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# Transfer Points Location Problem and Optimal Allocation of Injuries in the Crisis Relief Process Transfer Points Location in Crisis

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**Original Article**

## Abstract

**INTRODUCTION:** In times of crisis, the timely transfer of the injured to medical facilities is one of the most important stages of relief and one of the most widely used methods to achieve the transfer point designing goal. The transfer point in literature is a place to collect and transfer the optimal demand for a particular service. For example, in times of natural disasters such as earthquakes, the injured (customers) are transferred by ambulance to the transfer points and then by helicopter to the hospital (facility).

**METHODS:** In this study, two single-objective and double-objective complex integer number programming models were presented for the problem of locating transfer points and optimal allocation to facilities, taking into account the limitations in facility capacity and transfer points as well as assuming two types of normal and bad injuries.

**FINDINGS:** In the single-objective model, the reduction in the time of sending the injured in the relief chain, and in the double objective model, in addition to the previous goal, the reduction of the fine for not sending the injured were examined. It is only possible to transfer each injured person to the hospital using the transfer points, and the treatment of the normally injured individuals is performed at the transfer points. The models were solved with two approaches, mild and severe. In order to show the efficiency of the proposed models, a case study was conducted in districts 10, 11, and 17 of Tehran metropolis, Iran.

**CONCLUSION:** Setting up transfer points has a great impact on speeding up the process of providing services to the injured. Additionally, given the disproportionality of the number of injured with the capacity of hospitals in severe crises, it is necessary to anticipate transfer points to manage relief and respond to all injured.

**Keywords:** Hub Location; Transfer Points Location; Mathematical Programming; Crisis Management

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## Introduction

Preventing surprises during natural disasters, as well as planning and making the necessary preparations under normal circumstances are a necessity in crisis management. During natural disasters such as earthquakes, the number of injured increases dramatically, far exceeding the nominal capacity of the existing hospitals. Therefore, the injured must be transferred to the hospital at the right time, and a method for screening the injured must be considered in order not to overcrowd the hospitals as well.

The transfer point in literature is the intermediator for transfer of goods from origin to final destination. The goods are sent to the transfer point at a lower speed (usually road transport) and then from the transfer point to the

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destination at a higher speed (usually air transport) (1).

Finding the right location for transfer points for a faster, more efficient, and less costly relief is among the practical and scientific issues of location in times of crisis, especially in earthquakes, and for road accidents in non-crisis times. In the problem addressed in the present study, the injured are transported by ambulance to the hospital at the time of the earthquake crisis and then transferred to the hospital by helicopter.

The problem of locating the transfer point in the simplest case is choosing a transfer point to serve the demand points when the facility location is specified, as shown in figure 1. This model is known as the transfer point location problem. In the multiple transfer point location problem, the problem is to select multiple transfer points for a set of demand points assuming that the facility location is specified. In the facility and transfer point location problem, the problem is to select the location of the transfer and facility points and assign the demand points to the transfer points as well as the transfer points to the facilities (2).

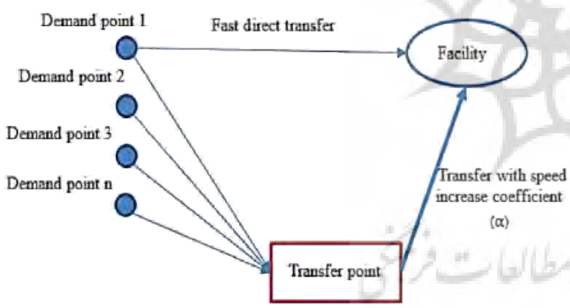


**Figure 1.** Geometric representation of the transfer point

In the current study, two models have been presented to find the optimal location of the transfer points with the aim to reduce the total cost of travel for all customers (injured) and reduce the cost of shortages in providing aid to the injured. The other output of the models is to find the optimal allocations from the damaged points to the transfer points and from the transfer points to the hospitals. The proposed model assumes that transfer points and facilities have a limited capacity to meet the demands.

Another hypothesis is to consider two types of injuries with normal and bad physical condition. As the cost of shortages in relief varies from the normal casualty to the bad casualty, so for the injured individuals not transferred from the accident site to the transfer points and from the transfer points to facilities, we are fined for not transferring the injured in terms of the injury type. In order to examine the efficacy of the proposed model, it was implemented in Districts 10, 11, and 17 of Tehran Municipality, Iran.

