Sustainable walkability in inner areas of Italy: a research proposal on AI-based simulation for older adults

Frida Milella[1,*], Eleonora Clarizia[1], Alessio De Pellegrin[1] and Stefania Bandini[1]

[1]Department of Informatics, Systems and Communication (DISCo), University of Milano-Bicocca, viale Sarca 336, Milano, 20126, Italy

Abstract

This paper aims at discussing the ongoing research activities that are being conducted on the use of AI-based solutions to promote walkability indexes in the Italian inner areas. Although social sustainability is an expected outcome of the walkability concept, the literature has focused on urban social sustainability and the development of socially sustainable urban communities, while attention to pedestrian-friendly rural areas is lacking. The paper examines existing research on the subject and emphasises the potential of agent-based simulation to create indicators that promote service accessibility and inclusion, specifically in terms of sustainable walkability in rural areas with a high density of older people.

Keywords

social sustainability, sustainable walkability, inner areas, artificial intelligence, agent-based simulation

1. Introduction

The significance of walking and the concept of walkability are becoming increasingly important in urban planning, partly as a result of the increasing public demand and the goal of sustainable urban development [1]. The concepts of walkability and walking are strongly interconnected with the notions of the livability of local communities, as well as sustainability and its three fundamental dimensions: economic, social, and environmental [1]. Owing to a long-standing focus on tackling environmental issues, the field of sustainability has placed considerable emphasis on the convergence of environmental and economic factors [2]. In contrast, the social aspects of sustainability are frequently acknowledged but receive limited analysis [2, 3], often being perceived as the least strong and least clearly defined element [2].

Social sustainability is concerned with promoting development that encourages social engagement, social inclusion, and cultural enrichment [3], and walkability is an essential component in the pursuit of social sustainability [4]. The concept of a walkable neighbourhood is indeed frequently discussed in literature as a key element in promoting urban social sustainability and the development of socially sustainable urban communities [5, 6] (e.g., [7, 8, 9, 10, 11]).

The importance of social sustainability is becoming increasingly important in an ageing population [12]. Improving pedestrian mobility is essential for promoting active ageing and enhancing the quality of life of older adults by facilitating social engagement and independence [13], as well as fostering a sense of community and reducing social isolation among older population [14, 15]. Furthermore, the incorporation of high-quality mobility conditions and accessibility in urban public spaces is essential in ageing, in order to ensure convenient access to services and promote conducive environments for social interaction [16, 17, 13]. In particular, it is imperative to guarantee that older people have easy accessibility to healthcare services [18, 19], as to effectively improving and safeguarding their general state of health and well-being [19]. Currently, the issue of accessibility to healthcare is being studied from a user-centered approach and is being integrated with a personal mobility aspect [20]. Indeed, recently, there has been a rise in the number of studies examining the quality of public spaces and their impact on the capacity of older adults to walk and access services and activities [13], acknowledging accessibility as a contributing component in urban social sustainability [5]. Nevertheless, the accessibility to services is contingent upon the geographical aspect [21], with rural communities need to face challenges in terms of accessibility to services as a result of their frequent disconnection from main centres of infrastructure [22, 21]. The existing body of research on walkability is predominantly concerned with urban and metropolitan areas [23, 24, 25] making it less applicable to rural, small urban, or semi-urban communities which do not have access to pedestrian spaces of the same nature as major cities [26, 25]. The geographical characteristics and sizes of rural areas differ from those of urban areas, which makes it difficult to measure the walkability of rural areas using the neighborhood-level geography typically used in research [25]. This implies that research on

Ital-IA 2024: 4th National Conference on Artificial Intelligence, organized by CINI, May 29-30, 2024, Naples, Italy

*Corresponding author

frida.milella@unimib.it (F. Milella); e.clarizia@campus.unimib.it (E. Clarizia); a.depellegrin@campus.unimib.it (A. D. Pellegrin); stefania.bandini@unimib.it (S. Bandini)

0000-0002-0522-2804 (F. Milella); 0000-XXXX-XXXX-XXXX (E. Clarizia); 0000-XXXX-XXXX-XXXX (A. D. Pellegrin); 0000-0002-7056-0543 (S. Bandini)

the influence of walkability on socially sustainable communities should take into account the local conditions of accessibility, i.e. broaden the focus to include rural communities as well.

