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Original Study

Reduced Waiting Times by Preference-Based Allocation of Patients to Nursing Homes

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A B S T R A C T

Objectives: The long waiting times for nursing homes can be reduced by applying advanced waiting-line management. In this article, we implement a preference-based allocation model for older adults to nursing homes, evaluate the performance in a simulation setting for 2 case studies, and discuss the implementation in practice.
Design: Simulation study.
Setting and Participants: Older adults requiring somatic nursing home care, from an urban region (Rotterdam) and a rural region (Twente) in the Netherlands.
Methods: Data about nursing homes and capacities for the 2 case studies were identified. A set of preference profiles was defined with aims regarding waiting time preferences and flexibility. Guidelines for implementation of the model in practice were obtained by addressing the tasks of all stakeholders. Thereafter, the simulation was run to compare the current practice with the allocation model based on specified outcome measures about waiting times and preferences.
Results: We found that the allocation model decreased the waiting times in both case studies. Compared with the current practice policy, the allocation model reduced the waiting times until placement by at least a factor of 2 (from 166 to 80 days in Rotterdam and 178 to 82 days in Twente). Moreover, more of the older adults ended up in their preferred nursing home and the aims of the distinct preference profiles were satisfied.
Conclusions and Implications: The results show that the allocation model outperforms commonly used waiting-line policies for nursing homes, while meeting individual preferences to a larger extent. Moreover, the model is easy to implement and of a generic nature and can, therefore, be extended to other settings as well (eg, to allocate older adults to home care or daycare). Finally, this research shows the potential of mathematical models in the care domain for older adults to face the increasing need for cost-effective solutions.

Inadequate access to nursing homes caused by long waiting times on a national or regional level is a problem many countries face (eg, Australia, Canada, South Africa, and the Netherlands).[1–4] A report on long-term care by the European Commission reveals the urgency of the matter by presenting high fractions of older people in need of institutional care who are currently on a waiting list (eg, 30% in Slovakia and 47% in Lithuania).[5] Moreover, 16% of older adults in Spain who are waiting for a place in a nursing home die before they are

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admitted.[5] Regional shortages might even lead to more alarming situations. In Copenhagen, the waiting time for a bed in a nursing home is over 3.5 years.[5]

The excessive waiting times lead to anxiety of older adults and a burden on informal caregivers.[6,7] Next to this unwanted affliction, delayed admissions also lead to high costs for the healthcare system, as older adults often wait at expensive hospital beds or older adults at home are injured because of the lack of proper care.[8,9] The current waiting time problem is expected to become even more prominent in the future caused by the aging population.

The most common (and costly) approach to reduce waiting times is to increase facility capacity, while the alternative to improve the waiting-list management is often not considered. An approach for this is to use mathematical modeling, which has shown to be effective in the health context, such as for patient scheduling[10] or emergency department planning,[11] but little research has been conducted specifically on waiting-list management in the care for older adults setting.[12] However, in a recent study by Arntzen et al, a mathematical allocation model was developed that allocates older adults-in-need to nursing homes.[13] The researchers found that by applying the allocation model, the waiting times for older adults were reduced, whereas at the same time their personal preferences were served better.

In this article, we aim to extend the research by Arntzen et al by addressing the allocation model from a practical perspective.[13] The allocation model is preference-centered and, therefore, a crucial aspect is to make sure the individual preferences are correctly obtained. We test the allocation model using preference profiles on 2 real-life case studies. Hence, the following research questions are answered in this article: (1) How can the allocation model be implemented in practice? and (2) How does the allocation model perform regarding the different preference profiles?

Methods

We first summarize the background of the study, then describe the allocation model and discuss aspects of the implementation in practice. More information about the (mathematical) set-up of the model is described in Arntzen et al.[13]

Context and Data

In this research, we focused on 2 different regions in The Netherlands: Rotterdam, a densely populated city region, and Twente, a rural area. The locations of the nursing homes were obtained from the website www.zorgkaartnederland.nl, which is an open database containing all nursing homes in the Netherlands. An extra check for address and care provided was done by inspection of the nursing homes' websites. Data on access requests for nursing homes and length-of-stays were obtained by nonpublic microdata from Statistics Netherlands. The data that were used as input for the model are summarized in Supplementary Material 1.

