

Capacity Planning for Ambient Assisted Living

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Abstract: Housing services and utilities represent the highest share of the EU Silver Economy. EU Member States are ageing. The demand for specialised housing for older adults and ambient assisted living technologies is expected to triple in the next 40 years. The ageing population is driving the expenditures of health care (HC) and long-term care (LTC) provision without visible improvement in the quality of life of older adults. Ambient assisted living technologies and ambient intelligence can enable residents to live longer in their own homes and in specialised housing in the community while mitigating the increasing public expenditures for health care and long-term care. We present the results of the survey, how older adults in Slovenia perceive the ambient assisted living housing, where large share of older adults, who are already included in municipality home care programs, want to live after a severe decline in their functional capacities. These results enable us to forecast the dynamics of the expected demand for specialised housing for older adults and the expected directions of the development of specialised housing and the supply networks. We present the multiple decrement model to forecast the dynamics of this demand when developing the silver economy. This structure of demand, we show, depends on the demographic and the income of the older adults. Therefore, it influences the probabilities of transitions in a multiple decrement model for forecasting the dynamics of development of specialised housing with embedded AAL technologies for older adults.

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1 INTRODUCTION

Europe is confronted by demographic decline and an ageing population. The Ageing Report 2018 (EC, 2017) offers projections of the ageing population between 2016–2070.

The functional capacities, both physical and cognitive, grow during childhood. The peak is reached in early adulthood, after which it begins to decline. One before, the other later, individuals reach the threshold when they need to find a more suitable living environment or move to nursing home all of which is associated with higher expenditures. The numerical values of the curve of functional capacities in the later years can be measured with different scales, such as the Care Dependency Scale (CDS).

An individual's independence and autonomy do not depend exclusively on his or her physical and cognitive abilities, but also on the environment (Drobne and Bogataj, 2005, 2012, 2013, 2015, 2017; Drobne et al., 2011, 2011a, Bogataj et al., 2011, 2012; Liseč et al., 2008). The investments in specialised housing should be determined systematically (Janež et al., 2016, 2018; Janež and Bogataj, 2018) where location of such facilities is major factor (Kovačić and Bogataj, 2013;

Kovačić et al., 2015 ; Szander et al., 2017; Kovačić et al., 2017).

The rate of decline is largely dependent on and linked to the way of life and external social, environmental and economic factors. 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. Using ambient intelligent technologies enable older adults to live independently for as long as possible. Such technologies offer an ecosystem of different types of sensors, computers, mobile devices, wireless networks and software applications for personal healthcare monitoring and telehealth systems. These technologies should be used in combination with the development of an age-friendly environment. For instance, buildings and streets without obstacles promote the mobility and independence of people with declined functional capacities. Families experience less stress if their older members have community support and a suitable living environment. AAL housing with ICT support embedded in the age-friendly environment is adapted to the needs and functional capacities of older adults. An age-friendly environment enables safe mobility, and the residents are

provided with ICT-supported monitoring and health services. AAL housing forms a significant part of human rights and can create value for organisations providing long-term care (Božič and Dimovski, 2019) and improve their sustainability (Peterlin et al., 2018). Especially as ageing and shrinking of workforce will reduce available human resources (Žnidaršič, Dimovski, 2009; Grah et al., 2018; Dimovski, V, Grah, B., Colnar, S. (2019)) including shortage of nurses. Better education can significantly improve productivity and sustainability of supply systems (Peterlin, Dimovski, Tvaronavičiene, Grah and Kaklauskas, 2018) especially when supported by smart technologies (Arh, Jerman-Blažič and Dimovski, 2012). Interactive learning environments (Škerlavaj and Dimovski, 2007) and knowledge-intensive learning environments (Škerlavaj et al., 2010). Could support faster dissemination and acquisition of knowledge among organisations providing facilities and services to older adults. Intra-organisational learning (Dimovski et al, 2008) could contribute to faster adaptation of long-term care services to needs of older adults and improve organisational performance (Dimovski, and Škerlavaj, 2005; Hernaus, Škerlavaj, and Dimovski, 2008).

