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Digital Transformation of Care in Lifetime Neighbourhoods

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Abstract: If we want to achieve an effective digital transformation of neighborhoods, we need to understand the interaction between social determinants of health and emerging ambient technologies. Older adults suffer from frailty and the decline in physical and cognitive functional capacities and, therefore, experience decreased mobility, which can lead to difficulties with activities of daily living. Care settings located in smart buildings supported by Cyber-Physical Systems using the Internet of Things as an infrastructure with embedded Ambient Assisted Living Technologies, Wireless Sensors Networks, Big Data, and Machine Learning can support older adults to stay longer independent in their community and mitigate the risk of events leading to ill health and disability. The central gap found in the literature review is the lack of a common dataset for measurement of values of social determinants of health in various care settings. The paper presents the multistate competing risk model as framework for measurement of values of social determinants of health.

Keywords: digital transformation, social determinants of health, assistive technologies, social infrastructure, ageing, long-term care, smart city, community, facility management

1. INTRODUCTION

In September 2022 the European Commission has published European Care Strategy (European Commission, 2022a) to ensure quality, affordable and accessible care services across the European Union and improve the situation for both care receivers and the people caring for them. The commission staff working document highlights that those digital solutions implemented in long-term care and healthcare service, as well as digital assistance systems and care applications can reduce inequalities in access to care (European Commission, 2022b). The documents also states that rehabilitation and social inclusion of older people in community life are key success factors for active and healthy ageing. Remobilisation measures ensure that people with care needs can stay in their usual environment for as long as possible. For this to be achieved cities and communities should develop smart lifetime neighbourhoods. According to the World Health Organization (WHO, 2007), physical and social environments are key determinants of whether people can remain healthy, independent, and autonomous long into their old age. WHO defines social determinants of health (SDH) as non-medical factors that influence health outcomes. SDH are the conditions in which people are born, grow, work, live, and age, and the wider set of forces shaping the conditions of daily life. Forces and systems of SDH include economic policies and systems, development agendas, social norms, social policies and political systems that influence accessibility to the care settings which accommodate the functional capacities of older residents and therefore enable them to live longer in the community. Ambient Assisted Living Technologies (AALT) enabling real-time control of activities of older adults in their communities are expected to improve the control of decline in functional capacities of older adults and improve their quality of life. Ambient intelligence (AI) has the potential to enable older adults to live safer and therefore longer in their own homes or community social infrastructure. Control of ambient conditions such as temperature in homes of older adults can prevent thermal discomfort (Marchenko and Temeljotov Salaj, 2020; Marchenko et al., 2020) and therefore improve wellbeing of residents. AALT and AI have the potential to enable a growing number of frail older adults with a decline in physical and cognitive functional capacities and sarcopenia to live longer in their communities (Addante et al., 2019). Combination of technological innovations and social innovations in health care and social care provision present opportunity for the digital transformation of support networks for older adults living in the community. Digital transformation of long-term care can facilitate deinstitutionalization and radically transform how developed societies care for more senior members of society with declining cognitive and physical abilities. Digitally supported health care and social care services provided in smart age-friendly environments will be an essential part of how EU member states will maintain and improve the quality of life for older individuals (Gandarillas and Goswami, 2018) and reduce delays in a service provision (Grubbstrom et al., 2010; Bogataj and Bogataj, 2007; Bogataj and Usenik, 2005; Kovačić and Bogataj, 2017). Due to a decline in physical, cognitive and social capacities, older adults suffer decreased mobility and frailty, which can lead to social isolation. Living in a smart age-friendly environment with adapted, digitally connected smart homes in the age-friendly community (Augusto et al., 2014) facilitates safer living for older adults (Leone, Diraco

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and Siciliano, 2011) and influence postponing relocation to a nursing home. A decline in cognitive capacities, sensory functions and social isolation issues can lead to a low quality of life which can be mitigated by passive monitoring (Berridge, 2017) and AAL technologies (Blackman et al., 2016). Different types of sensors and wearable devices embedded in clothes of older residents facilitate activity recognition (Davis et al., 2016). AAL technologies enable monitoring of daily activities of older adults connected in wireless sensor network supported by Ambient Intelligence using internet of things (IoT) (Dlodlo, Gcaba and Smith, 2016) as infrastructure can detect (Del Campo et al., 2016) when individuals reach the disability threshold (the moment when living environments become dangerous to residents) and can advise when residents need to move to more accommodative living environment with a more suitable care settings. AAL technologies can facilitate longer tenure in the community by development of smart care settings and therefore facilitate provision of health care and long-term care services in the home of users, therefore becoming an essential part of the care infrastructure of smart cities (Doukas et al., 2011) and therefore mitigate risk of falls (Stevens and Lee, 2018).

