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A fuzzy optimization approach to hierarchical healthcare facilities network design considering human resource constraint: A case study

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Abstract

The purpose of this study was to investigate designing a two-level hierarchical healthcare facilities network under human resource constraint. To this end, a mixed integer model has been proposed in which the location of facilities, optimal flow of patients between the levels of the network, capacity planning and the planning of the required human resources are considered as the most important decisions. The proposed model aimed to minimize the total costs including the costs for the establishment of facilities, the cost of setting up services in different facilities, the costs of non-fulfilled demand at the second level of the network and the travel costs for patients to receive a variety of services. In this model, some of the parameters were considered uncertain that in order to cope considered uncertainty credibility-based chance constraint programming method was used. Then, the proposed model was implemented for planning in the several districts of Sari city in Mazandaran province. Finally, sensitivity analysis was carried out on some parameters such as the maximum available human resources and the average number of referral of each patient zone to family physician centers. Results revealed that if the maximum available human resources increase by 50%, network costs will be considerably reduced since the shortage costs get zero.

Keywords: Hierarchical network design, location-allocation, human resource constraint, capacity planning, credibility-based chance constrained programming.

1-Introduction

The topic of designing a healthcare facilities network has long been one of the most important issues for managers and planners because it directly affects the health of individuals and any defects in this field may cause irreparable damage to the people and society. In the design of the healthcare facilities network, concepts such as determining the optimal location of the healthcare facilities, allocating those facilities to the patient zones, the capacity of each facility, and the planning of the required human resources in each active facility are of the important concepts. These decisions will bring several goals for network including reducing the system costs, reducing the shortage, increasing the satisfaction of the patients and the available human resources in each facility, preventing the construction of the facilities in the appropriate places, making full use of the capacity of all facilities and other goals.

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In what follows, we will refer to articles that have focused on the network design and the location-allocation of healthcare facilities in recent years.

Healthcare network design models, according to their structures, are classified into single-level and multilevel (hierarchical) structures. Most of the papers presented in the recent years have considered the network as a single-level structure and little attention has been paid to multi-level networks. In the context of single-level networks, Kim and Kim (2010) presented a mixed-integer linear programming model for locating long-term care facilities. In the proposed model objective function minimized the maximum number of patients assigned to a center. Then, in another article (Kim and Kim, 2013), they examined the problem of locating public facilities; therefor, they divided the patients into two categories: low-income and high-income, and the hospitals into two categories, i.e., public and private. For this purpose, they presented an integer programming model that maximizes the number of low-income patients allocated to public hospitals and the number of high-income patients allocated to the public and private hospitals. In another study, Syam and Cote (2010) addressed the location-allocation problem for the specialized healthcare services. For this purpose, they provided a model for determining the optimal location of treatment centers for one of the integrated service networks of the Department of Veterans Affairs. In the proposed model, the objective function is minimizing the total cost including the fixed cost associated with the opening of the treatment units, the variable labor cost, the patients travel costs, the lodging cost of patients' families and the shortage cost.

In a paper, Sharif et al. (2012) considered the location-allocation problem of the treatment centers in one of Malaysia's regions. They then provided a maximum coverage model for those facilities with the assumption of capacity constraints. Afterwards, Ghaderi and Jabalameli (2013) provided a multi-period model for designing a network of facilities considering the budget constraints. In the proposed model objective function is minimizing the costs including the patient travel costs and the operational costs associated with facilities and connections between the network nodes. Then, Mohammadi et al. (2014) studied a reliable healthcare network design problem. They provided a two-objective and multi-service model under uncertainty associated with the number of patients and the coverage threshold. In the proposed model first the objective function minimizes the total costs including the treatment costs, the transportation costs and the expected failure cost based on the natural disasters, employee strikes, terrorist attacks, changes in management, etc. The second objective function minimizes the sum of the maximal travel time of patients. Davari et al. (2015) presented a fuzzy bi-objective model for the preventive healthcare network design problem considering the budget constraint in which the demand for each area is estimated by the Poisson distribution, and the attractiveness of each center modeled as the negative exponential function of distance. In their model the first objective function maximizes the sum of the covered individuals, and for the purpose of maximizing equity between the different regions, the second objective function minimized the minimum number of the covered individuals among the different regions.

In the context of hierarchical structure, Galvao et al. (2002) presented a three-level hierarchical model to locate the maternal and perinatal needed healthcare facilities in Rio de Jenio in that the objective function minimizes the total traveled distance by mothers. They have then developed this model considering the capacity limitations (Galvao et al., 2006). In a recent research, Mestre et al. (2015) developed two bi-objective, multi-service, and multi-period models with a hierarchical structure for designing a hospital network considering the uncertainty in demand. In the proposed model it is assumed that the hospitals are in a two-level hierarchy including the regional hospitals and the central hospitals, in that the regional hospitals provide the low-level (non-specialized) services in their direct coverage areas, while the central hospitals provide the specialized services in the larger areas. In the presented models two objective functions are considered in which the first objective function minimizes the total costs and the second objective function improves geographical accessibility. Beheshtifar and Alimohammadi (2015) proposed a multi-objective location-allocation model for locating new clinics with four objectives including minimizing the total travel cost for the service users, imbalance in accessibility, ground-use unsociability in the study area and the costs of land ownership and new facilities construction. The authors used a multi objective genetic algorithm to receive Pareto solutions, and used the TOPSIS approach with various weight vectors in order to select the best solution.

In another article, Karamyar et al. (2016) presented a bi-objective hybrid location-allocation and scheduling model for the healthcare facilities. The objective function in their study was to minimize the completion time of the patients and the total cost. Further, they considered establishment cost of facilities as uncertain and thus, a robust approach was used in order to cope with such uncertainty. Since this model was NP-hard, the authors solved it using a hybrid algorithm based on the simulated annealing and benders decomposition. Then Pouraliakbari et al. (2017) presented a location model for the healthcare facilities in a competitive and user choice environment. In their proposed model, space was assumed discrete and each hospital consisted of the low and high level sections. A hierarchical structure was also used to show the patients' referral from a low level server to a high level server. In this model, the objective function was to maximize the total demand covered by the new hospitals.

In another research, Zarrinpoor et al. (2016) developed a novel model for designing a reliable multi-level hierarchical network considering the heterogeneous probabilistic disruptions of facilities. In the proposed model, objective function minimized the total cost such as the fixed establishment cost, expected customer traveling cost and the expected customer serving cost by the established facilities then in another work (2017), they presented a reliable bi-level facility location-allocation model for the healthcare service networks considering the risk of unexpected disruptive events under uncertainty. In the proposed network, hospital is divided into two types including the lower level and the higher level hospital that the lower level hospital is providing public services and the higher level hospital is providing both public and specialized services. In the proposed model, the objective function is minimizing the total costs including the fixed hospital locating costs and the patient travelling cost and authors used queuing system in order to cope with the uncertainty related to the demand and service. Finally, for solving the two proposed model, Benders decomposition algorithm is used by them. In another paper, Mousazadeh et al. (2016) presented a new model for the healthcare network design considering two levels of referral system under uncertainty in which the proposed model objective function is minimizing the total costs of establishing facilities and the traveling patient to facilities. Then, in another study (Mousazadeh et al., 2017), they presented a nonlinear integer model for designing a three-level hierarchical healthcare network. The proposed model consists of two goals, which first minimizes the total cost of the establishment of the facility (in which the cost of saving from the construction of two facilities in one place has been reduced) and the second objective function minimizes the total patients travel cost. Further, in order to overcome the uncertainty, authors have used a hybrid robust possibilistic programming approach. It should be noted some presented assumptions in these works such as human resource and capacity planning, which have not been considered in this research.

In this study one of the assumptions of the presented model is considering the variable capacity for facilities; in other words, the capacity of each facility is considered as the decision variable, which is determined by the model. Among the articles associated with the healthcare network design, Tavakkoli et al.'s (2016) article and Javanmardi et al.'s (2017) article are the ones that considered this concept in modeling to plan the capacity of each facility. It is to be noted that in comparison to the presented model in this research, the assumption of the hierarchy and the human resource planning have not been considered in the previous articles. In Tavakkoli et al.'s paper (2016), a bi-objective model is proposed in which the first objective function minimizes the total costs and the second objective function maximizes the equity in the provision of health care services and then in another article Javanmardi et al. (2017) proposed an MINLP model to deal with the problem of designing a network of preventive healthcare facilities with the objective function of maximizing the total number of patients who participate in these preventive facilities. A summary of the reviewed articles is illustrated in table 1.