Furthermore, a recent systematic review of the literature [27] on the role of AI-powered and sensor-based technologies in assisting informal carers (often volunteers or relatives) who provide care for older adults, revealed a lack in the reviewed literature concerning the application of location-based technologies for older adults residing in remote regions, suggesting to focus on exploring the integration of emerging technologies, such as AI and Geographic Information System (GIS) [28], to improve healthcare for informal carers and older adults in rural regions. Similarly, a second systematic review by the authors [29] determined that employing innovative strategies to create outdoor spaces that cater to the needs of adults in need of care, while also providing additional support to their informal carers, has the potential to provide significant assistance to these carers.

This article aims to discuss the ongoing research on the use of AI-based technologies to enhance a sustainable walkability in inner areas of Italy. This research is a component of the ongoing project called "Care provision across different territorial contexts"[1]. Its objective is to address the current lack of walkability indexes for inner areas by investigating the potential of AI-based technologies and promoting the achievement of a sustainable walkability in inner areas within an ageing society.

2. Walkability and Inner Areas

The term rural is commonly understood to refer to areas with a small population, few settlements, and remoteness [30]. However, there is no consensus among academics on whether all of these characteristics need to be present together in order to define a settlement as rural, or if it is enough for just one of these elements to be present [30]. A significant portion of the Italian territory is organised spatially according to "minor centres", which are commonly of small size and frequently provide residents with limited access to essential services [31]. The characteristics of this territory can be summarised using the term "inner areas" [31] which overlap with the identification of rural regions that face a notable deficiency in the provision of essential services [32, 33]. However, inner areas exhibit three primary attributes [34]: sociodemographic fragility caused by an ageing population, physical and ecological instability resulting from insufficient handling of semi-natural resources, and underutilization of a significant amount of land resources in numerous localities.

Walkability metrics gauge the level of pedestrian-friendly in a neighborhood's built environment, and walkability evaluation is employed to evaluate this friendliness [35]. Several walkability indices have been created to objectively assess the features of the built environment that promote walking habits [36]. These indices range from ones that concentrate on urban form factors at the neighbourhood level (such as population density, land use diversity, and street connectivity) to those that focus on urban design factors at the street level (such as the size and layout of streets, the design and condition of buildings, and street furniture) [36]. However, walkability in rural communities presents a unique challenge as its theoretical and practical basis has not been thoroughly examined in this specific context [25]. This presents a substantial opportunity for the Italian territory, as inner areas comprise over 4,000 municipalities and over 20 percent of the country's resident population, or approximately 60 percent of the national territory [37]. On the other hand, there is a clear need for more research focused on rural older adults and their connection to the community, as the current evidence is insufficient [38, 39]. The high occurrence of residential proximity, with family members living together and multigenerational households, has created a strong intergenerational exchange and family support system for older adults requiring care in rural areas [33]. This makes these areas highly promising for the development of new walkability indices aimed at creating socially sustainable communities. Our research activity is indeed being focused on studying how AI-based solution can aid in developing sustainable walkability indexes in Italian inner areas.

3. AI-based solutions to improve walkability in Italian inner areas: the intended value of using agent-based simulations

Scholarly literature provides several examples of using Artificial Intelligence (AI) techniques to assess walkability. For instance, scholars employed machine learning (ML) techniques to evaluate the state of sidewalks, as a substantial predictor of a pedestrian-friendly neighbourhood, through the analysis of pedestrians' physiological responses as gathered by wearable accelerometers [35]. Several studies have examined the integration of deep learning (DL) with environmental sensors to evaluate the walkability of urban streets [40], have explored the utilisation of Streetview Image and semantic segmenta-

[1]This publication was produced with the co-funding of European Union – Next Generation EU, in the context of the National Recovery and Resilience Plan, PE8 Conseguenze e sfide dell'invecchiamento", Project Age-It (AGE - IT - A Novel Public-private Alliance to Generate Socioeconomic, Biomedical and Technological Solutions for an Inclusive Italian Ageing Society- Ageing Well in an Ageing Society) - AGE-IT- PE00000015 – CUP: H43C22000840006

tion to create a walkability evaluation index [41] or have estimated walkability measures at a street level [42]. Furthermore, a few studies have suggested a network-based measure of walkability that incorporates road network structure and user opinions using machine learning techniques with the aim to get predictive models that yield comprehensive walkability scores at a spatial level [43]. Other studies have suggested novel methods for utilising pre-trained models to create adaptable models that can predict walkability scores for cities that were not included in the original training process [44].

