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Research Article

Modeling the allocation and transfer of emergency patients according to the type of disease

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Abstract

Background and Objectives: The increase in the number of patients in hospitals and the long wait due to overcrowding are some of the main concerns in health system research. Transferring patients to emergency departments is one way to reduce the congestion of the emergency department.

Methods: This study deals with the allocation of patients in the emergency department of hospitals, according to the segregation of the type of disease, which reduces the congestion by transferring patients to other hospitals, if necessary, and minimizes the total cost of the system. In this paper, a linear model is presented for patient allocation and the model is solved using GAMS software.

Results: Patients admitted to the hospital are divided into different types in terms of the type of disease. To reduce the cost of waiting and reduce the waiting time for patients, patients who cannot be treated at the hospital due to lack of expertise in their illness are transferred to other hospitals. All costs, including the cost of increasing the patient's capacity, the cost of admitting the patient, the cost of transporting patients, the cost of waiting fines, the cost of unmet demand and the cost of overtime are calculated in the mathematical model.

Conclusion: by transferring patients, the number of expected patients and the number of patients who are considered as unmet needs can be reduced. Because with the increase in the number of patients waiting and patients who have not been considered as an unmet demand, the mortality rate, medical errors and patient dissatisfaction will increase and irreparable risks will arise, especially for patients with acute problems.

Keywords: Emergency Department, Patient Transfer, Patient Assignment, Overcrowding, Key Performance Index.

Background and Objectives

The increase in the number of patients in hospitals and the long waiting time due to overcrowding are some of the main concerns in health system research. If a hospital becomes overcrowded, patients may need to be transferred to other hospitals. Therefore, this paper examines the effect of transferring patients to other hospitals in multi-hospital settings. In multi-hospital settings, it may be more appropriate to transfer patients to other hospitals with available resources, rather than enduring unmet demand or long waiting times. Depending on its policy, the source hospital may consider a limit on the number of patients it can transfer at a time. Decisions about patients who are to be transferred are based on awareness of the availability of resources and the availability of expertise at the target hospital. The three parameters of hospital income from patient admission, hospital waiting time and the time required for patient transfer between hospitals are considered random. Patients admitted to the hospital are divided into different types in terms of the type of disease.

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To reduce the cost of waiting and reduce the waiting time for patients, patients who cannot be treated at the hospital due to lack of expertise in their illness are transferred to other hospitals. All costs, including the cost of increasing the patient's capacity, the cost of admitting the patient, the cost of transferring patients, the cost of the waiting fine, the cost of unmet demand, and the cost of overtime are calculated in the mathematical model. The complexity and importance of the emergency department requires planning and management in order to optimize time and costs in the best possible way, which can be done by modeling the problem with the help of random planning. In this model, all variables may be random or even a random variable that may have different scenarios.

In the rest of the article, the following sections are composed: In the second section, a review of the existing studies with the focus on patient transfer is reviewed. In the third part, mathematical modeling is done. In the fourth part, the case study is implemented and finally in the last part of the article, future results and suggestions are discussed.

The emergency department is the part of the hospital known as the emergency room. The main purpose of emergencies is to provide immediate and accurate health care. Today, the problem of overcrowding in the emergency room, which is created for various reasons, such as poor resource management, excessive patient admission rate in proportion to emergency capacity, patients who do not need to go to the emergency room, lack of predictability of patient admission rate and many other reasons has caused some problems in providing services. Excessive overload of the patient leads to medical errors and adverse outcomes, prolonged patient waiting time, increased patient complaints, reduced employee satisfaction and reduced physician productivity. In addition, overcrowding in emergencies also affects hospital costs. A common solution to manage overcrowding, is returning incoming patients and ambulances (by referring them to other emergency rooms in the region), and not accepting non-emergency patients. Most studies focus on predicting patient size, scheduling the work of physicians and nurses, the chain of medical processes, and resource use planning. Many studies in the field of emergency workflow is using computer programming and simulation methods to identify ways to increase the efficiency of health care and reduce the length of time a patient stays in the emergency chain. Therefore, overcrowding and long-term patient stay have been interesting for staff and health care researchers for many years, and several methods have been developed to improve emergency workflow[1].

Resource allocation has a direct impact on the patient's operational capacity and admission rate system. One of the most common concerns in many studies related to emergency resource optimization is managing high level of uncertainty in demand. The concept of fuzzy set is one of the useful tools for combining uncertain variables. A multi-step queuing system model to optimize the number of nurses in the outpatient department[2]. The dynamic simulation model for the UK Department of Health by Esensoy and Carter is the first model with an overview of the entire system used to assess the impact of capacity allocation decisions during the waiting period for selective selection and discharge time in acute care hospitals[3]. Claudio et al. presented a model for a dynamic decision support system to demonstrate nurses' preferences and simplify data by providing nurses to each patient with the highest priority[4]. Increasing the number of non-emergency patients in the emergency department and the long waiting time due to overcrowding are some of the main concerns in health system research. According to Nezamoddini and Khasavaneh's study, the strategy of transferring patients between hospitals can be used to minimize patient waiting time without increasing the number of resources required. It should be noted that improper patient transfer has been identified as an important reason for the increase in adverse referral rates. The patient was transferred to hospitals in Hong Kong, Saudi Arabia and the United States based on actual data available at hospitals[5].Gonz et al. used three-step linear programming models to optimize hospital planning for optimal bed allocation based on set goals and for a specific situation[6].

