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Sustainable and Adequate Home-Care Logistics Including Precedence Constraints[1]

Marija Bogataj *, Alenka Temeljotov-Salaj, David Bogataj *****

**Institute INRISK & SEB-University of Ljubljana, Kardeljeva ploščad 17, 1000 Ljubljana , SI; marija.bogataj@ef.uni-lj.si*

*** Department of Civil and Environmental Engineering-NTNU, Norway; alenka.temeljotov-salaj@ntnu.no*

****Institute INRISK & SEB-University of Ljubljana, Kardeljeva ploščad 17, 1000 Ljubljana , SI; david.bogataj@ef.uni-lj.si*

Abstract: Development of community home-based care for servicing the growing number of older adults with declining functional capacities is the priority of EU Member states to keep sustainable social systems of long-term care. For optimal utilisation of human resources, it is necessary to balance the activities of caregivers and other professionals who perform services in a network and evaluate their services in combination with the strategic development of networks. The number of users is increasing. Since the optimal solution for servicing is changing, the system should dynamically adapt to the new requirements of building capacities, infrastructure and human resources. The purpose of this paper is to develop an innovative model to support these needs with a minimum number of caregivers who would balance their activities within the time window of their working day and combining investments and organisational decisions to achieve the above objectives at the minimal net present value of expenses. The number of caregivers and scheduling is decided by using a nonlinear assembly balancing algorithm in the manner of assembly-line balancing. This algorithm is combined with the multiple Travelling Salesman Problem and network investments planning, which provides a new tool written in the R programming language for decision making by evaluating the net present value of services and combining it with the investment costs to maintain a sustainable social system that provides adequate services. The case of planning in the East Slovenian region is presented.

Keywords: long-term care; social infrastructure, logistics; investments; nonlinear balancing.

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1. INTRODUCTION

1.1 Problem identification

Social infrastructure and services for seniors are playing an essential role in community care and are of emerging importance in industrial engineering. The importance of adequately built and hierarchically structured infrastructure has been established through some of the innovative models of community care systems. The built environment should become better adapted to the older cohorts (Schorr and Khalaila, 2018; Stevens and Lee, 2018; Wood, 2017), but also must be at a lower cost of human resources. The dispersion (location) of housing units adapted for the needs of the seniors and service hubs and their accessibility influence the operational costs. New investments in service networks should be designed carefully. Making family housing or community facilities for seniors more adjustable to their needs and providing them the choice of more suitably located accommodation and other facilities is also desirable. It facilitates effective health intervention and daily care in terms of frequency and time spent on intervention and daily care (Bentley et al., 2001, Wahl et al., 2007). The location of new facilities in particular and arrangements for travelling among them affect the costs of health and social services in long term care. Therefore, it is necessary to strike a balance between investing in social infrastructure and providing services. Also, the location of the hubs in the hierarchical structure of social infrastructure is essential (Drobne and Bogataj, 2015). Therefore, the operational costs and their net present value (NPV) for different arrangements of care should be compared before making the final decision on new investments in facilities for senior citizens. But the preference of seniors on when to be served should not be neglected.

1.2 Research question

In home-care systems, the costs of care consist of the cost of care itself and travel costs of caregivers. The first depends on the quality of investments (adaptation to the elderly) and the second on the location of the chosen