Given the literature in this regard, it can be argued that most of the articles have considered single-level with certain conditions. Among the reviewed articles, there seems to be no research on the concept of human resource planning in the healthcare facilities network design. On the other hand, since the constraints of the human resources have not been seen in any of the papers, and in all papers it is assumed that all the demands in the network should be answered, thereby minimizing the shortages have not been seen in any of these papers. In general, the main innovations that distinguish this research from the previous ones are:

- a novel mathematical model for designing a hierarchical healthcare facilities network considering the human resource constraint.

- Considering the important decisions such as human resource planning and the capacity planning in addition to location-allocation decisions.

Table 1. A summary of reviewed articles.

Reference	Status of parameters		Objective function							Considering hierarchical structure	Considering capacity planning	Considering human resource planning	Case study
	Deterministic	Non-deterministic	Minimize sum of costs	Minimize total distance (or time)	Minimize maximum distance (or time)	Maximize demand coverage	minimize maximum load	Minimize imbalance in accessibility	maximization of market share				
Galvao et al. (2002)	*			*						*			*
Galvao et al. (2006)	*			*						*			*
Kim and kim (2010)	*						*						*
Syam and cote (2010)	*		*										*
Sharif et al. (2012)	*					*							*
Kim and kim (2013)	*					*							
Ghaderi and Jabalameli (2013)	*		*										*
Mohammadi et al. (2014)		*	*		*								*
Beheshtifar and Alimohammadi (2015)	*		*					*					*
Davari et al. (2015)		*				*							*
Mestre et al. (2015)		*	*	*						*			*
Karamyar et al. (2016)		*	*	*									
Mousazadeh et al. (2016)		*	*	*						*			*
tavakoli et al. (2016)	*		*								*		*
Zarrinpour et al. (2016)	*		*							*			
Javanmardi et al. (2017)	*					*					*		*
Pouraliakbari et al.	*					*				*			
Zarrinpour et al. (2017)		*	*							*			*
Mousazadeh et al. (2017)		*	*	*						*			*
This research		*****	*****	*****						*****	*****	*****	*****

- Considering uncertainty about the average number of referrals of patient zones to family physician centers and the rate of referral between the levels of the network and also using credibility-based chance constrained the programming approach to cope with the associated uncertainty.
- Implementation of the proposed model for planning in several districts of Sari city in Mazanderan province.

In this study, a two-level and multi-service model has been proposed for the healthcare facilities network design under the human resource constraints. In the proposed model, locating various facilities, allocating patient zones to family physician centers, determining the appropriate referral pattern between the family physician centers and the second-level facilities, the capacity planning for the specialized facilities, and the required human resources planning in various facilities are considered as the main decision variables. In the presented model, the objective function is minimizing the total costs, including various facilities establishment costs, the costs of services setting up at the second level facilities, shortage costs and the patient travel cost. In the proposed model, the parameters such as the average number of patient zones referrals to family physician centers and the rate of the patient referral between the levels of the network are considered uncertain. Then, in order to overcome the considered uncertainty, the credibility-based chance constrained programming approach has been used. It should be noted that in order to examine the characteristics of the proposed model, the model is implemented for analyzing the data from Sari city as a case study and finally the results of various sensitivities were reported.

The structure of the current research is set as follows: In the section 2, the problem description is discussed. In the section 3 the mathematical model for the proposed problem is described and in the section 4, the case study is presented. In section 5 the computational results and in the Section 6 results of the sensitivity analysis are provided. Finally, in the section 7, conclusions and future research are explained.

2- Problem description

As shown in figure 1, the considered healthcare facilities network in this study is a two-level hierarchical network that at first level there are family physician centers that offer a range of public and primary services to patients and are the patients entering point to the network. At the second level, there are specialized facilities including specialized hospitals and clinics that hospitals provide the specialized inpatient services and the clinics offer specialized outpatient services to the referred patients from the first level. Decisions such as optimal locations for each facility, the capacity of each specialized facility, the allocation of the patient zones to family physician centers, the referral pattern between the family physician centers and each specialized facility, general physician, nurse and midwife planning, for each established family physician center, the planning of the specialist physicians and nurses for each established hospital and the specialist physician planning for the specialized clinics is one of the most important decisions within the network that are determined by the model. Given the described network, the main assumptions of the problem are:

1.There is no pre-established facility at the beginning of the planning horizon.
2. The health network is intended as a multi-service network and the considered services are in non-emergency categories.
3-Potential locations for the establishing various facilities and the population of each patient zones are definite and certain.
4. The capacity of the specialized facilities is considered as a decision variable that is determined by the model and the maximum allowable capacity for the various facilities within the network is specified and limited.
5. Each patient zone should be assigned only to a family physician center, and each family physician center is allowed to refer to patients mostly to a specialized hospital and to a specialized clinic. (Thus, there is no shortage at the first level of the network, and there is only shortage at the second level).
6. Each patient zone is allocated to the nearest facility.
7. In some clinics there is no possibility to set up some services.

8. In the field of human resource planning, physician and nurse planning for the specialized hospitals, physician planning for the specialized clinics and general physician, nurse and midwife planning for family physician centers are considered.
9. In the model, it is assumed that each family physician center needs a general physician and that for each general physician, a midwife or a nurse should be assigned to the relevant physician.
10. Human resource constraints, such as specialist physician, midwife, and nurse are considered in the model, and it is assumed that there is no limitation to the general physician (since all patient zones should be assigned to family physician centers at the first level).
11. Due to human resource constraints, the proportion of patients in the second level of the network may not be met.

In the following, a new model is provided for the important decisions in the healthcare network such as locating various healthcare facilities, capacity and human resources planning with the assumption that the number of human resources has been limited. In the proposed model, the objective function aims to minimize the total cost for the establishment of the facilities, the cost for setting the services up at various facilities, the shortage costs, and the patients travel costs.

