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Inclusive transformation of age-friendly communities based on digital technology support

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Abstract

The world's population is ageing. New measures and concepts of population ageing are significant for assessing the living conditions and living arrangements of the elderly, their contributions to society, and their needs for social protection and health care. In 2018 the World Health Organization (WHO) published a report subtitled "Looking back over the last decade, looking forward to the next", which explicitly mentions technology as a support for age-friendly environments. Although the WHO has discussed the involvement of technology and computers in terms of access to information etc., and uses technology as a "supplementary indicator" regarding "internet access," in 2019 Marston and van Hoof are critical of WHO's Age-Friendly Cities and Communities model, which lacks reference to and recognition of technological solutions in multiple domains. Increasingly, scholars are finding recognition of the importance of technology and digitalisation as the third pillar of age-friendly cities and communities, particularly in terms of use-friendly and sustainable design, acceptance of technology, and implementation and caregiver needs. The creation of genuine multisectoral action based on cooperation between the various disciplines make it possible to achieve a truly age-friendly society for present and future generations. In the context of active ageing and global digital trends, this study focuses on the analysis of two digital practices (digital twins and artificial intelligence) in the built environment of age-friendly communities, discusses inclusive transformation strategies for age-friendly communities, presents a proposed framework for inclusive digital age-friendly community transformation, illustrates future trends in age-friendly community design planning, and provides a reference point for future research.

Keywords

Inclusive transformation; Age-friendly community; Digital technology; Digital twins; Artificial intelligence

Introduction

According to data from *World Population Prospects: the 2019 Revision*, one in six people in the world will be over age 65 (16%) by 2050, up from one in eleven in 2019 (9%) (United Nations, 2019). Demographic change brings enormous challenges and pressures in areas such as social welfare, healthcare, public policy, and infrastructure (Davern et al., 2020; van Hoof et al., 2018). Urban ageing (van Hoof et al., 2018; van Hoof & Kazak, 2018) raises questions for communities in all areas of urban life. New measures and concepts for population ageing will have a profound impact on the quality and way of caring for older people and their potential contribution to social production.

According to the World Health Organization (WHO), *"An age-friendly city is an inclusive and accessible community environment that optimises opportunities for health, participation and security for all people, so that quality of life and dignity are ensured as people age (WHO, 2007b)"*. The concept of age-friendly cities and communities was introduced as a response to two global trends, *population ageing* and *urbanisation*, whereas the third global trend, *digitalisation*, has been overlooked (Reuter et al., 2020). Meanwhile, technology still does not appear in any of the eight domains of the WHO Age-Friendly Cities, despite the need to create smart age-friendly ecosystems that meet the needs of the various sectors that assist communities to work together (Marston et al., 2020). There is therefore an urgent need to develop a proposition that recognises the role and impact of digital technology in the inclusive transformation of ageing populations and age-friendly communities, and to apply it to a wider range of areas.

Age-Friendly Community (AFC)

The "age-friendly" community is where *"policies, services, environments and structures support and enable active ageing (WHO, 2007b)"*. In addition to accessing geriatric care and services within the local community, older people can live in a community they are familiar with and maintain a degree of independence and dignity (Zhang & Pan, 2021). Scholars agree that creating and maintaining age-friendly environments is a core component of a positive approach to the challenges of population ageing (Lui et al., 2009).

Social inclusion is linked to the health and well-being of older people, enabling the ability to maintain significant relationships with others, the ability to engage in meaningful community activities and the continuation of lifelong interests (Graham et al., 2014). International policies on ageing have begun to focus on promoting more socially inclusive societies (Keating & Scharf, 2012). In socially inclusive commu-

nities, people can participate in meaningful ways (Scharlach & Lehning, 2013). AFC characteristics can mitigate social disadvantage by providing more inclusive and supportive communities (Lui et al., 2009; Scharlach & Lehning, 2013) and enable physical and social environments that promote the social inclusion of older community members and provide opportunities and support in multiple domains (Scharlach & Lehning, 2013).

Figure 1. Age-Friendly City domains (WHO, 2007b, illustrated by authors).

Figure 2. Eight domains for age-friendly action (WHO, 2018a, illustrated by authors).

In 2006, WHO categorised the key characteristics of AFC into eight domains: outdoor spaces and buildings, transportation, housing, respect and social inclusion, civic participation and employment, social participation, community and health services, and communication and information, see figure 1. Over time and in response to changes in the social environment, the framework has expanded to emphasise three additional themes that transcend the domain of age-friendly environments—the physical and social environments, and municipal services (Ronzi et al., 2020), see figure 2, with different elements but overlapping and interrelated domains, demonstrating the multifaceted nature of caring for older people in a complex reality (Menec et al., 2014).

