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A Model for Research of Transitions among Different Care Settings in Smart Lifetime Neighbourhoods

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Abstract: Neighbourhoods in EU member states are ageing, increasingly becoming the subjects of geo-gerontology and supply network analyses. Geo-gerontological aspects of the care and supply networks are becoming essential in the processes of deinstitutionalisation of long-term care and services and are crucial for the successful development and implementation of Ambient Assisted Living technologies (AAL_T). A growing number of older adults suffer from declining functional capacities and, thereby, experience decreased mobility and increasing frailty, which can lead to difficulties in carrying out essential activities of daily living as well as increased exposure to the risk of falls. Aid in managing one's daily life needs to be provided on time and in a properly built environment. Ambient intelligence for real-time monitoring of daily activities and supporting older residents with AAL_T will become essential means by which ageing cities will be able to maintain and improve the quality of life for older adults with declining functional capacities. This development will further influence the delineation of service areas and the timing of services. AAL_T and ambient intelligence will enable older adults to live longer in their dwellings and specialised facilities in the community and postpone or even avoid relocation to a nursing home altogether. Development in AAL_T has raised the possibility of developing more efficient services if the functional area of service networks is optimised. Based on these developments, we propose the adaptation of a multi-state competing risk model based on time to failure as modelled in reliability engineering to model and control the trajectories of declining functional capacities and related events that lead to the ill-health and disabilities. In this model, the built environment and timing in service networks are supposed to be embedded. The final goal of such a model is to support decision making that would extend the physically and mentally active life of seniors and enable them to live autonomously and be engaged with their communities. This paper aims to review the development of condition monitoring systems in ambient technologies, shape the model and propose a future research agenda.

Keywords: AAL technology, lifetime neighbourhood, functional area, multistate transition model, social infrastructure, geographical gerontology

1 INTRODUCTION

Today, many older individuals, whose population is increasing as given in Figure 1, have a strong desire to continue living and age in their own communities (Van de Weerd et al., 2020). This desire can be facilitated by the use of advanced health technologies (Meznarec and Bogataj, 2021).

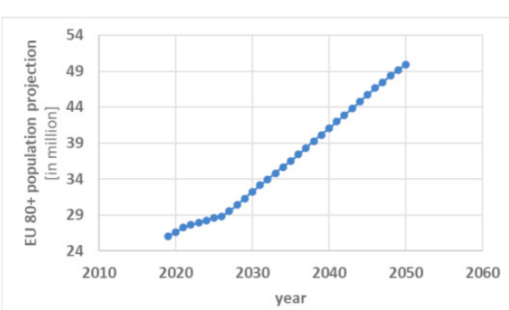

Figure 1. Expected dynamics of population growth for persons 80+ in EU member states (EUROSTAT, 2020).

Telecare services (Colnar, Dimovski and Bogataj, 2021) and assistive technologies embedded in smart homes (Colnar et al., 2020) have the potential to radically transform how developed societies care for the increasing number of older adults (Temeljotov and Bogataj, 2021) and facilitate digital transformation of social infrastructure for the provision of community health care and social care services at a neighbourhood level. The use of smart mobile devices by older adults (Hosnjak and Pavlovic, 2021) and development of gerontechnology as ICT supported solutions can strengthen their social network and reduce social isolation (Nedeljko, Bogataj and Kaucic, 2021). Mobile apps also have the potential to support independent living of people with dementia (Zgonec, 2021) and improvement their cognitive abilities (Zepic, 2021). Ambient Assisted Living technologies (AAL_T) enable long-term care providers to monitor and support activities of care services users in their own homes (Bogataj et al., 2020). For proper use of technologies knowledge management is important issue (Colnar et al., 2021)

