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RESEARCH PAPER

A Hybrid Approach for Home Health Care Routing and Scheduling Using an Agent-Based Model

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Abstract

Home health care systems, as a growing economic system in the field of health systems, face various problems and issues such as routing, scheduling and allocation. Given that a growing number of home health care workers in health care systems around the world tend to work for themselves instead of hospitals or other health care institutions. As a result, centralized and one-factor models are not responsible for solving these problems. Therefore, this paper focuses on situations by designing an agent-based planning system that is simulated in a decentralized environment and using the Fuzzy C-Means clustering algorithm and the repetitive suggestion mechanism (Vickery) as a negotiation protocol focuses on situations that a home health care agency needs to schedule a home visit among a group of independent physicians. The goal of the home health care agency is to minimize the overall cost of the service by covering all patients by qualified physicians. The results of the implementation of the proposed algorithm for real geographical data in the city of Tehran in GAMS show that this framework achieves a high efficiency of optimal solutions.

Keywords:
Agent Based Model;
Home Health Care;
Decentralized;
Fuzzy C-Means;
Iterative Bidding;
Routing;
Scheduling

Introduction

Home health care plays a very important role in the health care system. With changes in population and urbanization, the demand for home health care has increased. Also, reducing the birth rate and improving health care will increase the elderly population. Due to the increasing globalization of young people's desire to move and employment status, they are not allowed to provide care services to their relatives. Therefore, it can be imagined that there is a growing trend in demand for home care services. Ensuring the sustainability of health care systems by focusing on human needs and wants is, therefore, a major challenge. The overall goal is to ensure the provision of quality health care services, economic stability and at the same time respecting the preferences of employees (type of skill, time window, etc.). Traditional methods cover only the scheduling and routing of caregivers in a centralized environment. Although significant efforts have been made to address the challenges of home health care planning, only a handful of researchers have proposed solutions that consider a decentralized environment with independent physicians. The purpose of this study is to develop an agent-based scheduling system to support cost reduction in home health care by assigning cost-effective schedules to practitioners. Our contribution is the design of a decentralized scheduling algorithm by considering routing, scheduling and allocation for 20 areas in Tehran city, implemented by a bidding mechanism. This also serves as the negotiation protocol of an agent-

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based system, enabling both the agency and the practitioner to construct efficient home visit schedules through an automated multilateral negotiation. We also present decision-making tools for both agencies and practitioners in the system.

The organization of this study is as follows: Section 2 presents a literature review. Section 3 presents the definition of the problem. Section 4 presents the research method and mathematical modeling and Section 5 presents the case study used in this research and solving. Finally, in Section 6 conclusions and suggestions for future research are presented.

Literature review

Castelnovo et al. [1] provide an agent-based system (ABS) simulation framework in which different actors interact in home care processes and used the contract network protocol to model the distribution of work between agents in a case study of the Italian home care program for evaluation. Itabashi et al. [2] developed a multi-agent system to support home care services with the goal of reducing overall service costs as a care schedule for handling current requests effectively. In this process, the decision for the care program is made independently through negotiation among the representatives according to the patient's time priorities and the individual skills of the caregivers. It also provides an example with artificial data and implementation in JADE software to illustrate the feasibility of this approach.

López et al. [3] proposed a multifactorial approach using a mixed-integer programming model for caregiver planning and routing in a home health system that can be used to simulate dynamic routing problems. This method is implemented for only one area with fixed travel time in the software (JADE) that works for only a small number of patients (less than 15). And it needs exploratory methods to solve problems on a larger scale. In the approach presented by Mohammadi et al. [4], the problem of planning and routing is solved by a central unit using extensive coverage mechanisms. To demonstrate the feasibility of the proposed algorithm, the authors have implemented a model to reduce the number of required therapists in two scenarios consisting of 10 different parameters in MATLAB software. Mutingi et al. [5] proposed a framework for developing multifactorial systems for scheduling home health care personnel and assignment decisions when management goals, staff priorities, and physician priorities are conflicting.