In 2005, Berman et al. introduced the first transfer point location model, which was a subset of location-based problems. In this model, the location of a transfer point was examined, assuming that the facility location was known (1).

In another study, Berman et al. examined the transfer point location problem on surface and network, and presented analytical solution methods to solve the problem, then solved the problem with the sensitivity analysis and parameter changing under different conditions, and finally investigated the model results (3).

In another study, Berman et al. explored the multiple location of the transfer point, assuming a known location for the facility on surface and network, and introduced an optimal algorithm for two-level problems (4).

Sasaki et al. proposed the facility and transfer point multiple location problem. To provide the optimal solution of the minimum total sum state, they formulated the problem as a p-median problem, and for the optimal solution of the mini-max state, they formulated the problem as a p-center problem (5).

Hosseinijou and Bashiri provided a stochastic model of the mini-max state of the transfer point location problem. In this study, unlike previous ones, the demand point was weighed and the customers' entry was considered as a uniform stochastic function (6).

In another study, Hosseinijou and Bashiri expanded the previous model taking into account several demand points and presented the optimal solution of the problem with the same previous approach (7).

Mahmudian et al. suggested two algorithms for solving transfer point location problems, with the first algorithm initially clustering the demand points, then connecting the demand point cluster to the transfer point. However, in the second algorithm, the transfer point was determined first and then the demand points were allocated to it (8).

Kalantari et al. offered a nonlinear fuzzy model without the transfer point location constraint and presented an analytical solution to the problem. Then, due to the inefficiency of the analytical solution for the decision-making managers, a fuzzy controller was provided to solve the model and make decisions in critical situations (9).

In another investigation, Kalantari et al. developed the previous model considering a fuzzy weight for the demand points. The model presented in this study, like the previous one, was a nonlinear unconstrained fuzzy model that was solved by a fuzzy controller with the Mamdani approach (10).

Mohammadi et al. examined the chance-constrained transfer point location fuzzy model. In this model, in addition to considering the transfer point location, the release warehouse location was also added to the model, in addition to considering the possibility of failure of the routes. The model was formulated as a multi-objective linear problem and then the Pareto solutions were presented for the problem (11).

## Methods

This study examined a network of demand, transfer, and facility points where a limited number of the transfer points could be selected. The demand points had two types of customers (injured) that could only go to the facility points through the transfer point.

Due to the high volume of injuries compared to the capacity of hospitals at the time of crisis, one of the important assumptions made in this problem was the possibility of treating the normal injuries in the transfer point. If the injured were sent to the transfer point, they would be treated and only the critically injured would be transferred from the transfer point to the hospital. For this reason, two admission and transfer of the injured capacities were considered for the transfer point.

In the first model, there was no possibility of shortage or non-response, but in the second model, it was possible that the cost of non-response vary according to the type of customer. The transfer of the injured faced shortage in two cases: the injured would not be transferred from the demand point or the badly injured individuals would not be transferred from the transfer point to the hospital. In other words, the injured, both normal and bad, might remain at the demand point, or after being transferred to the transfer point and screening, the transfer point might not have the required capacity to admit the badly injured individuals. Therefore, in general, there were two cases of shortages with different costs. The mathematical model of the problem is described in the following.

*Indices, parameters, and variables of model 1*

Indices:

$i$: Demand point index

$j$: Transfer point index

$k$: Facility point index

Parameters:

$D_i$: Total injured demand of node $i$

$\beta$: Ratio of badly injured to the total number of injured of node $i$

$t_{ij}$ : Travel time between demand point $i$ and transfer point $j$

$t_{jk}$: Travel time between transfer point $i$ and facility point $k$

α: Travel time reduction coefficient from transfer point to facility point 0 <α <1

$cap\_t_j$: Capacity to transfer the critically injured from the transfer point $j$

$cap\_h_j$: Capacity to hold normally injured in the transfer point $j$

$Cap_k$ : Capacity of facility $k$

P: Number of transfer points for selection

Q: Number of facility points for selection

Variables:

$Y_j$: is equal to one if node $j \in J$ is selected as a transfer point; Otherwise zero.

