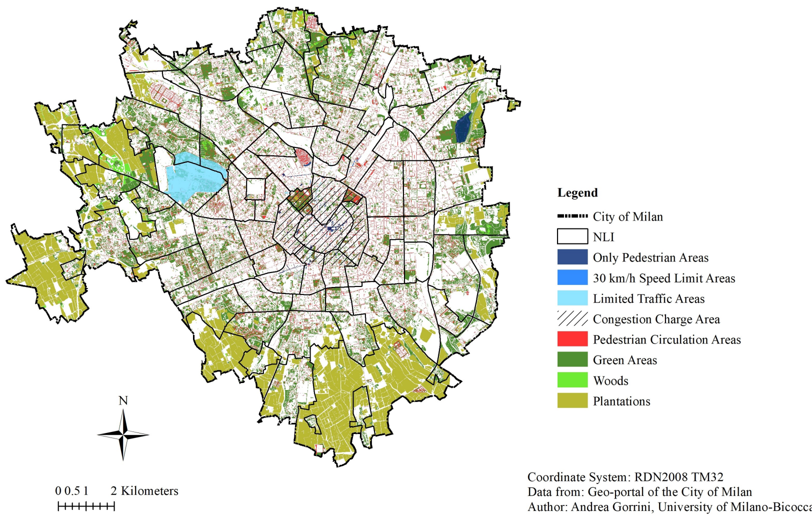

Fig. 6. The localization of PFA-Pedestrian Friendly Areas, PCA-Pedestrian Circulation Areas and UGA-Urban Green Areas among the NLI of the City of Milan.

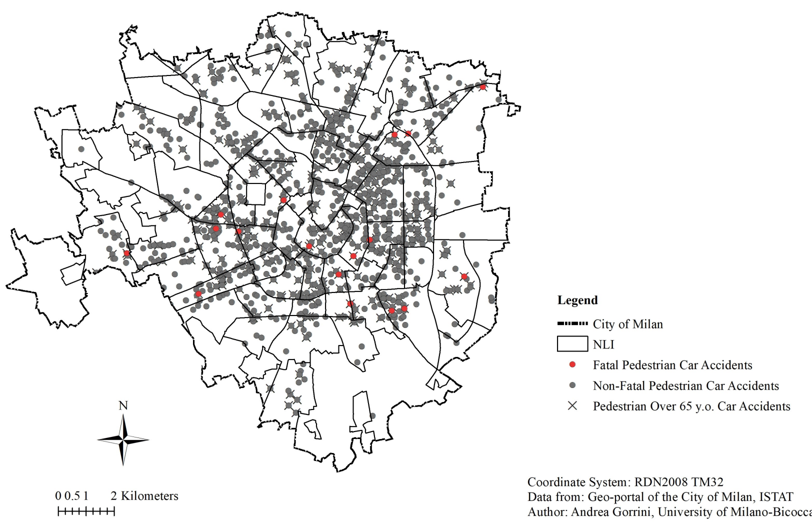

Fig. 7. The localization of PA-Pedestrian accidents and of the car-accidents involving elderly pedestrian among the NLI of the City of Milan.