As a result, it creates a decision-making platform, in which information is incorrect and dynamic, in-home health care. In another study, Stojanova et al. [6] proposed a factor-based approach that focuses solely on planning, regardless of the routing problem. The resulting simulation in the software (Any logic) is presented briefly without experiments and produced results. Becker et al. [7] proposed an agent-based planning and scheduling algorithm in which agents with different competencies to improve operational processes to meet the needs and wants of patients with limited resources and specialists and the challenges of using limited resources in the field of home health care. Becker et al. [8] showed that increasing productivity and improving the use of limited resources can increase coordination between factors, as well as the fact that scheduling issues in the field of home health care have a distributive structure among participants, provides a framework for operational management processes in terms of planning and scheduling by agent-based systems and decision support systems. Hamdani et al. [9] have proposed a multifactorial system framework for multi-organizational planning issues, in particular, human resource planning management and the optimization of multiple home treatment structures. Widmer et al. [10] used an auction protocol to optimally assign caregivers to patients with the goal of maximizing social well-being by adopting the time required for each service, the skills of each caregiver, and the priority of the service. Finally, it developed a scenario-based evaluation during an auction using the Development Kit (JADE) without a proprietary software framework for agent-based approaches. Xie and Wang [11] developed a multi-agent system (MAS) that is an iterative routine for negotiating home health programs between the two agents of the home care agency and physicians. In this study, without considering the routing of caregivers and by covering time windows, caregivers 'skills, and customers' priorities seeks to reduce the cost of services. It then compares the experimental results with the solution of the optimal problem generated by the optimization software (ILOG CPLEX) without presenting the model implementation.

Xie and Wang [12] also proposed a plan to generate and evaluate a home health plan using a repair algorithm. And for the possible approach, they have used software (Any Logic) for implementation. The use of auctions and bidding mechanisms in the field of home care planning is a relatively new research approach. Whereas previous home care research using factor-based approaches rarely included economic models. Bajo et al. [13] developed multi-factor systems built from digital architecture, which included service facilitators for the organization's management system and the platform core. This architecture is used in the field of home care and home patient monitoring. There are four types of home care providers: patient, physician, family, and service provider. In this model, entities in different roles communicate with each other based on complex automated reasoning and programming mechanisms. Because home care operations require effective communication in a distributed environment, Bajo et al. [13] suggested that agent-oriented methods provide better interactive mechanisms for modeling securely distributed systems, taking into account social and organizational considerations. The proposed solution focuses more on improving the information system than scheduling resources. Table 1 summarizes the information related to the articles and in the last line of the table, the information related to this research can be seen.

State of the problem

In this case, a completely decentralized environment is considered, in which the two agents of physicians (service providers who have sufficient independence to control their programs) and the health care agency, communicate through auctions to achieve their goals. Each doctor has different costs to cover a program (visit package) based on working time, travel costs and even client preferences. A specific schedule may not be possible for a physician on a specific day due to scheduled conflicts. The main tasks of the agency include collecting visit requests and information (address, time window of service, type of service received) from the customer and classifying them using the Fuzzy C-Means (FCM) clustering algorithm to separate input data into different regions. It also integrates data based on skills in a cluster according to geographical coordinates and sends information to physicians. After receiving the recommended programs from physicians based on a profit-based vehicle routing problem with soft time windows (VRPSTW), the input information was obtained. Schedule patient visits to meet the physician and patient time constraints and cover all appointments with appropriate physicians while minimizing overall costs. The conceptual diagram of the research method is shown in Fig. 1.

Table 1. summary of studies in home health care

Reference	Approach					Agent	User			Input data		Software
	Negotiation	Routing	Allocation	Scheduling	Clustering		Healthcare	Therapist	HHC service provider	Case study	Synthetic data	
Castelnovo et al. [1]	-	-	-	-	-	Assumption: participants of a proposed home care reference model	-	-	✓	✓	-	Arena
Itabashi et al. [2]	✓	-	-	✓	-	interface, schedule, helper	-	-	✓	-	✓	JADE
López-Santana et al. [3]	-	✓	-	✓	-	Patients, organizer, coordinator, caregiver	-	-	✓	-	✓	JADE
Mohammadi et al. [4]	-	✓	-	✓	-	Patient, therapist, hospital	-	-	✓	-	✓	MATLAB
Mutingi et al. [5]	-	-	-	✓	-	Manager, patient, nurse, supervisor, resource, scheduler	-	-	✓	-	-	-
Stojanova et al. [6]	-	-	-	✓	-	Patient, caregiver	-	-	✓	-	-	AnyLogic
Becker et al. [7]	-	-	-	✓	-	cooperative agents	-	✓	-	✓	-	-
Becker et al. [8]	-	-	-	✓	-	cooperative agents	-	✓	-	✓	-	-
Hamdani et al. [9]	✓	-	-	✓	-	Patients, planning agent, coordinator	✓	-	-	-	✓	JADE
Widmer et al. [10]	✓	-	✓	-	-	Patient, caregiver, auctioneer	-	-	✓	-	-	JDK
Xie et al. [11]	✓	-	-	✓	-	Practitioner, healthcare agency	✓	-	-	-	-	AnyLogic
Xie et al. [12]	✓	-	-	✓	-	Practitioner, healthcare agency	-	-	✓	-	-	AnyLogic
Bajo et al. [13]	-	-	-	-	-	provide services, Patient	-	-	✓	✓	-	-
This paper	✓	✓	✓	✓	✓	Practitioner, healthcare agency	✓	-	✓	✓	-	Gams