For both Rotterdam and Twente, a map is presented in Figure 1, where each triangle represents a nursing home in which older adults in need of somatic care reside. Rotterdam is an urban area with many nursing homes (39 in total) over a small area. In contrast, Twente is a rural region in which nursing homes (62 in total) are spread out over the entire geographic area. Public data by Statistics Netherlands indicate that both regions have approximately 600,000 inhabitants, whereas Twente region is approximately 5 times larger.

We found that the current waiting list procedure for the 2 regions is that each nursing home manages its own waiting list (ie, almost no regional coordination on waiting-line management is performed).[14] Moreover, the current policy, henceforth denoted as the current practice policy, is that each older adult can apply for 1 nursing home.[14] However, if the waiting time is overlong (set to 6 months) and a decrease in functional capacity takes place, the older adult is placed as soon as possible in any nursing home that is available within an acceptable region.

Model Description

An alternative for the current practice policy is the proposed allocation model. The mathematical technique used is linear programming; more details about the model us described in Arntzen et al.[13] In the allocation model, for each older adult, the 'willingness' to be placed in a specific nursing home is included. The model then finds an allocation of older adults to nursing homes such that the total 'sum' of willingness is maximized. In this article, the focus lies on the practical perspective, therefore, here only the needed input is described such that the preferred output can be obtained.

Model Input

For the implementation of the allocation model, we selected the following input elements for the 2 regions: (1) Older adult population. The older adult population needs to be selected in such a way that all older adults require the same type of care in a nursing home, in order to make sure that the specified beds in the nursing homes can be used interchangeably by the older adults. The population selected in this article is 'older adults in need of a somatic long-term care nursing home bed' within the specified region. (2) Nursing homes. The nursing homes are all nursing homes in the same region with beds available for the selected older adults' population, thus all nursing homes with somatic departments. (3) Capacities. The capacity of a nursing home is the number of beds that is available in the nursing home for the selected older adults. Hence, the capacities in the model were the number of somatic nursing home beds.

Moreover, for each older adult, a preference profile is required. To select these profiles, we need to illuminate the distinction in the model between preferred nursing homes and temporary nursing homes. The preferred nursing homes are the nursing homes in which the older adult wants to reside permanently, while the temporary nursing homes are used as temporary location where an older adult can stay until a bed is available in a preferred nursing home. Now the selected preference profiles can be described, which for simplicity reasons we kept to a limited number of four.

The preference profiles were defined in the following way. We first specified the flexibility of the older adults: namely, we defined that older adults may select 1 or 2 preferred nursing homes. The more preferred nursing homes, the more flexibility the older adult offers, which leads to a shorter (average) waiting time. Moreover, for the waiting time preference, we formulated 2 options as well: the type of older adults who want a fast placement and the type of older adults who want a preferred placement. The type fast placement wants to be placed as fast as possible in a (temporary) nursing home because the older adult's situation at home is unlivable (eg, acute care patients). On the other hand, the type preferred placement only wants to be placed in a nursing home that is one of the preferred nursing homes, and otherwise prefers to stay at home. After selecting both the flexibility number of preferred nursing homes and the waiting time preferences, the 4 preference profiles were obtained, as provided in Table 1.

Model Output

The output of the model is the decision which older adults are allocated to which nursing homes and which older adults still need to wait at home. The quality of the output decisions of the allocation model was evaluated in a simulation setting, for which we selected 5 outcome measures: (1) Mean waiting time until placement. The