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assets in the hub. The activities of nurses and other caregivers, also facility managers, wherever they have been appointed, should be so organised that their work and travel are balanced. The change of location of a user can influence this balancing. How to balance the activities? How to balance healthcare and facility management in the daily eight-hour time-window? How to invest (based on quality and location criteria) in a new facility in the network so that the NPV of organisational costs and investment costs would be minimal? We wish to develop a model to support investment decision making, and scheduling and routing in long-term care. To support European directions towards deinstitutionalisation (FEANTSA, 2013)), the networks of facilities for senior citizens and services for them should be better developed and optimised (a) to meet the wishes of seniors, and (b) minimise the costs of services and (c) investment costs of facilities located in a hierarchical spatial structure. All criterions could be included in the proposed model. These services are very work-intensive and spread over a large region. Therefore, the optimisation methods should be developed for these services based on maps to achieve minimum investment costs and health-status benefits. For balancing the activities (servicing, waiting, and travelling) on these maps, the use of methods similar to those used for balancing production lines is suggested. Yet these methods should be modified significantly to accommodate the travelling time among users who have their desired time windows for receiving service and are spread over a wide area. Therefore, we will examine to what extent the mathematical model for line balancing introduced by Patterson and Albracht (1975) could be used in this mathematical formulation of optimisation procedures and how it should be modified. For this purpose, the vehicle routing problem with Time Windows (VRPTW) could be modified and combined with the Patterson-Albracht algorithm. How can these results influence investment in housing for senior citizens? How it affects the choice of the geographic location of a hub?

2 LITERATURE REVIEW

Long-term care can be provided in more or less dispersed housing units. The cost of care depends on the dispersion and accessibility of the built environment and the homes of users. In Slovenia as in many European countries, the users are dispersed in small villages scattered around the central place of a functional region. It is necessary to deliver the set of services in a given time windows accepted by users. Each user's priorities about when to be served within a time window are listed. The aim is to distribute the activities among caregivers in such a way that their working day is balanced. The worktime of each caregiver is eight hours when short exceed ω of it is increasingly extra paid ($C(\omega)$) and the waiting time in the eight-hour working time is to be paid for as active work. When we searched on the internet for the previous works using home health care & scheduling & routing and combinations of these keywords, we found only 181 papers in Web of Science (WoS) Core Collection that consider home health care routing and scheduling problems (HHCRSP). A search on Patterson and Albracht or Paterson-Albracht as the additional keyword does not give any results. The optimisation procedures in these papers deal with assigning and routing caregivers to provide care or other services at users' homes. Basically, these are vehicle routing problems with time windows and additional other specific constraints. To solve such issues, the papers in the WoS database propose an analytical approach in case of only a few tasks, or they propose a heuristic approach, that combines mixed-integer linear programming with some other algorithms. The authors are often satisfied with a good, not necessarily the optimal, solution achieved in a reasonably short time.

Table 1. Dynamics of publishing articles on the home health care routing and scheduling problems in the WoS

Years of publishing	2010 and before	2011–2015	2016–2020
No. of articles	6	22	93

Table 2. Objectives of Home Care routing and scheduling problem, and service time windows as objectives (P) or the main constrains (PC)

Year	Authors	T	C	D	B	P	NC	PC
2006	Bertels, Fahle		x			x		x
2006	Eveborn et al.		x					x
2008	Bredström, Rönnqvist	x			x	x		
2008	Steeg, Schröder	x	x			x		
2011	Trautsamwieser, Gronalt,	x				x		
2011	Trautsamwieser, Hirsch,	x				x		
2012	Gamst, Jensen	x	x			x		
2012	Barrera et al.		x		x		x	
2014 a,b	Ait Haddadene et al.		x			x		
2015	Issaoui, et al.			x		x		x
2015	En-nahli, et al.		x			x		
2015	Maya Duque et al.			x		x		x
2016	Braekers, et al.		x			x		x
2016	Afifi et al.			x	x	x		
2016	Lin, et al.		x					x
2017	Laesanklang, Landa-Silva		x			x		
2017	Szander et al.						x	x
2018	Lin et al.		x					x
2018	Decerle et al.	x			x			x
2020	Dengiz et al.	x				x		x

T: Travel, waiting or over-time; C: Any other costs; D: Travelled distance; B. Balancing and synchronising; P-Patient or caregivers time preferences; NC: Number of caregivers; PCt.: Preferences as constrains.