Capron et al. proposed a classification plan for brain injury guidelines by which patients were divided into three groups: brain injury guidelines 1 (mild head injury), brain injury 2 (moderate brain injury), and brain injury 3 (severe head injury or anticoagulant use). Based on this classification and based on a comparative scale, it can be decided which patients need to be transferred and which can be treated in the existing[7].

Table (1) provides a summary of some of the relevant research work in the field of emergency congest

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Table1: Summary of articles

Case study	Transfer with considering to type of disease	Solution				approach				cost						References
		simulation	Meta heuristic	Heuristic	exact	exact	Robust	fuzzy	Stochastic	Doctors expertise	patients transfer cost	Unmet demand cost	Waiting cost	Overtime cost	capacity cost	
USA hospitals	-	-	-	-	-	•	-	-	-	•	•	•	•	•	•	5
USA hospitals	-	-	-	-	-	•	-	-	-	-	•	-	-	-	-	8
-	-	•			-		-	-	-	-	•	-	-	-	-	1
U.K Belfast	-	-	-	-	-	•	-	•	-	-	•	-	-	-	-	2
yoga Portugal hospital	-	-	-	-	-	•	-	-	-	-	-	-	•	-	-	9
Mardin state hospital	-	-	-	-	-	•	-	-	-	-	•	-	-	-	-	10
-	-	-	-	-	-	•	-	-	-	-	-	•	-	-	-	4
Chile hospitals	-	-	-	-	-	•	-	-	-	•	•	•	-	-	-	6
Ontario states	-	•	-	-	-	-	-	-	-	•	•	•	-	-	-	3
Carl oriental hospital	-	-	-	-	-	•	-	-	-	•	•	-	-	-	-	7
-	-	-	-	-	-	•	-	-	•	-	•	-	-	-	-	11
UK hospitals	-	•	-	-	-	-	-	-	-	-	•	-	-	-	-	12
-	-	•	-	-	-	-	-	-	-	-	•	-	-	-	-	13
-	-	-	-	-	-	•	-	-	•	•	•	-	-	-	-	14
Imam Reza Hospital in Tabriz	-	-	-	-	-	-	-	-	-	•	-	-	-	-	-	15
hospitals in Ardabil province	•	-	-	-	•	•	-	-	-	•	•	•	•	•	•	Present study

In previous studies, considering that the aspect of disease segregation in the issue of patient transmission has not been regarded, so in this article, we intend to consider this issue as well. Also, to match the model with the real-world conditions, a number of random problem parameters have been considered. So far, no patient transfer research has been conducted in Ardabil province.

Method

Most allocation and transfer of emergency patient's models available in the literature are trying to minimize total costs. Figure 1 shows a schematic of the approaches taken in this paper. First, a single objective model is developed for blood collecting and testing. Then in Step 2, validating model in GAMS software is considering. Next, data is Gathering in Step 3. Finally, Solve model using the CPLEX solver in Step 4. In what follows, these steps are described in details.

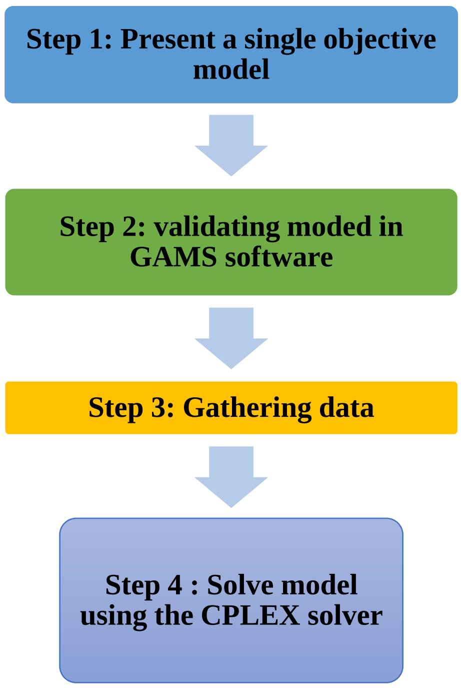

Fig 1.Modeling and solving approach

The model tries to decide the following decisions in each period involved in the planning horizon:

- The number of patients admitted to each hospital at each time.
- The number of unmet patient requests in each hospital at each time with all specialization.
- The number of patients waiting in each hospital at each time t and with all specialization, under each scenario.

Research assumptions:

1. In this study, various centers are considered for hospitals.
2. Hospital income from admitted patients, waiting time for hospital service, time required for transfer between hospitals is random.

3. An ambulance is provided as a means of transfer and will only carry one person at a time.
4. All geographical events such as heavy rains, floods, etc. have been ignored.
5. The transfer of a patient will be done according to the specialty of the doctors of the target hospital.