$W_k$ : is equal to one if node $k \in K$ is selected as a facility point; Otherwise zero.

$f_{ij}$: Volume of flow between the demand point $i$ and the transfer point $j$

$\psi_{jk}$: Volume of flow between the transfer point $j$ and the facility k (only critically injured)

Mathematical Model 1, a mathematical programming model with an objective function

Mathematical Model 1 assuming the impossibility of shortages and objective of minimizing the demand time:

$$\min z = \sum_{i\in I}\sum_{j\in J} t_{ij} * f_{ij} + \alpha \sum_{j\in J}\sum_{k\in K} t_{jk} * \psi_{jk} \qquad (1)$$

t.S

$$\beta \sum_{i\in I} f_{ij} = \sum_{k\in K} \psi_{jk} \qquad \forall j \in J \qquad (2)$$

$$\sum_{j\in J} f_{ij} = D_i \qquad \forall i \in I \qquad (3)$$







[ DOI: 10.52547/jorar.11.3.192 ]

$$(1-\beta)*\sum_{i\in i} f_{ij} \le Cap\_h_jY_j \qquad \forall\, j \in J \qquad (4)$$

$$\beta \sum_{i\in I} f_{ij} \le Cap\_t_jY_j \qquad \forall\, j \in J \qquad (5)$$

$$\sum_{j\in J} \psi_{jk} \le Cap_k w_k \qquad \forall\, k \in K \qquad (6)$$

$$\sum_{j\in J} Y_j = P \qquad (7)$$

$$\sum_{k\in K} W_k = Q \qquad (8)$$

$$\emptyset_{ij}, f_{ij} \ge 0 \qquad \forall\, i \in I \;\; \forall\, j \in J \qquad (9)$$

$$\psi_{jk} \ge 0 \qquad \forall\, j \in J \;\; \forall\, k \in K \qquad (10)$$

$$Y_j \in \{0,1\} \qquad \forall\, j \in J \qquad (11)$$

$$W_k \in \{0,1\} \qquad \forall\, k \in K \qquad (12)$$

Relation 1 indicates the objective function of minimizing the total time of transferring the injured to the transfer point and the badly injured to the hospital. Relation 2 indicates that all of the badly injured patients transferred to a transfer point are transferred to the facility point. Relation 3 shows that the total number of the injured transferred from the demand point to the different transfer points should be equal to the demand of that point. Relation 4 indicates that the total number of the badly injured patients sent to the transfer point should be less than the transfer capacity of that point if selected. Relation 5 indicates that the total number of the normally injured sent to the transfer point should be less than the admission capacity of that point if selected. Relation 6 indicates that the total number of the injured sent to the hospital should be less than the admission capacity of that hospital if selected. Relations 7 and 8 specify the number of transfer and facility points required. Relation 9 determines the number of critically injured to the total number of injured in the demand point. Relations 10, 11, and 12 determine the range of variables.

*Indices, parameters, and variables of model 2*

In addition to the indices, parameters, and variables of the previous problem, the following are added to the model.

Parameters

$c_1$: Cost of non-response to the injured at the origin

$c_2$: Cost of not transferring the critically injured from the transfer point to the facility

Variables:

$B_i$: The amount of the injured demand that is not responded from the demand point $i$.

$S_j$: The amount of the injured demand that is kept at the transfer point $j$ (It is not transferred to the facility)

Mathematical Model 2, a mathematical programming model with two objective functions

Mathematical Model 2 assuming the possibility of shortages and objectives of minimizing time and cost of shortage:

$$\min z_1 = \sum_{i\in I}\sum_{j\in J} t_{ij} * f_{ij} + \alpha \sum_{j\in J}\sum_{k\in K} t_{jk} * \psi_{jk} \qquad (13)$$

$$\min z_2 = \sum_{i\in I} c_1 B_i + \sum_{j\in J} c_2 S_j \qquad (14)$$

t.S

$$\sum_{i\in I} f_{ij} + B_i = D_i \qquad \forall\, i \in I \qquad (15)$$

$$\beta \sum_{i\in I} f_{ij} = \sum_{k\in K} \psi_{jk} + S_j \qquad \forall\, i \in I \qquad (16)$$

$$(1-\beta)\sum_{j\in J} f_{ij} + S_j \le Cap\_h_jY_j \qquad \forall\, j \in J \qquad (17)$$