The dynamics of publishing show that these topics got more attention in the last decade (Table 1), but only one author worked on the problem of balancing that would minimise the number of caregivers (Barrera et al., 2012). However, sequencing, which led to the development of Patterson's and Albracht's sequencing, has not been considered as a constraint by these authors. Home care routing problem has often been formalised as a problem of routing vehicles in a given caregivers' time window (VRPTW), which resulted in the development of spatial decision support models to support scheduling and routing decisions. It was first presented by Begur et al. (1997) and much later by Eveborne et al. (2006). In the same year, a mathematically formalised problem was also studied by Bertels and Fahle (2006) and a year later by Akjiratikar et al. (2007). Table 2 describes the published articles on constraints or optimisation of the number of caregivers listed in WoS Core Collection (WoS). These are listed the articles published in this millennium. Only the papers of Barrera et al. (2012) and Szander et al. (2017) included minimisation of the number of caregivers directly influencing the cost of human resources through an optimisation procedure. Bredström and Rönnqvist (2008) were the first authors who addressed synchronisation and precedence constraints between pairs of visits. They minimised the differences in workload as a balancing problem, but not the balancing of total work, travel and waiting time. In their paper, the difference in workload is measured. But optimization and balancing of total work, travel and waiting time among caregivers has not been attempted while considering the preference of seniors regarding servicing time windows. Therefore, our study provides a new method for determining the costs of servicing older adults in widely scattered villages in a functional area around a central place where the care centre (hub) is located and embedded in the hierarchical structure of facilities for long-term care (LTC). Thus, the method that we suggest will be useful for local authorities, social care services, and spatial planners to study senior citizens' logistics, other care, and housing needs and investments in new facilities.

3. THE MODEL

3.1 The dispersion of users in the functional region

The model is aimed at meeting the following requirements: (a) working time of all caregivers, included service providers should be balanced (including travel and waiting time); (b) the timing of services in all areas should be close to the desired time windows of service chosen by users and (c) the costs of caregivers (nurses) in case that they are working eight hours or less is the same. The workload beyond eight hours per day would be increasingly more expensive. The total number of nurses influences the NPV of wages, which should be minimised as also the investment costs. For this reason, the network optimisation model is combined with the line balancing algorithm of Patterson and Albracht (1975).

Table 3. National standards of time spent per visit

k	I	II	III	IV
τ(k) in [h]	1/2	1	3/2	2

The results are also considered for the extension of the service area and suggested to be embedded in the hierarchical structuring of the LTC facilities as described in Drobne and Bogataj (2015), who studied only the investments. We are assuming that in the network we have n number of users in villages. Their functional capacities are in one of four categories of care (k=I–IV) with the prescribed time of care τ(k) as given in Table 3.

3.2 Multiple travelling salesman problem

We use the multiple Travelling Salesman Problem (mTSP) approach so that every user would be visited once along the shortest possible route according to the service preferences of the elderly in long-term care. The mTSP was modified and formalised as described in Bektas (2006) also Szander et al., (2017). Equations (1–3) describe the assignment part, complemented with (4) based on the Miller–Tucker–Zemlin (MTZ) formulation (Miller et al., 1960). The integer programming for the mTSP is described in the following formulations: Consider a graph $G=(A,L)$ where A is the set of n nodes $(i,j=A,B,C,\ldots)$, representing n users in long-term care of the assistance hub as a facility, known by geocodes on the map, and L is the set of the shortest paths, $l_{i,j}\in L$, marked on the roads of the map between all possible pairs (i,j) on which the minimum values of time spent by travelling in-between $c_{i,j}$ are known. Therefore, to each pair of nodes (i,j), the shortest edge $l_{i,j}\in L$ is allocated and evaluated by the travel time $c_{i,j}$. Here $c_{i,fk}$ is the travel time back to the hub from any node i of each caregiver *k*. Each service provider moves between the users' homes, starting and returning to the assistance hub. The objective is to minimise the total number of caregivers (min m) at the constraint (1)-(2), where the average duration $c(k)$ of daily service of worker k, which influences long-term service costs *(NPV(c))* equals the sum of travel times between the pair of nodes (i,j) – $c_{i,j}$ which is equal to or smaller than caregivers' morning workload (eight hours). This workload is reduced by the lunch break t_0 and increased by the load of hours over full-time *c(k, ω).* The total travel time $c(k)$ of caregiver k, is, therefore, the sum of time taken to traverse the distances between users $c_{i,j}$ for the caregiver k and the prescribed care time at the user's place $j,(\tau_j)$, which depends on categories of service needed by the users (Table 3) plus the outbound (from node $i=0$) and inbound travel time to the hub facilities (to the node $j=f(k)=f_k$), where an eight-hour workday