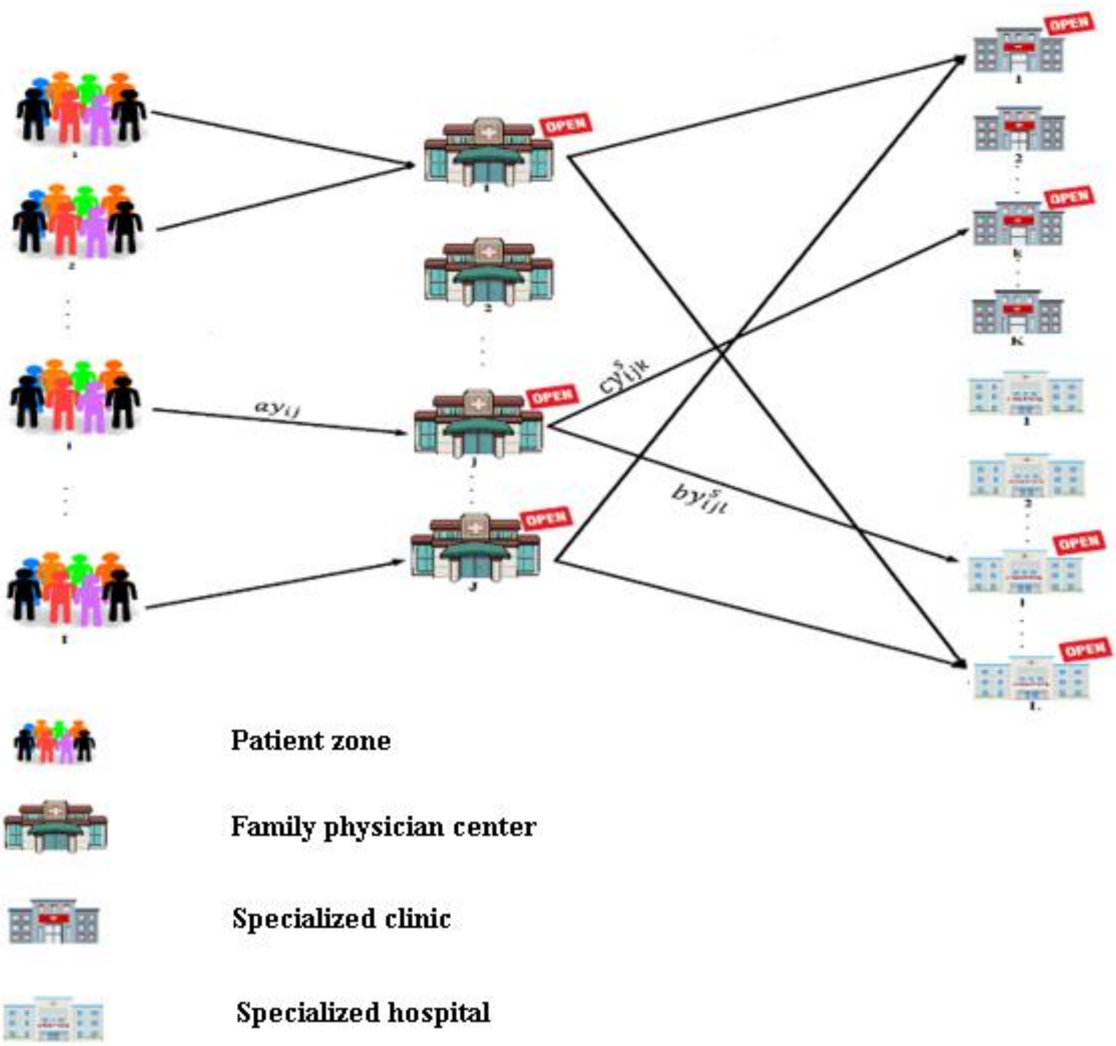

Fig. 1 The structure of the described health service network

3- Mathematical model

In this section the mathematical model of the described problem for the previous section is presented.

3-1- Notations

The indexes, parameters, and decision variables are defined as follows:

Indices

i	Index of patients zones
j	Index of candidate locations for family physician centers
l	Index of candidate locations for the specialized hospitals
k	Index of candidate locations for the specialized clinics
s	Index of types of specialized services

Parameters

f_j	Fixed cost of opening a family physician center at the candidate location *j*
g_l	Fixed cost of opening a specialized hospital at the candidate location *l*.
h_k	Fixed cost of opening a specialized clinic at the candidate location *k*.
w_i	Population in patient zone i.
$\tilde{d}_i$	Average number of referral of patient zone i to family physician center j during the planning horizon.
hb	At least percentage of referring patients from a patient zone to a family physician center who should receive each inpatient service by specialized hospitals.
hc	At least percentage of referring patients from a patient zone to a family physician center who should receive each outpatient service by specialized clinics.
du_s	Average treatment length of specialized service s (day)
to	Length of planning horizon (day)
ms_s	The coefficient of required specialized physician for the specialized inpatient service s per beds.
ns_s	The coefficient of the required specialized physician for specialized outpatient service s per number of patients.
qs_s	The coefficient of the required nurse for the specialized service s per beds.
cay_j	maximum capacity of opened family physician center at the candidate location *j*.
caw_l^s	Maximum capacity of the opened specialized hospital at the candidate location *l* for service type s .
caz_k^s	Maximum capacity of the opened specialized clinic at the candidate location *k* for service type s .
cw_l^s	The cost of setting up for each capacity unit inpatient service type s in specialized hospital *l*.
cz_k^s	The cost of setting up for each capacity unit outpatient service type s in specialized clinic *k*.
tx_{ij}	Travel cost between patients zone i and family physician center *j*.

tb_{il}	Travel cost between patients zone i and specialized hospital *l*.
tc_{ik}	Travel cost between patients zone i and specialized cl*inic k*.
α_i^s	The average number of referrals to a specialized hospital for inpatient service type s per each person's referral in the patient zone i to the family physician center.
β_i^s	The average number of referrals to a specialized clinic for outpatient service type s per each person's referral in the patient zone i to the family physician center.
vp_k^s	1, if setting up the service type s in specialized clinic k is possible;0, Otherwise.
ue_s	The maximum number of available specialist physicians in the network
up	The maximum number of available general physicians in the network
un	The maximum number of available nurses in the network
um	The maximum number of available midwives in the network
πa	The cost of each unit shortage for the inpatient services in specialized hospitals.
πb	The cost of each unit shortage for the outpatient services in specialized clinics.

Variables

y_j	1, if a family physician center is opened at candidate location *j*; 0, otherwise.
w_l	1, if a specialized hospital is opened at candidate location *l*; 0, otherwise.
z_k	1, if a specialized clinic is opened at candidate location *k; 0, otherwise.*
ay_{ij}	The flow of patients from patients zone i to family physician center j in planning horizon.
by_{ijl}^s	The number of patients from the patient zone i after referral to the family physician's center j are referred to a specialized hospital l for specialized inpatient service s.
cy_{ijk}^s	The number of patients from the patient zone i after referral to the family physician's center j are referred to a specialized clinic k for specialized outpatient service s.
ax_{ij}	1, if patients zone *i* is assigned to family physician center *j ;0, otherwise.*
bx_{jl}^s	1, if family physician center *j* will refer patients to specialized hospital *l* for inpatient service type s; 0, otherwise.
cx_{jk}^s	1, if family physician center *j* will refer patients to specialized clinic *k* for outpatient service type s; 0, otherwise.
ew_l^s	The number of beds of specialized hospital l for the inpatient service type s.
ez_k^s	the capacity expansion (number of admitted patients) of the specialized clinic k for outpatient service type s.
wy_l^s	1, if inpatient service type s to be provided in specialized hospital l; 0, otherwise.
zy_k^s	1, if outpatient service type s to be provided in specialized clinic k; 0, otherwise.
nm_l^s	Number of required specialist physicians in specialized hospital l for service type s.

nn_k^s	Number of required specialist physicians in specialized clinic k for service type s.
nq_l^s	Number of required nurses in specialized hospital l for service type s.
nf_j	1, if a nurse is assigned to family physician center j; 0, otherwise.
mf_j	1, if a midwife is assigned to family physician center j; 0, otherwise.

3-2-Model

The mixed-integer nonlinear programming model for two-level health facilities network design is as follows:

$$Min\left\{\sum_{j\in J} f_j y_j + \sum_{l\in L} g_l w_l + \sum_{k\in K} h_k z_k\right\} + \left\{\sum_{l\in L}\sum_{s\in S} ew_l^s cw_s + \sum_{k\in K}\sum_{s\in S} ez_k^s cz_s\right\} \tag{1}$$

$$\left\{\left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi a * Max\left(\tilde{\alpha}_i^s ay_{ij} - \sum_{l\in L} by_{ijl}^s, 0\right)\right) + \left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi b * Max\left(\tilde{\beta}_i^s ay_{ij} - \sum_{k\in K} cy_{ijk}^s, 0\right)\right)\right\} +$$

$$\left\{\sum_{i\in I}\sum_{j\in J} tx_{ij} xy_{ij} + \sum_{i\in I}\sum_{l\in L} tb_{il}\left[\sum_{j\in J}\sum_{s\in S} by_{ijl}^s\right] + \sum_{i\in I}\sum_{k\in K} tc_{ik}\left[\sum_{j\in J}\sum_{s\in S} cy_{ijk}^s\right]\right.$$