Measuring the Age - Friendliness of Cities and Communities

To assist cities in becoming more age-friendly, the WHO established *the Global Network of Age-friendly Cities and Communities (GNAFCC)* in 2010. The age-friendliness of a city is measured by a set of "core indicators" that are based on the characteristics of the eight domains of AFCs (WHO, 2007a). The indicators can be used to measure the city's age-friendliness baseline level and monitor how it changes over time as relevant interventions are implemented. They can also be leveraged to foster political and social commitment, which can lead to further actions to promote and sustain age-friendly cities (Davis & Kingsbury, 2011).

Figure 3. Core Indicators of Age-Friendly Cities (WHO, 2015, illustrated by authors).

The fundamental principles reflected in the core *indicators are equity, accessibility and inclusiveness* (WHO, 2015), see figure 3.

Supplementary indicators are *accessibility of priority vehicle parking, accessibility of housing, participation in leisure-time physical activity in a group, engagement in life-long learning, internet access, public safety, and emergency preparedness* (WHO, 2015).

The supplementary indicators listed were strong candidates for inclusion in the core indicator set but were not included for various reasons (see indicator selection criteria described by WHO, 2015). Where appropriate, these indicators should be considered for inclusion in a local context, along with the core indicators.

Digital Technology

In *The Global Network for Age-Friendly Cities and Communities: Looking back over the Last Decade, Looking Forward to the Next (2018b)*, the WHO states that age-friendly cities enable residents to age actively in their families, communities and civil society, provide a wide range of opportunities for older people to participate in their communities, and should make cities and communities more inclusive, while technology can act as a support for age-friendly environments. However, the WHO model of age-friendly cities and communities does not explicitly consider the involvement of technology (Marston & van Hoof, 2019). Over the years, technology has become one of the necessary conditions to support the rapid development and digitisation of society. The development of smart cities seeks to ensure that the needs of senior citizens are met and to promote solutions that suit their digital literacy, skills and perceptions (Podgórniak-Krzykacz et al., 2020). In recent years, digital technologies which support the inclusive transformation of AFCs came into view. While there are several digital technologies available for study, including Internet of Things (IoT), mobile applications, Augmented Reality, and Virtual Reality (VR), among others, Digital Twin (DT) and Artificial Intelligence (AI) were selected to be analysed in depth for the purpose of this paper, because of their potential in improving the quality of life for older adults through physical built environment transformations, personalised solutions and real-time feedback.

DT and AI are two examples of digital technologies that can be utilised to boost age-friendliness in urban areas and improve the livability and accessibility of the built environment for senior citizens. These technologies have shown promise in a number of fields, including healthcare, transportation, and smart home environments. For instance, Lin et al. (2022) created a smart healthcare system based on AI for ageing monitoring and fall detection, while Madubuike et al. (2022) explored the potential of DTs in healthcare facilities. Similar to this, Colnar et al. (2020) observed that age-friendly smart homes and AI have the potential to improve life quality.

Moreover, the quality of life for an increasing number of older persons with declining functional capacities could be improved through the use of intelligent, age-friendly surroundings with embedded ambient-assisted living technologies, which can be provided through DT and AI (Kavšek et al., 2021).

As with all digital technologies, the use of DT and AI presents a number of possible issues, challenges, dangers, and limitations. This includes concerns with acceptance and

adoption, cost and resource constraints, bias and discrimination, privacy and data security, and accessibility challenges. The processing of personal data may give rise to privacy problems, and some AI algorithms may exhibit bias against specific populations. Additionally, elderly users may show hesitation towards implementing such technologies, and older persons with disabilities may experience accessibility challenges, which could limit their effectiveness. It is also worth mentioning that the implementation of AI and DT systems requires significant investment in infrastructure, hardware, and software.

Considering the above, this paper proposes a general framework which can be used to address gaps in the existing framework, in order to support cities' initiatives to build more liveable and inclusive communities for residents of all ages.

Methods

This research utilises and builds upon secondary sources including published, peer-reviewed literature, journal articles and reliable sources of information as well as verified media sources and medical opinions regarding ageing populations. For the purpose of this article, the methods rely on data collection and narrative assessment of existing case studies, which are relevant to the fields of digital technologies and ageing. The case study selection is subject to a number of criteria as follows:

1. It concerns itself with ageing populations aged 65 and above.
2. It incorporates one or more uses of digital technologies (i.e. DT and AI models) which are relevant for this article.
3. It relates to and builds upon the pillars for age-friendly living environments.
4. It was conducted during the past 10 years and was documented in the English language.