(480 min) can be exceeded, but with higher hourly overtime rates ω which can increase.

$$c(k) = \sum_{j=0}^{n}\sum_{i=0}^{n}[(c_{ij} + \tau_j)x_{ij(k)} + c_{if(k)}x_{if(k)}] \leq$$
$$\leq 480 - t_o + c(k,\omega) \qquad k = 1,2,\dots,m,$$

$$x_{ij(k)} \in \{0,1\};\ c_{ij} = s_{ij} * d_{ij} \qquad (1)$$

Variable $x_{ij(k)}$ equals 1 if the k^{th} caregiver goes immediately from i to j, and 0 otherwise; d_{ij} is the shortest distance between i and j, and s_{ij} is the optimal speed at which can possibly be reached on the given road. All caregivers start their daily circular route at the municipal care center (CCE), which facility serves as a hub and is denoted here as node 0 at the beginning and f as the final destination. The caregivers return to the same location at the end of their working day. Equations (2) and (3) were added to the traditional TSP formulation, to ensure that precisely m caregivers depart from and return to the CCE. If the caregiver is at a particular user location at a given moment, then the caregiver could have reached there from only one of the previous places. The caregiver has to leave location i after the caregiving has been performed and go on to only one location j among all the locations in the area as described by (2).

$$\sum_{j=1}^{n} x_{ij(k)} = 1 \quad \forall\, i, \forall\, k; \quad \sum_{i=1}^{n} x_{ij(k)} = 1 \quad \forall\, j, \forall\, k$$

$$\sum_{k=1}^{m}\sum_{i=1}^{n} x_{if} = m \qquad \sum_{k=1}^{m}\sum_{j=1}^{n} x_{0j} = m \qquad (2)$$

The sub-tour elimination constraint are given in (3). Therefore, the arbitrary real numbers are introduced as 'dummy' variables u_i, which represent the sequence in which location i is visited, and p denotes the maximum number of nodes visited by any caregiver (Bektas, 2006). For i=0,...n-1;j=1,...,n; k=1,2,..m.

$$u_i - u_j + p \cdot x_{ij(k)} \leq p - 1; \quad u_s \geq 0; \quad s = i,j \qquad (3)$$

3.3 Determining the sequencing at a given time window to satisfy the desired service time

The following steps are required: **Step 1**: the determination of cycle time following (1). **Step 2:** Determine the number of caregivers: $m^* = (\sum_j t_j + c(k)_{\max} + \omega)/c$. Minimum chosen ω, in which the solution with Patterson-Albracht sequences exists, is the value that goes through the further procedure. We are simulating ω value and add the costs of C(ω)*ω to the criterion function. The next higher integer is chosen to define the number of caregivers m. **Step 3:** The precedence relations restrict the number of activities to which a task can be assigned, delimited by the earliest activity E_j and the latest L_j

$$E_j = \left\lceil \frac{\left(t_j + \sum_{h\in P_j^*} t_h\right)}{c} \right\rceil \quad L_j = m + 1 - \left\lceil \frac{\left(t_j + \sum_{h\in F_j^*} t_h\right)}{c} \right\rceil \qquad (4)$$

Step 4: Finally, the f is minimised:

$$f = [C_{cg} * m * 8 + C(\omega) + \textstyle\sum_{j=1}^{n} C_{d,j}\delta_j] \qquad (5)$$

Where C_{cg} is the workload, including travel costs; $C_{d,j}$ is the cost of evaluated delays in each village separately, and $C(\omega)$ is the cost of additional time.