Repeated 5 to 12 Equations

$$B_i \ge 0 \qquad \forall\, i \in I \qquad (18)$$

$$S_j \ge 0 \qquad \forall\, j \in J \qquad (19)$$

Relation 13 indicates the objective function of minimizing the total time of transfer of the injured to the transfer point and the critically injured to the hospital. Relation 14 indicates the objective function of minimizing the total cost of the lack of relief to the injured at the demand points or transfer points. Relation 15 indicates that the injured are either sent to the transfer point or remain there as a shortage. Relation 16 means that the badly injured individuals are sent to the hospital from the transfer point or remain at the transfer point as a shortage. Relation 17 indicates that the total number of the normally injured transferred to the transfer point and the number of critically injured who were not sent to the hospital is less than the admission capacity of the transfer point. Relations 18 and 19 represent the range of variables.

*Case study:* In this section, to show the efficiency of the proposed model, Districts 10, 11, and 17 of Tehran were selected as case studies. These districts are located in the south-central part of Tehran and form an interconnected area of Tehran, and in addition to being old and dilapidated, they have a very high population density. As shown in table 1, the average population density of these three districts is 29798 people per hectare and about 3 times the average of that of Tehran City. In other words, the aging of the urban development and the existence of narrow alleys and streets, the dilapidation of buildings, as well as the high population of the regions, challenge the relief work during the crisis. Therefore, it is necessary to plan carefully to help these areas. For this reason, in this study, these areas were selected for the case study.

**Table 1.** Population density of selected districts and the city of Tehran, Iran (12)

| District | Population | Area (km$^2$) | Population density |
|---|---|---|---|
| 10 | 326885 | 8.19 | 39913 |
| 11 | 308176 | 12.03 | 25617 |
| 17 | 278354 | 8.25 | 33740 |
| Sum of the above districts | 913415 | 28.47 | 32083 |
| City of Tehran | 8679936 | 615.62 | 14099 |

The number of injured in each of the demand points depends on the population of the district and its vulnerability index, which depends on factors of the severity of the crisis, the type of crisis, and the dilapidation of texture in that area. The three districts were divided into 19 sections based on their neighborhoods, and the number of injured in each section was estimated based on a 7-Richter earthquake. In total, out of a population of 851951, there would be 53626 injured in these districts. The predicted transfer points were:

1. Azeri and Imamzadeh Hassan neighborhoods, 2. Abuzar Gharbi, Yaftabad, Sajjad neighborhoods, 3. Bolursazi, Bagh-e Khazaneh, Moghaddam neighborhoods, 4. Abuzar Sharghi, Golchin neighborhoods, 5. Jalili, Zamzam neighborhoods, 6. Vesfanard, Zehtabi neighborhoods, 7. Karun-e Shomali, Zanjan-e Jonubi neighborhoods, 8. Hashemi, Karun-e Jonubi neighborhoods, 9. Shoberi, Soleimani neighborhoods, 10. Haft Chenar, Beryanak neighborhoods, 11. Salsabil-e Shomali, Jamalzadeh-Jomhuri neighborhoods, 12. Salsabil-e Jonubi, Eskandari neighborhoods, 13. Enghelab-Felestin, Heshmatodoleh neighborhoods, 14. Sheykh Hadi neighborhood, 15. Moniriyeh, Horr neighborhoods, 16. Amiriyeh neighborhood, 17. Makhsus, Salamat neighborhoods, 18. Forouzeh, Ghalamestan, Agahi neighborhoods, 19. Helal-e Ahmar, Anbar-e Naft, Abbasi neighborhoods.

14 points were considered as candidate points for establishing the transfer point. These areas had to have the capability of creating a helicopter-landing site, constructing a warehouse for essential goods, establishing sites for outpatient treatments, adequate access, and familiarity of the area to people living in these areas. The transfer points projected were:

1. Daneshjoo Park, 2. Heidarnia Stadiums, 3. North part of Meidan-e-Horr Military Zone, 4. South end of Meidan-e-Horr Military Zone, 5. Imam Ali University (PBUH), 6. Razi Park, 7. Ofogh Park, 8. Rah Ahan (demand points of District 11), 9. General Directorate of Fire and Rescue Services, 10. Malik Ashtar Stadium, 11. Imamzadeh Masoom (demand points of District 10), 12. Baharan Parks, 13. North of Bustan Velayat, 14. Air Force Military Zone (demand points of District 17).