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The existing systems of care are still heavily dependent on providing institutional services in the context of residential care (Drobez and Bogataj, 2022). Community care services are not well developed in many EU member states and long-term care systems are poorly prepared to respond to the needs of the growing number of homecare users (Figure 2). Legal aspects of social infrastructure for housing and care for the elderly were presented by Drobez and Bogataj (2022). Members of the society unambiguously indicated that they wish to spend their old age in their own neighbourhoods and receive community care and care services in their own homes (Mather et al., 2015). The rise in costs related to healthcare and social care services is a significant issue for the sustainability of public finances, which necessitates the effort to improve the management and delivery of healthcare and social care services. Such developments motivate academics and healthcare practitioners to a deeper study of this important field with a special focus on the effectiveness of and ability to utilize in practice the concepts of health monitoring and rendering assistance that is focused on the elder's personal environment (Cook, 2006) and by adapting the environment toward their needs (Grum and Kobal, 2020).

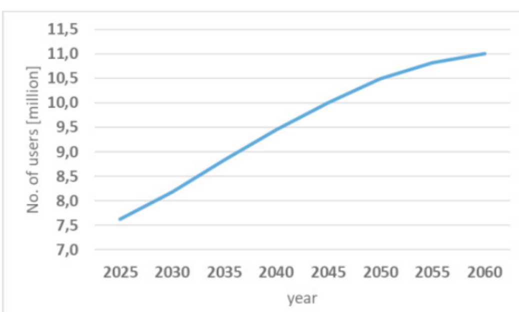

Figure 2. Expected dynamics of home care users in EU member states till the middle of the century based on data provided by European Commission (2021).

Time to failure is a fundamental approach in reliability engineering. In our model, failure means reaching the disability threshold when the older adult is unable to negotiate their environment, and, therefore, the environment becomes dangerous for them. Monitoring of activities of residents by AAL_T and using ambient intelligence (Rogelj and Bogataj, 2020) can help older adults know when the environment has become hazardous to them so that they can timely relocate to a safer, more manageable environment and thus prevent events like falls that lead to ill-health and disability. Nowadays, smart homes and home health monitoring technologies are typically needed to help monitor the activities of daily living, mental health, cognitive decline and possible health condition in older individuals who have a set of complex needs (Liu et al., 2016). The care networks should be adapted to the size of the neighbourhood and proper capacities of service and supply networks for optimal timing of services (Grubbström et al., 2010, Bogataj and Bogataj, 2007). Current technology solutions to support older adults are inspiring other future technological innovations, which are now emerging at an unprecedented pace (Chen and Chan, 2014). For example, an artificial intelligence (AI) based prediction model has been created to assess vitality performance and improve the performance of its user based on indoor activity tracking. Also, an AI face recognition model has been developed to detect discomfort (Marchenko and Temeljotov, 2020; Marchenko et al., 2021). IoT has also been used as technical infrastructure in monitoring activities of daily living. The current focus to improve people' health and well-being, including better housing condition and services to the older population, should use the community-based approach to recognize the risks, enable the enhancement and contribute to a healthier society (Novak et al., 2016, Temeljotov and Senior, 2021). Notably, these technologies do not have to be embedded in the building structure. Designed for home use by older individuals with chronic conditions and in need of continuous care, they are generally wearable sensors that monitor and react to potential changes in vital signs (Reeder et al., 2013). Several such smart wearable systems are available, and their older adult users can obtain immediate feedback on the state of their vital signs, including blood pressure and heart rate. Such real-time healthcare data is then transmitted through wireless sensor networks to a medical centre, where healthcare experts closely follow any deviation from the normal state of an individual (Li et al., 2019).

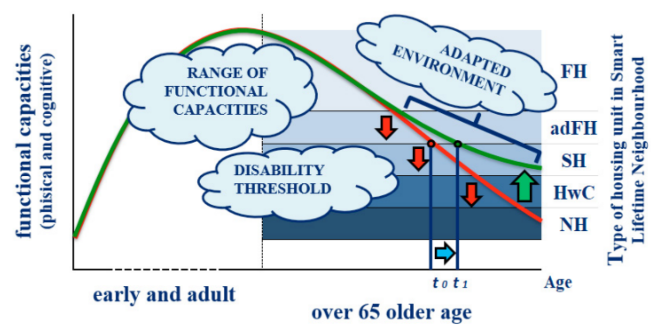

Figure 3: Dynamics of human functional capacities mitigated by the ambient technologies embedded in the care settings of smart lifetime neighbourhoods.

