Nursing Practice Today

Nurs Pract Today. 2016; 3(4):140-151.

Original Article

A new mathematical model for multi period multi depot home health care routing scheduling problem

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ARTICLE INFO

Received 3 April 2016
Revised 23 August 2016
Accepted 1 December 2016
Published 20 December 2016

Available online at:
http://npt.tums.ac.ir

Key words:
homecare services,
community health planning,
mathematical concepts,
patient satisfaction

ABSTRACT

Background & Aim: Nowadays, home health care services play significant roles in modern societies. Such services allow the elderly and needy people to pass their treatment process at their own houses in a friendly environment. In this paper, weekly routing and scheduling problem of home health care personnel was investigated.

Methods & Materials: Insufficient number of expert personnel or overlapping time windows of some patients would result in delayed beginning of the service time for patients. This paper attempted to solve multi-period multi-depot routing-scheduling problem with regard to the delay in giving services to patients, simultaneously. Presented model is solved by GAMS software in small scale and hybrid genetic-imperialist competitive algorithm in large scale.

Results: For planning and managing the home health care institutions' activity, it must be determined that which personnel will visit the patient and when the visit is met. This paper, considering the probable delay in giving services to the patients, would determine the best plan for personnel visit. Starting time of each visit, number of patients that would be assigned to each personnel, occurred delay in patients' visits, and each personnel's overtime are the results of the proposed paper.

Conclusion: Proposed model will minimize home health care institution's total cost and increase the satisfaction of patients through minimizing the occurred delay. Also, the hybrid algorithm indicates good performance for the model of this paper.

Introduction

Nowadays, the number of the elderly and those who need home health care (HHC) services has escalated due to the decreased birth rate and increased life expectancy. For instance, the population growth rate of people over 60 in European Union countries has increased from 17% to 22%. It is expected that this rate will reach 32% in 2030 (1). The diversity of this group's needs and the sensitivity of some health care services have made the family of this group to recourse to medical doctors, nurses and other experts. Formerly, the presence of medical personnel was more predominant in hospitals and private clinic. However, increase in the costs of hospitalization, difficulty in transporting the elderly, low healthcare quality of suchlike centers and limited beds in hospitals have dragged people's attention to HHC institutions. Thus, paying attention to this subject and the necessity of optimal programming in this field have become important more than ever. It is vital for HHC institutions to schedule healthcare personnel for patients and determine their optimal route in a way that the total operation costs of the system are decreased and the service quality to patients are constantly improved so that they can be most responsive to the increasing demands of this industry. Of course, reaching suchlike conflicting goals is subject to responsiveness

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Please cite this article in press as: Arabzadeh E, Fatemi-Ghomi S.M.T, Karimi B. A mathematical model for multi period home health care routing scheduling problem. *Nurs Pract Today. 2016; 3(4):140-151*

to different limitations; limitations such as available human resources, different patients' needs, time windows of each personnel and patient, visit preferences of the healthcare personnel and patients, quality level, competence and experience of each personnel, career laws and overtime costs. These institutions which are responsible for offering a wide range of services at patients' houses have several personnel with different quality levels. Each of these personnel visits some patients according to their educational level, ability, experience and the time they can be available to the institution. These personnel, who start their route from their own houses and finally arrive at patients' houses, use different means of transportation –personal car, public transportation vehicle, bicycle or on foot- to visit patients and take care of them.

Also, the patients have different medical needs which must be met as much as possible. For example, some patients call for female nurses to visit them or some others need a once-a-day visit and some others need to be visited twice a day in a definite time order; such preferences must be considered in the institutions' scheduling that have been mentioned in many articles (2,3,4,5)

Scheduling and routing, in HHC institutions, is comprised of scheduling personnel for patients, scheduling their visits and determining their routes (visit order). For the first time, Begur et al assumed a mathematical model in the US for scheduling and routing of nurses at an institution that offered home health care (6).

Braekers et al (1) investigated the problem of scheduling and routing of HHC institutions in their study. Their study had two objectives of minimizing all costs including the cost of personnel transportation and overtime and minimizing patients' dissatisfaction resulting from improper personnel scheduling and deviation from the desired time window. Hiermann et al (7) presented a two-stage approach to schedule HHC institutions optimally. The random solution in the first stage was improved in the second stage by utilizing each of the four meta-heuristic algorithms. The four algorithms consisted of simulated annealing, memetic algorithm, scatter search and variable neighborhood search. Mankowska et al (8) in their study about HHC scheduling and routing divided patients into two groups: 1) Patients who needed single service 2) Patients who needed double service. The former is also divided into two sub-groups: 2.a) those who needed simultaneous double service at their house and 2.b) those who needed time interval between services.