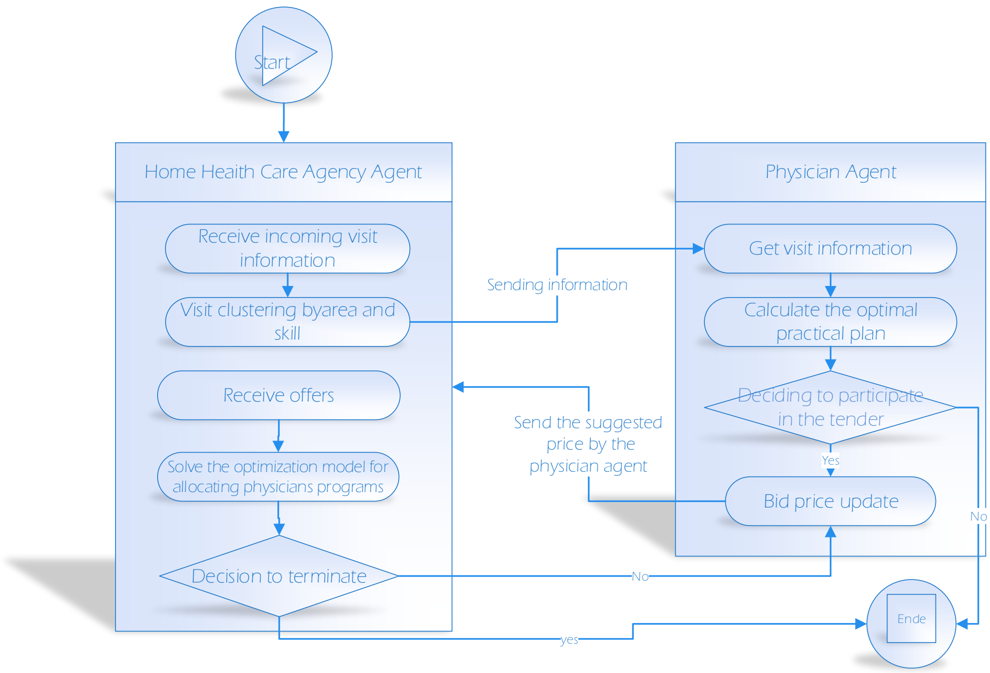

Fig. 1. Conceptual diagram of the Performed Research Method

Research Method

Clustering with Fuzzy C-Means Algorithm

Fuzzy C-Means (FCM) is an algorithm for clustering a set of data softly or indefinitely in such a way that, like the hard case of this algorithm, a cost function is minimized from the criterion of dissimilarity. In clustering using this algorithm, each point can belong to more than one cluster with different degrees of membership. In fact, in this algorithm, the goal is to group the data set as n dimensions of the next p vector x_k (k = 1, …, n) inside the c cluster or group G_i (i = 1,…, c). The number of clusters (c) is predetermined. Cost function in FCM algorithm as relation (1), The degree of belonging of each data to all clusters in Eq. 2 and the update of the center of each cluster vi and the u_{ij} membership function are shown in Eqs. 3 and 4, respectively [14, 15].

$$E(U,V) = \sum_{i=1}^{k} \sum_{j=1}^{n} (u_{ij})^m \|\bar{x}_j - \bar{v}_i\|^2 \tag{1}$$

$$\sum_{i=1}^{k} u_{ij} = 1 , \quad \forall j = 1, \dots, n \tag{2}$$

$$u_{ij} = \frac{1}{(\frac{\|\bar{\bar{x}}_j - \bar{v}_i\|}{\|x_j - v_L\|})^{\frac{2}{m-1}}} \tag{3}$$

$$v_i = \frac{\sum_{j=1}^{n} (u_{ij})^{m \overline{x_j}}}{\sum_{j=1}^{n} (u_{ij})^m} \tag{4}$$

Fuzzy C-Means has been used as the primary category in this study. Incoming visits are clustered based on geographical coordinates, where each cluster represents a region of Tehran, and then, based on the type of service requested, each cluster is divided into sub-clusters that indicate the type of service received.