The scientific publications on walkability studies have significantly expanded over the past twenty years [45]. However, our current study is revealing that scholarly research on the use of AI algorithms to evaluate walkability in rural areas, and especially in the Italian inner areas, is under-investigated. Nonetheless, AI has significant potential for evaluating the pedestrian-friendliness of inner areas. Geographical information, socio-economic data, and pedestrian behavioural patterns can be utilised through the application of ML algorithms to provide walkability scores that are specifically customised for the distinct attributes of inner areas and ageing population. Some existing studies in urban context have highlighted the need of using Geographical Information Systems (GIS) to define an index that measures the walkability of older people and supports the creation of advanced simulation models based on AI [46]. In a similar vein, another study assessed the emotional experience of pedestrians, specifically focusing on older adults, proposing an "affective walkability" indicator [47]. The aim was to investigate how safe, comfortable, and walkable an environment was, within the context of promoting social and active inclusion of older adults in urban areas. Based on this, our research activity is being focused on studying villages in Italian inner areas, including Premeno (VB) and Petrella Tifernina (CB), with a high aged population density. Our goal is to understand the factors that affect walkability in inner areas and its accessibility, and how the integration of AI techniques can promote social inclusion and equity of access to healthcare services, ie a sustainable walkability in these areas. Indeed, one potential benefit of integrating AI-based tools, such as remote sensing or GIS technologies, is the provision of comprehensive mapping and geographical analysis. This information can be utilised to guide targeted measures that improve the walkability of inner areas by revealing crucial details regarding pedestrian access, connectivity, and safety. In addition, according to a recent systematic review of the literature [48] the combination of wearable sensors and GIS-based approach shows potential as a method for accurately capturing older people's immediate physical reactions to environmental stressors. This could lead to the integration of simulation-based models into Digital Twins environments with GIS-based analysis, maybe allowing for a deeper understanding of older adults personal mobility also in inner areas. In this regard, Liu et al [49] recently examined the benefits of employing agent-based models (ABM) as a quantitative tool for assessing walkability due to their inclusion of subjective aspects, integration of many parameters, and capacity to distinguish between various populations. Similarly, Bandini et al [50] conducted a study with the purpose to evaluate the walkability of the city of Milan by simulating the age-driven pedestrian dynamics, which involve various behaviours such as different speeds and crossing behaviour. Badland et al. [51], instead, devised an agent-based modelling tool that integrated the advantages of Service Area Approach mapping to examine the correlation between amenity access and neighbourhood walkability while also enabling the testing of various planning scenarios. Therefore, given that agent-based simulation models simulate the actions and interactions of individual agents from various demographic groups in a specific environment, the incorporation of AI techniques may have the potential to accurately depict the pedestrians' mobility patterns or the barriers for their personal mobility at each age categories, contributing to attain our goal to define a sustainable walkability concept in Italian inner areas for older population.

4. Conclusions

Although social sustainability is an expected outcome of the walkability concept, the literature has focused on urban social sustainability and the development of socially sustainable urban communities, while attention to pedestrian-friendly rural areas is lacking. Moreover, there exists a dearth of scholarly publications both in walkability metrics targeted to rural communities and in the use of AI-based techniques to promote pedestrian friendliness in rural areas. The article reviews some of the currently available contributions on the topic and highlights the potential of agent-based simulation to develop indicators that facilitate service accessibility and inclusivity, i.e., sustainable walkability in rural areas with a significant older population density. Further research will be carried out using multiple case studies to derive a generalised research methodology for the specific context of Italian inner areas.

References

[1] A. Baobeid, M. Koç, S. G. Al-Ghamdi, Walkability and its relationships with health, sustainability, and livability: elements of physical environment and evaluation frameworks, Frontiers in Built Environment 7 (2021) 721218.