Torres-Ramos et al (9) presented a mixed integer linear programming model for a periodic schedule of medical personnel and nurses and also their routing to visit the patients. Their model that was devised for three groups of doctors, nurses and physiotherapists had an object to minimize the time spent to visit patients. Nickel et al (10) presented a mid-term and short-term planning for scheduling and routing of HHC institutions. Rasmussen et al (11) presented a model to minimize the costs of transportation, dissatisfaction resulting from improper scheduling of personnel to patients and the number of unmet visits. Nowak et al. (12) presented a model by emphasizing that a constant relationship between nurses and patients can improve the therapeutic process; they prepared situations so that each patient is assigned to one or two nurses.

Cheng and Rich (13) presented mixed linear programming model for healthcare personnel's scheduling and routing. In their proposed model personnel were divided into two categories: full time and part time personnel. For each of the personnel a period time was allocated for rest and hard time windows. The objective of the presented model was to minimize the costs of the system including overtime costs of the personnel.

But the most important point which is the essential innovation of this paper is considering the delay in giving services to the patients. Insufficient number of expert personnel or overlapping time windows of some patients will result in delayed service time for the patients. Therefore, the model will consider penalty cost for occurred delays to prevent great delays in giving services to the patients and increases the satisfaction of the patients. Also, some patients will require two visits a day which must be paid within the minimum and maximum gaps. This assumption is also considered as an innovation in the proposed model.

The outline of the article's contents is as follows. In Methods the mathematical model and the solution method are presented. Numerical results and sensitivity analysis are presented in the Results section and the final conclusion is provided in the last section.

Methods

The present study was a practical research and data are used from previous papers or related books. The presented model in this article was illustrated as G=(V,A) in which V={0p , 1, 2, 3, …, np} that included the houses of personnel and patients as nodes of this graph and A={(i,j)│i , j ϵ V , i≠j} are the connective routs of these nodes. Patients will need one or two visits a day and eventually, in the considered time period they would need specific number of visits. The treatment plan of each patient is specified at the beginning of the week. On the other hand, there are a specific number of personnel in a HHC institute. Some of them are in the institute all the time, however some others are only there once or twice a week which is shown as γkd parameter. Daily employment of each personnel imposes a fixed cost on the system according to their qualitative level and competence. Generally, every day, the personnel move from their house, visit some of the patients using their own means of transportation and eventually come back to their house. Thus, the presented problem is multi-depot. The parameters and variables of the model are as follows.

- c_{ij}^{p} : Cost of movement of the personnel p with respect to the mode of transportation from node i to node j.
- Ca_i^p: Cost of visiting the patient i by the personnel p.
- Cf_p: Cost of each overtime unit of personnel p.
- γ_p^d: Equals to 1 if personnel p is available at day d; otherwise 0.
- β_i^p: Equals to 1 if personnel p can visit patient i; otherwise 0.
- q_p^d: Personnel p is allowed to start his/her activity at day d after this time.
- q'^d_p: Personnel p must finish his/her activity at day d before this time.
- LT: Legal time of activity of each personnel during a day.
- PT: The maximum time a personnel is allowed to have overtime during a day.
- S_{ib}^d: Equals to 1 if patient i needs service s at day d; otherwise 0.
- e_i^d: The earliest time asked by patient i at day d.
- l_i^d: The latest time asked by patient i at day d.

- TS_{ij}^{p}: Movement time from patient i's house to patient j's house added to patient j's visiting time by personnel p.
- V_{ij}^{min}: The minimum time interval between two visits of patient i.
- Tr_i: Delay time in giving services to patient i.
- V_{ij}^{max}: The maximum time interval between two visits of patient i.
- f_i: The number of required visits for patient i in the planned time period.
- TR_{Max}^{*}: The maximum occurred delay in giving services to the patients.
- x_{ij}^{pd}: Equals 1 if personnel p moves from patient i's house to patient j's house during day d; otherwise 0.
- t_i^{pd}: Starting time of visiting patient i by personnel p at day d.
- Ot_p^d: Overtime of personnel p in day d.