Physician's Decision

At this stage, physicians receive visit information, previously categorized by the agency with the Fuzzy C-Means clustering algorithm, and other information such as service time window and maximum payment through a call from the health care agency. And then with the help of the mathematical model of vehicle routing problem with soft time windows (VRPSTW), they get the best possible programs with the most profit, which is in accordance with their skills and working hours. In calculating such a plan, Physician j solves a maximization problem, obtains a set of programs with a maximum refund, and then sends a set of maximum refund programs at the bid price to the Agency for bidding.

Parameters and Assumptions

- Patients have a time window to receive services.
- Doctors have specific and different working hours.
- Every doctor has one or more skills.
- Doctors have a unique fee for each visit, which is known only to themselves.
- It is possible to perform the service outside the patient's time window by imposing a fine.
- Each visit has a unique benefit.

Sets:
v = {s, 1, 2, …, n, e}: A set of nodes where s = e represents the node of the physician's home.

Input parameters:
t_{ij}: Travel time between node i and node j
$[l_i, e_i]$: Time window for receiving services for the patient i
[A, B]: Physician working hours
$[LB_i, UB_i]$: Soft time window for patient i
P: The amount of profit from each visit
Pe: Penalty for a service delay unit
Pl: Penalty for an expedited service unit
M: Large constant
Decision variables:

$$x_{ij}: \begin{cases} 1 & \text{If the path i to j is selected} \\ 0 & \text{Otherwise} \end{cases}$$

$$y_j: \begin{cases} 1 & \text{If we see the vertex v} \\ 0 & \text{Otherwise} \end{cases}$$

T_i: Time to reach node i
Ye_i: The amount of delay in starting the service
Yl_i: The amount of time the service starts earlier.
4.2.1 The model formulation

In this section, the mathematical model of vehicle routing problem with soft time windows (VRPSTW) is presented. the aim of the section is maximizing profits to facilitate physicians decisions.

$$\max \ \sum_{i\in\backslash\{s,e\}} py_i - \sum_{i\in\backslash\{s,e\}} (pe * Ye_i + pl * Yl_i) \quad (5)$$

$$\sum_j x_{sj} = 1 \quad (6)$$

$$\sum_i x_{ie} = 1 \quad (7)$$

$$\sum_i x_{ij} \leq 1 \qquad \forall\, j \in v\backslash\{s,e\} \quad (8)$$

$$\sum_j x_{ij} \leq 1 \qquad \forall\, i \in v\backslash\{s,e\} \quad (9)$$

$$\sum_i x_{ij} - \sum_i x_{ji} = 0 \qquad \forall\, j \in v\backslash\{s,e\} \quad (10)$$

$$\sum_i x_{ij} = y_j \qquad \forall\, j \in v\backslash\{s\} \quad (11)$$

$$T_i \leq UB_i \qquad \forall\, j \in v\backslash\{s,e\} \quad (12)$$

$$T_i \geq LB_i \qquad \forall\, j \in v\backslash\{s,e\} \quad (13)$$

$$Ye_i \geq T_i - e_i \qquad \forall i \in v \quad (14)$$

$$YL_i \geq l_i - T_i \qquad \forall i \in v \quad (15)$$

$$T_i + \ t_{ij} \leq T_j + M\left(1 - x_{ij}\right) \qquad \forall\, (i,j) \in v \quad (16)$$

$$T_0 \geq A \quad (17)$$

$$T_i + t_{ie} - M(1 - x_{ie}) \leq B \qquad \forall\, i \in v \quad (18)$$

$$x_{ij} \in \{0,1\} \qquad \forall (i,j) \in v \quad (19)$$

$$y_j \in \{0,1\} \qquad \forall j \in v \tag{20}$$

In this model, Eq. 5 seeks to maximize the profits by increasing coverage and minimizing the total cost of fines resulting from non-compliance with the patient time window. Eqs. 6 and 7 indicate that the beginning and end of the path to the doctor's home. Eqs. 8 and 9 ensure that each visit is completed at most once. Eq. 10 shows the equilibrium constraint. Eq. 11 expresses the relationship between the variable y_i and x_{ij}. Eqs. 12 and 13 represent a soft time window for the patient that ensures that the physician does not see the patient outside this interval. Relationships (14) and (15) show the degree of delay and urgency of the appointment from the patient's difficult time window. Eq. 16 ensures that visit j cannot be met before the time of $T_i + t_{ij}$ if traveling between visit i to visit j. Relationships (17) and (18) guarantee compliance with the physician's working hours. And Eqs. 19 and 20 specify the decision variable.