Subject to:

$$\sum_{i\in I} w_i ax_{ij} \le cay_j y_j \qquad \forall j\in J \tag{2}$$

$$\sum_{i\in I}\sum_{j\in J} by_{ijl}^s \le ew_l^s (to/du_s) \qquad \forall l\in L, s\in S \tag{3}$$

$$\sum_{i\in I}\sum_{j\in J} cy_{ijk}^s \le ez_k^s \qquad \forall k\in K, s\in S \tag{4}$$

$$\sum_{l\in L} by_{ijl}^s \ge \tilde{\alpha}_i^s ay_{ij} hb \qquad \forall i\in I, j\in J, s\in S \tag{5}$$

$$\sum_{k\in K} cy_{ijk}^s \ge \tilde{\beta}_i^s ay_{ij} hc \qquad \forall i\in I, j\in J, s\in S \tag{6}$$

$$ew_l^s \le caw_l^s wy_l^s \qquad \forall l\in L, s\in S \tag{7}$$

$$ez_k^s \le caz_k^s vy_k^s \qquad \forall k\in K, s\in S \tag{8}$$

$$vy_k^s \le vp_k^s \qquad \forall k\in K, s\in S \tag{9}$$

$$wy_l^s \le \sum_{i\in I}\sum_{j\in J} by_{ijl}^s \qquad \forall l\in L, s\in S \tag{10}$$

$$vy_k^s \le \sum_{i\in I}\sum_{j\in J} cy_{ijk}^s \qquad \forall k\in K, s\in S \tag{11}$$

$$\sum_{s\in S} wy_l^s \le |S| w_l \qquad \forall l\in L \tag{12}$$

$$\sum_{s\in S} vy_k^s \le |S| z_k \qquad \forall k\in K \tag{13}$$

$$w_l \le \sum_{s \in S} wy_l^s \qquad \forall l \in L \qquad (14)$$

$$z_k \le \sum_{s \in S} zy_k^s \qquad \forall k \in K \qquad (15)$$

$$ay_{ij} \ge \tilde{d}_i . w_i . ax_{ij} \qquad \forall i \in I, j \in J \qquad (16)$$

$$ay_{ij} \le M . ax_{ij} \qquad \forall i \in I, j \in J \qquad (17)$$

$$\sum_{i \in I} by_{ijl}^s \le M . bx_{jl}^s \qquad \forall j \in J, l \in L, s \in S \qquad (18)$$

$$\sum_{i \in I} cy_{ijk}^s \le M . cx_{jk}^s \qquad \forall j \in J, k \in K, s \in S \qquad (19)$$

$$\sum_{j \in J} ax_{ij} = 1 \qquad \forall i \in I \qquad (20)$$

$$\sum_{l \in L} bx_{jl}^s \le 1 \qquad \forall j \in J, s \in S \qquad (21)$$

$$\sum_{k \in K} cx_{jk}^s \le 1 \qquad \forall j \in J, s \in S \qquad (22)$$

$$ay_{ij} \le M . y_j \qquad \forall j \in J \qquad (23)$$

$$bx_{jl}^s \le M . y_j \qquad \forall j \in J, l \in L, s \in S \qquad (24)$$

$$bx_{jl}^s \le M . w_l \qquad \forall j \in J, l \in L, s \in S \qquad (25)$$

$$cx_{jk}^s \le M . y_j \qquad \forall j \in J, k \in K, s \in S \qquad (26)$$

$$cx_{jk}^s \le M . z_k \qquad \forall j \in J, k \in K, s \in S \qquad (27)$$

$$\sum_{j \in J} y_j = up \qquad (28)$$

$$y_j = nf_j + mf_j \qquad \forall j \in J \qquad (29)$$

$$ew_l^s . ms_s = nm_l^s \qquad \forall l \in L, s \in S \qquad (30)$$

$$ez_k^s . ns_s = nn_k^s \qquad \forall k \in K, s \in S \qquad (31)$$

$$ew_l^s . qs_s = nq_l^s \qquad \forall l \in L, s \in S \qquad (32)$$

$$\sum_{j \in J} nf_j + \sum_{l \in L} \sum_{s \in S} nq_l^s \le un \qquad (33)$$

$$\sum_{l \in L} nm_l^s + \sum_{k \in K} nn_k^s \le ue_s \qquad \forall s \in S \qquad (34)$$

$$\sum_{j \in J} mf_j \le um \qquad (35)$$

$$y_j, w_l, z_k, ax_{ij}, bx_{ijl}^s, cx_{ijk}^s, wy_l^s, zy_k^s, nf_j, mf_j \in \{0,1\} \qquad \forall i \in I, j \in J, l \in L, k \in K, s \in S \qquad (36)$$

$$ay_{ij}, by_{ijl}^s, cy_{ijk}^s, ew_l^s, ez_k^s, nm_l^s, nn_l^s \ge 0 \qquad \forall i \in I, j \in J, l \in L, k \in K, s \in S \qquad (37)$$

Target function (1) minimized the total cost of designing a hierarchical healthcare facilities network including the total cost of establishing various facilities, the total cost of setting up services at the different levels of the facility, the total cost of unsatisfied demands in the second level of the network and the total patients travel costs. Constraints (2) to (4) state that patients assigned to each facility should not be more than the allocated capacity. Constraints (5) and (6) indicate the minimum number of patients referred from each family physician center to the second level facility, which should be covered by this facility. Constraints (7) and (8) guarantee that the allocated capacity to each facility should be less than the maximum allowable capacity for that facility. Constraint (9) states that only one type of healthcare service can be set up in a specialized clinic if it is possible. Restrictions (10) and (11) guarantee that in a facility, a type of service will only be launched if there is a demand for it. Constraints (12) and (13) state that health services can only be launched in the opened facilities. Restrictions (14) and (15) will ensure that a facility will only be built when at least one service requires to be launched in the related facility. Constraint (16) expresses the flow between each patient zone and each family physician center. Constraint (17) states that there is a flow between a patient zone and a family physician center if the patient zone is assigned to the family physician center. Restrictions (18) and (19) show that there is only flow of patients between the first and the second level facilities when these facilitates are assigned together. Constraints (20) ensures that during the planning horizon, each patient zone should be allocated to one family physician center. Limitations (21) and (22) state that each family physician center is allowed to refer to patients at most to one specialized clinic and at most to one specialized hospital. Constraint (23) ensures that each patient zone can only be assigned to a family physician center that has been established. Constraints (24) to (27) state that there is the referral only between two opened facilities in the first and the second level of the network. Limitation (28) states the maximum needed number of general physician in the network. Limitation (29) states that if a family physician center is established, a nurse or a midwife should be assigned to that center. Constraint (30) to (32), respectively, is determining the number of specialist physician in the specialized hospitals, specialist physician in the specialized clinics, and the required nurses in hospitals. Constraint (33) ensures that the number of nurses assigned to the family physician center and the specialized hospitals should not exceed the maximum available nurses. Restrictions (34) and (35) relate to the limited number of available nurses, specialist physician, and the midwives. Constraints (36) and (37) represent the types of variables.

3-2-1- The proposed credibility-based fuzzy chance constrained programming model

Given the literature review, various categories are presented for the uncertainty types. Mula et al. (2008) have categorized the uncertainty in the data into two categories of randomness uncertainty and epistemic uncertainty. Randomness uncertainty stems from the random nature of the parameters, while the epistemic uncertainty arises from the lack of knowledge about the real values of uncertain parameters. In order to cope with the randomness uncertainty, stochastic programming method is used and to overcome the epistemic uncertainty, the possibilistic programming approach is often used.

In the proposed model in the Section 3, the precise values for some parameters such as the average number of each patient zone referral to the family physician centers during the planning horizon and the rate of the referral of the patients between different levels of the network are uncertain. The uncertainty associated with these parameters due to the lack of sufficient data and the lack of knowledge regarding the exact value belongs to epistemic uncertainty. Therefore, in this study from the various methods of the possibilistic planning credibility-based chance constrained programming approach is used to overcome related uncertainty.

Credibility-based chance constrained programming approach is an efficient fuzzy mathematical programming approach based on the strong mathematical concepts such as "expected value" and "credibility measure" of fuzzy numbers. This method helps the decision maker to solve some chance constraints at a minimum level of confidence. It can also be applied to uncertain parameters with different membership functions such as the triangular, trapezoidal, and nonlinear membership functions, both in symmetric and asymmetric modes (Liu and Liu , 2002), (Li and Liu , 2006). Contrary to the possibility and the necessity measure that have no self-dual nature, the credibility measure is self-dual measure (Zhang et al., 2010). Thus, if the credibility value of a fuzzy event be 1, fuzzy event will certainly occur, but when the possibility value of a fuzzy event attains 1, fuzzy event may not happen. In other words, if the value of the possibility of a fuzzy event achieves 1, that event may not occur, and if the necessity value of a fuzzy event is 0, that fuzzy event may occur. But if the credibility value of a fuzzy event attains 1, the fuzzy event will occur and if the credibility value of a fuzzy event attains 0, the fuzzy event will not occur.