Considering the parameters and variables defined in the previous section, following gives the mathematical model of the problem.

$$Min \quad \sum_i \sum_j \sum_p \sum_d c_{ij}^{p}\, x_{ij}^{pd} + \sum_i \sum_{j \in V-\{0_p\},\{n_p\}} \sum_p \sum_d x_{ij}^{pd}\, Ca_j^p + \sum_p \sum_d Cf_p\, Ot_p^d \quad (1)$$

$$Min \quad \sum_i TR_i + TR_{Max}^{*} \quad (2)$$

$$\sum_{i \in \{0_p\}} \sum_j x_{ij}^{pd} = 1 \qquad \forall\, p, d (3)$$

$$\sum_i \sum_{j \in \{n_p\}} x_{ij}^{pd} = 1 \qquad \forall\, p, d (4)$$

$$\sum_i x_{ik}^{pd} = \sum_j x_{kj}^{pd} \qquad \forall\, k \in V - \{0_p\},\{n_p\}, p, d (5)$$

$$\sum_j x_{ij}^{pd} \le \gamma_p^d\, \beta_i^p\, S_{ib}^d \qquad \forall\, i \in V - \{0_p\},\{n_p\}, b, p, d (6)$$

$$TR_{Max}^{*} > TR_i \qquad \forall\, i \in V - \{0_p\},\{n_p\} (7)$$

$$e_i^d \le t_i^{pd} \qquad \forall i \in V - \{0_p\},\{n_p\}, p, d (8)$$

$$t_i^{pd} \le l_i^d + TR_i \qquad \forall i \in V - \{0_p\},\{n_p\}, p, d (9)$$

$$q_p^d \le t_i^{pd} \le {q'}_p^d \qquad \forall\, i \in V - \{0_p\},\{n_p\}, p, d\ (10)$$

$$t_i^{pd} + TS_{ij}^{p}\, x_{ij}^{pd} \le t_j^{pd}(1 - x_{ij}^{pd}) \qquad \forall\, (i,j) \in V - \{0_p\},\{n_p\}, p, d\ (11)$$

$$e_i^d + \sum_p t_i^{pd} + V_{ij}^{min} \le \sum_p t_j^{pd} \le e_j^d + \sum_p t_i^{pd} + V_{ij}^{max} \qquad \forall\, (i,j) \in \delta, d\ (12)$$

$$x_{ij}^{pd} = 0 \qquad \forall\, i, j (i = j), p, d (13)$$

$$\sum_j \sum_d \sum_p x_{ij}^{pd} s_{ib}^d = f_i^{\,b} \qquad \forall\, i, b (14)$$

$$\sum_i \sum_j TS_{ij}^{p}\, x_{ij}^{pd} - LT = Ot_p^d \qquad \forall\, p, d\ (15)$$

$$Ot_p^d \le PT \qquad \forall\, p, d\ (16)$$

$$x_{ij}^{pd} \in \{0, 1\} \qquad \forall\, i, j, p, d\ (17)$$

$$t_i^{pd}, Ot_p^d, TR_{Max}^{*}, TR_i \ge 0 \qquad \forall\, i, p, d (18)$$

The first part of the objective function (1) calculates the cost of transportation between the current nodes. The second part tends to minimize the visiting costs. The third part calculates the personnel's overtime cost in the planned period. The objective function (2) minimizes the total delay in giving services to the patients. The constraints (3) and (4) determine the start and end of the personnel's movement. Constraint (5) represents the balance of the current. Constraint (6) guarantees that a staff who is scheduled to a patient in a specific day will provide the three following conditions at the same time: 1) the patient needs to be visited on that specific day, 2) the personnel is not on leave on that day and present in the institute, and 3) that personnel is competent enough to treat the patient. Constraints (7) and (9) calculate the occurred delay in giving services to the patients. Also, constraints (8) and (9) indicate the time when the healthcare personnel get to the patient's house. Constraint (10) shows the time when the service starts and stops by any of the personnel. This constraint enables us to consider time limitations of the personnel too. Constraint (11) depicts the time of two consecutive visits by one personnel in one day. Constraint (12) is related to two consecutive visits per day for one patient. Some patients will require two visits a day which must be paid with minimum and maximum gaps. Constraint (13) guarantees that no transmission takes place twice for one house. Constraint (14) determines the number of required visits for each patient. Constraints (15) and (16) also takes into account the amount of overtime work of the personnel and the limit of overtime work for each personnel. Finally, constraints (17) and (18) designate the type of decision-making variables.