[2] S. H. Rogers, K. H. Gardner, C. H. Carlson, Social capital and walkability as social aspects of sustainability, Sustainability 5 (2013) 3473–3483.
[3] S. Bahadure, R. Kotharkar, Social sustainability and mixed land use, in: Proceedings of International Conference on Advances in Architecture and Civil Engineering (AARCV 2012), volume 21, 2012, p. 725.
[4] Y. Gul, The effectiveness of walkability index for social sustainability in developing countries using geographical information system, Journal of Design Sciences and Applied Arts 2 (2021) 141–154.
[5] N. Dempsey, G. Bramley, S. Power, C. Brown, The social dimension of sustainable development: Defining urban social sustainability, Sustainable development 19 (2011) 289–300.
[6] W. Sabir Abdullah, Optimizing social sustainability in walkable university campus: A comparison between the old and new campuses of sulaimani university, Amazonia Investiga 9 (2020) 44–56.
[7] K. M. Leyden, Social capital and the built environment: the importance of walkable neighborhoods, American journal of public health 93 (2003) 1546–1551.
[8] P. Morales-Flores, C. Marmolejo-Duarte, Can we build walkable environments to support social capital? towards a spatial understanding of social capital; a scoping review, Sustainability 13 (2021) 13259.
[9] S. Rogers, S. Aytur, K. Gardner, C. Carlson, Measuring community sustainability: Exploring the intersection of the built environment & social capital with a participatory case study, Journal of Environmental Studies and Sciences 2 (2012) 143–153.
[10] A. N. Mohamed, A. A. E. Elmokadem, S. M. Ali, N. Badawey, Improve urban form to achieve high social sustainability in a residential neighborhood salam new city as a case study, Buildings 12 (2022) 1935.
[11] A. Sonta, X. Jiang, Rethinking walkability: Exploring the relationship between urban form and neighborhood social cohesion, Sustainable Cities and Society 99 (2023) 104903.
[12] K. Komp-Leukkunen, J. Sarasma, Social sustainability in aging populations: A systematic literature review, The Gerontologist (2023) gnad097.
[13] F. Alves, S. Cruz, A. Ribeiro, A. Bastos Silva, J. Martins, I. Cunha, Walkability index for elderly health: A proposal, Sustainability 12 (2020) 7360.
[14] N. Shellito, N. V. Roldan, Walking away from loneliness: The mediating role of social isolation, Innovation in Aging 3 (2019) S836.
[15] T. Sugiyama, E. Leslie, B. Giles-Corti, N. Owen, Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships?, Journal of Epidemiology & Community Health 62 (2008) e9–e9.
[16] S. Cinderby, H. Cambridge, K. Attuyer, M. Bevan, K. Croucher, R. Gilroy, D. Swallow, Co-designing urban living solutions to improve older people's mobility and well-being, Journal of urban health 95 (2018) 409–422.
[17] B. Aguiar, R. Macário, The need for an elderly centred mobility policy, Transportation research procedia 25 (2017) 4355–4369.
[18] R. Bayar, M. Yılmaz, Measuring age-friendliness based on the walkability indices of older people to urban facilities, Urban Design International 28 (2023) 35–51.
[19] L. Cheng, M. Yang, J. De Vos, F. Witlox, Examining geographical accessibility to multi-tier hospital care services for the elderly: A focus on spatial equity, Journal of Transport & Health 19 (2020) 100926.
[20] J.-F. Levesque, M. F. Harris, G. Russell, Patient-centred access to health care: conceptualising access at the interface of health systems and populations, International journal for equity in health 12 (2013) 1–9.
[21] H. Wang, P. C. Coyte, W. Shi, X. Zong, R. Zhong, Social governance and sustainable development in elderly services: Innovative models, strategies, and stakeholder perspectives, Sustainability 15 (2023) 15414.
[22] C. Tacoli, The links between urban and rural development, 2003.
[23] R. C. Brownson, C. M. Hoehner, K. Day, A. Forsyth, J. F. Sallis, Measuring the built environment for physical activity: state of the science, American journal of preventive medicine 36 (2009) S99–S123.
[24] S. S. Frost, R. T. Goins, R. H. Hunter, S. P. Hooker, L. L. Bryant, J. Kruger, D. Pluto, Effects of the built environment on physical activity of adults living in rural settings, American journal of health promotion 24 (2010) 267–283.
[25] C. I. Nykiforuk, K. Coupland, L. M. Nieuwendyk, J. Ann McGetrick, Universal design for the rural walks of life: operationalizing walkability in bonnyville, alberta, canada, Critical Public Health 28 (2018) 213–224.
[26] L. G. Hart, E. H. Larson, D. M. Lishner, Rural definitions for health policy and research, American journal of public health 95 (2005) 1149–1155.
[27] F. Milella, D. D. Russo, S. Bandini, How artificial intelligence can support informal caregivers in their caring duties to elderly? a systematic review of the literature, in: AIxIA 2023 Italian Workshop on Artificial Intelligence for an Ageing Society, co-located with the 22nd International Conference of the Italian Association for Artificial Intelligence (AIxIA 2023), 2023, pp. 6–9.
[28] B. Mullachery, S. Alismail, A smart healthcare