Parameters

H	The total number of hospitals
T	Optimal course
T '	A period during which admission of patients will require overtime
G	Transmission matrix
S	Total number of scenarios
$\alpha_{i,m,s}$	The cost of a capacity increase unit in hospital i and specialty m under scenario s
$\beta_{i,m,s}$	Income from patients admitted to hospital i and m specialty, under scenario s
v_i	The cost of overtime in the hospital i
$y_{i,j}$	The cost of transferring the patient from hospital i to hospital j
$\delta_{i,m,s}$	The cost of waiting for a patient in hospital i and the specialty m, under scenario s
$\eta_{i,m}$	The cost of the unmet patient demand in the hospital i and the specialty m
$\lambda_{i,t,m}$	Patient admission rate in hospital i at time t and specialty m
$\mu_{i,m}$	waiting time for hospital i and specialty m
$d_{i,j}$	The time required to transfer a patient from hospital i to hospital j
$L_{i,m,s}$	The number of patients allowed to be transferred at any time from hospital i and the specialty m, under scenario s
$g_{i,m,s}$	1; if the type of specialty m available at the hospital i under scenario s, otherwise 0

Indices

i, j	Index of hospitals and demand area
m	Index of available specialties
t	index of a time period $(t = 1,2, \dots, T)$
s	index of a scenario $(s = 1,2, \dots, S)$

Decision variables

$X_{i,m.s}$	Capacity of hospital i and specialty m, under scenario s
$Y_{i,t,m,s}$	The number of patients admitted to hospital i at time t and specialty m, under scenario s
$Z_{i,t,m,s}$	The number of patients discharged from hospital i at time t and specialty m, under scenario s
$C_{i,t,m,s}$	Available capacity in hospital i at time t and specialty m, under scenario s
$u_{i,t,m,s}$	The number of unmet patient requests in hospital i at time t and specialty m, under scenario s
$W_{i,t,m,s}$	The number of patients waiting in hospital i at time t and specialty m, under scenario s
$f_{i,j,t,m,s}$	The number of patients transferred from hospital i to hospital j at time t and specialty m, under scenario s
$O_{i,s}$	Overtime for hospital i, under scenario s
$h_{i,t,m,s}$	total number of patients received from hospital i to another hospital with specialty m under scenario s

Model

$$\text{Min } Z = \sum_{i,m} \alpha_{i,m,s} X_{i,m.s} g_{i,m,s} + \sum_{t\in T} \sum_{i\in H} \sum_{m} \beta^{s}_{i,m,s} Y_{i,t,m,s} g_{i,m,s} + \sum_{t\in T} \sum_{i\in H} \sum_{j\in H\notin\{i\}} \sum_{m} Y_{i,t,m,s} f_{i,j,t,m,s} + \sum_{m} \sum_{t\in T} \sum_{i\in H} \delta^{s}_{i,m,s} w^{s}_{i,t,m,s} + \sum_{m} \sum_{t\in T} \sum_{i\in H} \eta^{s}_{i,m,s} U^{s}_{i,t,m,s} + \sum_{i\in H} v_i O_i \quad (1)$$

$$w_{i,m,t,s} + Y_{i,t,m,s} + U_{i.t,m,s} = w_{i,m,s,t-1} + h_{i,t,m,s} \quad \forall_t > 1, \forall_i \in H, \forall_m \in M, \forall_s \in S \quad (2)$$

$$\sum_{j\in H} f_{i,j,t,m,s} + Y_{i,t,m,s} + w^{s}_{i,m,t,s} + U^{s}_{i,m,t,s} = w^{s}_{i,m,s,t-1} + h^{s}_{i,t,m,s} + \sum_{j} f^{s}_{j,i-(di,j),m} \quad \forall_t > 1, \forall_m \in M, \forall_i \in H, \forall_s \in S \quad (3)$$