Proposed GA-ICA in this paper is composed from the combination of Genetic and Imperialist Competitive Algorithms, so at first these two algorithms are explained.

Genetic Algorithm: Genetic Algorithm (GA) is one of the methods for optimization and searching which is built according to principles and mechanisms of natural Genetics and selection of the fittest survival. Since, this algorithm follow the principle of top generation survival, it provides a condition for finding desired answer. This algorithm is consists of three operators: 1) selection, 2) intersection, and 3) mutation

Selection operator generates a new population by selecting several members of the population. This selection is conducted in such a way that the possibility of attendance of members with more suitability in the final population is more than the other members. After selection, intersection operator acts on a pair of members which is selected. Intersection operator can be single point or multipoint. In a single-point mode, two members (Chromosome) will randomly displace from a broken point and parts of two chromosomes. Thus, two new members are created. Initial members are called parent members and members of the intersection operator are called children population. In genetic algorithm, the possibility of selection is calculated as relation (19).

$$p_i = \frac{F_i}{\sum_{j=1}^{\mathrm{pop\ Size}} F_j} \tag{19}$$

Where F_i is the amount of suitability for member i. Producing a new generation is done by two operators: crossover with possibility of P_c and mutation with possibility of P_m. Genetic algorithm ends when certain number of generation is provided.

Imperialist Competitive Algorithm: Imperialist competitive algorithm (ICA) that was presented by Atashpaz-Gargari and Lucas (14) is an evolutionary algorithm which is suggested by political-social evolutionary theories. Steps of the imperialist competitive algorithm are explained in detail.

*Initial solution***:** The initial solution and the manner of selecting the structure are effective on the performance and quality of the final solution. To start the algorithm, a series of initial answers is produced randomly considering the set of problem constraints. Figure (1) displays that. This presentation represents as follow: this problem is containing 2 nurses and 13 patients. 1 and 2 are indicating the starting point of every personnel and 12 and 13 are indicating the final point of their movement (every personnel leave their houses and finally return to the same place, constraints (3), (4)). 3 to 11 are indicating the houses of every patient. For example, nurse 1, after leaving home, first visits patient number 7, then visits patient 14 and finally patient 6 (constraints 5 and 13) and then returns home. Patient 9 needs 5 visits during 4 days. First, nurse 2 visits this patient and after a specific time, the patient is visited by nurse 1 and the second visit is done (constraints 12, 14). Meanwhile, patient 13 needs only one visit at the second day that is done by nurse 2. Nurse 2 is not able to visit patient 10 (grouping medical personnel), for this reason, this patient is only visited by the first nurses during the 4-day period (constraint 6).

Producing the early empire:

Every solution in imperialist competitive algorithm is shown as an array. In the proposed algorithm, the title of country is used for every array which define as Country={p_1,p_2,….,p_N} where p_i is an optimized variable. Every variable determines a political-social characteristic in a country. Therefore, the algorithm is searching the best country with the best compound of political-social characteristics like culture, language, and economic policy.

After producing countries, non-domination and distance density techniques are used for creating foreheads and ranking of every member of the foreheads. Then, members of the forehead 1 will be stored in the archive. Then, the rest of the answers to every emperor will be allocated based on their power. For calculating the power of every emperor, the value of objective function is calculated for every emperor using relation (20):

$$\mathrm{Cost}_{i,n} = \frac{\left|f_{i,n}^{p} - f_{i,n}^{p,best}\right|}{\left|f_{i,total}^{p,max} - f_{i,total}^{p,min}\right|} \qquad (20)$$

That $cost_{i,n}$ is a normalized value of the objective function i for emperor n. Also, $f_{i,n}^{p,best}$, $f_{i,total}^{p,max}$ and $f_{i,total}^{p,min}$ are the best, maximum and minimum value of the objective function i in every repeat respectively. Finally, the value of the normalized cost for every emperor will be achieved using the relation (21):

$$\text{Total Cost}_n = \sum_{i=1}^{r} \text{Cost}_{i,n} \qquad (21)$$

	First day	Second day	Third day	Fourth day
P.1	1, 7, 14, 6, 15	1, 10, 9, 15	1, 4, 9, 15	1, 10, 5, 7, 12, 15
P.2	2, 4, 9, 16, 2	8, 9, 13, 16	2, 3, 14, 6	16, 2, 3, 11, 9, 16