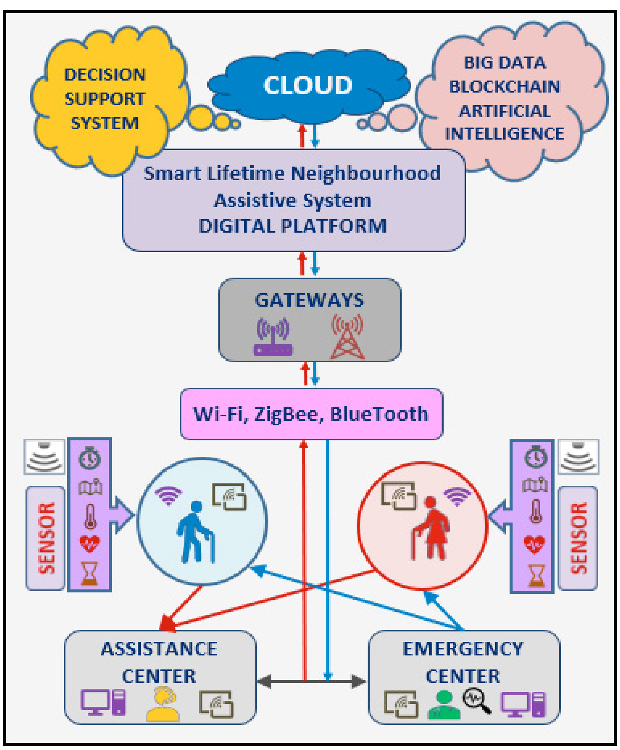

Figure 1: Monitoring of daily activities of older adults with Ambient Assisted living Technologies.

2. LITERATURE REVIEW

Ambient Assisted Living (AAL) are concepts, products and services that combine new technologies and the social environment to improve the quality of life at any age. Ambient Assisted Living technologies offer an ecosystem of different types of sensors, wireless networks, mobile devices, computers, and software applications for personal ambient and healthcare real-time control.

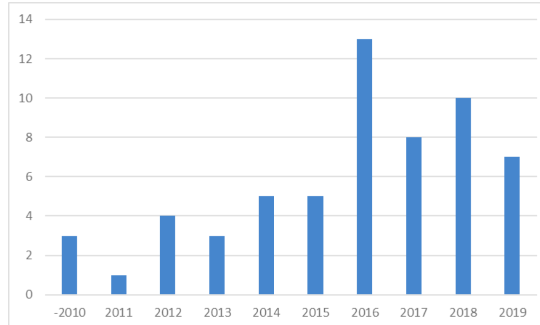

Figure 2: The dynamics of publications on topics Condition monitoring and Assistive Technologies in the journals indexed by WoS