Based on the aforementioned criteria, the selected case studies will be analysed in order to assess the impact of digital technologies on fostering age-friendly living environments, as well as the impact on the livelihood and wellbeing of individuals as a direct result of interacting with such technologies. Following the assessment, a framework of suggested recommendations for technological support of AFC will be extracted and synthesised, in order to lay a foundation for future research.

Case Studies

This section provides a brief explanation of the digital technologies relevant to this research, and supports the selection with a case study which portrays the impact of said technology on the livelihood of ageing populations.

Case 1 - Digital Twins (DT)

DT technology is one of the digital tools for the physical environment, which has the potential to transform the way we design and manage AFCs. It is a real-world representation of physical things (people, activities, situations, processes) (Grieves, 2014; El Saddik, 2018). Digital transformation has been enriched with the help of the IoT, which enables easy implementation of DT, which is used in many areas, including age-friendly support (De Maeyer & Markopoulos, 2020; Kobayashi et al., 2022; van Leeuwen et al., 2022). Below are a few examples of how DT can be used in the built environment and smart cities to support an AFC:

Smart Transportation: van Leeuwen et al. (2022) mentioned age-friendliness for older people with DT based on three workshops in Spain, Finland, and Belgium conducted by H2020 URBANAGE. They proposed the data for older people in their daily life. Some of these data can be used for public transport to estimate the walkability of the city for older people. So, it could help the policymakers to provide inclusive spaces for all. It is also possible to calculate the distress of elderly on their daily route using wearable devices (Ahn et. al, 2020).

Architecture and Design: De Maeyer & Markopoulos (2020) give insight into their study on a theoretical overview of ageing in place with DT which can have several categories according to intention and fed data such as layers of medical, lifestyle, home, or workplace. Data can be obtained from medical devices for the medical layer, wearables for the lifestyle layer or devices inside a house. Ambient Assisted Living (includes technical systems for elderly people for their special needs in their daily life, Dohr et al., 2010) can be used for older people's status and health monitoring, providing independent living, providing a secure and safe environment with the help of IoT (Dohr et al., 2010; Hsu et al., 2017; Risteska Stojkoska et al., 2017), providing engagement with their community remotely, giving a chance to explore several scenarios, and making simulations for predicting future situations. It is aimed to protect and demonstrate the autonomy of the elderly and their safety in the environment they live in (Dohr et al., 2010).

Intelligent Monitoring: Kobayashi et al. (2022) proposed a DT tool that mirrors the mental health and living spaces of older people. They provide a DT agent in roles regarding the support functions for mental health and society cooperation and monitoring indoor and outdoor spaces using distributed sensors. The DT agent is applied to the smartwatch to monitor the elderly. Their experimental study provides recognition of the early stage of cognitive and liver function disorders. DT abilities can also be used for historical records to prevent the future actions of the elderly.

Predictive Maintenance: With the help of smart sensors, DT can be used to predict the maintenance of built environment problems (Zhao et al., 2022). These problematic places that older people encounter in the built environment may be areas such as sidewalks and resting places (van Leeuwen et al., 2022).

According to the use cases mentioned above, one of the benefits of DT in AFCs is their ability to provide real-time data and analytics. Another aspect is facilitating collaboration and communication. Here, the designer's first task is to understand these DT before using them in design. The final section of DT includes the service layer for management, advice and decisions (Lu et al., 2020; Emir Isik & Achten, 2022). Within this, DT can facilitate dialogue and decision-making between designers and communities by providing a common platform for stakeholders to hold and analyse data. It can be especially vital in AFCs where the needs and preferences of older people are not represented in the traditional planning process, as in the digital planning process. DT systems can help assess the accessibility and usability of public spaces, transportation, and other infrastructures. It can also support monitoring the health and well-being of older people. By providing a real-time, comprehensive view of a community's infrastructure, servic-

es, and resources, it can be subsidiary to identify and chart the needs and monitoring faced by older adults. They can also help optimise systems and services, leading to more efficient and sustainable communities.

Case 2 - Artificial Intelligence Applications (AI)

The current rise of AI applications as well as their adaptability to a majority of fields and industries make this a widely discussed and timely topic. Through providing older persons with enhanced access to resources, support, and opportunities, AI applications can help them lead safe, comfortable and independent lives.