Suppose $\tilde{\varepsilon}$ is a fuzzy variable with a membership function $\mu(x)$ and r is a real number. According to Liu and Liu (2002), the credibility value is determined by the relationship (38).

$$Cr\{\tilde{\varepsilon} \le r\} = \frac{1}{2}\left(\sup_{x \le r} \mu(x) + 1 - \sup_{x > r} \mu(x)\right) \tag{38}$$

Since $Pos\{\tilde{\varepsilon} \le r\} = \sup_{x \le r} \mu(x)$ and $Nes\{\tilde{\varepsilon} \le r\} = 1 - \sup_{x > r} \mu(x)$, so the credibility value can be rewritten as an equation (39).

$$Cr\{\tilde{\varepsilon} \le r\} = \frac{1}{2}\left(Pos\{\tilde{\varepsilon} \le r\} + Nes\{\tilde{\varepsilon} \le r\}\right) \tag{39}$$

Given the above formula, the credibility value is defined as an average of possibility measure and necessity measure. Further, the expected value, based on Liu and Liu (2002), is calculated as formula (40).

$$E[\tilde{\varepsilon}] = \int_0^{\infty} Cr\{\tilde{\varepsilon} \ge r\} dr - \int_{-\infty}^{0} Cr\{\tilde{\varepsilon} \le r\} dr \tag{40}$$

Now if the parameter $\tilde{\varepsilon}$ has a triangular fuzzy distribution function in the form of $\varepsilon = \left(\varepsilon^1, \varepsilon^2, \varepsilon^3\right)$, its expected value is calculated according to the equation (41) and its credibility is calculated according to formula (42) and (43).

$$E[\tilde{\varepsilon}] = \frac{\varepsilon^1 + 2\varepsilon^2 + \varepsilon^3}{4} \tag{41}$$

$$Cr\{\tilde{\varepsilon} \le r\} = \begin{cases} 1 & r \le \varepsilon^1 \\ \dfrac{r - \varepsilon^1}{2\left(\varepsilon^2 - \varepsilon^1\right)} & \varepsilon^1 < r \le \varepsilon^2 \\ \dfrac{r - 2\varepsilon^2 + \varepsilon^3}{2\left(\varepsilon^3 - \varepsilon^2\right)} & \varepsilon^2 < r \le \varepsilon^3 \\ 0 & r > \varepsilon^3 \end{cases} \tag{42}$$

$$Cr\{\tilde{\varepsilon} \ge r\} = \begin{cases} 1 & r \le \varepsilon^1 \\ \dfrac{2\varepsilon^2 - \varepsilon^1 - r}{2\left(\varepsilon^2 - \varepsilon^1\right)} & \varepsilon^1 < r \le \varepsilon^2 \\ \dfrac{\varepsilon^3 - r}{2\left(\varepsilon^3 - \varepsilon^2\right)} & \varepsilon^2 < r \le \varepsilon^3 \\ 0 & r > \varepsilon^3 \end{cases} \tag{43}$$

Given the relations (42) and (43), it can be proved that if $\tilde{\varepsilon}$ be a triangular fuzzy number and $\alpha \ge 0.5$, then we will have (Li and Liu, 2006).

$$Cr\{\tilde{\varepsilon} \le r\} \ge \alpha \leftrightarrow r \ge (2 - 2\alpha)\varepsilon_2 + (2\alpha - 1)\varepsilon_3 \tag{44}$$

$$Cr\{\tilde{\varepsilon} \ge r\} \ge \alpha \leftrightarrow r \le (2\alpha - 1)\varepsilon_1 + (2 - 2\alpha)\varepsilon_2 \tag{45}$$

The relation (41) can be used to convert objective function with uncertain parameters into definite objective function and the relations (44) and (45) can be used to convert constraints including non-deterministic parameters into definite constraints. In the proposed model of the previous section, the objective function (1) and the constraints (5), (6), and (11) have non-deterministic parameters, based on the assumption that the distribution function of non-deterministic parameters follows the triangular distribution function; thus, these equations change to equations (46) - (49) and the rest of the constraints remain unchanged.

$$Min\left\{\sum_{j\in J} f_j y_j + \sum_{l\in L} g_l w_l + \sum_{k\in K} h_k z_k\right\} + \left\{\sum_{l\in L}\sum_{s\in S} ew_l^s cw_s + \sum_{k\in K}\sum_{s\in S} ez_k^s cz_s\right\}$$
$$\left\{\left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi a * Max\left(\left[\frac{\left(\alpha_i^{s1} + 2\alpha_i^{s2} + \alpha_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{l\in L} by_{ijl}^s, 0\right)\right) + \right. \tag{46}$$
$$\left.\left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi b * Max\left(\left[\frac{\left(\beta_i^{s1} + 2\beta_i^{s2} + \beta_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{k\in K} cy_{ijk}^s, 0\right)\right)\right\}$$
$$\left\{\sum_{i\in I}\sum_{j\in J} tx_{ij} xy_{ij} + \sum_{i\in I}\sum_{l\in L} tb_{il}\left[\sum_{j\in J}\sum_{s\in S} by_{ijl}^s\right] + \sum_{i\in I}\sum_{k\in K} tc_{ik}\left[\sum_{j\in J}\sum_{s\in S} cy_{ijk}^s\right]\right.$$

$$\sum_{l\in L} by_{ijl}^s \geq \left((2\chi - 1)\alpha_i^3 + (2 - 2\chi)\alpha_i^2\right) ay_{ij}.hb \qquad \forall i\in I, j\in J, s\in S \tag{47}$$

$$\sum_{k\in K} cy_{ijk}^s \geq \left((2\nu - 1)\beta_i^3 + (2 - 2\nu)\beta_i^2\right) ay_{ij}.hc \qquad \forall i\in I, j\in J, s\in S \tag{48}$$

$$ay_{ij} \geq \left((2\eta - 1)d_i^3 + (2 - 2\eta)d_i^2\right) w_i.ax_{ij} \qquad \forall i\in I, j\in J \tag{49}$$

It should be noted that the parameters η, ν, χ are the confidence level of chance constraints (47) to (49), with minimum value of 0.5.

3-2-2- Model linearization

The model presented in the previous section is nonlinear. For the transformation of this model into a linear model, the auxiliary variables (50) and (51) are defined as follows:

$$Max\left(\left[\frac{\left(\alpha_i^{s1} + 2\alpha_i^{s2} + \alpha_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{l\in L} by_{ijl}^s, 0\right) = ka_{ij}^s \qquad \forall i\in I, j\in J, s\in S \tag{50}$$

$$Max\left(\left[\frac{\left(\beta_i^{s1} + 2\beta_i^{s2} + \beta_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{k\in K} cy_{ijk}^s, 0\right) = kb_{ij}^s \qquad \forall i\in I, j\in J, s\in S \tag{51}$$

According to the defined auxiliary variables, in the linear model the objective function is changed by equation (52) and restrictions (53) to (56) are added to the constraints.