In Slovenia from 2004 there exists building standard regarding specialised housing for older adults with embedded ambient assisted technologies, published in Slovenian Official Gazzete (Ueadni list no. 110/04, 81/09 in 17/11). More than 1000 such apartments were already built in last 15 years. They are widely recognised as alternative to nursing home. Article 9 stipulates that this apartments should be connected and tele-assistance provided. Also other EU member states are preparing for development of Ambient Assisted living in Germany is described by Marsiske et al. (2010). Japan is going even further considering robots as substitute for caregivers (Gallagher et al., 2016)

Several international covenants impose a binding obligation on the EU Member States to fulfil the right to housing, such as the Universal Declaration of Human Rights (UN General Assembly, 1948) in Article 25 and International Covenant on Economic, Social and Cultural Rights (UN General Assembly, 1966) in Article 11(1). According to the General Comment No. 4 on Adequate Housing, the right to housing is a right enjoyed by all individuals (UN Committee on Economic, Social and Cultural Rights, 1991). Although the General Comments are not binding, they impose a binding obligation on the state to fulfil the right to adequately built housing units. The state's progressive commitments to take steps towards the full realisation of the right to the proper housing was reaffirmed in the Mohamed Ben Djazia and Naouel Bellili v. Spain case (CESCR, 2017). The European Charter of Fundamental Rights (EU, 2012) ensures the rights of the elderly to lead a life of dignity and independence and participate in the social and cultural life (Article 25) as well as the right to social and housing assistance to ensure a decent existence to all who lack sufficient resources (Article 34(3)). We believe that among the obligation of the EU countries is also the obligation to ensure that older adults can choose between (a) independent living in special housing units, and (b) institutionalisation and, therefore, to freely choose their lifestyles and lead decent and independent lives.

2 CASE STUDY: SURVEY ON THE HOUSING NEEDS OF VERY OLD ADULTS THAT ARE INCLUDED IN MUNICIPALITY HOME CARE PROGRAM

2.1. Collecting the data

We surveyed 198 recipients of long-term care, of which 100 recipients of home care and 98 residents of nursing homes in four Slovenian municipalities. The caregivers administered the questionnaire under the guidance of responsible researchers (Kavšek & Bogataj, 2016).

We studied if the organisation of home care services is satisfactory and if residents could still live at home after a significant reduction of their functional capacities. We used open questionnaire regarding where older adults would like to live after significant decline of their functional capacities. We also asked them regarding their income. Even though in 2018 the average pension benefit in Slovenia was 620 EUR per month, pension benefits of some groups of retirees like farmers were lower than 300 EUR per month and they are were unable to afford to pay the rent of specialised housing.

The results of the statistical analyses of survey data of home care users in four different municipalities on preferential dwelling and services are the following:

- 44.4% of older adults would like to stay in their old homes in any case;
- 39.7% of older adults want to live autonomously in AAL housing;
- 1.6% in the retirement community (in Slovenia, there is no such community and, therefore, it is not known if this share would be higher if such possibilities would exist, but some respondents consider that such communities can protect their independence and dignity);
- 12.7% of respondents would like to remain completely autonomous and independent and live in barrier-free and accessible ground floor apartments with proper home care services,
- only 1.6% of respondents would go to a nursing home.

2.2 The results

Based on the results of the research, we can conclude that more than 40% of Slovenian older adults expects from their municipalities to start development of connected specialised housing with age-friendly environments and barrier-free, walkable housing units (p -value \cong 0.01) with the existing income structure and without social subventions. However, we can expect that if rent of AAL housing units would be financially accessible (publicly subsidised) to older adults with lowest pension benefits, the percentage would be even higher. The awareness that rent in specialised housing is financially unaffordable for older adults with lowest income has led many of them to decide that they will stay in the existing home, despite the barriers of its environment and the greater danger of falling or other forms of accidents. Currently, the Slovenian housing market does not offer enough opportunities for AAL. In general, there is no significant difference in the percentage of those who would like to stay in an existing home and those who would want to relocate to AAL community, but there is a

very low proportion of those who prefer to move to a nursing home. The percentage of those who would want to receive the institutional care in a nursing home is quite low (1.6% in the sample).

