Smart Cities and Older-Adults Mobility

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Smart cities have a set of characteristics: smart governance, smart economy, smart environment, smart people, smart living, and smart mobility. This entry aimed to identify: (i) the relevant applications based on information technologies and requiring smart cities' infrastructure to facilitate the mobility of older adults in URBAN SPACES; (ii) the type of data being used by the proposed applications; (iii) the maturity level of these applications; and (iv) the barriers TO their dissemination.

smart city older adults mobility

1. Introduction

Population ageing is taking place worldwide. In most countries, people live longer and, overall, in better health conditions than before. Coping with such a demographic shift has become a major issue for public policies and has gained attention from international institutions [1][2].

Currently, the ideal political paradigm considered for the care of older adults is that they should continue living in the community rather than being forced to move to residential care units because of their cognitive and physical limitations. Though not recent, it is within this context that the concepts such as ageing in place [3] or active ageing [4][5] have been developed. According to these concepts, the maintenance of patterns of activities and values typical of middle age can optimize opportunities for social participation, health conditions, and the safety of the individuals as they age [5][6][7][8]. This depends not only on the characteristics of the individuals but also on environmental factors [9], such as, for instance, urban infrastructures and services.

The Ageing in Cities Report from the Organisation of Economic Cooperation and Development (OECD) states that "designing policies that address ageing issues requires a deep understanding of local circumstances, including communities' economic assets, history and culture. (…) Cities need to pay more attention to local circumstances to understand ageing, and its impact. They are especially well-equipped to address the issue, given their long experience of working with local communities and profound understanding of local problems" [10] p. 18.

The World Health Organization (WHO) age-friendly cities and communities' approach [11] is in line with this concern. Following the idea that an age-friendly city is as a place where older adults are actively involved, valued, and supported with infrastructure and services that accommodate their needs, the WHO produced a guide identifying the key characteristics of an age-friendly environment in terms of service provision (e.g., healthcare services or transportation), built environment (e.g., housing, outdoor spaces, or buildings), and social aspects (e.g.,

civic, or social participation) [12]. Based on the experience, the WHO provides guidance [13] to ensure that research and initiatives held at country and regional levels on topics relevant to healthy ageing can be widely shared.

Although ageing societies pose diverse challenges, they also provide a large set of opportunities that society can benefit from [10]. Such opportunities include new developments in technology and innovation. In fact, due to technological advances in the last couple of decades, the use of smart technologies is increasingly considered an important means to promote active ageing [1][14]. Therefore, many researchers aimed to develop new services based on Information Technologies (IT), such as Ambient Assisted Living (AAL) [15][16][17], to enable older adults to achieve their full potential in terms of physical, social, and mental wellbeing.

Additionally, due to the technological developments, during the last few years the smart city paradigm has been the object of great attention from different sectors: scientific journals publish specific issues on this topic, local governments fight to label their city as such, firms advertise smart cities' solutions, and international and national programs aim to promote adequate implementations [18]. In this respect, several initiatives of the European Commission, namely the Digital Agenda (one of the seven pillars of the Europe 2020 Strategy) and the Smart Cities and Communities initiative, aimed at bringing together cities, industry, and citizens through more sustainable integrated solutions [19].

1.1. Smart Cities and Smart Mobility

A set of characteristics has been identified as relevant in the context of smart cities [20][21]: smart governance, smart economy, smart environment, smart people, smart living, and smart mobility.

Smart mobility includes local, national, and international accessibility, and the availability of communication infrastructure or sustainable and safe transport systems and is aligned with the United Nations (UN) Sustainable Development Goals [22][23]. Smart mobility is often seen as related to the use of IT to adequately orchestrate services designed to improve urban mobility [24]. In this respect, a wide range of information services can be foreseen, such as intelligent transportation systems [25][26][27][28] or algorithms to infer mobility patterns [29][30]. These information services might contribute to the reduction of air and noise pollution, traffic congestion, and travel costs, while increasing individuals' safety [24][31][32].

Moreover, smart mobility might facilitate older adults' activities and participation, in line with the goals of active ageing and age-friendly cities and communities' approaches [13]. In its baseline report for the decade of healthy ageing, the WHO states that "engagement of older people and municipalities can steer the use of digital technology to support enabling environments—and reduce the digital divide between older and younger people" [1] p. 67, pointing out Chicago as a good example of a city in which the labels of Age-Friendly and Smart City have been brought together.

1.2. An Overview of Related Reviews

Several articles published in scientific journals [33][34][35][36][37][38][39][40][41][42][43][44][45][46][47][48][49][50][51][52][53][54][55][56][57][58][59][60][61][62][63][64][65] reported different types of reviews, including systematic literature reviews, related to various aspects of smart cities' implementation, including data analytics [33][34][35][36][37], systems architectures [38], data security [39][40][41], data security and Internet of Things (IoT) [42][43][44], IoT [45], ontologies [46], healthcare [47][48][49], energy efficiency [50], citizenship [51], smart city indicators [52], mobility [53][54][55][56][57][58] and age-friendly initiatives [59][60][61][62][63][64][65].