framework: Opportunities for integrating emerging technologies (5g, iot, ai, and gis), in: Proceedings of the Future Technologies Conference, Springer, 2022, pp. 325–340.
[29] F. Milella, D. D. Russo, S. Bandini, Ai-powered solutions to support informal caregivers in their decision-making: A systematic review of the literature 1, OBM Geriatrics 7 (2023) 1–11.
[30] N. Morelli, S. Barello, M. Mayan, G. Graffigna, Supporting family caregiver engagement in the care of old persons living in hard to reach communities: A scoping review, Health & social care in the community 27 (2019) 1363–1374.
[31] UVAL, Strategia Nazionale per le aree interne: definizione, obiettivi, strumenti e governance, https://www.agenziacoesione.gov.it/wp-content/uploads/2020/07/MUVAL_31_Aree_interne.pdf, 2014.
[32] P. Bertolini, F. Pagliacci, Quality of life and territorial imbalances. a focus on italian inner and rural areas., Bio-Based & Applied Economics 6 (2017).
[33] M. Arlotti, Older people and care networks in rural areas: An exploratory study in italy, Sociologia Ruralis (2024).
[34] G. Basile, A. Cavallo, Rural identity, authenticity, and sustainability in italian inner areas, Sustainability 12 (2020) 1272.
[35] H. R. Ng, I. Sossa, Y. Nam, J.-H. Youn, Machine learning approach for automated detection of irregular walking surfaces for walkability assessment with wearable sensor, Sensors 23 (2022) 193.
[36] B. W. Koo, S. Guhathakurta, N. Botchwey, How are neighborhood and street-level walkability factors associated with walking behaviors? a big data approach using street view images, Environment and Behavior 54 (2022) 211–241.
[37] G. Dematteis, Montagna e aree interne nelle politiche di coesione territoriale italiane ed europee, Montagna e aree interne nelle politiche di coesione territoriale italiane ed europee (2013) 7–15.
[38] P. R. Baker, D. P. Francis, J. Soares, A. L. Weightman, C. Foster, Community wide interventions for increasing physical activity, Cochrane database of systematic reviews (2015).
[39] A. Klann, L. Vu, M. Ewing, M. Fenton, R. Pojednic, Translating urban walkability initiatives for older adults in rural and under-resourced communities, International journal of environmental research and public health 16 (2019) 3041.
[40] Y. Li, N. Yabuki, T. Fukuda, J. Zhang, A big data evaluation of urban street walkability using deep learning and environmental sensors (????).
[41] J. of the Korean Cartographic Association, et al., Development of walkability evaluation index using streetview image and semantic segmentation, Journal of the Korean Cartographic Association 22 (2022) 53–68.
[42] M. M. Hasan, V. Kwigizile, J.-S. Oh, Automated measurement of walkability applying artificial intelligence (ai) and spatial analysis techniques, Journal of Transport & Health 22 (2021) 10.
[43] A. M. S. Alfosool, Y. Chen, D. Fuller, Alf–score—a novel approach to build a predictive network–based walkability scoring system, Plos one 17 (2022) e0270098.
[44] A. M. Alfosool, Y. Chen, D. Fuller, Alf-score++, a novel approach to transfer knowledge and predict network-based walkability scores across cities, Scientific Reports 12 (2022).
[45] X. Li, D. Xie, Z. Zhou, X. Zhang, R. Li, J. Li, Z. Chen, J. Zhang, Visualization analysis of research progress for walkability, Scientific Reports 14 (2024) 1989.
[46] A. Gorrini, S. Bandini, Elderly walkability index through gis: Towards advanced ai-based simulation models., in: AI* AAL@ AI* IA, 2018, pp. 67–82.
[47] S. Bandini, F. Gasparini, Social and active inclusion of the elderly in the city through affective walkability, The Review of Socionetwork Strategies 15 (2021) 557–573.
[48] F. Milella, M. Oltolini, S. Bandini, Can wearable technologies contribute to an age-friendly walkability environment? First insights from a systematic review of the literature. In Conferenza PErvasive Technologies Related to Assistive Environments (PETRA) (PETRA '24), 26- 28 giugno 2024, Creta , Grecia. ACM, New York, NY, USA, 7 pages. https://doi.org/10.1145/3652037.3652046, 2024. In press.
[49] Y. Liu, D. Song, Z. Wang, X. Yu, R. Wang, Walkability assessment using agent-based model: Why it becomes an advantageous way, in: World Congress of Architects, Springer, 2023, pp. 367–374.
[50] S. Bandini, L. Crociani, A. Gorrini, K. Nishinari, G. Vizzari, et al., Walkability assessment for the elderly through simulations: The longevicity project., in: AI* AAL@ AI* IA, 2018, pp. 83–91.
[51] H. Badland, M. White, G. MacAulay, S. Eagleson, S. Mavoa, C. Pettit, B. Giles-Corti, Using agent-based modelling to inform neighbourhood walkability, Spatial Data Access and Integration to support liveability (2013) 23.