Several examples of home health monitoring technologies are already provided by Demiris and Hensel (2008). They include physiological monitoring, emergency detection and response, functional monitoring, safety monitoring and assistance, social interaction monitoring and assistance, security monitoring and assistance, and sensory assistance. Helal et al. (2005) more specifically identified three steps in monitoring the health and wellbeing of older individuals. Emerging technologies enable the implementation of a more efficient process and also reduce the financial burden of meeting the expenses of healthcare services on the society in specific national contexts (Li et al., 2019). Similarly, the option of remote services in telemedicine and e-health enable older adults to connect with their healthcare professionals or caregivers using online solutions for home-based healthcare, reducing the typical travel costs incurred on physical visits to medical institutions (Murnane et al., 2016). Furthermore, a higher level of implementation of such technologies provides numerous benefits to experts that are in charge of health evaluation and decision support. As emphasised in the literature, the current applications of smart wearable systems mainly focus on monitoring and providing data on vital health signs, patterns of body movement, location and activities and are aimed at preventing falls (Rosenbloom, 2016). Previous research indicates also that a user's indoor movement patterns can reveal their clinical status. This finding implies that indoor localized systems can be used to monitor the frailty of older people (Tegou et al., 2019).

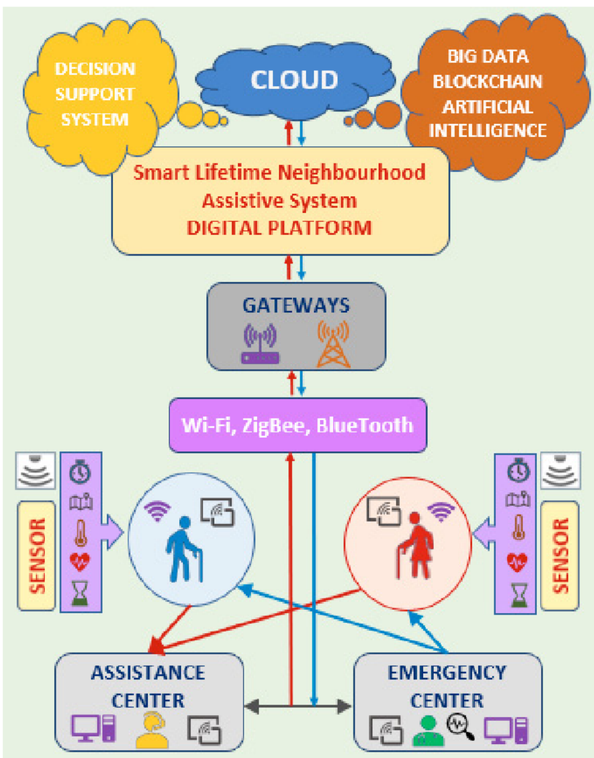

Figure 4: A smart lifetime neighbourhood assistive system supporting older adults' daily activities and mitigating the risk of events leading to ill health and disability.

However, though technology offers numerous benefits, ageing in one's home community involves considerable risks. In case appropriate observation and support are absent, older individuals are increasingly likely to suffer some potentially negative consequences that typically include noncompliance with a treatment plan, higher risk of accidents and associated injuries, adverse health outcomes, higher probability of experiencing morbidity issues, and even death (Feng et al., 2017). It is vital that we do not neglect the part of the elderly population that is living in remote rural areas or alone. These conditions make them even more vulnerable (Van de Weerd et al., 2020).