$\sum_{j\in H} f_{i,j,t,m,s} + Y_{i,t,m,s} + w^{s}_{i,m,t,s} + U^{s}_{i,m,t,s} = h^{s}_{i,t,m,s} \quad t = 1, \forall_{i} \in H, \forall_{m} \in M, \forall_{s} \in S$	(4)
$Y_{i,t,m,s} \leq C^{s}_{i,m,t,s} \quad t \in T, \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(5)
$C^{s}_{i,t,m,s} \leq X_{i,m.s} \quad \forall t > 1, \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(6)
$C^{s}_{i,m,t,s} = X_{i,m.s} \quad \forall t = 1, \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(7)
$C^{s}_{i,m,t,s} = C^{s}_{i,m,t-1,s} - y^{s}_{i,t-1,m,s} + z^{s}_{i,t-1,m,s} \quad \forall t > 1, \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(8)
$z^{s}_{i,t,m,s} \leq y^{s}_{i,t-(\eta i,m),m,s} \quad \forall t > \mu^{s}_{i,m,s}, \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(9)
$z^{s}_{i,t,m,s} = 0 \quad \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S, \forall t < \mu^{s}_{i,m,s}$	(10)
$\alpha^{s}_{i,m,s} X_{i,m.s} \leq \sum_{i} B_{i} \quad \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(11)
$\sum_{i} \alpha^{s}_{i,m,s} X_{i,m.s} \leq \sum_{i} B_{i} \quad \forall_{m} \in M, \forall_{s} \in S$	(12)
$f_{i,j,t,m,s} \leq \min(C_{j,m,t} + d_{i}, L_{j}) \quad \forall_{i,j} \in H, \forall t \in T, \forall_{s} \in S$	(13)
$f_{i,j,t,m,s} \leq L_{i} \quad \forall_{i,j} \in H, \forall t \in T, \forall_{m} \in M, \forall_{s} \in S$	(14)
$f^{s}_{i,j,t,m,s} \leq C_{j,m,t} + d_{i,j} \quad \forall_{i,j} \in H, \forall t \in T, \forall_{s} \in S$	(15)
$O_{i} = \sum_{t\in T} \sum_{m\in M} y^{s}_{i,t,m,s}(t + \mu_{i} - T) \quad T' : \{t + \mu_{i} > T\}$	(16)
$Y_{i,t,m,s} \leq g_{i,m,s} \quad \forall_{i} \in H, \forall t \in T, \forall_{m} \in M, \forall_{s} \in S$	(17)
$Y_{i,t,m,s} \leq g_{i,m,s} \quad \forall t \in T, \forall_{i} \in H, \forall_{m} \in M, \forall_{s} \in S$	(18)
$Y_{i,t,m,s} \leq g_{i,m,s} E \quad \forall_{m} \in M, \forall_{i} \in H, \forall_{s} \in S$	(19)

The objective function in relation to (1) is to minimize the total cost, including the cost of increasing capacity, the cost of acceptance, the cost of transfer, the cost of waiting penalty, the cost of unmet demand, and the cost of overtime working. Constraint (2) implies that patients who have been waiting for the previous time and those who have just arrived may be accepted, or remain waiting, or be considered as unmet demand and not be accepted. Constraint (3) state that patients who have been waiting for a long time and those who have recently been admitted, as well as patients who have been admitted to another hospital, may be admitted, transferred or considered as unmet demand. Constraint (4) states that the rate of hospital admission is equal to the total number of patients received from another hospital, the expected patients, the hospitalized patients, and the demand is not met. Constraint (5) indicates that the total number of patients admitted cannot exceed the capacity of the hospital. Constraint (6) indicates that at time t> 1, the available capacity of the small hospital is greater than the capacity intended for the hospital. Constraint (7) states that at the beginning of the time period, the available capacity of the hospital is equal to the capacity intended for the hospital. Constraint (8) states that the capacity available in each hospital for m specialization is equal to the previous capacity altered by patients admitted and discharged. Constraint (9) indicates that the number of patients discharged at each time cannot exceed the number of patients admitted for treatment. Constraint (10) states that there will be no clearance at the beginning of the shift. Constraint (11) states that the cost of increasing the capacity of each hospital for each specialty must be less than the available budget. Constraint (12) states that the cost of increasing the total capacity of hospitals for specialties should be less than the budget available to all hospitals. Constraint (13) states that the number of patient transfers should be less than the transfer limit of the source hospital and the existing capacity of the target hospital. Constraint (14) states that the number of patients transferred from hospital i to hospital j at time t and with m specialization should be less than the number of patients allowed to be transferred by hospital i. Constraint (15) states that the number of patients transferred from hospital i to hospital j at time t and with each specialization should be less than the available capacity of target hospital j. Constraint (16) states that overtime working will be equal to the overtime working required by multiplying the number of accepted patients whose discharge time will be after the end of the shift. Constraint (17) states that if the m specialty is available in each hospital, the patient who needs the m specialty will be admitted there; otherwise he/she will not be accepted. Constraint (18) states that if the specialty m is present in the each hospital, the patient who needs the specialty m will wait there; otherwise he/she will not wait, and the Constraint (19) states that if the specialty m is present in the hospital i , the intended capacity will be significant; otherwise he/she will not wait.

Data collection

To transfer patients among hospitals, hospitals in Ardabil province have been considered. Hospitals and their information are divided into six categories in Table (2) and all specializations available in Hospitals according to Table (3).