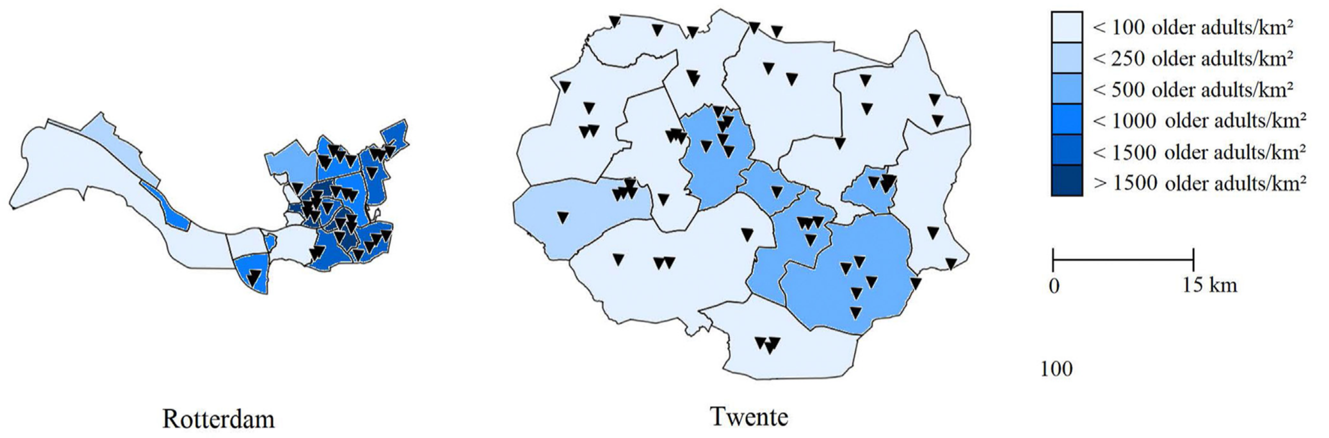

Fig. 1. Focus regions with nursing homes and density of older adults (60+ years).

average time duration of an older adult waiting at home until placement in a nursing home. (2) Mean waiting time until placement in a preferred nursing home. The average time duration of an older adult waiting (at home or in a temporary nursing home) until placement in a preferred nursing home. (3) Fraction of older adults that depart the system from home. (4) Fraction of older adults that depart the system from a temporary nursing home. (5) Fraction of older adults that depart the system from a preferred nursing home.

We defined that for the best performance of our model, we aim for short waiting times (outcome measures 1 and 2). Moreover, we want outcome measure 3 to be low because most older adults were admitted to a nursing home, and outcome measure 5 to be high, such that more older adults ended up in the nursing home of their desire. More of the older adults in a temporary nursing home (outcome measure 4) are favored over adults at home, although it is preferred that older adults end up at their preferred nursing home.

To evaluate the allocation model and the current practice model in terms of the outcome measures, a simulation study was performed. This was done for the Rotterdam and Twente regions. More information about the simulation procedures is described in Arntzen et al.[13]

Results are given in total days, calculated in means and confidence intervals. The 95% confidence intervals indicate the probabilistic bounds on the statistics (ie, if 2 values show nonoverlapping confidence intervals, the statistics are significantly different).[15]

Implementation in Practice

In addition to evaluating the allocation model by simulation, we formulated guidelines for the implementation of the allocation model in practice. For this purpose, we identified the 3 stakeholders that are involved, namely a placement office, older adults, and the nursing home logistic managers. We describe here the needs and requirements of all stakeholders to describe the use of the allocation model in practice.

First, a placement office needs to be set up or an existing institution must be appointed to take on this role. This office should organize the placement of older adults in nursing homes for the surrounding region. The placement office must have a digital infrastructure that stores older adult applications and nursing home capacities, and uses this as input for the allocation model. The placement office runs the allocation model at specified times (eg, every morning). Then, the placement office needs to inform the older adults and the logistic managers about the relocations that are the outcomes of the allocation model.

The next stakeholders are the logistic managers that are currently involved with monitoring the waiting lists of their nursing homes. After implementation of the allocation model, this task is transferred to the placement office. The new task of the logistic managers is to provide the placement office with real-time data about the capacities (ie, free beds and temporarily placed older adults), such that the allocation input remains up-to-date.

Finally, the older adults need to express their preferences for nursing homes to the placement office. For that purpose, the older adults need to fill in a, preferably digital, preferences form, as provided in Figure 2. An older adult can choose whether to be placed as fast as possible in a temporary nursing home, which is in expected 2 days in the example, or wants to wait at home. Moreover, the older adult can select how many and which nursing homes are chosen as preferred ones, and subsequently the expected waiting times are displayed automatically. When these projected waiting times are too long, the older adult may reconsider preferences (ie, be more flexible) to obtain lower waiting times. This way, the older adult can interact with the system until the older adult is satisfied with the outcome.