TABLE I. ARTICLES PUBLISHE IN WOS ON CONDITION MONITORING AND AMBIENT ASSISTED LIVING TECHNOLOGIES

Lazarou et al. (2016) presented intelligent home monitoring system for care support of elders with cognitive impairment.
Diraco et all (2017) presented a radar-based smart sensor for unobtrusive elderly monitoring in AAL aplications
Hatzivasilis et all (2018) presented management of embedded systems in ambient environments
Mulero et all (2018) presented Internet of Things as infrastructure for elderly-friendly cities
Forkan et. All. (2017) showed how big data ca ne used for context-aware monitoring-a in assisted healthcare
Eldib et. all (2016) presented how behavior analysis for elderly care can be performed using a network of low-resolution visual sensors.
Forkan, Khalil and Tari (2014) presented a cloud-oriented context-aware middleware in ambient assisted living.
Gonzalez et. all (2016) presented comparison between passive vision-based system and a wearable inertial-based system for estimating temporal gait parameters.
Dobbins, Rawassizadeh and Momeni (2017) presented detecting physical activity with the aim of preventing obesity.
Marques and Pitarma (2019) presented mobile phone-based system for indoor environmental quality measurement using internet of things as infrastructure.
Corcella et al. (2019) presented how personalization of remote elderly assistance is possible.
Dasios et. all (2015) presented their experience in deploying cost-effective ambient-assisted living systems.
Ludwig et. all (2012) presented overview of health-enabling technologies for the elderly
Roy, Abidi and Abidi (2017a) presented monitoring activities related to medication adherence in ambient assisted living environments
Floeck, Litz and Spellerberg (2012) presented monitoring patterns of inactivity in the home with domotics networks
Sadek and Mohktari (2018) presented nonintrusive remote monitoring of sleep in home-based situation
Roy, Abidi and Abidi (2017b) presented technologies for activity recognition with uncertain observations to support medication adherence in an assisted ambient living setting
Al-Shaqi, Mourshed and Rezgui (2016) presented progress in development of ambient assisted systems for independent living by the elderly
Navarro et. all (2018) presented real-time distributed architecture for remote acoustic monitoring of activities of older adults in residential-scale ambient assisted living scenarios
De, Chatterjee and Rakshit (2018) studied recognition of human behavior for assisted living using dictionary learning approach
Al-khafajiy et al. (2019) presented remote health monitoring of elderly through wearable sensors
Syed et al. (2019) presented smart healthcare framework for ambient assisted living using IoMT and big data analytics techniques

Technologies embedded in the care settings are adapted so that the care settings can accommodate functiona decline of care users. European AAL joint programme expects that technologies will have important impact on population health and wellbeing (Van Grootven and Van Achterberg, 2019). TZo achive this user needs and preferences should be taken into account when developing AAL systems that support older adults and their carers (Cesta et al., 2018). Care settings adapterd to the needs of older adults with declining functional capabilities improve the safety of residents and therfore decrese the risk of events leading to ill health and disability. Such care setting enables safe mobility, and the residents are provided with the ICT-supported 24/7 monitoring of their activities, immediate real-time response and appropriate assistance and emergency services. Control based on Ambient Technologies embedded in samrt care settings can create value for organisations providing long-term care and improve their sustainability ol long-term care systems.

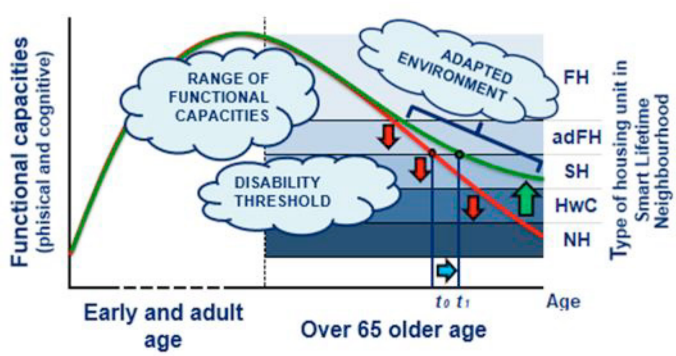

Figure 2: Social determinants of health influencing dynamics of functional decline and disability treshold.

3. IDENTIFIED GAPS

The research challenges of control embedded in AALT, however, are similar to those for urban health. There is an insufficient understanding of the effects of technologies on efficiency of care settings, and of the various dimensions of inequity and exclusion that affect older adults. Thus, more evidence is needed on how the care settings can be supported by control of AALT to accommodate functional decline of residents and therefore affect their health and wellbeing. More rigorous research of role of technologies in different care settings, routine evaluation and evidence of effectiveness are necessary to advance scientific knowledge, improve practice and persuade policymakers to support Ambient Assisted Living Solutions in community carte initiatives when appropriate. In the literature review, we have identified the following gaps:

1. There does not yet exist a model for measurement of values of social determinants of health.
2. There also does not yet exist model to measure patterns od functional decline in different smart care settings supported by AALT.
3. There also does not exist model of AALT supported control of daily activities of residents in different smart care settings and how it influences the development of community care.
4. Digital technologies supporting delivery of health and care services in the smart care settings is not systematically embedded in the health and social infrastructure and are not connected to the community health and care systems which are decreasing its usefulness and uptake. Spatial dispersion of housing units is an important factor influencing long-term care operational costs.
5. Impact of AALT embedded in smart care settings as part of social infrastructure of smart lifetime neighbourhoods on the provision of health care and social care services is not yet well understood. The efficiency of AALT is also dependent on regional investments in other infrastructure (Drobne and Bogataj, 2012, 2013, 2017; Janež et al., 2018). Systems engineers should take into the account perturbations and delays especially in connection with emergency services when designing community care systems.