The 20 hospitals in the area and adjacent areas were considered as facilities. The total capacity of these hospitals was 4416 people, which could respond to approximately 0.08 of the total number of injured. Therefore, screening of the injured before sending them to hospitals would be highly required. The existing hospitals included:

1. Sorena and Baher, 2. Marvasti and Omid, 3. Najmieh, 4. Madain, 5. Rouzbeh, 6. Loghman, 7. Farabi, 8. Fahmideh, 9. Parsa, 10. Baharlou (hospitals in District 11), 11. Iqbal, 12. Lolagar, 13. Shahriar, 14. Babak, 15. Meimanat (hospitals in District 10), 16. Ziaeian, 17. Ghiasi (hospitals in District 10), 18. Razi, 19. Sina, 20. Sharkat-e Naft (hospitals in Districts 11 and 12).

To solve the problem, the distance between the demand centers and the transfer points was calculated from the road route on the map. To calculate the time for the transfer from the demand points to the transfer points, a ratio of the road distance between the two points, and to calculate the time for the transfer from the transfer point and the hospital, a ratio of the direct distance between the two points were calculated, which is multiplied by the reduction factor α. In this study, the reduction coefficient of the transfer time from the transfer point to the hospital was 0.3 and the ratio of the critically injured to the total number of injured was 0.1.


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## Findings

The two models were solved in 2 modes, with the first mode selecting 5 transfer points and 5 hospitals, and the second mode assigning all transfer points and selected hospitals for relief.

In both cases, a change had to be made in the existing conditions. In the first mode, transfer points with a capacity of ten thousand people had to be created, and the capacity of the selected hospitals had to be increased about 10 times in order to meet the desired demand. This mode which is the current method of solving the transfer point location problem was not applicable in the context of this study, where the number of injured was much higher than the actual capacity of the hospitals, but assuming lighter earthquakes in which the number of injured is greatly reduced can only be used, so that if needed, the transfer points and the hospitals selected by the model solution are activated.

In the second case, the executional limitation was the impossibility of accepting the injured by air transfer in all selected hospitals. Therefore, in the case where the desired capacity of transfer points and hospitals is closer to reality, the study assumption was the possibility of air admission in all hospitals. This could be implemented by increasing the capacity of all hospitals by 25% by adding extra hospital beds; Furthermore, the capacity of the transfer points could be considered according to the space available and the equal capacity for all transfer points could be avoided.

*Solving Model 1 in the first mode*

Assumptions and parameters:

- Selecting 5 transfer points and 5 facilities (P = 5, Q = 5)
- 10 times increase in hospital capacity
- Admission capacity for all transfer points is 10,000 people and sending capacity is 1200 people.

By solving the model by Lingo software, the final value of the objective function was obtained as $0.5681992 * 10^8$, with the transfer points and selected hospitals listed in table 2.

**Table 2.** Selected hospitals and transfer points

| Row | Transfer point | Hospital |
|---|---|---|
| 1 | North of Horr Square | Loghman |
| 2 | Razi Park | Farabi |
| 3 | Malik Ashtar Stadium | Fahmideh |
| 4 | Imamzadeh Masoom | Meymanat |
| 5 | Baharan Park | Ziaeian |

The method of allocation is also demonstrated in figure 2.