Results

The outcomes of the simulation studies are displayed in Table 2, where each output column corresponds to one of the selected outcome measures. We only report differences between values for which the 95% confidence intervals are nonoverlapping.

Table 1
Explanation Preference Profiles

Abbreviations	Preference Profile	Explanation
FP1	Fast placement 1	Older adult wants to be placed fast in a nursing home and has 1 preferred nursing home
PP1	Preferred placement 1	Older adult wants to be placed in a preferred nursing home and has 1 preferred nursing home
FP2	Fast placement 2	Older adult wants to be placed fast in a nursing home and has 2 preferred nursing homes
PP2	Preferred placement 2	Older adult wants to be placed in a preferred nursing home and has 2 preferred nursing homes

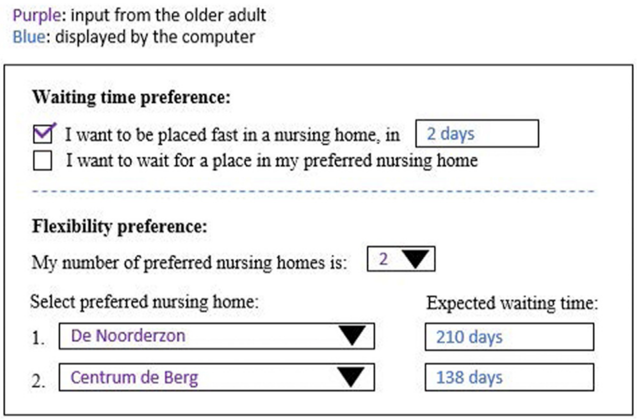

Fig. 2. Example digital preferences form.

The allocation model outperforms the current practice policy for all output measures (Table 2). First, the average waiting times show improvements (eg, for Twente both the waiting time until placement and until preferred placement is reduced when the allocation model is used from 178 and 637 days to 82 and 256 days). Next to that, more of the older adults eventually enter their preferred nursing home; for example, in Rotterdam this is 33.5% for the current practice policy and 49.3% for the allocation model. Hence, the results show that for both a rural region and an urban region, the allocation model is capable of increasing the efficiency in the system compared with the current practice.

Waiting times of the different preference profiles are explained in Table 1. Fast placement preference profiles are placed within 1 day in a nursing home (Table 3), which is in line with their preferences. Moreover, the quick placement is at the cost of obtaining a bed in a preferred nursing home because the waiting time for a preferred placement is rather long. In contrast, the preferred placement profiles wait on average at least 4 months for a placement in a nursing home, but are placed faster into the nursing home of their preference. If an older adult chooses a preferred placement profile, the chance that this older adult ends up in a preferred nursing home is over 70% in Rotterdam and over 50% in Twente, which is above the current practice fractions of 33.5% and 22.1%, respectively (Table 2).

Furthermore, the profiles with 2 preference nursing homes are placed faster in preferred nursing homes than the profiles that selected one preferred nursing home. For example, for Twente, preferred placement 1 is placed in 9 months (270 days) in a preferred nursing home, which reduces to 6 months (177 days) for preferred placement 2.

Discussion

We discussed how the allocation model developed by Arntzen et al can be implemented in practice using preference profiles.[13] The performance of the allocation model was evaluated using simulation in 2 real-life case studies in the Netherlands: an urban area (Rotterdam) and a rural area (Twente). In comparison with the current practice policy, the allocation model reduced the waiting times until placement by at least a factor of 2 (from 166 to 80 days in Rotterdam and 178 to 82 days in Twente). Moreover, the preferences of the older adults were also better retained: more of the older adults ended up in the nursing home of their desire and older adults that wanted to be placed fast were able to be placed within 1 day. Hence, these results show that the allocation model improved the waiting process in both efficiency and individual preferences.