Figure 1. Displaying the solutions

So that r is the value of the objective function. The power of every emperor is calculated after achieving the normal cost using the relation (22) and colonies will be distributed among them according to the power of every emperor.

$$p_n = \frac{\text{Total Cost}_n}{\sum_{i=1}^{N_{imp}} \text{Total Cost}_i} \qquad (22)$$

Then the initial numbers of an emperor's colonies will be determined using the relation (23).

$$NC_n = \text{round}\,\{ P_n * N_{col} \} \qquad (23)$$

Where, NC_n is the initial number of the emperor's colonies n and N_{col} is the total number of the colonies. NC_n is selected randomly from the colonies and given to every emperor. The emperor with more power will have more colonies than weaker emperors.

The total power of an emperor: The total power of an emperor is affected by the total power of that emperor's country. Therefore the power of the emperor's colonies would be effective on the total power of the emperor.

The total power of the emperor will be calculated using the relation (24).

$$\text{TP Emp}_n = \left(\text{TotalCost}(\text{imperialist}_n)\right) + \xi * \text{mean}(\text{TotalCost}(\text{Colonies of empire}_n))) \qquad (24)$$

TP Emp_n is the total power of the emperor n and ξ is a positive number less than one.

Movement of the colonies of an emperor toward their emperor: After dividing colonies among emperors, the colonies will move toward their emperors.

Data transfer among colonies: For transferring data among colonies, intersection operator in genetic algorithm will be used. For selecting the colonies, we have used the tournament mode.

Revolution: In every period, revolution happens on some colonies. This method is similar to genetic algorithm method and it occurs for escaping from local searches.

Imperial power: The power of the Weak imperials will be reduced and stronger imperials' power will be increased. For calculating the possibility of possessing every emperor, the total normalized cost will bw assumed according to the relation (25).

$$\mathrm{NTP\ Emp_n} = \max \{ \mathrm{TP\ Emp_n} \} - \mathrm{TP\ Emp_n} \qquad (25)$$

The NTP $\mathrm{Emp_n}$ and TP $\mathrm{Emp_n}$ are the normalized total power and the total power of the emperor n. Now the possibility of possessing every emperor will be calculated using the relation (26).

$$P_{Pn} = \frac{\mathrm{NTPEmp_n}}{\sum_{i=1}^{N_{imp}} \mathrm{TNTPEmp_i}} \qquad (26)$$

Then, roulette wheel selection method will be used for allocating selective colony to one of the emperors.

Stop condition: Stop condition of imperialist competition is when there is only one emperor in all the countries.

Proposed GA-ICA: Genetic algorithm has statistically more population density than imperialist competitive algorithm. This characteristic is suitable for finding better answers. But the low convergence pace of the algorithm may cause the answers to not converge toward the optimal solution. But imperialist competitive algorithm has less population density and the convergence pace of the desired answers toward the optimal solution is high, so using this feature, can help overcoming the problems of genetic algorithm and modify parent generation in the genetic algorithm. Therefore, genetic and imperialist competitive could be good supplements for each other. The general process of the proposed GA-ICA algorithm is presented as follows:

1. Choosing multiple points randomly and generating primary empires
2. Moving colonies toward the imperialist countries
3. Absorbing a colony from the weakest imperialist by other imperialists (imperialist competition)
4. Coding answers as the provided chromosome for the genetic algorithm as the initial population
5. Applying intersection operator on the initial population.
6. Applying mutation operator on the initial population.
7. Coding answers as countries to provide them to the imperialist competitive algorithm.
8. Repeating the second stage until achieving the total repeats

Now try to bring the numerical examples in large scale so that they will include all the situations which are considered in the model. So, in this example, the supply chain is including the HHC institution with 5 personnel– doctors and nurses- and 30 patients. Some parameters of the solved problem for 10 patients are presented in tables (1) and (2). Also, in order to evaluate the quality of the proposed algorithm, 24 examples are provided randomly.

Results

The model was applied on Intel(R) RAM of 4GB and 2.2 GHz with Core i3-2328M CPU computer by GAMS software 24.1.2 with time limitation of 7200 seconds. For the medium and large scale of the model, GAMS could not find the answer so we used GA-ICA, GA and ICA which are implemented in MATLAB software. The value of the objective function by GAMS software and GA-ICA, are presented in table (3) and compared with GA and ICA algorithms.