Decision of the Health Care Agency

At this stage, after receiving the programs and costs offered by the doctors, the bids are submitted to the tender and with the help of a mathematical model that seeks to minimize costs to the satisfaction of patients and decides on how to allocate programs to physicians. If the desired result is achieved by the health care agency, the tender will end; Otherwise, it enters the second stage of the tender. The agency will resubmit the results to the physicians and the physicians will submit their new recommendations. We assume that in the home care agency decision-making process, support physicians are always willing to visit at a standard price, meaning that the home care agency can schedule a supporting physician to visit at any time. It then examines the termination clause against valid bids that meet the following conditions in determining the winner:

Parameters and assumptions

- In case of temporary allocation of a program in round t-1, the doctor must offer a price equal to or one ε less than the previous round for this program.
- If the doctor has a price offer for a program that was temporarily assigned to another doctor in the previous round, he must offer a price equal to or less than the previous round for this program.
- In case of a proposal for a program that is not assigned to any physician, the proposed price can be less than or equal to the standard price of the program.

Sets:

N_t: A group of doctors who have participated in each round of bidding.

V: A set of scheduled visit categories.

Index:

i: Indicates visits

t: Indicates the round of auctions

Parameters:

p_{jvt}: The cost of a visit v by a doctor j in the Tth round of the auction.

SP_i: High payment limit set for i visit by the agency.

$$L_v = \sum_{i \in v} sp_i \quad \forall v$$

$$k_{vi}: \begin{cases} 1 & \text{If the visit i is in category v} \\ 0 & \text{Otherwise} \end{cases}$$

Decision variables:

X_{jvt}: $\begin{cases} 1 & \text{If category v is assigned to doctor j in round t} \\ 0 & \text{Otherwise} \end{cases}$

e_{jt}: $\begin{cases} 1 & \text{If doctor j offers a price equal to the previous round} \\ 0 & \text{Otherwise} \end{cases}$

f_{vt}: $\begin{cases} 1 & \text{If category v is temporarily assigned before} \\ 0 & \text{Otherwise} \end{cases}$

A_{vt}: The lowest price of category v allocated during the Tth round of auctions.

y_i: The price of the visit i if provided by the supporting physicians.

The model formulation

In this section, the mathematical model is presented with the aim of minimizing costs to facilitate health care agency decision Making.

$$\min \sum_{j \in N_t} x_{jvt} p_{jvt} + \sum_i y_i \tag{20}$$

S.t

$$\sum_{j \in N_t} x_{jvt} \leq 1 \qquad \forall v, t \tag{21}$$

$$\sum_v x_{jvt} = 1 \qquad \forall j \in N_t, t \tag{22}$$

$$x_{jvt} p_{jvt} \leq L_v \qquad \forall j \in N_t, t = 1, v \tag{23}$$

$$x_{jvt} p_{jvt} \leq \left[\left[e_{jt} p_{jvt-1} + (1 - e_{jt})(p_{jvt-1} - \varepsilon) \right] x_{jvt-1} + A_{vt}(1 - x_{jvt-1}) \right] + M(1 - f_{vt-1}) \qquad \forall j \in N_t, t > 1 \tag{24}$$

$$A_{vt} \leq \sum_j x_{jvt-1} p_{jvt-1} \qquad \forall v, t > 1 \tag{25}$$

$$x_{jvt} p_{jvt} \leq L_v + M f_{vt-1} \qquad \forall j \in N_t, t > 1, v \tag{26}$$

$$\sum_v \sum_j k_{vi} x_{jvt} = 1 \qquad \forall i \tag{27}$$

$$Sp_i \leq y_i + M \sum_j \sum_v k_{vi} x_{jvt} \qquad \forall i, t \tag{28}$$

$$e_{jt} \in \{0,1\} \qquad \forall j \in N_t, t \tag{29}$$

$$x_{jvt} \in \{0,1\} \qquad \forall j \in N_t, t, v \tag{30}$$

$$f_{vt} \in \{0,1\} \qquad \forall v, t \tag{31}$$

In this model, Eq. 20 shows the objective function that seeks to minimize the set of costs. Eqs. 21 and 22 ensure, respectively, that each category will be performed by only one physician in each round of bidding, and that each nurse will visit only one batch of programs in each round of bidding. Eq. 23 ensures that the maximum bid price for physician j should not exceed the sum of the upper limit of those visits. Eq. 24 controls the conditions for participating in the tender (if physician j was temporarily assigned to a batch in the previous round, the bid price for that batch in that round must be equal to the previous round or one epsilon lower. The price offered by doctor j in the new round for each category must be less than or equal to the price of the same category that was temporarily assigned to another doctor in the previous round.). Eq. 25 shows the lowest price assigned to category v in the previous round. Eq. 26 specifies the conditions for participation in the tender for category v, which has not been assigned to any physician in the previous round. Eq. 27 ensures that each visit can be assigned to physicians in only one category. Eq. 28 Calculates the cost of visit coverage by the supporting physicians if it is not allocated to any physician in the tender. Relationships (29) to (31) represent decision variables.