Table 1 show that a relatively large proportion of older adults with very low pension benefits want to stay in their current family home in any case. From the interviews with them, it was possible to understand that in a large number of cases this answer is influenced by their awareness that the pension income they receive is too low to consider anything else than staying in their existing homes. Moreover, in continental Europe, the reverse mortgage products are not suitably developed. The AAL housing was the preferred option among those with higher pension incomes.

Table 1: Number of older adults included in the survey, according to the type of dwelling and the amount of the pension benefit

Pension benefits (in EUR)	Ambient Assisted Living housing	Ground level housing	To stay in current dwelling	Retirement community	Nursing home	No answer	Sum
0–300	5	2	8			11	26
300–500	6	2	9			10	27
500–800	7	2	7			8	24
800–1.500	6	2	4			1	12
1.500+				1			2
no answer	1				1	5	7
Sum	25	8	28	1	1	35	98

For this reason, we have checked the hypothesis: "Older adults in the income classes of 800+ who can afford rent and care in specialised housing, want to stay in their family home in a smaller proportion, when their functional capacity decline significantly, than those in the lowest income brackets (up to 500 euros). This finding opposes the claim of Eurobarometer (2007) that 90% of the elderly want to stay at home, which is the base for European directives on deinstitutionalisation.

Owing to the small sample, the test was performed using the Agresti-Caffo method (Agresti and Caffo, 2000), which is applicable to small samples. We have performed z+4-test to compare two proportions. Table 3 shows the data for the parameterised test of difference according to the Agresti-Caffo method.

Table 2: The number of older adults involved in the survey, regarding their preferences and pension incomes

Pension benefits (v EUR)	Prefers to move	Prefers to stay in current dwelling	Sum
0–500	15	17	32
800+	9	4	13
Sum	24	21	45

So, with the *p-value* = 0.05, we can confirm the hypothesis: "People in the income classes of 800+, who in Slovenia are better able to afford care in AAL community, want to stay at their current home in a smaller proportion when their functional capacity drops significantly than those in the lowest income brackets (up to 500 euros).

Table 3: Values *p'* in *q'* in z+4-testu

Pension benefit (€)	Prefer to move	Prefer to stay in the current dwelling	Prefer to move	Prefer to stay in current dwelling <i>q'</i>
0–500	$f_{11}+1$	$f_{12}+1$	16	18
800+	$f_{21}+1$	$f_{22}+1$	10	5
	n_1+2	n_2+2	26	23

$$H_0: p_1=p_2; p'_1 = \frac{(f_{11} + 1)}{n_1 + 2}; p'_2 = \frac{(f_{12} + 1)}{n_2 + 2}; q'_1 = \frac{(f_{21} + 1)}{n_1 + 2}; q'_2 = \frac{(f_{22} + 1)}{n_2 + 2}$$

$$SE = \sqrt{\frac{p'_1 q'_1}{n_1 + 2} + \frac{p'_2 q'_2}{n_2 + 2}} = 3,64; z_{AC} = \frac{p'_1 - p'_2}{SE} = 1,648 \rightarrow p - value = 0,05$$

Based on these conclusions, we can expect that a good community AAL housing financing policy for older adults will attract several of them into AAL housing, where they can stay autonomous and less dependent for longer. This is a new challenge for the municipality administration and construction industry. So, it is worthwhile to consider a strategy and other measures to better meet the needs of the ageing population.

According to our research done in 2018, most of the municipality residents (58%) do not have experiences with the decline in functional capacities. They do not have a friend or family member who is dependent on the help of others. From this, we can conclude that a survey that includes the whole population in the sample is not properly constructed to capture the preferences of older adults who are dependent on the help of others. Demand for AAL housing to meet the needs of older adults with decreasing functional capacities could be calculated using the multiple decrement model. Therefore, we can determine the needed structure of housing stock on the base of the multiple decrement approaches developed by Bogataj et al. (2016), using the principles of actuarial mathematics (Gerber, 1997).

3 THE MODEL OF DEMAND FOR THE SPECIALISED HOUSING WITH EMBEDDED AMBIENT INTELLIGENCE

3.1 Multiple decrements model

Knowing (a) the possible and (b) desired options of older inhabitants to move in a AAL housing unit, we shall evaluate the demand for new and more accommodative housing stock, with embedded AAL technologies.