Despite the promising results, with the implementation of the allocation model there is also organizational challenges and costs involved. As discussed in this article, regional collaboration is needed between a newly set-up placement office and the nursing homes. Moreover, the digital infrastructure for the database containing the available capacities and preferences must be developed, which is likely to be costly. Thus, because of the innovative nature of the allocation model, for the implementation an investment in both time and costs is required.

Besides the practical potential of the model, the allocation model presented in this article adds greater depth to the currently existing research on long-term care waiting-list management. A meta-review of waiting-list management specifically for the long-term care by Chafe et al showed that the majority of research on waiting-list management is focused on the organization of the waiting process (ie, how waiting older adults can be taken care of).[12] Little research has been performed on the organization of the waiting list (ie, what older adult should be placed where), as a meta-analysis only report two studies on that topic.[12] Both those studies are about altering the priority setting from first-come-first-served to a needs-based criterion, so no mathematical model was involved.[16,17] In the light of that background, the allocation model based on preference profiles is a new concept in the geriatrics domain.

The care domain for older adults offers a wide spectrum of problems that can be improved or optimized by mathematical models. For example, studies have been conducted on optimal staffing strategies in nursing homes, shortest routes for staff members in home care services, and treatment scheduling for rehabilitation patients.[18–20] However, compared with mathematical research applied to other health care areas, such as the emergency departments or surgery planning, an unbalanced small fraction of research is devoted to long-term care.[21] Therefore, this research also contributes by broadening the scope of mathematics in the care for older adults setting.

Conclusions and Implications

The simulation studies showed that the allocation model is a useful tool for reducing waiting times in care for older adults. These reduced waiting times without access to appropriate care can lead to reduced incidents.[9] Especially when an incident leads to hospitalization, high costs and hospitalization-associated disabilities are involved.[22] Therefore, the allocation model not only provides a solution for a reduction of waiting times directly (and the direct consequences such as reduced

Table 2
Allocation Model Compared to Current Practice Policy

Region	Policy	Mean Waiting Time (d) until		Fraction of Older Adults Who Depart System from		
		Placement	Preferred Placement	Home	Temporary Nursing Home	Preferred Nursing Home
Rotterdam	Current practice	166 (162–169)	544 (431–657)	22.7% (20.5%–24.9%)	43.8 (40.7%–46.9%)	33.5 (30.8%–36.1%)
	Allocation model	80 (75–85)	315 (285–345)	11.9% (10.8%–13.1%)	38.8% (37.9%–39.6%)	49.3% (47.4%–51.3%)
Twente	Current practice	178 (175–181)	637 (435–840)	26.6% (22.0%–31.2%)	51.3% (46.1%–56.5%)	22.1% (19.9%–24.3%)
	Allocation model	82 (66–98)	265 (189–341)	19.3% (17.4%–21.2%)	42.3% (40.9%–43.6%)	38.3% (35.3%–41.3%)

The values in parentheses are the 95% confidence intervals.

Table 3
Preference Profiles Compared

Regions	Preferred Profile	Mean Waiting Time (d) until		Fraction of Older Adults that Depart System from		
		Placement	Preferred Placement	Home	Temporary Nursing Home	Preferred Nursing Home
Rotterdam	FP1	0 (0–1)	515 (458–572)	0% (0%–0%)	80.7% (79.0%–82.5%)	19.2% (17.4%–21.0%)
	PP1	179 (167–191)	179 (167–191)	26.6% (24.7%–28.7%)	0% (0%–0%)	73.4% (71.3%–75.5%)
	FP2	1 (0–1)	425 (382–469)	0% (0%–0%)	74.5% (72.5%–76.5%)	25.5% (24.2%–26.8%)
	PP2	140 (132–148)	140 (132–148)	20.9% (18.6%–23.3%)	0% (0%–0%)	79.1% (76.7%–81.4%)
Twente	FP1	0 (0–1)	418 (244–592)	0% (0%–0%)	88.5% (85.6%–91.4%)	11.5% (9.4%–13.6%)
	PP1	270 (208–332)	270 (208–332)	46.2% (42.1%–50.3%)	0% (0%–0%)	53.8% (50.7%–56.9%)
	FP2	1 (0–1)	386 (243–529)	0% (0%–0%)	80.9% (78.2%–83.6%)	18.9% (15.7%–22.1%)
	PP2	177 (136–218)	177 (136–218)	30.8% (28.1%–33.5%)	0% (0%–0%)	69.2% (65.3%–73.1%)