4. RESEARCH AGENDA

AALT can collect sufficient quantities of data to understand patterns of decline in functional capacities of older adults and develop risk mitigation strategies to decrease risk of events leading to ill health and disability. Based on this data, we can develop model for measurement values of SDH. This model is necessary to develop a risk mitigation model associated with timely transitions between care setting in family home and different types of community care settings, and develop knowledge regarding the optimal time to move to Ambient Assisted Living Technologies supported care setting, Influence of various Ambient Assisted Living Technologies on the relocations among family care setting and different types of community care settings needs to be monitored and reported based on dataset presented. Spatial planners should acquire special knowledge, skills and competencies (Temeljotov Salaj et al., 2010) for development and financing (Temeljotov Salaj et al., 2011) of smart lifetime neighbourhoods as social infrastructure of smart city (Temeljotov Salaj and Bogataj, 2021).

Figure 2 shows how build environment and services as social determinants of health influence decline in functional capacities of older adults and different disability thresholds that exists in family care settings and different age-friendly housing, which will be under consideration. The notation in the diagram is the following: adFH – adapted family house, FH – family home, SH – independent living housing: sheltered housing, HwC – AAL supported smart housing units with care. We denote the initial state where older adult lilves in hers/his family home as state 0 (care setting 0) and the decrement which requires adaptation to certain type of community-based care setting as relocation by the line of the graph from the current family care setting (parent node) to community based care setting (state j, $j = 1, 2, ..., m$). On this graph, we describe the probabilities of transition from the family care setting (state) 0 to further community-based care setting $j \epsilon CS$. In general, we model transitions from the care setting representing parent node to the care setting representing child node j at various ages. The probabilities of transition and risk realisation depend on the age of residents, and available Ambient Assisted Technologies embedded in the environment. The transitions between different types of family and community care settings are successive according to the decline in functional capacities, associated risk of events leading to ill-health and disability, the available Ambient Assisted Living Technologies, the intensity of available care and related characteristics of family and age-friendly care settings with embedded Ambient Assisted Living Technologies. We shall denote by i = 0 family care settings (FH - family home) with no Ambient Assisted Living Technologies;

i = 1: family care settings (FH = family home) with embedded AALT (adFH);
i = 2: community care settings in sheltered housing with embedded AALT for independent living (SH);
i = 3: community care setting in Asisted living facility with embedded AALT for assisted living (HwC); and
i = 4: care setting in institution - nursing home (NH);
i = 5 graveyard (D).

We shall denote by i the care setting in which the resident is currently residing (i = 0), community care setting (i=1 to 3) and care setting in institution (i = 4), and by j the kind of community care setting (j=1 to 3) or institutional care (j = 4) to which the resident is relocating due to decline in his functional capacity and reaching disability threshold after which resettlement from the care setting of type i to care setting of type j (j = 1 to 5) is necessary to prevent event leading to ill health and disability. The patterns of the migrations can be modelled as a directed graph in Figure 1, as simplified in Figure 2.

To successfully evaluate social determinants of health of various care settings supported by Ambient Assisted Living Technologies in relations to older adults and disability threshold – the older residents with the decreasing functional capacities and relocation dynamics, we must know the probability distribution of time-to-event $T_i(x)$, the time that an older adult will spend in the care setting of type i, $i \in$A.

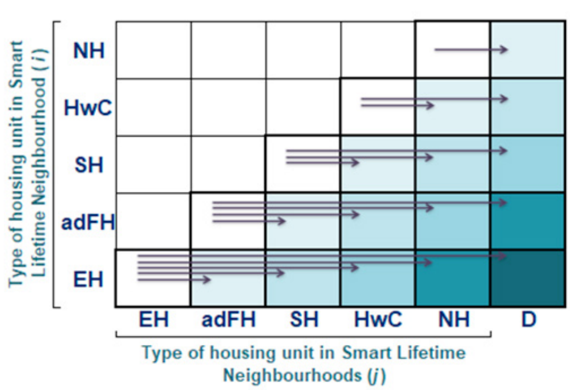

Figure 3: Admissible transitions of older adults from/to different types of care settings