3.4 Inclusion of the procedure in the decision model supporting investment policies and the optimal allocation

In case of evaluation of an investment in the new hub from where the caregivers would be visiting the users, we have to run the procedure for each potential location h (INV(h)) among the locations available and the quality of the dwelling according to the characteristics of safety and accessibility to the residences of the senior citizens. In the end, we arrive at a list of pairs of investments and costs of services depending on the number of caregivers: [*INV(h), NPV(f *(h, m, ω)*] which should be presented to the investors. The rational choice would be –

$$Min\,[INV(h) + NPV(f^*(h, m, \omega))] \qquad (6)$$

Investment in hubs is subject to hierarchical optimisation described in Drobne and Bogataj (2015). These researchers presented the method for optimal coverage of the state territory with functional regions of hubs in a hierarchical structure of services to arrive at an optimal allocation of investments to services and staff assigned to the hubs. Sets of functional regions were modelled using the *INTRAMAX* method. An optimal regionalisation based on the number of functional regions was presented where the optimal number was chosen according to the investment cost of services and cost in staff in the hubs. Still, the variation in the costs of caregivers in homecare was not considered. Therefore, in the formula (3) of this paper c_{ij}^h should be multiplied with coefficients of changes in m, giving the optimal number of human resources, which was not considered by Drobne and Bogataj (2015).

4. NUMERICAL EXAMPLES

4.1 Scheduling caregivers

In the service area, there are 28 senior citizens. They are served by m caregivers who visit an optimal set of users in 480+ω minutes. The caregivers have a 30 min lunch break. At the final node (centre of the facilities or the hub) they must write the report and leave the bag of their equipment and medicines there, which requires additional 15 minutes. The preferred timings of services reported by users are formalised in the precedence matrix (Table 4). For this case we developed the *Patterson-Albracht algorithm* as the program linked to *mTPS* developed in R. Allocation of caregivers is given in Table 6. The travel time from the parent node to the user without priority sequencing is described in column A, service times in column B, and travel times in case of priority constraints determined with precedence matrix in column C of Table 5. In Table 7, we can see that in the case when areas are four times larger and the distances between nodes increase by 100%, the cost of human resources increases by 16,7% (2960/2653) which amounts to an additional € 25,000 for human resources per year. Therefore, we have included the evaluation of *NPV* of wages for caregivers in the optimisation procedure described in Drobne and Bogataj (2015), where c_{ij}^{h} is multiplied by 1,167 if the lowest area of a hierarchical structure of facilities increases by factor 4.

Table 4. Precedence matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
1	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1
2	0	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1
3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
	0	0	0	0	1	0	1	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1
5	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1
6	0	0	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
7	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
8	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
9	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
10	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	1	1	1	0	0	0	1
12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
13	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
14	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
16	1	0	0	0	1	0	0	1	1	1	1	0	0	0	0	0	1	0	1	1	1	1	1	1	0	0	0	1
17	0	0	0	1	1	0	0	1	1	1	1	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	1
18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
20	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	1
21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	1
22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	1
25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 5. Service and travel time

Resi-dents	A	B	C	Resi-dents	A	B	C
res.1	5	86	5	**res.15**	10	177	20
res.2	10	136	10	**res.16**	5	14	5
res.3	5	15	5	**res 17**	10	98	20
res.4	15	144	15	**res 18**	5	8	5
res.5	15	124	15	**res. 19**	10	51	10
res.6	10	38	10	**res. 20**	13	88	13
res.7	5	50	5	**res. 21**	10	204	10
res.8	12	43	12	**res. 22**	5	24	5
res.9	10	177	20	**res.23**	5	52	5
res.10	15	58	15	**res. 24**	15	126	15
res.11	15	109	15	**res .25**	2	24	2
res.12	5	46	5	**res. 26**	10	189	20
res.13	10	49	10	**res. 27**	5	44	5
res.14	10	118	20	**res. 28**	10	54	10

With the simulation procedure, this influence can be evaluated in any *INTRAMAX* result and, therefore, the result can be better assessed.