Looking specifically for reviews related to mobility or age-friendly initiatives (**Table 1**), is possible to conclude that the state-of-art studies did not aim to analyze relevant IT-based applications requiring smart cities' infrastructures to facilitate the mobility of older adults.

Table 1. State-of-the-art reviews related to smart city mobility and age-friendly initiatives.

Topic	Reference	Title	Year
Mobility	[53]	*Emerging big data sources for public transport planning: a systematic review on current state of art and future research directions.*	2019
	[54]	*Smart parking: a literature review from the technological perspective.*	2019
	[55]	*The quality of smart mobility: a systematic review.*	2020
	[56]	*A systematic review of urban navigation systems for visually impaired people.*	2021
	[57]	*Enabling technologies for urban smart mobility: recent trends, opportunities and challenges.*	2021
	[58]	*Barriers and risks of Mobility-as-a-Service (MaaS) adoption in cities: a systematic review of the literature.*	2021
Age-friendly initiatives	[59]	*Implementation of age-friendly initiatives in smart cities: probing the barriers through a systematic review.*	2020

Topic	Reference	Title	Year
	[60]	*Smart and age-friendly cities in Romania: an overview of public policy and practice.*	2020
	[61]	*Smart and age-friendly cities in Russia: an exploratory study of attitudes, perceptions, quality of life and health information needs.*	2020
	[62]	*Smart and age-friendly communities in Poland: an analysis of institutional and individual conditions for a new concept of smart development of ageing communities.*	2020
	[63]	*Quality of life framework for personalised ageing: a systematic review of ICT solutions.*	2020
	[64]	*The role of mobility digital ecosystems for age-friendly urban public transport: a narrative literature review.*	2020
	[65]	*Use of [60][61][62] technologies to assess barriers and stressors for age and disability-friendly communities.*	2021

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2. Current Insights in Smart Cities and Mobility of Older Adults

Looking for the first research question (i.e., the relevant smart city applications to facilitate the mobility of older adults), seven application domains emerged from this work: (i) requirements and development platforms (three articles); (ii) accessibility (two articles); (iii) localization (three articles); (iv) mobility assistance (five articles); (v) health conditions monitoring (four articles); (vi) promotion of healthy lifestyles (eight articles); and (vii) data analytics (three articles).

These results are in line with current concerns related to the improvement of environmental factors [9], including urban infrastructure and services, to facilitate active ageing [10][11] and the promotion of the wellbeing of older adults [66], and show that smart cities, if well-equipped to address the needs of their older adults, might facilitate their mobility [10][11].

In terms of the type of data being used by the proposed applications (i.e., the second research question), the different articles reported the use of data acquired from the smart city infrastructure, such as air quality, weather conditions, or light conditions and open data available in the smart city databases, namely static data (e.g., city accessibility, transport infrastructures and touristic points of interest), and real-time data about public transport. On the other hand, sensors deployed in the older adults' smartphones and wearables were used to acquire continuous monitoring data to determine localization, movement, speed, points of interest, or utilization of public transport, as well as to monitor physiological parameters. Moreover, one fourth of the articles reported the implementation of crowdsensing mechanisms.

Using sensors to constantly monitor individuals has the potential to put them at risk. Therefore, secure data transmission and the guarantee that the stored data would only be accessed by individuals who are authorized are important requirements [39][40][41]. If these requirements are not satisfied, data such as the location of an individual at a given time might be used for nefarious purposes (e.g., to know when and for how long the individuals are out of their homes). Despite the importance of data privacy, integrity, and confidentiality, just one of the included articles described mechanisms to guarantee data protection. This can be considered a major barrier for the dissemination of the applications being developed and future work must pay special attention to privacy and security issues when using emerging sensor technologies.

Considering the need to use huge amounts of data from different sources, interoperability and data quality, standardization and aggregation are key aspects [46]. However, these aspects are almost absent in the studies reported by the included articles, which also negatively impacts the dissemination of the applications.

Concerning the maturity level of the applications being reported (i.e., the third research question), most of the included articles generally tended to describe technological solutions, which were still far from consolidated solutions.

Twenty-seven articles proposed concepts for further development, defined architectures, or presented prototypes that were developed to demonstrate the feasibility of the concepts. Four articles reported the participation of older adults in the evaluation of the prototypes, although the experimental setups had limitations in terms of the measured outcomes, and the number of participants. Only one article reported the assessment of the proposed application in a real-life scenario. It is worth emphasizing the importance of going beyond technological determinism and, accordingly, to consider the impact on the target users.

This low maturity level is an important drawback when comparing the included studies with similar research using different approaches. For instance, in terms of the monitoring of health conditions and the promotion of healthy lifestyles, the scientific literature reports relevant research studies based on robust methods and involving a significant number of participants to assess the impact of mobile health applications (e.g., [67][68]).