2 IDENTIFIED GAPS

The research challenges of monitoring of activities in different care settings of a lifetime neighbourhood, however, are similar to those of urban health. There is an insufficient understanding of the actual holistic effects of AAL_T on physical and social environment interventions, considering the delineation of functional areas, an adaptation of housing units and supply and care networks to users. The numerous difficulties in evaluating community-based initiatives notwithstanding, more rigorous research, routine evaluation and evidence of effectiveness are necessary to advance scientific knowledge, improve practice and persuade policymakers to support these initiatives when appropriate. In the literature review, we have identified the following gaps:

1. There is a need to better understand spatial dispersion of long-term care users and patterns of migrations among different care settings. This effort requires geographical gerontology (geo-gerontology) to be considered in the contexts of the care and supply networks as well as methods to reduce delays in care and supply (Bogataj and Grubbström, 2013), with increasing investments in facilities (Bogataj and Bogataj, 2007, 2011, 2019, Bogataj et al., 2011) and contributions towards the attractiveness of an area (Bogataj and Usenik, 2005, Bogataj et al., 2011a, 2015, 2016), and efficiency of supply and care (Bogataj et al., 2019, 2020), focusing to the challenges of ageing (2013, 2019, 2021).
2. There is a lack of academic discussion on emerging technologies supporting health and care services. The current state of technology readiness is not adequate for the creation of smart homes. Also, the use of technology for at-home health monitoring of older individuals is low (Liu et al., 2016).
3. Despite the improvements and constant advancements in wearable systems, the rate of acceptance of health monitoring technology by older individuals is low (e.g., Alaiad and Zhou, 2014). Therefore, future studies to fill this gap in existing research and extend the knowledge base with an in-depth understanding of the attitudes of older adults towards technology solutions should be encouraged. Under these circumstances, research should be aimed mainly at identifying the aspects of technology that would prove most effective in increasing their adoption by the older population (Li et al., 2019).

3 FRAMEWORK FOR UNDERSTANDING TRANSITIONS AMONG DIFFERENT TYPES OF CARE SETTINGS

The collection of time-to-event data through real-time monitoring of activities of older adults living in different neighbourhoods is necessary for 'survival analysis' (Allignol et al., 2011). The collected data enable health and care providers to understand the patterns of functional decline of neighbourhood residents and the relationship between different care settings and their disability threshold. Therefore, there is a need to develop the dataset and model to measure the effectiveness of different care settings and monitor transitions among different care settings, and a model of the dataset to be used in the proposed multi-state-competing risk approach for evaluation of different environments and functional capacities of care setting users have not been developed yet.

A framework for measuring patterns of transition among different care setting is based on competing risks models in medical research and is highlighted by methodological papers in various medical fields, as presented by Andersen et al. (2002). However, these approaches are not combined by the built environment, as suggested in our proposal. There are as many hazards as there are competing risks. Unless all of these hazards, which are often called cause-specific hazards, have been analysed, the analysis will remain incomplete. In particular, only a complete analysis will allow for predicting the transitions among different care settings (Allignol et al., 2011) and the demand for human resources that provide care. Availability of properly educated and trained human resources (Grah et al., 2019) is of utmost importance for sustainability (Bogataj, Bogataj and Drobne, 2020) of health and care systems (Grah et al., 2021).

As the AAL_T and environments have not yet been included in the studies, time-to-event research connected with the change in functional capacities of residents (Salvi et al., 2014), their health status and its influence on tenure in specific care settings supported by AAL_T is also a novelty when studying the competing risk matrices, trajectories of functional capacities of residents and disability thresholds. Some specifics of competing risk multi-state transition models have been presented by Christiansen et al. (2014) but do not introduce environmental and supply and care networks constraints. The basic multiple decrement models were already developed by Bogataj et al. (2016), which allow the calculation of the expected tenure in each type of dwelling according to the locational preferences, supply networks availabilities and functional capacities of a homeowner. But to date, AAL_T embedded in different types of care settings supporting older adults with declining functional abilities to live longer in their neighbourhoods and receive health and care services in their own home instead in nursing home have not yet been considered. Neighbour AAL_T infrastructure and development of smart homes can be financed from health care insurance or community resources determined for a functional area (Janež et al., 2016) where the neighbourhood is located (Janež et al., 2018). The method to define the number of functional regions was presented by Drobne and Bogataj (2012). The same authors developed a method for evaluating functional regions for servicing the elderly (Drobne and Bogataj, 2013) and a model for optimal allocation of public service centres in the central places of functional regions (Drobne and Bogataj, 2015). These methods and models where used to study the impact of public investments in facilities on the potential housing market for older persons (Drobne and Bogataj, 2017). However, these papers did not consider the development of neighbourhood AAL_T infrastructure, smart homes with embedded AAL_T or assistance centres. Also, the capacity of supply networks and the timing of services (Grubbström et al., 2010) have not yet been included in the evaluation of a neighbourhood AAL_T system (Bogataj et al, 2011). This approach is then similar to the one presented by Kovačić and Bogataj (2013) and improved later (Kovačić and Bogataj, 2017). Therefore, for each node shown in Figure 5, it would be necessary to use a structure according to the supply networks that would be available and to include their time component in the evaluation process with area constraints and related time delays in provision of services, which could lead to the spatial competitions of providers as observed by Bogataj and Usenik (2005).