$$Min\left\{\sum_{j\in J} f_j y_j + \sum_{l\in L} g_l w_l + \sum_{k\in K} h_k z_k\right\} + \left\{\sum_{l\in L}\sum_{s\in S} ew_l^s cw_s + \sum_{k\in K}\sum_{s\in S} ez_k^s cz_s\right\}$$

$$\left\{\left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi a * ka_{ij}^s\right) + \left(\sum_{i\in I}\sum_{j\in J}\sum_{s\in S} \pi b * kb_{ij}^s\right)\right\} \quad (52)$$

$$\left\{\sum_{i\in I}\sum_{j\in J} tx_{ij} xy_{ij} + \sum_{i\in I}\sum_{l\in L} tb_{il}\left[\sum_{j\in J}\sum_{s\in S} by_{ijl}^s\right] + \sum_{i\in I}\sum_{k\in K} tc_{ik}\left[\sum_{j\in J}\sum_{s\in S} cy_{ijk}^s\right]\right.$$

$$ka_{ij}^s \geq \left[\frac{\left(\alpha_i^{s1} + 2\alpha_i^{s2} + \alpha_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{l\in L} by_{ijl}^s \qquad \forall i \in I, j \in J, s \in S \quad (53)$$

$$ka_{ij}^s \geq 0 \qquad \forall i \in I, j \in J, s \in S \quad (54)$$

$$kb_{ij}^s \geq \left[\frac{\left(\beta_i^{s1} + 2\beta_i^{s2} + \beta_i^{s3}\right)}{4}\right] ay_{ij} - \sum_{k\in K} cy_{ijk}^s \qquad \forall i \in I, j \in J, s \in S \quad (55)$$

$$kb_{ij}^s \geq 0 \qquad \forall i \in I, j \in J, s \in S \quad (56)$$

4- Case study

In the recent years, the hierarchical networks design problem has been considered by many healthcare planners because in these networks, the cooperation and communications between network levels have led to some important purposes such as the reduction of costs, the reduction of direct referral of individuals to specialist physician, promoting the health of society, etc. In Iran, the referral system is a hierarchical healthcare network that has been implemented in Mazandaran and Fars provinces tentatively in the recent years. Therefore, in this research a part of the largest city of Mazandaran province (i.e., Sari) is used as a case study to show the applicability of the proposed model by real data. As shown in figure 2, this area of Sari is divided into 24 sections depending on the population density and the area of each section.

To solve the proposed model, each section is considered as a patient zone and a potential location for establishing a family physician center. Sections 2, 3, 9, 22 are also selected as the potential sites for the construction of specialized hospitals and sections 2, 3, 6, 8, 14, 19, 23, and 24 are selected as the potential sites for the establishing specialized clinics. It should be noted that the potential locations for facility establishment are selected based on indicators such as geographical location, population density of each region, and expert opinion, since the majority of population in each patient zone is located around the center of that region, the center of each patient zone has been considered as the potential location for establishing facilities. The population and area of each patient zone are presented in table (2), used to estimate the number of visits for the considered facilities.

The length of the planning horizon is considered eight years for planning the intended area of Sari. Given the experts' opinion in this area and the amount of information available for a variety of services, four types of specialized services including internal services, heart, eyes, and ears have been selected for planning in the specialized facilities. Due to the geographical features of the patient zone and the experts opinion, the average number of referrals each person to its allocated family physician centers has been estimated to be 60 times in the planning horizon and also the referral rate for referring patients from each family physician center for internal services, heart, eye, ear to specialized hospitals was estimated, respectively $75*10^{-4}, 90*10^{-4}, 105*10^{-4}, 120*10^{-4}$ and to specialized clinics are estimated respectively, $160*10^{-5}, 160*10^{-5}, 170*10^{-5}, 200*10^{-5}$. In order to convert these mean values to triangular distribution numbers, the brought coefficients in table 3 are used.

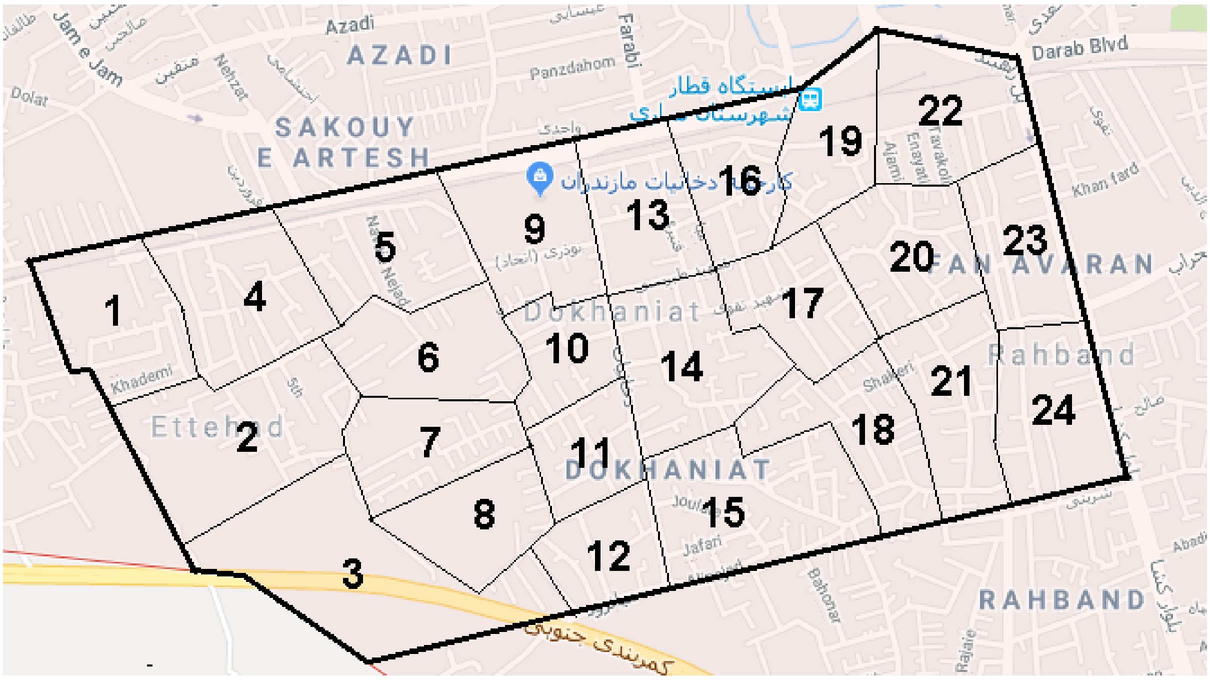

Fig. 2 Patient zones demarcation in considered district in Sari

Table 2. The amounts of each patient zone's population and area

Patient zone (*i*)	Population (w_i)	Area (km^2)
1	721	0.071
2	960	0.101
3	600	0.141
4	1081	0.086
5	1080	0.082
6	963	0.079
7	965	0.066
8	721	0.068
9	961	0.075
10	1215	0.050
11	1079	0.055
12	844	0.058
13	1115	0.063
14	1295	0.089
15	1438	0.099
16	1083	0.062
17	1119	0.065
18	1259	0.070
19	956	0.061
20	1126	0.073
21	1118	0.069
22	960	0.08
23	1131	0.064
24	1274	0.076
Total	25064	1.803

Table 3. Coefficients of transforming deterministic number for non-deterministic parameters into triangular fuzzy numbers

parameter	3 points calculators
$\tilde{d}_i$	(50%,100%,200%)
$\tilde{\alpha}_i^s$	(50%,80%,120%)
$\tilde{\beta}_i^s$	(80%,120%,200%)

The standard coefficients for determining the number of required physicians and nurses according to the number of active beds for four considered specialized services are shown in table 4.

Table 4. The human resources standards according to the number of active beds in hospitals

Type of healthcare service	The coefficient of physician	The coefficient of nurse
Internal	0.125	0.78
Heart	0.125	0.88
Eye	0.125	0.88
Ear	0.125	0.61

The coefficient of the required specialist physician in the specialized clinics is determined by the number of visits that a full-time physician may have in any type of service in one day, due to that the length of the horizons is eight years and based on the assumption that there are approximately 2240 working days per year, these estimated coefficients are presented in table 5.

Table 5. The human resources standards according to the number of entered patients in clinics

Type of healthcare service	coefficient
Internal	$1.489*10^{-5}$
Heart	$1.489*10^{-5}$
Eye	$1.117*10^{-5}$
Ear	$1.117*10^{-5}$

One of the most important considered constraints in the proposed model is maximum available human resources. Given the experts' opinions, for this region there are 6 internal specialists, 5 heart specialists, 4 eye specialists, 4 ear specialists, 70 nurses, and 15 midwives.

In the following section, tables 6-8 show the fixed cost associated with establishing family physician center, specialized hospital and the specialized clinic in the considered potential locations, respectively. It should be noted that the travel cost between the two districts is estimated based on the road distance between them. For example, the calculated road distance between each patient zone and each potential location for establishing specialized hospital has been brought in table 9. The cost of setting up different services in the specialized facilities is also presented in table 10.