American Association of Retired Persons (AARP)'s "Ageing in Place: The Role of Technology" (2020) explores how technology, especially AI, can help older persons age in place and live independently. In "The Potential of AI to Enhance Quality of Life for Older Adults" (Gao et al., 2020), a review of the potential applications of AI to assist older adults and enhance their quality of life is provided. These applications include those related to healthcare, transportation, and home environments. "Ageing in the digital world: difficulties and opportunities" (European Union Agency for Fundamental Rights, 2019) examines the opportunities and challenges associated with using digital technology, such as AI, to assist older individuals' rights and autonomy.

There are various instances of how AI can be utilised in the built environment and smart cities to support ageing populations:

Smart Transportation: by utilising self-driving cars or on-demand ride-sharing services, AI can be used to enhance older folks' transportation alternatives (Abduljabbar et al., 2019). Even if they are no longer able to drive, these technologies can assist older persons in keeping their independence and access to the community.

Architecture and Design: by using assistive technology and smart home technologies, for example, AI can be utilised to construct age-friendly homes and cities (van Hoof et al., 2019). These innovations can make it safer and more comfortable for senior citizens to live in their homes while also giving caretakers information on the health and wellbeing of their loved ones.

Intelligent Monitoring: AI can be used to keep an eye on older people's security and safety in the built environment, for example, by using wearable tech or sensors that can spot situations like falls (Security World Market, 2021).

Predictive Maintenance: using sensors and machine learning algorithms, AI can be used to forecast and avoid maintenance problems in the built environment (Rampini & Cecconi, 2022). This can lower the costs and inconveniences related to maintenance while also ensuring that the built environment is safe and usable for older persons.

In conclusion, the application of AI to the built environment and smart cities can assist senior citizens in many ways, improved access to transportation, architecture that is age-friendly, intelligent monitoring, and predictive maintenance are few of which. It is necessary to take into account the potential of these technologies to support age-friendliness and improve the livability and accessibility of the built environment for older residents, while also considering their social integration and inclusion into their respective communities.

Ethical and Inclusive Integration of Digital Technologies

"Ageing in the Digital Era" (UNECE, 2021) outlines the potential of digital technologies to support healthy ageing and improve the quality of life for ageing populations, and emphasises that these technologies are used in an ethical and inclusive manner, which prompts a critical outlook on data privacy and ownership concerns.

For example, the ethical issues and privacy problems regarding the usage of DTs are covered by De Maeyer and Markopoulos (2020). Although DTs may increase productivity and cut costs, the authors contend that such models could be exploited to establish a surveillance state or for nefarious intentions like cyberattacks, which is one of its possible threats. The authors also point out that the usage of DTs to gather enormous amounts of data on people could result in privacy violations and other ethical dilemmas.

The authors provide a framework for ethical and privacy considerations in the usage of DTs in order to alleviate these concerns. Four primary concepts that make up this framework: accountability, justice, respect for privacy, and transparency, which should be incorporated into the design and deployment of DT and AI models from an early stage.

Moreover, Harper et al. (2021) studied user privacy concerns and preferences in smart buildings, focused on how users perceive and prioritise privacy concerns in the context of smart buildings through surveys and interviews with participants in the UK.

Participants in the research expressed concern about a variety of privacy issues, including the collection and use of personal data, surveillance, and the possibility of hacking and data breaches. The survey also discovered that participants had varying preferences for the collection and use of their data, with some preferring to have control over their data and others willing to give data for specific advantages, such as energy savings.

The authors advise designers and decision-makers to adopt an inclusive, user-centric strategy for privacy. Further research is recommended to examine how user privacy preferences and concerns can alter over time as smart building technologies, including DT and AI, continuously advance.

The proposed New AFC Framework

Based on existing research in the literature and the current state of technological development and application, we find that a new inclusive digital AFC is emerging. It is therefore essential to add digital technology to WHO's original AFC framework, which facilitates the residential experience and quality of life of senior citizens in city and community environments, and helps to promote an inclusive transformation of all-age community residential environments. This proposed new inclusive Digital Age-Friendly Community Transformation Framework (DAFCTF), see figure 4, is an extension of the WHO model with DT and AI digital practices, which proposes four aspects and levels of technology involvement in AFC transformation based on the perspective of policymakers, architects and user groups: problem identification, data analysis and testing, monitoring and prediction. As the effectiveness of the collection and application of technical data is more difficult to measure and has no uniform standards in the social environment area, the four aspects have a relatively high weighting in the physical environment and services,

which will provide greater improvements, while the social environment is yet to be further developed, with data Analysis and testing having the least weighting. These four aspects are described below:

Problem Identification: accessibility, transport, social isolation and healthcare are a few representative examples. A city might conduct a study of older people to learn about their social connections, mobility, access to healthcare, and general contentment with the neighbourhood. Meanwhile, examining information on ageing-related patterns and problems, such as the incidence of long-term illnesses or the accessibility of housing. Based on this data, the city may decide what issues need to be addressed first in order to make the community more age-friendly. For instance, in the social sphere, utilising natural language processing to examine the content of social media posts or survey responses from elderly citizens could be analysed to find recurring themes and areas of concern for ageing populations.