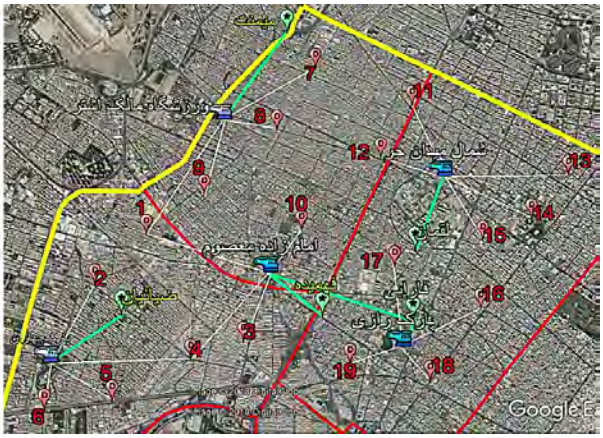

**Figure 2.** Allocation of demand points, transfer points, and facilitate in the solution of model 1 mode 1

*Solving Model 1 in the second mode*

Assumptions and parameters:

- Use of all transfer points and all hospitals (allocation problem)
- 25% increase in hospital capacity
- Admission capacity for transfer points between 3,000 and 4,500 and transfer capacity between 300 and 800 people, depending on the space and facilities available at the transfer point.

By solving the model by Lingo software, the final value of the objective function was obtained as $0.5915192 * 10^8$. For example, some of the transfer points assigned to each demand point for the transfer of critically injured and normally injured as well as the hospital assigned to each transfer point are presented in table 3.

**Table 3.** Demand and transfer points and hospital allocated

| Row | Number of demand point | Transfer point | Hospital |
|---|---|---|---|
| 1 | 11 and 13 | Daneshjoo Park | Marvasti and Omid, Madain |
| 2 | 14 and 18 | Heidarnia Stadium | Marvasti and Omid |
| ... | ... | ... | ... |
| 13 | 4 and 5 | North of Velayat Bustan | Farabi, Baharlou |
| 14 | 1 and 2 | Air Force Military Zone | Iqbal, Ghiasi, Sina |

*Fuzzy theory approach to solving multi-objective models*

Given that the second model had two objectives, it had to be solved by the multi-objective problem solving methods. In this study, fuzzy programming method was employed to solve the multi-objective models, so that:

$$\max w_1\alpha_1 + w_2\alpha_2 \quad (20)$$

s.t

$$z_1 \le z_1^- + (1-\alpha_1)(z_1^+ - z_1^-) \quad (21)$$

$$z_2 \le z_2^- + (1-\alpha_2)(z_2^+ - z_2^-) \quad (22)$$

$$0 \le \alpha_1 \le 1 \quad (23)$$

$$0 \le \alpha_2 \le 1 \quad (24)$$

Relations 13 through 19

$z^-$ and $z^+$ indicated the best and worst possible solutions for the objective functions of type minimum, respectively. Relation 20 indicates maximization of utility α, and relations 21 and 22 meet the utility level. Relations 23 and 24 show that the utility of the objective function is a value between 0 and 1, with the utility values 1 and 0 respectively indicating the complete utility and lack of utility of the objective function. The weights of the objective functions were positive values between 0 and 1, the sum of which is 1. By changing the values of these weights, the Pareto optimal solutions were obtained.

Model 2 solution in the first mode

*Hypotheses*

- Selecting 5 transfer points and 5 facilities (P = 5, Q = 5)
- 10 times increase in hospital capacity
- Admission capacity for all transfer points is 10,000 people and sending capacity is 1200 people.

The Pareto optimal solutions were obtained by changing the weights $w_1$ and $w_2$ and solving the model each time of change, as briefly shown in table 4.

**Table 4.** Pareto solutions

| $w_1$ | $w_2$ | z | Transfer points | Facility |
|---|---|---|---|---|
| 0.1 | 0.9 | 0.988 | 3, 6, 10, 11, 12 | 3, 6, 7, 19, 20 |
| 0.3 | 0.7 | 1.165 | 3, 6, 10, 11, 12 | 3, 6, 7, 10, 19 |
| 0.5 | 0.5 | 0.941 | 3, 6, 10, 11, 12 | 3, 6, 7, 10, 19 |
| 0.7 | 0.3 | 0.918 | 3, 6, 10, 11, 12 | 3, 6, 7, 10, 19 |
| 0.9 | 0.1 | 0.922 | 5, 6, 7, 11, 12 | 3, 6, 7, 10, 19 |
| 0.95 | 0.05 | 0.954 | 4, 6, 7, 9, 11 | 6,7,10,13,15 |

Columns $w_1$ and $w_2$ are the values of the weights considered for each objective function, column z is the values of the utility function, and columns of the transfer and facility points are the number of the transfer points and selected hospitals in each solution.