Table 6. Fixed costs associated to family physician centers establishment in potential locations ($*10^6$)

Potential location	Establishment fixed cost	Potential location	Establishment fixed cost
1	280	13	390
2	210	14	330
3	180	15	350
4	220	16	310
5	260	17	240
6	210	18	220
7	220	19	370
8	230	20	260
9	310	21	305
10	380	22	390
11	350	23	370
12	340	24	360

Table 7. Fixed costs associated the specialized hospitals establishment in potential locations (*10^6)

Potential location 2	Potential location 3	Potential location 9	Potential location 22
13350	17200	20500	24000

Table 8. Fixed costs associated specialized clinics establishment in potential locations (*10^6)

Potential location 2	Potential location 3	Potential location 6	Potential location 8	Potential location 14	Potential location 19	Potential location 23	Potential location 24
520	610	670	690	710	860	880	910

Table 9. Road distance between each patient zone and each potential location for establishing specialized hospital (km)

Patient zone	**Potential location 2**	**Potential location 3**	**Potential location 9**	**Potential location 22**
1	0.55	5.7	1.2	2.7
2	0	2.2	1	2.6
3	2.5	0	3	4.2
4	0.5	2	0.75	2.5
5	0.75	1.7	0.45	2
6	0.7	1.6	0.4	2
7	0.55	2.3	0.65	2.7
8	1.6	0.85	0.85	2.4
9	1	1.5	0	1.6
10	1.2	1.2	0.55	1.8
11	1.3	1.2	0.55	1.8
12	1.3	1	0.55	1.8
13	1.3	1.6	0.28	1.2
14	1.6	1.5	0.55	1.5
15	2	1.1	0.85	2.2
16	1.6	1.9	0.55	1
17	1.8	1.7	0.75	1.2
18	2	1.7	0.95	1.3
19	1.8	2.1	0.75	0.75
20	2	2	1	0.9
21	2.3	1.7	1.3	1.1
22	2.1	2.4	1	0.5
23	2.8	2.9	1.8	0
24	3	2.5	2	1.8

Table 10. Services setting up cost in specialized facilities (*10^6)

How to provide service	Internal	Heart	Eye	Ear
Inpatient	20	25	10	15
Outpatient	0.01	0.02	0.03	0.03

It should be noted that due to the space limitations, the values of a number of important parameters are given, and bringing the rest of parameters is relinquished.

5- Computational results

In this section, the presented mathematical model is implemented by the software GAMS 24.1.3 CPLEX Solver on a computer with Intel Core i5 and 4 GB. In the optimal point, the total objective function is 186149690996. Due to the high number of variables, some of the important variables of the problem such as opened facilities and the method of allocating patient zones to the family physician centers are presented in figure 3. For example, at a potential location 2, a family physician center was established and patient zones 1 and 8 were assigned to this family physician center.

5-1- Sensitivity analysis

In this section, in order to validate the proposed model, sensitivity analysis was performed on some of the important parameters. One of the important parameters of the proposed model is the maximum available human resources on the network, which has a significant impact on the gained results. To show the effect of this parameter's change on the target function, it is assumed that the value of this parameter has increased by 10, 20, 30, 40 and 50 percent. In figures 4 and 5, respectively, the effect of these changes on the total cost of the shortages and the total cost of the facility establishment, the launch of services and patients travel have been shown. In figure 6, the effect of these changes on the purposed objective function is also given.

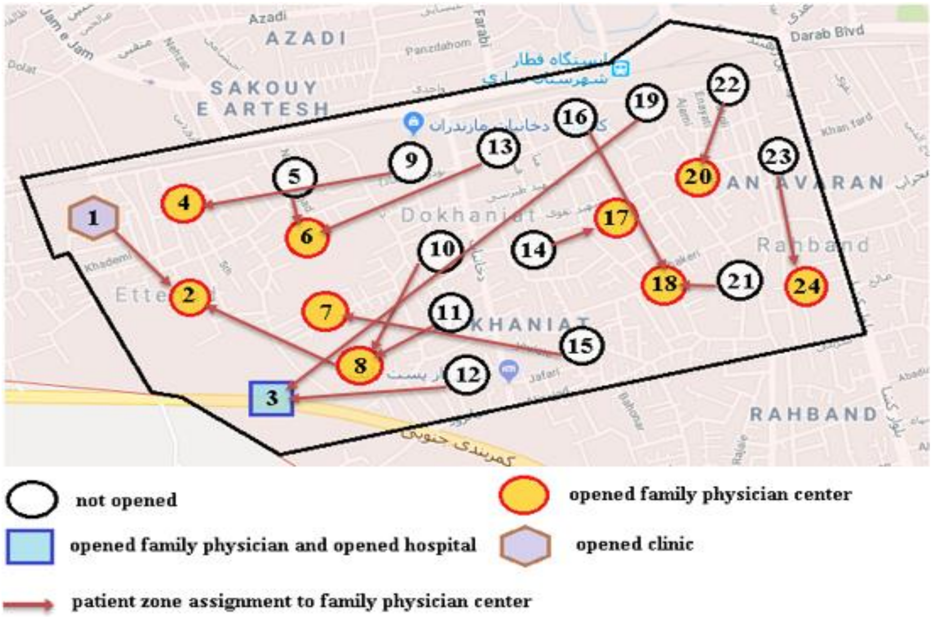

Fig. 3. The optimal results obtained for the examined area in Sari by GAMS software.

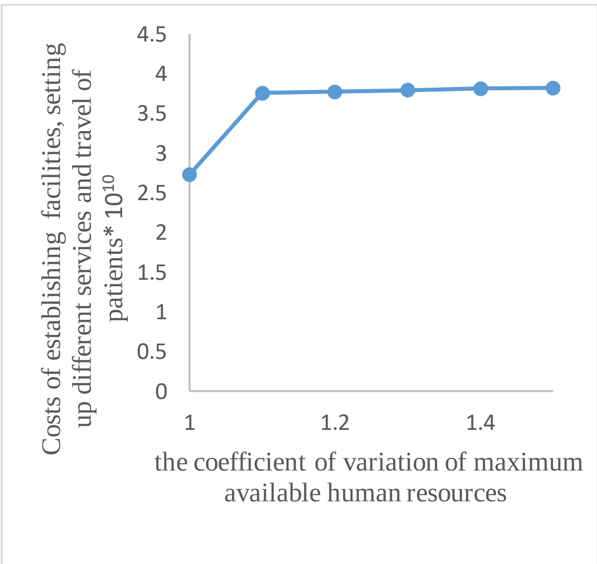

Fig. 4. The impact of the maximum available human resources variation on the costs of establishing facilities, setting up different services and the travel of patients

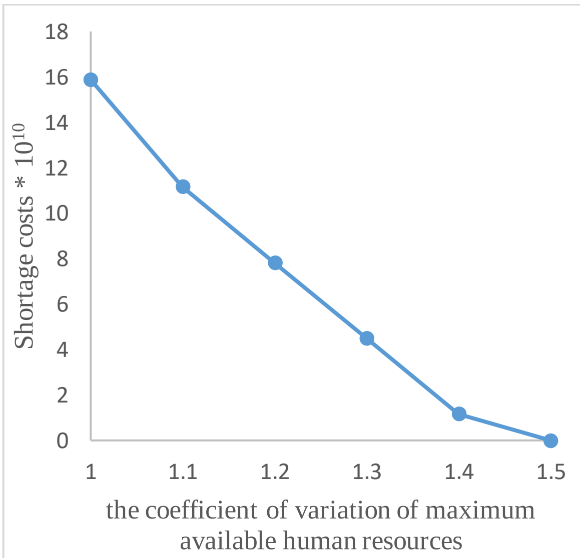

Fig. 5. The impact of the maximum available human resources variation on the shortage costs