Table2: information of hospitals in Ardabil province

	city	Number of bed	Hospital name
	Ardebil	65	Arta
	Ardebil	149	Bouali
	Ardebil	170	Alavi
	Ardebil	144	Sabalan
	Ardebil	190	Dr Fatemi
	Ardebil	128	Imam reza
	Ardebil	302	Imam khomeyni Ardebil
	Ardebil	40	Qaem
	Namin	5	Emamkhomeyni namin
	Khalkhal	123	Emam khomeyni khalkahl
	Germi	94	Velayat
	Meshkin shahr	115	Valiasr
	Bilehsavar	35	emamkhomeyni bilehsavar
	Parsabad	42	Aras
	Parsabad	117	Emamkhomeyni pars abad

Table3: break down of allocations

specialty / **hospitals**	m1: internal	m2: heart	m3: Public surgery	m4: eye	m5: Throat & nose	m6: blood
Arta	■	-	-	-	-	■
Bouali	■	-	■	■	-	-
Alavi	■	-	■	■	-	-
Sabalan	■	■	■	■	-	-
Dr.Fatemi	■	-	■	-	-	-
Imam reza	■	-	-	-	-	-
Imam.kh Ardebil	■	-	■	-	■	-
Qaem	■	-	■	-	-	-
Imam kh .Namin	■	-	■	-	-	-
Imam kh .khalkhal	■	-	■	■	-	-
Velayat	■	-	■	-	-	-
Valiasr	■	-	■	-	-	-
Imam kh Bilehsavar	■	-	■	-	-	-
Aras	■	■	-	-	-	-
Imam kho . Parsabad	■	■	■	-	■	-

Data review

Considering to the 15 existing hospitals into account in Ardabil province and six specialties, the one-hour optimization unit during the 8-hour period (T = 8) studying of the initial data, including the cost of increase in one unit of the capacity of hospitals, the cost of transferring patients among hospitals, the provided budget to give the resources allocated to hospitals, the cost of unmet patient demand, the rate at which patients enter hospitals, the length of time patients wait to receive service, the number of patients allowed to transfer, the income from hospital admissions, the time required to transfer patients , the cost of hospital overtime working and the cost of patient's waiting time waiting fine will be dealt with.

- The cost of one unit increase in hospital capacity: the cost of increasing capacity includes the cost of increasing the number of hospital beds, and for all hospitals and all specialties, the equivalent is 1,000$.
- The cost of transporting patients between hospitals: this cost is the same as the cost of transferring each patient to another hospital, and regardless of the distance between hospitals, a fixed rate of 20$ is considered.
- Budget allocated to provide resources to hospitals: This budget includes the total budget allocated to increase the capacity of each hospital, which is intended for two hospitals, Arta and Imam Reza, according to Table (4) in dollars.

Table 4: Total budget to increase capacity for each hospital

Hospital	Increasing capacity budget
Arta	5091741
Imam Reza	7293428

- The cost of patients' unsatisfied requests: This cost is the fine that is considered for the hospital in addition to the patient's unmet demand and the patient's leaving the hospital. It should be noted that this fine is the same for all hospitals in the province and specialties, and its 50$.
- Patient admission rate to hospitals: This rate determines the number of patients entering the hospital emergency room for each specialty and each 1-hour period. It should be noted that the duration of the period is 8 hours (T = 8).

According to Figure 2, patients' admission rates to Arta Hospital at time t = 1 are 32, 32, 32, 32, 34, 34, 0, and 19, respectively, for internal medicine, heart, general surgery, eye, throat, and nose specialties.

- Patients' waiting period for service: The time it takes for the patient admitted to the emergency room to be visited and treated by the treating physician. For convenience, this time is roughly the same for similar specialties in different hospitals. The waiting time for patients to receive the service is determined by considering the specialties listed in Table (5).

Table 5: Waiting time to receive service

Time(hour)					
Blood	Throat & nose	Eye	public surgery	internal	heart
0.54	0.83	0.24	0.45	0.24	0.33

Number of patients allowed for transfer: The number of patients allowed to transfer is determined by the hospital's policy of origin. In this case study, the number of patients allowed for transmission is considered a random parameter and has three scenarios: It has been less than average, moderate, above average, with probabilities of 1/3, 1/3 and 1/3, respectively. Tables (6) to (8) indicate the number of patients allowed in some hospitals for transferring in each scenario.

Table 6: Number of patients allowed for transmission under scenario 1

Expertise / hospital	Number of patients allowed for transmission					
	blood	Throat & nose	eye	Public surgery	Heart	Internal
Arta	2	2	4	3	2	2
Imam reza	4	5	2	3	7	2

Table 7: Number of patients allowed for transmission under scenario 2

Expertise / hospital	Number of patients allowed for transmission					
	blood	Throat & nose	eye	Public surgery	Heart	Internal
Arta	2	2	5	4	2	2
Imam reza	5	6	3	4	8	3

Table 8: Number of patients allowed for transmission under scenario 3

Expertise / hospital	Number of patients allowed for transmission					
	blood	Throat & nose	eye	Public surgery	Heart	Internal
Arta	4	4	6	5	4	4
Imam reza	6	7	4	5	9	4

- Income from hospital admissions: This income is the same as emergency income for the admission of each patient, which is the same for all hospitals and all specialties. In this paper, the income from patient admission is a random parameter and has three scenarios less than the mean, mean, and above-average, respectively, with probabilities of 1.4, 4.2, and 1.4. Thus, the income from hospital admissions for three scenarios is 28, 35 and 42 dollars, respectively.
- Time required transferring patients: This time is the time required to transfer patients from one hospital to another. Transition is in ideal conditions, with probabilities of 1/3, 1/3, and 1/3, respectively. Tables (9) to (11) specify the time required to transfer patients to some hospitals (in terms of hours).