Therefore, concerning the fourth research question (i.e., what are the barriers for the dissemination of the solutions that were identified?), it is possible to conclude that the lack of assessment in real-life scenarios, together with a

set of unsolved aspects related to the data being used (i.e., data privacy, integrity, and confidentiality, data interoperability, data aggregation, and data quality) constitute major barriers for the dissemination of smart cities' applications to facilitate the mobility of older adults.

3. Conclusions

The study reported by this work aimed to review smart city applications to facilitate the mobility of older adults. Relevant application domains were identified, including requirements and development platforms, accessibility, localization, mobility assistance, health conditions monitoring, promotion of healthy lifestyles, and data analytics.

The results show that there is an ongoing effort to take advantage of the smart cities' paradigm to make cities more age-friendly by facilitating the mobility of older adults, namely by using a diversity of sensing data provided by a broad range of sensors. However, issues such as user privacy, data standardization and integration, and sensors' characteristics were poorly addressed. The results also show that there is a lack of maturity of the developed applications, which constitutes a major barrier to their dissemination. Moreover, it is foreseen that the number of articles related to the topic will increase in the future, since the research effort increased over the years: the oldest articles that were included were published in 2013 and more than two-thirds of the included articles were published in the last four years.

According to the study protocol (e.g., search keywords and inclusion and exclusion criteria) this work only considered the research related to smart cities' applications specifically focused on facilitating the mobility of older adults. However, older adults constitute a heterogeneous population group with different needs, life experiences, expectations, and personal factors, which means that, when needed, there are older adults able to use applications developed for the general population. In this respect, one of the limitations of this study is related to the fact that there are other smart cities' applications and services developed for the general population that can be used by older adults to facilitate their mobility (e.g., pedestrian mobility [69], multi-modal routes' support [70], smart parking [54], traffic management [71], assistance to drivers [72][73], intelligent transport systems [25][72][73], or mobility as a service [38][58]). Moreover, it should be noted that this work did not consider other possible studies aiming to facilitate the mobility of older adults without being supported in smart city infrastructures, nor articles whose primary focus was not the use of IT (e.g., [74]). Additionally, the work did not consider articles published after March 2021.

Moreover, is always possible to point out limitations about both the chosen keywords and the databases that were used in the research. Likewise, since most articles were published in conference proceedings, there will certainly be similar articles that have not been included because they were presented in non-indexed conferences. It should also be noted that the grey literature was not considered in this work and that this can be seen as a gap of some significance.

Despite these limitations, in methodological terms, the authors tried to follow rigorous procedures for the articles' selection and data extraction, so that the results are relevant for identifying IT-based applications requiring smart cities' infrastructures to facilitate the mobility of older adults, which may contribute to future developments.

Based on the findings of this work, it is possible to conclude that most of the identified studies supported older adults' requirements, which means that there is a trend in the research of practical solutions. However, only one article reported an experimental set-up to assess the proposal solution in a real-life scenario. The remainder articles proposed concepts, architectures, and proof-of-concept prototypes. Four proof-of-concept prototypes were validated by older adults, but the respective experimental designs exhibit limitations.

The technological solutions should respond to user needs and not the other way around. As such, it is possible to conclude that the assessment of the smart cities' applications should be emphasized, as well as the use of robust methodological approaches. Robust evidence is required to show that new developments are valid, reliable, cost-effective, and able to make a difference. Collecting this evidence requires considerable resources to integrate new applications into real life conditions, to be used by many users for long periods of time [75].

Since this work identified a research trend to develop practical solutions and a considerable investment is being made to bring together smart city stakeholders, including industry, to create market-ready solutions [19], the low maturity level of the developments is a major gap on the current research related to IT-based applications requiring smart cities' infrastructures to facilitate the mobility of older adults.

Together with sustainable and environmentally friendly mobility, mobility-as-a-service, traffic management, namely using different data analytics techniques [33][34][35][36][37], and autonomous vehicles are important concerns in the current smart mobility research [57]. Surprisingly, these topics are almost absent in the set of the included studies. Moreover, other relevant topics of the smart cities' research, such as user privacy, data standardization and integration, IoT implementation, and sensors' characteristics, are poorly addressed by the included studies. Therefore, according to the results, another research gap emerged, which is related to the difficulty of incorporating into the specific topic of this work, the knowledge generated by the research related to other topics related to smart cities. Since smart cities are digital ecosystems resulting from a combination of business models and innovation to transform the cities' processes, structures, and strategies [38], researchers should consider these ecosystems to promote a comprehensive view and to take advantage of all relevant smart cities' developments.

After this work, it is possible to conclude that some attention should be given to the fact that the total number of included articles is not very representative within the total number of articles related to smart cities. Furthermore, most of the included articles were published in conference proceedings. Therefore, the implementation of smart cities is still not largely imbued within the active ageing domain, as can be seen in other topics (e.g., AAL [15][16][17]). Therefore, IT-based applications requiring smart cities' infrastructure to facilitate the mobility of older adults still represent a relevant research opportunity.

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