Computational results

In this section, a working example is provided to illustrate the designed system. A collection of 258 samples based on real geographical data has been produced in Tehran. Visit information includes two sections: unique features of the visit and doctors. The characteristics of the visit include the time window for receiving the service, the type of visit that is considered between (1 to 5) skills, the standard price that is randomly generated in this example, he also mentioned the travel time between visits, which is calculated through Google Maps. Doctors, on the other hand, have their own preferences depending on the time of work and the type of visit. In this example, the travel time between the doctors' home and each visit is zero.

258 Input data using clustering with Fuzzy C-Means Algorithm Relationships (1,4) to 20 clusters, each cluster represents one of the regions of Tehran and then clustered into 5 sub-clusters based on the type of visit. Given that the goal is to clarify the steps of the bidding process, we have kept the example as simple as possible and have solved the problem randomly for 76 patients, 15 sub-clusters and 8 physicians. Practical programs and their cost for physicians are generated using relationships (5, 20). Table 2 shows the practical plans of each physician and the associated costs.

Table 2. Practitioners' Feasible Packages and Corresponding Cost and Payment

Practitioner	Feasible Schedules	Cost	Payment
P1	<43,45,46>	150	150
	<53,54>	60	120
	<47,48,49>	90	90
	<32,31>	120	120
	<35,36,37,38>	120	120
	<39,40>	60	60
P2	<15>	30	30
	<27,28,29,30>	177	180
	<23,25,26>	175	180
	<46>	29	30
	<48,49,51>	99	120
	<52,53,54,55>	206	210
P3	<2>	27	30
	<6>	25	30
	<23>	57	60
	<27,28,29,30>	177	180
	<15,16,17,18>	203	210
P4	<53,54,55>	178	180
	<46>	29	30
	<49,51>	30	90
	<24,25,26>	176	180
	<29,30>	119	120
	<56,57,58,60,62>	256	270
	<64,65,66,67,69>	263	270
	<73,74>	120	120

Practitioner	Feasible Schedules	Cost	Payment
P5	<75,76>	118	120
	<18,59,62>	171	180
	<13,14>	56	60
	<8>	30	30
P6	<2,4>	87	120
	<6,7>	53	60
	<23,25,26>	175	180
	<15,16,17,18,21>	261	270
	<27,28,29,30>	177	180
P7	<7>	28	30
	<13>	27	30
	<24,25,26>	176	180
	<29,30>	119	120
	<17,19,22>	146	150
P8	<57,58,60,62>	226	270
	<73,74>	120	120
	<33>	90	90
	<42>	30	30

Supporting doctors are willing to visit at a standard price at any stage. To limit the number of bids, the price reduction ε = 10 Tomans is defined. The submitted proposals, the temporary allocation and the payment of the home care agency, which are calculated using the ratios (20 and 30) at each stage of the proposals, are summarized in Table 3.

Table 3. Submitted Bids, Provisional Allocation, Payment at Each Round of Bidding

Round	Submitted bids	Provisional allocation	Payment
1	P(1,1),p(1,2),p(1,3),p(1,4),p(1,5),p(1,6) P(2,7),p(2,8),p(2,9),p(2,10),p(2,11),p(2,12) P(3,13),p(3,14),p(3,15),p(3,16),p(3,17) P(4,18),p(4,19),p(4,20),p(4,21),p(4,22),p(4,23) ,p(4,24),p(4,25),p(5,26),p(5,27),p(5,28),p(5,29), P(6,30),p(6,31),p(6,32),p(6,33),p(6,34),p(7,35), P(7,36),p(7,37),p(7,38),p(7,39),p(8,40),p(8,41), P(8,42),p(8,43)	p(1,5), P(2,11), p(3,16), p(4,19), p(5,26),p(6,34), p(7,37),p(8,40)	3929000
2	P(1,1),p(1,2),p(1,3),p(1,4),p(1,5), P(2,7),p(2,8),p(2,9),p(2,10), p(2,12), P(3,13),p(3,14),p(3,15),p(3,16),p(3,17), P(4,18),p(4,19),p(4,20),p(4,21),p(4,22),p(4,23) ,p(4,24),p(4,25),p(5,26),p(5,27),p(5,28),p(5,29), P(6,30),p(6,31),p(6,32),p(6,33),p(6,34),p(7,35), P(7,36),p(7,37),p(7,38),p(7,39),p(8,40),p(8,41), P(8,42),p(8,43)	p(1,5), P(2,12), P(3,15), p(4,22), p(5,26),p(6,30), p(7,37),p(8,43)	3630000

After modeling with the case study data, the results show that using Fuzzy C-Means helps the model to schedule bigger problems in a reasonable time frame without the need to solve in GAMS 24.8.3 software with a computer of RAM 4 GB, Core i5 CPU. the tender in round 2 ends with the cost of the general solution for all visits 3630000 Tomans. Compared to the cost of the general solution to perform all visits at the standard price without considering the tender framework, which is equivalent to 3929000 Tomans, it causes 8 percent efficiency.