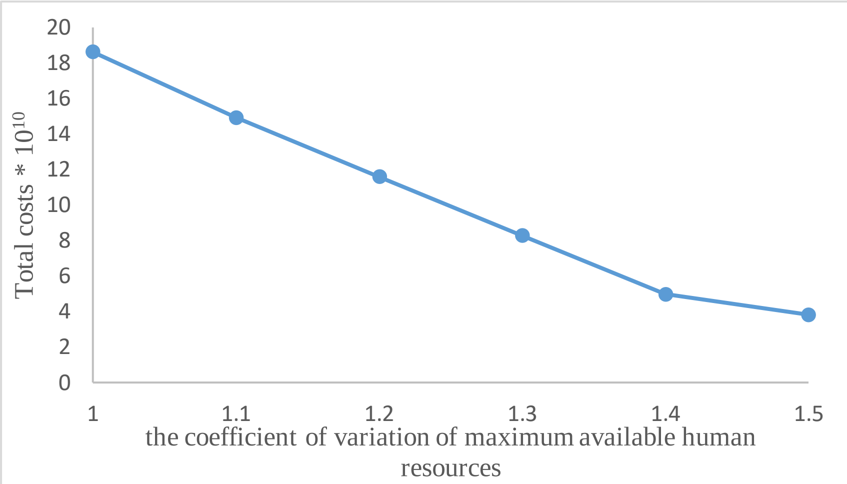

Fig 6. The impact of the maximum available human resources variation on the total costs

As shown in figure 4, with increasing the maximum available human resources, because of more launching capacity for the different services and the increase in the ability of facilities to accommodate more patients, the storage cost is reduced to the point where, if the maximum available resources will increase by 50%, the cost will be reduced to zero. On the other hand, according to Figure 5, with the increase in the maximum available human resources, the total cost for the facilities establishment, setting up services and the travel of the patients increases, since by increasing the maximum available human resources if the opened facilities are not used by the maximum allowable capacity, more capacity should be launched in the opened facilities; thus, the costs associated with the service launches are increased. If the facilities are used by the maximum allowable capacity, new facility must be established, which will also increase the cost of establishing the facilities. Moreover, by increasing the maximum available human resources and the ability of facilities for receiving more patients, patients travel costs will be increased as a result of increasing in the flow of patients between facilities.

Now, in the context of the effect of the considered parameter on the objective function of the proposed model, as shown in figure 6, in general, with the increase of the maximum available human resources, the objective function of the proposed model is reduced since although the cost of establishing the facilities, the launch of the different services and the patients’ travel is increased, these costs have a smaller share in the overall objective function in comparison with the shortage costs. Thus, according to figure 6, if the decision maker tries to reduce the costs, one of the ways is to increase the maximum available human resources by 50%.

Further, another effective parameter in the proposed model is the average number of patient zone referral to the family physician centers, which has been analyzed in this section. In figure 7, the results of this analysis and the effect of the parameter changes on the target function are presented.

As shown in figure 7, with increasing the average number of patient zone referral to the family physician centers, objective function is increased. This is because if there is no shortage in the needed resources including the capacity and the human resources, with increasing the desired parameter due to the increased demand at different levels of the network, the flow in the network increases and more centers should be built and more services should be launched; as a result, the costs of facilities establishment, services launching cost and the patients travel cost increase. with increasing demand, if there are no enough resources, the storage costs increase since a portion of demands will be faced with the shortages. Further, by reducing the desired parameter, objective function would be better because of the fewer facilities establishment, fewer services setting up in different facilities and the fewer shortages.

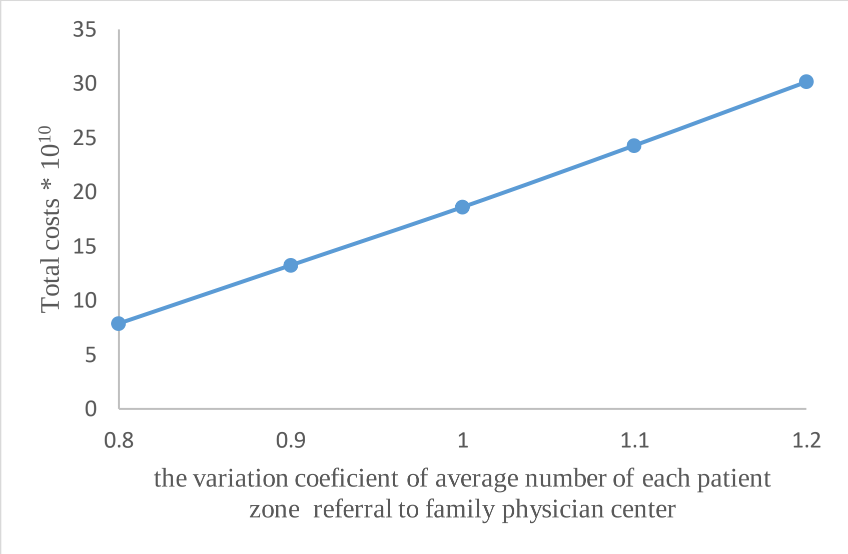

Fig. 7. The impact of the average number of each patient zone referral to family physician center variation on the total costs

In terms of managerial insights of this work according to the conducted research, the implemented referral system in some cities in Iran has been unsuccessful. Because in the referral system, for example one of the most important criteria is the allocation of patients and physicians to the health service provider facilities due to their travel cost, which is ignored in planning and is resulted in the referral system inefficiency in these cities. Therefore, since in this research the index of patients and physicians' allocation to the closest facility have been considered, the computational results obtained cover this defect in the implementation of the referral system in Sari and cause the better conditions. As a result, managers of the healthcare organization responsible for designing the healthcare facility network can use the proposed model to design an efficient healthcare facilities network considering the hierarchical structure under the limitation of the human resource. Further, according to the implemented analysis on the maximum available human resource, the computational results from solving the proposed model by case study data shows that in the current situation, due to the limitation of the human resources, a large portion of the network cost is related to the shortage cost. If employing more human resources is possible for the planner, they should be applied to more human resources since the cost of the network is significantly reduced due to the shortage cost reduction. On the other hand, given the above results, because in the assumed network decision variables are strategic decisions and the values of parameters such as average number of each patient zone referral to family physician center have a significant effect on the amount of decision variables and the objective functions, managers and planners should determine the values of these parameters correctly so that they can fulfill objectives such as satisfying patients, reducing system costs, avoiding waste of resources, etc.

6- Conclusions

In this research, a mixed integer programming model has been presented for a two-level hierarchical healthcare facilities network design problem under the human resource and facilities capacity constraint. In the proposed network at the first level there are family physician centers that are entry point of patients into the network, and at the second level there are the specialized facilities including the specialized hospitals (the provider of specialized services in the form of hospitalization) and the specialized clinics (outpatient services providers). In the proposed model, decisions such as the location of facilities, patients' allocation, appropriate referral pattern between the network levels, capacity planning and the human resource planning are most important decisions that are determined by the model. In the proposed model, the objective function is to minimize the total costs, including the cost of facilities establishment, setting up various services at the facilities, patients' travel, and the shortages. The model is also implemented based on the data obtained from parts of Sari in Mazandaran province by GAMS software. Finally, in order to validate the proposed model, sensitivity analysis was performed on a number of effective parameters such as the maximum available human resources and the average number of patient zone referral to family physician centers, for which the results were reported. and based on our results, we conclude that:

1-Since the considered network structure in this research is a two level hierarchy compared to a Single-level network, it reduces dramatically the cost. Because in the proposed hierarchical structure there is an effective coordination between the two levels of the network for providing a service to a patient.
2-Managers and planners of the health network design can use the proposed model for designing an efficient hierarchical healthcare network under the human resource limitation that cover some defects of the existing network.
3-One of the most important constraints assumed in the proposed model is the limitation of human resources. Therefore, by using the proposed model planners can use available human resources in such a way that the shortage costs are minimized.
4- One of the policies that planners can use in order to increase the proposed network efficiency is to increase the minimum available human resources that have a significant effect on reducing the costs of the network.

Areas for further research are (a) converting the proposed model to the multi-period model, (b) considering the model as a multi objective model, (c) considering the allocation of human resources to each of the centers as one of the model decisions, and (d) developing heuristic and meta-heuristic algorithms to solve the large-scale instances.

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