The migrations need to be monitored and reported based on evaluations presented in chapter 2 for the long-term improvement of the silver economy. Figure 1 shows the graph which will be under consideration. The notation in the diagram is the following (see the details in Bogataj et al., 2016): adFH – adapted family house, FH – family home, SH – independent living housing: sheltered housing, HwC – AAL housing units with care.

We denote the initial state as state 0 and the decrement which requires housing of type j by the line of the graph from this parent node to the state (child node) $j, j = 1, 2, \dots, m$. On this graph, we describe the probabilities of transition from the state 0 to further states to the child node (state) $j \in H$, or in general: from the parent node to the child node j at various ages. The probabilities depend on the age structure, wishes to move and the financial support of the potential users. All paths determine the needed dynamics for constructing the proper capacity of buildings of type j ; it means inventories of items in the process that should be completed at the time forecasted. In the multiple decrement setup, transitions between any two states from i to $j, i > j = 1, 2, \dots, m$, are not possible (directed graph), but with a good housing policy and also a multi-state transition, where we can also assume that reverse flows are possible (See the basics in Gerber, 1997; and some advanced solutions in Deshmukh, 2012).

The transitions are successive according to the functional capacities, the available intensity of care and related housing. We shall denote: $i = 0$: FH housing unit without special housing for seniors and with residents without the need for care, where they live with such functional capabilities that are autonomous;

- $i = 1$: homecare in the adopted family home (adFH);
- $i = 2$: housing unit in sheltered housing campus (SH);
- $i = 3$: housing unit with care services in AAL housing (HwC);
- and
- $i = 4$: nursing home (NH); $i = 5$ dead (D).

We shall denote by i the type of housing unit in which the resident is currently residing ($i = 0$ to 4); and by j the type of housing unit to which the resident is moving due to declining functional capacity (resettlement from the type of facility i to $j, j = 1$ to 5). The details of the migrations can be modelled as a directed graph in Figure 1, as simplified in Figure 2. Based on the demographic statistics including the population's income, one can calculate the expected needs of older adults in the studied area and the probabilities of transitions among the different types of dwellings. Such transitions can be financed by personal insurance products, properly developed reverse mortgages schemes or on the basis of national

insurance schemes (Bogataj et al., 2015, 2016; Bogataj and Bogataj, 2015).

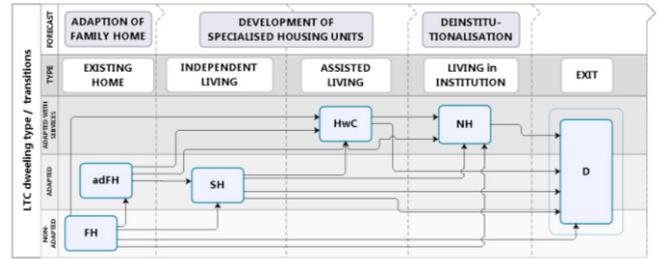


Figure 1: The graph of different paths between different types of dwellings from existing home (EH) to nursing home (NH) in the multiple decrement model

To successfully forecast the different dwelling needs of seniors – and therefore the optimal structure of the housing stock – based on the decreasing functional capacities of residents and the effective demand, we must know the probability distribution of $T_i(x)$, the time that a senior resident will spend in the dwelling of type $i, i \in H$. We suppose that the resident moves to the type of housing unit that optimally suits his/her functional capacities. The probability of transition in the model should be calculated based on the results of surveying among the elderly and the observations of moving from one dwelling type to another if the supply is high enough, and the state subsidies are adequate. In a multiple decrement setup, transitions between any two states, from i to $j, i > j = 1, 2, \dots, m$, are not possible (directed graph). However, in a multi-state transition, we can also assume such reverse transitions of functional capacities (see advanced solutions in Deshmukh, 2012) and, therefore, the use of housing stock can also be modelled with a multi-state transition model, which is not the case below.