Data Analysis and Testing: AFC should establish a data platform and regularly assess its impact. It is vital to test new projects and technologies and gather data on how effective they are. It may be necessary to evaluate new technology or methods through experiments or pilot programs, and to use data analytics to assess how these activities affect age-friendliness in the neighbourhood. The responsible parties can modify the digital strategy as necessary based on the findings of these assessments. For example, a DT of a city centre might be used to test how different architectural modifications, such the inclusion of parklets or the rearranging of streets, affect the area's accessibility and suitability for senior citizens.

Monitoring and Evaluation: data platforms need to be monitored and evaluated on an ongoing basis to ensure the accuracy of implementation. For example, a DT and AI-powered system in a city centre may be used to track the usage of age-friendly infrastructure and gather information on how effective it is, such as accessible bus stops and sidewalks or building entrances.

Prediction and Evaluation: it includes an evaluation of the city and community's current digital technology situation and plans how it can be used to address the difficulties experienced by older residents. To promote age-friendly initiatives, this may involve using DT and AI in the built environment.

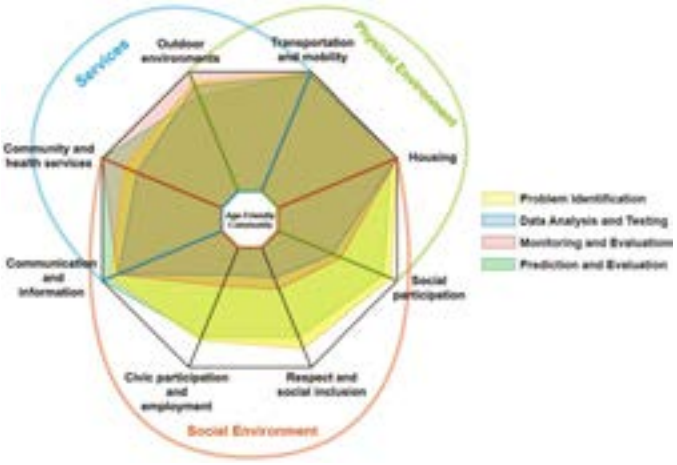

Figure 4. The proposed inclusive Digital Age-Friendly Community Transformation Framework (Source: authors).

For instance, the city may take into account using chatbots powered by AI to assist and enlighten senior citizens, or using DT to simulate and assess the effects of various design and policy changes on age-friendliness. To improve the accessibility and livability of the community for senior citizens, the city may also consider the use of other digital technologies, such as connected devices or VR. Although VR devices for example have been found to cause discomfort, disorientation, and even motion sickness in some users (Chang et al., 2020), studies have revealed that VR technology can be helpful for seniors, especially in the context of encouraging social engagement and minimising loneliness (Balki et al., 2022). Using VR to imitate social scenarios can help senior citizens connect with others in a secure setting.

When implementing various instances of emerging digital technologies in AFCs, it is crucial to employ a user-centred approach. This involves useability testing with senior citizens to make sure that the technology is accessible, pleasant, and does not lead to discomfort or disorientation (Doré et al., 2023).

Also, it's critical to give elderly users who might be less technologically-proficient the proper instruction and assistance. This may entail offering approachable user interfaces, detailed instructions, and human assistance as required, such avenues could be explored in further research.

As we propose this new DAFCTF, we acknowledge that it may not be suitable for all countries and regions' AFC, which means that the framework will need additional adaptation to meet different contexts and realistic foundations. However, what has to be acknowledged is the necessity of updating this framework. Future research should be complemented by the involvement of other disciplines and the inclusion of stakeholders in decision-making processes to validate the application and acceptance of the new model, as well as assessing the limitations of the suggested technologies and methods of implementation.

Conclusion

In line with the state of art on ageing, the WHO introduced a framework with definitions and iterative processes requiring periodic reviews and revisions. However, several aspects of the limitations of the framework stem from the fact that this is an evolving field of science and is not involved with digital technology yet. Some limitations point to specific topics that need further research and technological interventions. The rapid development and widespread use of digital technology offers the possibility of realising the vision of a truly more inclusive and age-friendly society for present and future generations.

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