Table 9: Time required transferring patients from hospital i to hospital j under scenario 1

Hospital	Qaem	Imam Reza	Bou Ali	Arta
Arta	0.18	0.27	0.05	0
Imam Reza	0.18	0	0.22	0.27

Table 10: Time required transferring patients from hospital i to hospital j under scenario 2

Hospital	Qaem	Imam Reza	Bou Ali	Arta

Arta	0.21	0.3	0.06	0
Imam Reza	0.2	0	0.25	0.3

Table 11: Time required transferring patients from hospital i to hospital j under scenario 3

Hospital	Qaem	Imam Reza	Bou Ali	Arta
Arta	0.24	0.33	0.06	0
Imam Reza	0.22	0	0.27	0.33

Scenario tree

Figure (2) shows the scenarios for three random parameters. The probability of scenario 1 in the scenario tree is equal to: (probability of the first scenario d) (probability of the first scenario B) (probability of the first scenario L) and similarly the probability of all 27 scenarios is calculated.

Figure 2: Scenario tree

Table 12: Amounts of probability and random parameters changes percent

Percent of changes			probability			Parameters
The time required to transport patients between	Earning incomes from hospital admissions	Number of patients allowed for transmission	The time required to transport patients between hospitals	Earning incomes from hospital admissions	Number of patients allowed for transmission	
10%	20%	20%	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{3}$	Less than average
-	-	-	$\frac{1}{3}$	$\frac{2}{4}$	$\frac{1}{3}$	average
10%	20%	20%	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{3}$	More than average

Model implementation

In this section, we will calculate EVPI and VSS by calculating $\mathbf{Z_{WS}}$, $\mathbf{Z_{WS}}$, and $\mathbf{Z_{WS}}$ which are GAMS software output outputs.

- $\mathbf{Z_{WS}}$
  In this method, we solve the random programming model for each of the scenarios and then calculate the value of the $\mathbf{Z_{WS}}$ objective function from Equation (20).

$Z_{WS} = \sum_{S}^{S} \overset{S}{P}Z$	(20)

- $\mathbf{Z_{EEV}}$
  In this method, first the average values for the random parameters are placed, and then the values of the variables of the first step that are definite are obtained. Then, by placing them in the random model, the value of the random variables in the second step is obtained and is $\mathbf{Z_{EV}}$ obtained. Then, with definite variables obtained, we solve the problem for each scenario and calculate $\mathbf{Z_{EEV}}$ from Equation (21).

$$Z_{EEV} = \sum_{S}^{s} p(x_{EV}, S) \quad (21)$$

- $\mathbf{Z_{HN}}$
  In this method, all scenarios are aggregated and solved in one model, and the $\mathbf{Z_{HN}}$ value is obtained from solving the model.

- The values $\mathbf{Z_{WS}}, \mathbf{Z_{EEV}}, \mathbf{Z_{HN}}$ derived from the GAMS software are given in Table (13) for a number of scenarios in terms of dollars.

Table 13: Amounts of Z_{WS} ،Z_{EEV} و Z_{HN}

Z_{WS}	Z_{EEV}	Z_{HN}
564620	544474	532567

- **Calculating EVPI and VSS**
  These two indicators show the importance of the answers calculated in different methods ($\mathbf{Z_{HN}}$, Z_{EEV}, Z_{WS}).

Average Total Information Value (EVPI): Indicates the importance of addressing information uncertainty. In fact, it shows how effective the lack and incompleteness of information is and how much money can be spent to get the full information. The value of complete information in Table (14) is presented in dollars.

Random Answer Value (VSS): Indicates the cost of ignoring uncertainty in decision making. The small value of the random answer indicates that the answer to the average value method is a good approximation of the real answer to the problem. The value of the random answer in Table (14) is presented in dollars.

Table 14: Mean value of complete information and value of random answer

The value of the random answer	Mean value of complete information
11907	20146

The average value of full information indicates that up to 20146$ can be spent on obtaining complete information about hospital income beyond patient admission, the number of patients allowed to transfer and the time required to transfer patients, and the value of random response; that is, if we ignore uncertainty, we will spend 11,907$. In other words, by saving the model, we saved 7666$.

- Capacity for Hospitals: The capacity for hospitals with relevant specializations is equal for all scenarios. Table 15 shows the capacity for some hospitals.

Table 15: Capacity for hospitals, under 27 scenarios

Specialties / hospital	Blood	Throat & nose	eye	Public surgery	Heart	Internal
Arta	8	-	-	-	-	20
Imam Reza	-	-	-	-	-	51

Number of patients admitted to hospitals: The number of patients admitted to hospitals for existing specialties is under 27 scenarios. Tables (16) and (17) show the number of patients admitted to a number of hospitals under some scenarios.