The probability $q_x^{(i,j)}$ of moving due to risk of event leading to ill-health and disability from the family care setting of type i to the community care setting of type j due to the declining functional capacities and related increase of risk of events leading to ill health and disability for the older adult, x years old, can be written by:

$$q_x^{(i,j)} = \frac{M_x^{(i,j)}}{AFE_x^{(i)}}; j = 1, 2, 3, 4; j > i \qquad (1)$$

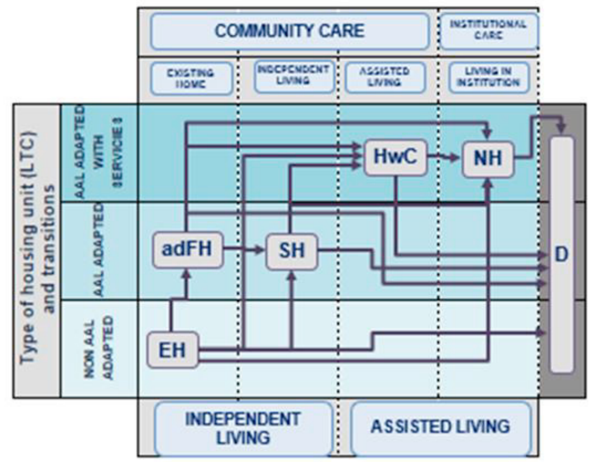

Figure 4: Model of transitions among different care settings.

Where $M_x^{(i,j)}$ is the number of older adults that move from care setting of type i to care setting of type j, and $CS_x^{(i)}$ is the total number of older adults who were previously living in the care setting of type i-1. Here $p_x^{(i)}$ is the probability of staying in the same care setting of type i. The final allocation of residents by the type of care settings for each cohort (x years old) in the year τ is described by vector $\mathbf{CS}_{x,\tau}$ which represents the structure of different types of care settings where older adult in the cohort x years old live in the year τ.

$$\mathbf{CS}_{vx,\tau} = \left[CS_x^{(0)}\ CS_x^{(1)}\ CS_x^{(2)}\ CS_x^{(3)}\ CS_x^{(4)}\right]_\tau \qquad (2)$$

The allocation of older adults by the type of care setting for the studied cohort in the year τ+1 (when they are x+1 years old) is:

$$CS_{x+1,\tau+1} = \left[CS_x^{(0)}\ CS_x^{(1)}\ CS_x^{(2)}\ CS_x^{(4)}\right]_\tau \cdot \begin{bmatrix} p_x^{(0)} & q_x^{(0,1)} & q_x^{(0,2)} & q_x^{(0,3)} & q_x^{(0,4)} & q_x^{(0,5)} \\ 0 & p_x^{(1)} & q_x^{(1,2)} & q_x^{(1,3)} & q_x^{(1,4)} & q_x^{(1,5)} \\ 0 & 0 & p_x^{(2)} & q_x^{(2,3)} & q_x^{(2,4)} & q_x^{(2,5)} \\ 0 & 0 & 0 & p_x^{(3)} & q_x^{(3,4)} & q_x^{(3,5)} \\ 0 & 0 & 0 & 0 & p_x^{(4)} & q_x^{(4,5)} \end{bmatrix}_\tau \qquad (3)$$

5. CONCLUSIONS

How to provide care in community for the growing number of older Europeans is a challenge for the policymaker and researchers. The organization of care for older adults in smart care settings of lifetime neighbourhoods supported by AAL technologies reduce the risk of falls, social exclusion, loneliness and mitigate growth of public health care and long-term care expenditures. Creating age-friendly lifetime neighbourhoods facilitating active and healthy ageing with care settings for different intensity of care, supported by Ambient Assisted Living Technologies considering social determinants of health is one of the most effective approaches mitigating effects of demographic ageing. Ambient Intelligence for real-time control daily activities and support of older adults will be an essential part of how ageing societies will be able to maintain and improve the quality of life for growing number of older adults with declining functional capacities. The development of such age-friendly care settings has the potential to support development of community care and postpone relocation to nursing homes and therefore, considerably lower the cost of care for older adults. Currently, there are no papers in the WoS that measure the effectiveness of different care settings supported by Ambient Assisted Living Technologies. When studying systems supporting active and healthy ageing in general and ambient assisted living technologies in particular the time of relocation between care settings is major factor, therefore their performance should be measured using a multiple decrement/competing risk model.

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