Monitoring the activities of older adults living in a lifetime neighbourhood, we can collect a sufficient volume of data to develop patterns of decline in functional capacities of residents. Based on this data, we can build a model of transitions of residents with declining functional capacities between different types of care settings in the community and in residential care. Based on this data, long-term care providers can develop knowledge regarding the disability threshold and the optimal time of transition to a more accommodative care setting, therefore adapting the environment to the functional capacities of residents. The influence of various technologies on the transitions (relocations) among different care settings (types of environments where care is provided) needs to be monitored and reported based on the presented framework. Figure 5 shows the potential transitions of older adults (see details in Bogataj et al., 2016), where adFH = adapted family house, FH = family home, SH = independent living housing or sheltered housing and HwC – AAL housing units with care. At each state, the service level depends on the capacities of care and supply network (CNi), which depend on technology, specialisation of human resources and area (neighbourhood) to be served. The probabilities depend on the age of residents and available AAL_Ts embedded in the environment (Deshmukh, 2012). The patterns of transitions among different care settings are then modelled as a directed graph.

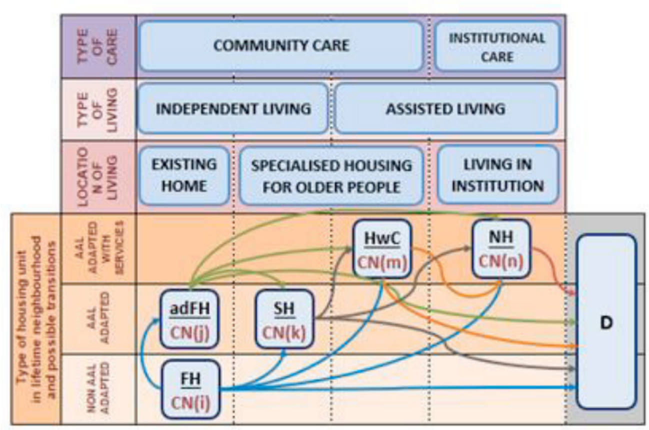

Figure 5: The framework for research of transitions among different care settings.

4. CONCLUSIONS

Geo-gerontological aspects of the care and supply networks are becoming essential in the processes of deinstitutionalising long-term care and services and are crucial for the successful development of AAL_T. Organised monitoring of functional capacities of older adults through AAL_T s reduces the risks of events such as falls that lead to ill-health and disability. Condition monitoring enabled by AAL_T and the development of ambient intelligence supported environment can potentially postpone relocation to a nursing home and, thereby, considerably reduce the cost of healthcare and long-term care incurred by older adults. This adoption's effectiveness depends on the area covered by the care and supply network and its capacity, as well as on the characteristics of the built environment in the neighbourhood. Currently, WoS does not have papers on the comparative effectiveness of monitoring of activities and functional decline by various AAL_T in various environments. When studying systems that support active and healthy ageing in ageing societies, the competing risk model should be used to compare the performance of care in different types of neighbourhoods.

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