Table 16: Number of patients admitted to Arta Hospital for existing specialties, under a number of scenarios

Specialties / scenario	Blood					Internal				
	T					T				
	6	5	4	3	2	6	5	4	3	2
1	2	2	1	3	1	20	20	20	20	20
15	6	2	1	3	1	20	20	20	20	20
27	2	2	1	3	1	20	19	20	20	20

Table 17: Number of patients admitted to Imam Reza Hospital for existing specialties, under a number of scenarios

specialties / scenario	Internal				
	T				
	6	5	4	3	2
	17	17	17	17	17
	17	18	17	17	17
	16	17	17	17	18

Number of patients discharged from hospitals: The number of patients discharged from hospitals for existing specialties is obtained under 27 scenarios using GAMS software. In Tables (18) and (19), the number of patients discharged from a number of hospitals, under some Scenarios is given.

Table 18: Number of patients discharged from Arta Hospital with available specialties, under a number of scenarios

Specialties / scenario	Blood					Internal				
	T					T				
	6	5	4	3	2	6	5	4	3	2
1	2	1	0	0	0	20	20	20	20	20
15	2	1	0	0	0	20	20	20	20	20
27	2	1	0	0	0	20	20	20	20	20

Table 19: Number of patients discharged from Imam Reza Hospital with available specialties, under a number of scenarios

specialties / scenario	Internal				
	T				
	6	5	4	3	2
1	17	17	17	0	0
15	17	18	17	0	0
27	16	17	17	0	0

Available capacity of hospitals: The available capacity of hospitals for existing specialties has been obtained under 27 scenarios. In Tables (20) and (21), the available capacity of a number of hospitals is given under some scenarios.

Table 20: Available capacity of Arta Hospital for existing specialties, under a number of scenarios

Specialties / scenario	**BLOOD**							**Internal**						
	T							T						
	7	6	5	4	3	2	1	7	6	5	4	3	2	1
1	2	2	3	4	7	8	8	20	20	20	20	20	20	20
15	2	2	3	4	7	8	8	20	20	20	20	20	20	20
27	2	2	3	4	7	8	8	20	20	20	20	20	20	20

Table 21: Capacity available for Imam Reza Hospital for existing specialties, under a number of scenarios

specialties / scenario	**Internal**						
	T						
	7	6	5	4	3	2	1
1	17	17	17	17	34	51	51
15	17	17	17	17	34	51	51
27	17	17	17	17	34	51	51

Number of unmet patient requests: The number of unmet patient requests in hospitals for existing specialties is 27 scenarios. In Table (22), the number of unmet patient requests of some hospitals is given under Scenario 1.

Table 22: The number of unmet patient demands of some hospitals for existing specialties, under Scenario 1

hospital	specialties	T8	T7	T6	T5	T4	T3	T2	T1
Arta	internal	-	13	10	28	-	-	-	16
	heart	23	34	35	34	25	40	34	35
	Public surgery	33	50	40	35	18	24	33	40
	eye	21	23	45	20	14	21	23	20
	Throat & nose	5	4	2	1	2	3	1	1
	blood	-	-	-	-	-	-	-	-
Imam Reza	internal	43	12	44	-	43	25	-	24
	heart	41	22	42	32	34	43	28	26
	Public surgery	24	27	46	31	22	41	19	28
	eye	26	20	20	37	36	40	17	29
	Throat &nose	-	1	-	1	-	-	-	-
	blood	-	1	-	-	1	-	-	-

Number of patients waiting: The number of patients waiting to receive service in each hospital for existing specialties is 27 scenarios, which are shown in Table (23), the number of patients waiting, under some scenarios.

Table 23: Number of patients waiting for available specialties, under some scenarios

Specialties / scenario	blood								Internal							
	T								T							
	8	7	6	5	4	3	2	1	8	7	6	5	4	3	2	1
1	2	3	5	3	4	5	4	3	15	16	15	16	15	15	14	13
15	2	3	5	3	4	5	4	3	15	16	15	16	15	15	14	-
27	2	3	5	3	2	5	4	3	15	16	15	16	15	15	14	12

Overtime working time for hospitals: According to the data of this 8-hour period, there is no need for overtime working, so the overtime working time is zero.

According to table (24)-(26) Number of patients transferred between hospitals: The number of patients transferred from i hospital to j hospital with a specialization of m has been obtained under 27 scenarios. It should be noted that all transfers took place at time t = 1.

Table 24: Number of patients transferred from hospital i to hospital j with specialization m, under scenario 1

hospital	Imam Reza	Arta	specialties
Arta	1		internal
Imam Reza		1	internal

Table 25: Number of patients transferred from hospital i to hospital j with specialization m, under scenario 15

hospital	Imam Reza	Arta	specialties
Arta	1		internal
Imam Reza		1	internal

Table 26: Number of patients transferred from hospital i to hospital j with specialization m, under scenario 27

hospital	Imam Reza	Arta	specialties
Arta	1		internal
Imam Reza		1	internal

The value of the objective function: The values of the objective function are for each of the 27 scenarios of the GAMS software output. In Table (27), the values of the objective function are given for a number of scenarios.