As results are shown, the proposed algorithm has a good performance in small scales and it has achieved the optimal solution except in two cases. For studying the model behavior, examples 1 to 8 are selected. The values of their objective function are presented in figure 2. Because of the increasing number of the patients and especially increase in the cost of the personnel's overtime, the cost of the problem 1 to problem 3 were increased. Indeed, the optimal decision in this situation is employing new personnel and balancing the workload. This point has been seen in problem 3. The cost is decreased despite of the fact that the number of the patients in problems 2 and 3 are the same. The increased cost of problem 4 compared to problem 3 is because of the increase in the number of patients. But it is clear that, in this situation, three personnel are suitable for 20 patients and overtime costs do not have a significant growth. The increase in costs from problem 4 to problem 5 is due to the simultaneous increase in the number of personnel and patients.

Decrease in the costs from problem 5 to problem 6 is due to no need for new personnel for visiting the patients. In problem 5, 4 personnel are visiting 30 patients, while, in problem 6, 3 personnel are visiting 30 patients. Actually, decreasing the number of personnel is due to the optimal decision in problem 6. In other words, the institution prefers the overtime costs instead of the high cost of hiring new personnel. Problems 7 and 8 express that the increase in costs is due to the simultaneous increase in the number of the personnel and the number of the patients. For better understanding, table (4) presents the detail of the model solution for personnel number 3 which is related to example 9 and its input parameters have been mentioned early. As mentioned in the table, personnel number 3 leaves the house every day and visits a number of patients using public transportation and finally returns home.

Results indicate better performance of GA-ICA algorithm than GA and ICA algorithms (Figure 3).

Table1. The input parameters (patients)

Patient i	Time windows asked by patient i	The day(s) that patient i needs service(s)	Service time (Min)
1	[11:15-13:00]	Saturday ،Tuesday	15
2	[8:00 - 9:45]	Friday	15
3	[11:30 – 13:00]	Wednesday	10
4	[11:00 – 13:00]	Sunday ،Tuesday	20
5	[12:15-13:00]	Saturday	20
	[15:30 – 17]	Saturday	15

Table2. The input parameters (personnel)

Patient i	Cf_p	The day personnel p is available	Ability to visit patient i	Means of transportation
1	35	Sun, Mon, Tue, Wed, Thu, Fri	All patients	Personal cars

2	32	Sat, Mon, Wed, Fri	All patients except [5,11,17]	Personal cars
3	30	Sat, Sun, Mon, Tue, Wed, Thu	All patients except [4,8,14,19,26]	Public transportation
4	30	Sat, Sun, Mon, Tue, Wed, Thu, Fri	All patients except [3,13,17,20,23]	By bike
5	30	Sat, Sun, Mon, Tue, Wed, Thu, Fri	All patients except [2,9,15,18,25,26]	Personal cars