Table 6. Allocation of caregivers A–F(G) to users 1 -28 in the basic territory and in the case of 4-times broader area

	Basic territory						Extended territory (doubled distances)						
Cli-ent	A	B	C	D	E	F	A	B	C	D	E	F	G
1	1	0	0	0	0	0	1	0	0	0	0	0	0
2	1	0	0	0	0	0	0	1	0	0	0	0	0
3	0	0	0	1	0	0	1	0	0	0	0	0	0
4	0	1	0	0	0	0	1	0	0	0	0	0	0
5	0	1	0	0	0	0	0	1	0	0	0	0	0
6	0	1	0	0	0	0	1	0	0	0	0	0	0
7	0	1	0	0	0	0	1	0	0	0	0	0	0
8	0	0	1	0	0	0	0	0	1	0	0	0	0
9	0	0	1	0	0	0	0	0	0	1	0	0	0
10	0	0	1	0	0	0	0	0	0	1	0	0	0
11	0	0	0	1	0	0	0	0	0	0	1	0	0
12	1	0	0	0	0	0	0	0	1	0	0	0	0
13	0	0	0	0	1	0	0	0	1	0	0	0	0
14	1	0	0	0	0	0	0	0	1	0	0	0	0
15	0	0	0	1	0	0	0	0	0	0	0	1	0
16	1	0	0	0	0	0	1	0	0	0	0	0	0
17	0	0	1	0	0	0	0	1	0	0	0	0	0
18	0	1	0	0	0	0	0	0	0	0	1	0	0
19	0	0	0	0	0	1	0	0	0	0	1	0	0
20	0	0	0	1	0	0	0	0	0	1	0	0	0
21	0	0	0	0	1	0	0	0	0	0	0	1	0
22	0	0	0	0	1	0	0	0	0	0	0	0	1
23	0	0	0	0	0	1	0	0	0	0	0	0	1
24	0	0	0	0	1	0	0	0	0	0	1	0	0
25	0	1	0	0	0	0	0	0	0	1	0	0	0
26	0	0	0	0	0	1	0	0	0	0	0	0	1
27	0	0	0	0	0	1	0	0	0	0	1	0	0
28	0	0	0	0	0	1	0	0	0	0	0	0	1

Table 7. Total travel and servicing time of each caregiver in minutes in case of balanced Patterson–Albracht algorithm at the basic (I) and doubled (II) travel time**.**

Caregiver [min]	A	B	C	D	E	F	G
A (I): 2653	445	440	443	442	443	440	0
B(II): 2960	437	448	350	447	438	441	399

5. DISCUSSION AND CONCLUSIONS

The paper shows how the spatial design of facilities for seniors influences their independence and costs of services, but also the users' desired timelines influence the total costs. Therefore, spatial arrangement, when considering investments in facilities, should be studied, and optimised jointly with the provision of services.

The optimisation is seen from two perspectives:

- To improve the spatial arrangement of the facilities, which will reduce the costs of daily assistance and ensure regular maintenance of facilities and devices, and for maintaining a safe and neat lounge and environment for the older adults.
- To optimise the routing of the caregivers for servicing the users to reduce the cost of servicing and increase the satisfaction of seniors by giving them service at their desired times.

We have demonstrated how the mathematical programming tool, modified the Patterson-Albracht algorithm, which includes service sequencing, and the concepts for minimising the number of human resources, such as mTPS, enable us to examine the outputs under various scenarios. The method is also suitable for the more precisely measured time needed for services, and not only for 3-4 categories. The proposed approach might help professionals to adapt in advance for the coming changes caused by the growing number of seniors and rapid changes in technologies.

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