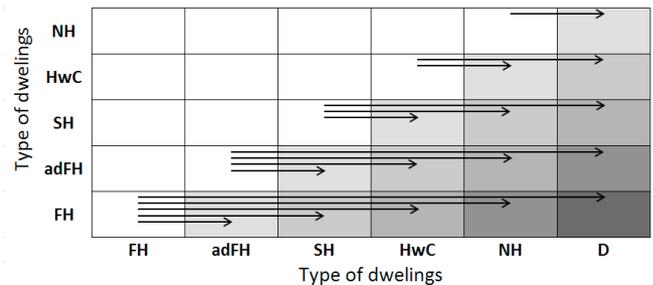


Figure 2: Admissible transitions of older adults from/to type of housing unit

The probability $q_x^{(i,j)}$ of moving from the facility of type i to facility type j due to the declining functional ability for resident age x is written by:

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

Where $M_x^{(i,j)}$ is the number of residents that move from i to j , and $S_x^{(i)}$ is the total number of residents who were previously living in $i-1$. Here $p_x^{(i)}$ is probability of staying in the dwelling. The final allocation of residents by the type of facility for each cohort (x years old) in the year τ is described by the following matrix, as the transition based on Allignol et al. (2011) and

Sieber et al. (2012), now adapted to the given built environment:

Vector $S_{x,\tau}$ represents the structure of dwellings where residents in the cohort x years old live in the year τ . Migrations can also be added according to the gravity model, presented by Janež et al. (2016, 2018) and Janež and Bogataj (2018).

$$S_{x,\tau} = \left[S_x^{(0)} S_x^{(1)} S_x^{(2)} S_x^{(3)} S_x^{(4)} \right]_{\tau} \quad (2)$$

The allocation of residents by the type of facility for the studied cohort in the year $\tau+1$ (when they are $x+1$ years old) is:

$$\begin{aligned} S_{x+1,\tau+1} &= S_{x,\tau} P_{x,\tau} = \\ &= \left[S_x^{(0)} S_x^{(1)} S_x^{(2)} S_x^{(3)} S_x^{(4)} \right]_{\tau} \cdot \\ &\begin{bmatrix} p_x^{(0)} & q_x^{(0,1)} & q_x^{(0,2)} & q_x^{(0,3)} & q_x^{(0,4)} & q_x^{(0,5)} \\ 0 & p_x^{(1)} & q_x^{(1,2)} & q_x^{(1,3)} & q_x^{(1,4)} & q_x^{(1,5)} \\ 0 & 0 & p_x^{(2)} & q_x^{(2,3)} & q_x^{(2,4)} & q_x^{(2,5)} \\ 0 & 0 & 0 & p_x^{(3)} & q_x^{(3,4)} & q_x^{(3,5)} \\ 0 & 0 & 0 & 0 & p_x^{(4)} & q_x^{(4,5)} \end{bmatrix}_{\tau} \\ &= \left[S_{x+1}^{(0)} S_{x+1}^{(1)} S_{x+1}^{(2)} S_{x+1}^{(3)} S_{x+1}^{(4)} \right]_{\tau+1} \end{aligned} \quad (3)$$

4 CONCLUSION

The organisation of care for older adults in the AAL housing communities reduces the risks of falls, social exclusion and loneliness, which postpone need to move to nursing home and considerably lower the cost of health care and long-term care for older adults. Knowing the housing preferences of an ageing population with declining functional abilities and dependent on the help of others, we can better forecast the demand for specialised housing stock with embedded ambient intelligence, facility management and care networks. The results of our research differ from others because the sample was exclusively consisted by people who are already dependent on the help of others and have already acquired the right to home care which is at least 50% financed by municipality. Moreover, our results are more reliable because of their ability to recognise the impact of low pension benefits on the housing choice. When an older adult is confronted with barriers of the environment of their current home that she/he cannot negotiate, her/his desire can change, as has been shown here. Thus, our results differ significantly from the findings of the study Eurobarometer 283: Health and long-term care in the European Union (EU, 2007), which states that 90% of the elderly want home care mostly in their family homes where they have lived most of their life. This is not the case with our respondents, and the test further proves that even more people would choose AAL housing if it were affordable for them.

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