The values in parentheses are the 95% confidence intervals.
FP, fast placement with 1 or 2 preferred nursing homes; PP, preferred placement with 1 or 2 preferred nursing homes.

anxiety of older adults),[6] the allocation model might indirectly reduce demand for care in a broader sense as well.

The allocation model also offers opportunities other than allocating older adults to nursing homes. Namely, other areas in which a scarcity of supply exists may benefit also from the model, such as assigning older adults to home care or daycare. This is, however, slightly more complicated because capacity is not defined as the number of beds, but as available hours per day. Hence, if the allocation model is extended to include this type of capacity as well, the allocation model can be used in other contexts within the care domain for older adults.

Finally, this research reveals the potential of mathematical models in the care domain for older adults. We have shown that mathematical models can be preference-centered and, thus, not solely focused on efficiency at the expense of customization. As far as we are concerned, correctly developed mathematical models increase the cost-effectiveness of care and are indispensable in retaining the care for older adult expenses at acceptable level. Therefore, we suggest that future research focuses on developing logistically efficient solutions that are easy to implement to contribute to solving the enormous puzzle regarding the aging of the population.

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Supplementary Material 1. Input values

The interpretation of the input parameters can be found in Arntzen et al.[13] For completeness, we provide the values that were used in the study. Supplementary Figure 1 contains the data for Rotterdam and Supplementary Figure 2 the data for Twente.

Parameter	Value	Parameter	Value
$\lvert N \rvert$	39	$v_p^U(w_p)$	$\begin{cases} 0.1w_p & \forall\ p \in P^{FP1} \\ 0.1w_p - 11000 & \forall\ p \in P^{PP1} \\ w_p & \forall\ p \in P^{FP2} \\ w_p - 11000 & \forall\ p \in P^{PP2} \end{cases}$
λ^{-1}	1.11/day		
θ^{-1}	666 days ($\approx$ 2 years)		
μ^{-1}	666 days ($\approx$ 2 years)		
M	1000	$v_p^F(w_p)$	$\begin{cases} 0.1w_p & \forall\ p \in P^{FP1} \cup P^{FP2} \\ w_p & \forall\ p \in P^{PP1} \cup P^{PP2} \end{cases}$
Δ	1 day		
g_{pn}	$\begin{cases} 100 & \text{if dist}_{pn} \leq 10 \\ 50 & \text{if } 10 < \text{dist}_{pn} \leq 20 \\ 10 & \text{else} \end{cases}$	c_n	Initial values: 50% 23 and 50% 24

Supplementary Fig. 1. Input values Rotterdam.

Parameter	Value	Parameter	Value
$\lvert N \rvert$	62	$v_p^U(w_p)$	$\begin{cases} 0.1w_p & \forall\ p \in P^{FP1} \\ 0.1w_p - 11000 & \forall\ p \in P^{PP1} \\ 5w_p & \forall\ p \in P^{FP2} \\ 5w_p - 11000 & \forall\ p \in P^{PP2} \end{cases}$
λ^{-1}	1.46/day		
θ^{-1}	666 days ($\approx$ 2 years)		
μ^{-1}	666 days ($\approx$ 2 years)		
M	1000	$v_p^F(w_p)$	$\begin{cases} 0.1w_p & \forall\ p \in P^{FP1} \cup P^{FP2} \\ 5w_p & \forall\ p \in P^{PP1} \cup P^{PP2} \end{cases}$
Δ	1 day		
g_{pn}	$\begin{cases} 100 & \text{if dist}_{pn} \leq 20 \\ 50 & \text{if } 20 < \text{dist}_{pn} \leq 30 \\ 10 & \text{else} \end{cases}$	c_n	Initial values: 50% 15 and 50% 16

Supplementary Fig. 2. Input Values Twente.