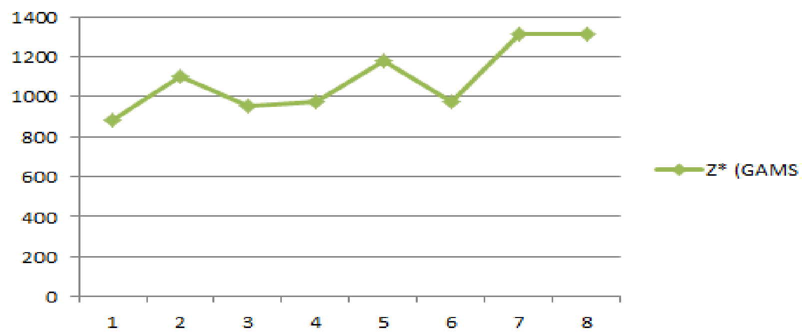

Figure 2. The value of the objective function

Table3. Results of numerical experiments

N	Patient * personnel	GAMS Z*	GA-ICA Z*	GA-ICA GAP	GA Z*	GA GAP	ICA Z*	ICA GAP
1	8 * 2	884,6	884,6	0	898,3	0.015	884,6	0
2	15 * 2	1099,3	1100,4	0	1100,4	0	1100,4	0
3	15 * 3	950,9	950,9	0	950,9	0	950,9	0
4	20 * 3	970,5	970,5	0	970,5	0	970,5	0
5	30 * 4	1175,1	1175,1	0	1175,1	0	1175,1	0
6	30 * 3	974,8	975,7	0	975,7	0	975,7	0
7	45 * 5	1314,0	1314,0	0	1314	0	1314,0	0
8	50 * 5	1315,2	1315,2	0	1318,5	0.002	1318,5	0.002
9	55 * 6	-	1573,9	0	1589,1	0.009	1588,8	0.009
10	60 * 6	-	1903,8	0.052	1896,3	0.048	1809,4	0
11	70 * 6	-	2159,1	0	2172,2	0.006	2180,2	0.009
12	80 * 6	-	2017,6	0.009	2004,8	0.002	1999,5	0
13	50 * 7	-	2259,1	0.009	2237,4	0	2257,0	0.008
14	80 * 9	-	2768,5	0.015	2734,2	0.003	2725,6	0
15	100 * 7	-	4016,9	0	4042,2	0.006	4037,9	0.005
16	100 * 10	-	4301,8	0	4329,9	0.006	4316,5	0.003
17	125 * 10	-	13332,7	0.007	13239	0	13306,2	0.005
18	125 * 12	-	14122,3	0	14181,1	0.004	14352,6	0.016
19	150 * 15	-	12419,0	0.005	12421,9	0.005	12352,9	0
20	200 * 18	-	13326,0	0.015	13182,6	0.004	13123,7	0
21	250 * 20	-	12964,4	0.007	12197,1	0.008	12870,9	0
22	300 * 25	-	19458,2	0.011	19317,8	0.003	19240,9	0
23	350 * 28	-	19325,0	0	19471,5	0.007	19393,9	0.003
24	450 * 35	-	18859,5	0.007	19472,9	0.039	18726,4	0

Table 4. The value of variables of the model for personnel 3

Personnel	Day	The start time of the movement from home	Time of coming back home	The passed route by personnel 3
3	Saturday	08:13	13:17	0-21-25-17-1-5-0
	Sunday	08:17	12:29	0-9-11-24-29-0
	Monday	-	-	-
	Tuesday	-	-	-
	Wednesday	08:19	12:33	0-12-7-25-6-3-0
	Thursday	-	-	-
	Friday	Not in access	Not in access	Not in access

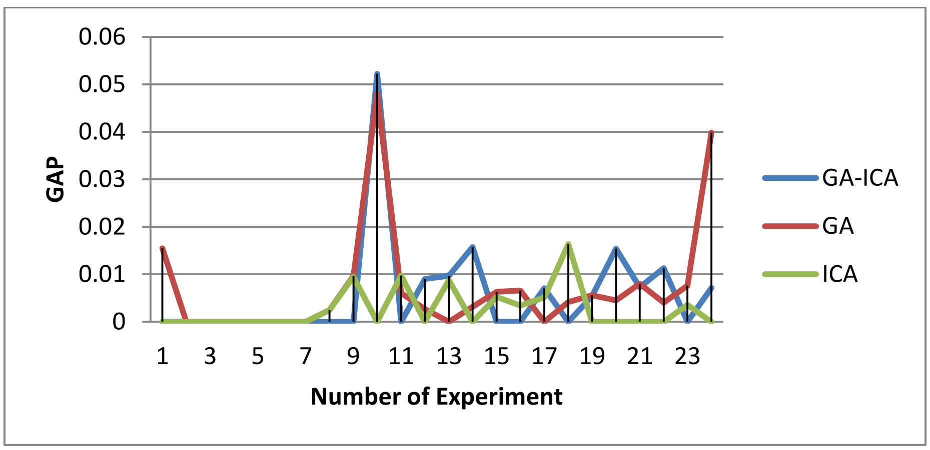

Figure 3. Comparison of three algorithms

Discussion

This paper presents a model for optimizing routing-allocation problem of the HHC institutions. Actually, the aim of this research was to find the best sequence of visiting patients while maintaining the conditions of the medical personnel and patients and minimizing the institution's costs and patient's dissatisfaction.

Solving the model was difficult because of the Np-hard nature of the problem and so, the time of solving the problem increased exponentially. Therefore, for solving small problems, GAMS software and for solving big problems, GA-ICA algorithm and GA and ICA algorithms were used. The results of the algorithm have implies the desirable quality and the right solution time. For future research, improving the efficiency of the solution performance by other meta-heuristic algorithms is suggested.

Conflict of Interest

The authors declare that they have no conflict of interests.

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