Also, as the number of participating physician's increases, so does productivity (Fig. 2). This is while increasing the number of rounds in the tender from one limit to another causes the value of the objective function to be fixed. Therefore, reducing the salary received due to costs will not be justified for the physician (Fig. 3).

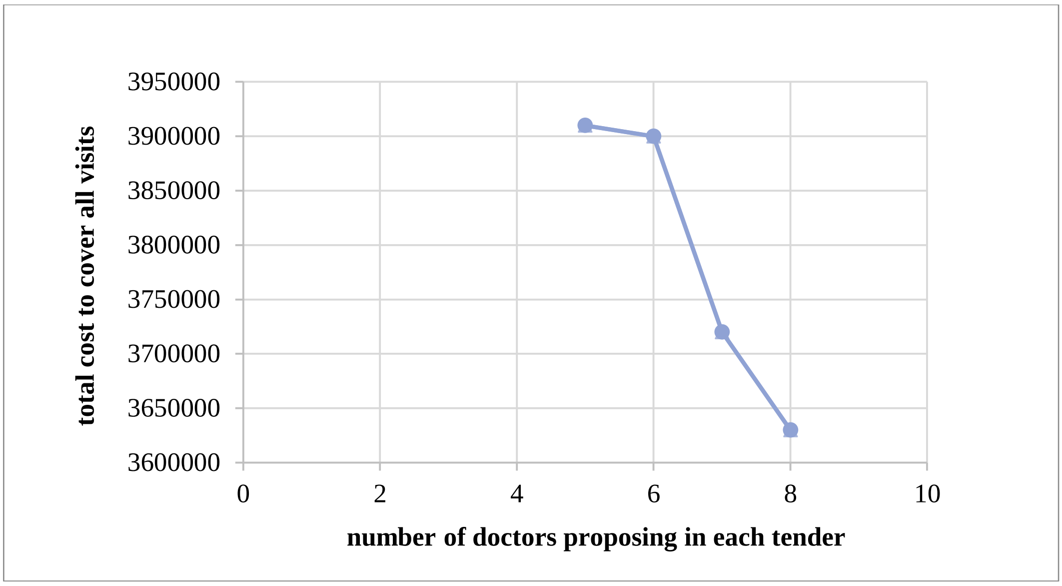

Fig. 2. Sensitivity analysis of the total cost to cover all visits according to the number of bidders for two rounds of bidding

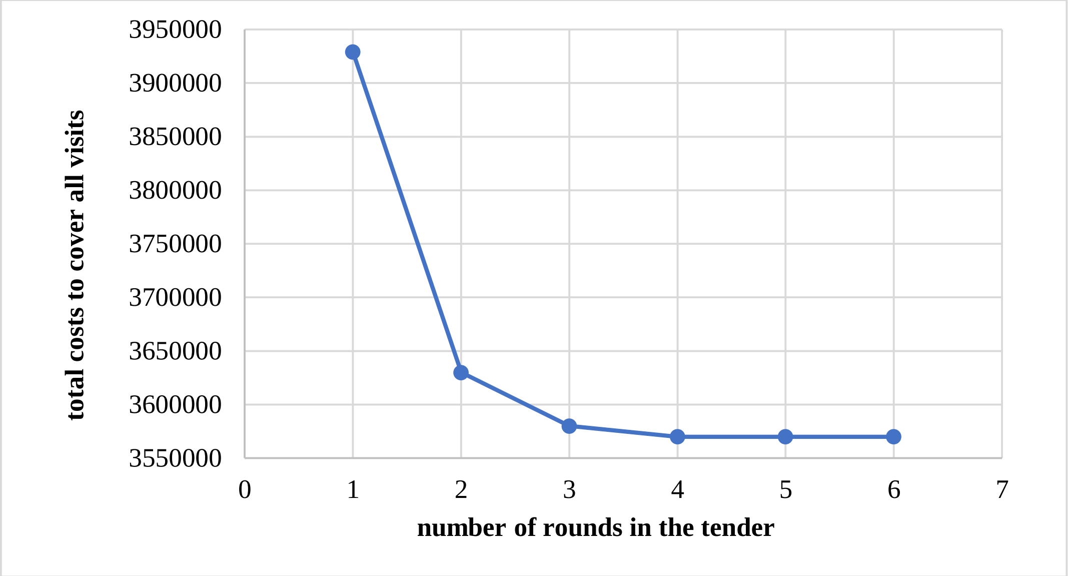

Fig. 3. Sensitivity analysis of the total cost to cover all visits according to the number of bids (t)