Table 27: The value of the objective function for a number of scenarios

scenario	**Amount of goal function**
1	511645
15	529463
27	547551

Sensitivity analysis

The first test is primarily the test of the effect of the waiting fine rate in relation to the number of patients waiting. The model was solved for seven different waiting fine rates, and the results were presented for the number of patients waiting and the transferred patients in Figure (3). Where the blue and red lines indicate the number of patients waiting and the number of patients transferred, respectively.

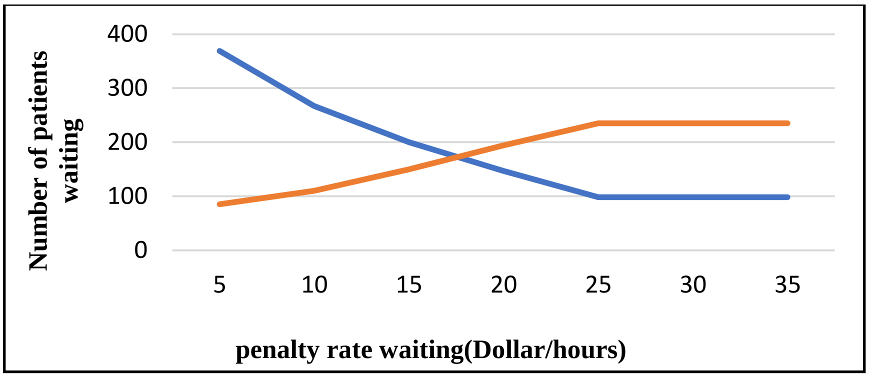

Figure 3: The effect of changing the expected penalty rate on the number of patients waiting and the number of patients transferred

As it can be seen in the figure, as the waiting rate increases, the number of waiting patients decreases and the number of transferred patients increases until the high rate of waiting fine rates forces the system to increase one unit of resources.

The second variable studied was that the demand rate was not met. As shown in Figure (4), an increase in the penalty rate reduces the number of unmet patients.

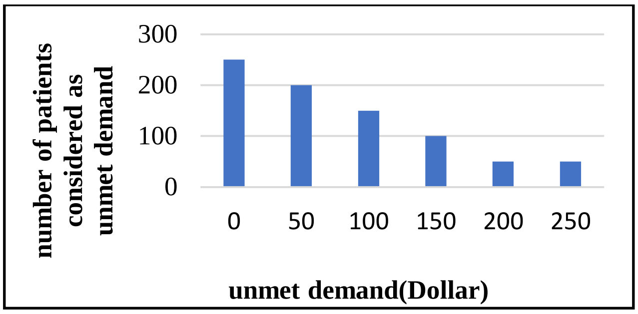

Figure 4: Impact of unmet demand on fines on the number of patients considered as unmet demand

Another factor that needs to be analyzed is the rate at which patients enter and the ratio of patients who can be transferred. As shown in Figure (5), the need for patient transfer increases with increasing patient rate. Therefore, it can be concluded that the patient transfer strategy in the hospital is more effective with a higher rate of patients.

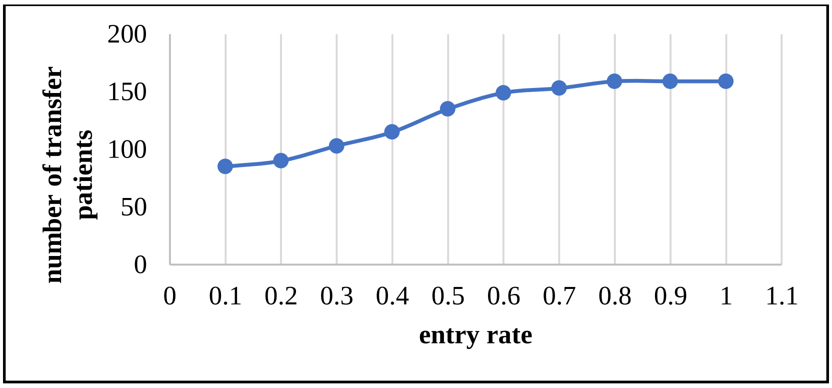

Figure 5: The effect of entry rate on the number of transfer patients

Conclusion

Transferring patients to hospitals is a way to reduce emergency congestion. Therefore, by transferring patients, the number of patients expected and the number of patients who are considered as unmet needs can be reduced. Because with the increase in the number of patients waiting and patients who have not been considered as an unmet demand, the mortality rate, medical errors and patient dissatisfaction will increase and irreparable risks will arise, especially for patients with acute problems. In this research, fifteen hospitals in Ardabil province have been studied in all aspects. Various scenarios have been developed for patient transfer, the best of which must be selected for transmission.

Therefore, the aim of this study was to investigate the allocation of patients to hospitals regarding reduced costs, and because the transfer of the patient under the first scenario has the lowest cost, it was considered as the best allocation. The following suggestions are provided for future research:

- ✓ The second objective function can be considered to reduce patient transfer time.
- ✓ In this study, we divided the specialties into 6 categories, which can be considered more in the future research.

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