Model 2 solution in the second mode

*Hypotheses*

- Selecting all transfer points and all facilities (allocation problem)
- 10 times increase in hospital capacity
- Admission capacity for transfer points between 3,000 and 4,500 and transfer capacity between 300 and 800 people, depending on the space and facilities available at the transfer point.

The Pareto optimal solution set in the second mode of model 2 did not change in the weight range of $0.1 \le w1 \le 0.9$, with part of the solution shown in table 5.

**Table 5.** Demand and transfer points and hospital

| Row | Number of demand point | Transfer point location | Hospital |
|---|---|---|---|
| 1 | 13 | Daneshjoo Park | Marvasti and Omid, Madain |
| 2 | 14 | Heidarnia Stadium | Marvasti and Omid |
| ... | ... | ... | ... |
| 13 | 3, 4, 5 | North of Velayat Bustan | Farabi, Baharlou |
| 14 | 1 and 2 | Air Force Military Zone | Ghiasi |

In the range $0 \le w1 \le 0.1$, since the value of the first objective function decreased sharply compared to the second objective function, the solutions progressed in such a direction that the injured were not sent to the transfer and facility points at all and remained as a shortage at the origin. These solutions were illogical and were not useful, so they were not provided.

## Discussion and Conclusion

In this study, the two single-objective and multi-objective complex integer number mathematical programming models were presented for the problem of multiple locations and transfer points and facilities. The main assumptions included the model of transfer of the injured through the transfer points to the hospital, the presence of two types of normally and badly injured patients, and the treatment of the normally injured in the





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transfer points. Moreover, in the two-objective model, a fine was considered for not transferring the injured from the incident points or from the transfer points. The single-objective model was optimally solved and the multi-objective model was solved using the fuzzy theory approach in the multi-objective programming by the Lingo software version 12. Each model was solved in two modes: selecting 5 transfer points and 5 hospitals and using the capacity of all transfer points and anticipated hospitals, with the computation results in the case study of three districts of Tehran including transfer points and selected hospitals, allocation of the injured to each transfer point and selected hospital provided in any case. Because there is a budget constraint on setting up transfer points relative to the desired perspective, places the use of which can be changed, such as parks and stadiums, have been identified as candidates for the facility. In other words, the problem space was considered as a network to make the results more practical. Due to the high number of injured, if the injured are admitted to hospitals without screening along with those who take the injured to the hospital, a severe congestion will be created in the hospital, definitely making the hospital operation difficult. Therefore, it is necessary to anticipate the transfer points and properly plan relief and training of citizens to deliver the injured to the transfer points. Predicting storage for drugs, essential goods, field hospital facilities, and helicopter pads to provide screening services, outpatient treatments and first aid, transporting the injured to transfer points and predicting an increase of capacity, and considering helicopter pads for air admission, and crisis warehouses in hospitals are among the appropriate relief requirements that must be taken into account. The first model was solved assuming no shortage, so it provided optimal values in optimal conditions; hence, these conditions must be reached for proper relief. However, in the second model, given the possibility of shortage, i.e. the possibility of non-transfer of the injured due to failure to reach the desired condition, until the relief infrastructure does not reach good condition, a decision must be made to minimize the human and property costs. The results indicated the effectiveness of the proposed model for application in real-life problems and can help crisis management planners in decision-making. Therefore, it is suggested that the model be implemented for the entire city of Tehran. In addition to the number of injured in this article, there are other important factors that affect the location of the transfer points and their allocation to the hospital. Taking into account these factors, mathematical models can be developed in future studies. Among these factors is the width of the passages and the degree of dilapidation of the urban texture, as in an earthquake crisis, there would be a higher risk of blockage of passages with a narrow width due to traffic and falling of debris of the surrounding dilapidated buildings compared to the wide passages with a proper urban texture.

Another factor is the strength of hospital buildings. In this study, it was assumed that hospitals would remain healthy after the crisis and would be able to provide services, while in many cases the structure of hospitals is worn out and there would be a possible demolition of all or part of it, which would stop providing services.

Furthermore, due to the very high cost of purchasing, maintaining, and using rescue helicopters, optimizing the number and capacity of helicopters required at transfer points will be another approach to model development.

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## Conflict of Interests

Authors have no conflict of interests.

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