Conclusion

This article describes a multi-factor planning system used to solve home health problems in a decentralized environment. Multilateral negotiation between physicians facilitates the reduction of health care agency costs. At the same time, the test results show that this framework achieves a high efficiency of optimal solutions. The designed system focuses on the allocation, scheduling, routing and clustering of incoming visit requests, in which the dynamic characteristics are reflected in part. This study is also intended for a period of one day and a fixed travel time at different times of the day without distinction in the direction of movement, while the proposed model can be developed for long periods of time, with travel time depending on the time of departure. Also, the proposed framework in this research is considered statically, which can be considered by dynamically simulating the performance of physicians and the scheduling process in accordance with unexpected situations. Designing a bidding language specifically for agent-based home health care scheduling is an interesting and potentially useful research direction. Based on the structure of requirement-based bidding language, a simple and sufficiently expressive bidding language could be designed for home health care scheduling, leveraging the domain-specific scheduling problem structure. In addition, while the current solution is adequate for relatively small-scale scheduling problems, it does not provide the required responsiveness with large scale data. Given that the richness of the language allows users to express complementarities over their preferences, implementable approximation mechanisms could be able to trade-off solution quality for a polynomial-time guarantee.

References

[1] Castelnovo, C., et al., *A multi agent architecture for home care services.* Reforming Health Systems: Analysis and Evidence: Strategic Issues in Health Care Management, 2006: p. 135-151.

[2] Itabashi, G., et al. *A support system for home care service based on multi-agent system*. in *2005 5th International Conference on Information Communications & Signal Processing*. 2005. IEEE.

[3] López-Santana, E.R., J.A. Espejo-Díaz, and G.A. Méndez-Giraldo. *Multi-agent approach for solving the dynamic home health care routing problem*. in *Workshop on Engineering Applications*. 2016. Springer.

[4] Mohammadi, A. and E.S. Eneyo, *Home health care: a multi-agent system based approach to appointment scheduling.* Int. J. Innov. Res. Technol, 2015. **2**(3): p. 37-46.

[5] Mutingi, M. and C. Mbohwa, *A home healthcare multi-agent system in a multi-objective environment.* SAIIE25 Proceedings, 2013: p. 636.

[6] Stojanova, A., et al., *Agent-based solution of caregiver scheduling problem in home-care context.* 2017.

[7] Becker, C.A. and I.J. Timm, *Planning and scheduling for cooperative concurrent agents with different qualifications in the domain of home health care management.* 2019.

[8] Becker, C.A. and I.J. Timm, *Planning and Scheduling for Cooperative Concurrent Agents in the Domain of Home Health Care Management.* 2019.

[9] Hamdani, F.E., A. El Mhamedi, and D. Monticolo. *Agent-based Approach of Multi-Structures Homecare Planning Problem*. in *2019 International Colloquium on Logistics and Supply Chain Management (LOGISTIQUA)*. 2019. IEEE.

[10] Widmer, T. and M. Premm. *Agent-based decision support for allocating caregiving resources in a dementia scenario*. in *German Conference on Multiagent System Technologies*. 2015. Springer.

[11] Xie, Z., N. Sharath, and C. Wang. *A game theory based resource scheduling model for cost reduction in home health care*. in *2015 IEEE International Conference on Industrial Engineering and Engineering Management (IEEM)*. 2015. IEEE.

[12] Xie, Z. and C. Wang. *A periodic repair algorithm for dynamic scheduling in home health care using agent-based model*. in *2017 IEEE 21st International Conference on Computer Supported Cooperative Work in Design (CSCWD)*. 2017. IEEE.

[13] Bajo, J., et al., *The THOMAS architecture in Home Care scenarios: A case study.* Expert Systems with Applications, 2010. **37**(5): p. 3986-3999.

[14] Miyamoto, S., et al., *Algorithms for fuzzy clustering*. 2008: Springer.

[15] Miyamoto, S., H. Ichihashi, and K. Honda, *BasicMethods for c-Means Clustering*, in *Algorithms for Fuzzy Clustering*. 2008, Springer. p. 9-42.