PRESENTING A NEW INTEGRATED HUMANITARIAN LOGISTIC MODEL CONSIDERING TO UNDETERMINED PROVISION SUPPLIES UNDER UNCERTAINTY AND REAL CONDITIONS

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ABSTRACT

Lives of many people around the world can be under the threat of unpredictable incidents and diseases. Sudden incidents and diseases are often in need of quick relief as they influence directly on people's lives, and the final result of relief delivery(1) is reflected by the aiding time span. Also, financial and therapeutic constraints result in finding a suitable solution. Recognition of the aiding space and understanding it are necessary for adoption of a decent response approach. The process of planning, managing and controlling the flow of aiding resources for injured and sick people are called the relief logistics. When using the available resources, best relief services are delivered to those in need, the relief logistics become apparent. Creating more suitable conditions for decision making relies on the integrated investigation of relief logistics. On the other hand, considering the unpredictable volume of relief inquiries, in order to have a better planning, the problem space should be reviewed in an uncertain condition which increases the complexity of the problem. In this article, we have attempted to conduct an emergency multiphase location, allocation and routing integrated study in uncertain conditions that is always of a robust response, so that minimum changes occur in various conditions. In the presented model, inquiries from emergency stations are defined as different scenarios with different ranges of occurrence probability, so that real conditions are indicated from them. On the other hand, the emergency inquiry provision supply is assumed to be uncertain which can satisfy the inquiry in an uncertain way. Considering the result analyses, we come to this conclusion that first, the problem space should be identified for decision making. In this article, in order to increase the inquiry satisfaction levels, more ambulances should be allocated to the emergency centres which results in cost elevation and sometimes it is out of resource provision capacities [2].

Keywords: emergency, ambulance, location, allocation, routing, uncertainty space.

LITERATURE REVIEW

Research issues in humanitarian logistic operations in terms of the problem size can be of different hierarchical levels such as single phase (8-13), dual phase (1-4), and multiphase (15). Also, in terms of the number of facilitations, it can be single-facilitation or multi-facilitation (2, 3, 6, 12, 13, 16, 17). The transportation staff size was also investigated as single-vehicle and multi-vehicle (5, 9, 11).

Emergency inquiry in research matters of humanitarian logistic operations, emergency inquiry can be certain (2, 4, 5), tentative (10, 13) and fuzzy[1]. Trip time for meeting requests are studied either as certain (11, 13) or tentative (10). Facilities and routs accessibility are reviewed with two measures of certainty (3, 4, 5, 6) and tentative (4). Capacity limitation in such models is either active (2, 3, 6) or sometimes inactive (4). The transportation vehicle can be in two types of with capacity (3) and without capacity (4, 5). In term of time window, 3 categories can be considered for research models in humanitarian logistic operation including unlimited time (3, 4), soft time window (14) and hard time window (5). These models can execute the operations of delivery (3, 5), loading (17), and simultaneous delivery and loading (19) at stations. The route type for these matters are considered as open (2, 12, 13) and closed (10). The location of costumers requires positioning of nodes (3, 4, 5) or edges (19). The objective functions can be in terms of cost (3, 18), humanitarian (12) or the combinations of these two (6) and (2, 3, 4) that are implemented as single objective (3, 4, 5, 18), double or multiple objectives (2, 3, 4, 5, 6). The implementation of these models includes different kinds of crisis such as earthquake (3, 5, 6), flood (2), etc. (4). The solution method of these models can be accurate (3, 6, 14), Metaheuristic (15) or heuristic (2). The decision-making levels in such issues are strategic (2, 3, 6), tactical (3), and operational (3, 4, 5). The study time horizon can be static (2, 3, 4) or dynamic (5). The load type in humanitarian logistic matters can be commodities (3, 4, 5), human (20) or a combination of these two (60. In some other articles, ambulances response procedure is analysed in large problems according to patients and inquiry districts categories, which in order to achieve a better response, location is studied under uncertainty conditions, so that decisions are made by observing changes (21, 22, 23, 24).

Emergency positioning issues are implemented in articles as follows:

Emergency facilities positioning issues modelling were introduced by the advent of WWII[1] with more specificity in scientific concepts. We can believe that the inception of emergency facilities positioning modelling to be in the 1970s. In this decade, first the basic models of LSCP and MCLP (25, 26) appeared that most of the emergency facilities positioning models are believed to be originating from them. The first model which instead of the coverage objective function has used the response time minimization (27) was created in this era. Berlin and

Liebman (28) presented the first dynamic model in a simple way in 1974. Also, for the first time, Schilling et al. (29) presented the FLEET[1] and TEAM[2] with multiple different servers.

Between 1970s and 1980s, models were mostly considered as certain, and uncertainty was rarely considered in parameters. The first probability model were generated in 1978 (3), and in 1980, most researchers considered models as probable and the parameters as random variables. Also, in this period, models with supporter coverage (31, 32) use were increased. One of the probability models with coverage objective function which has provided a ground for using probability models were suggested by Daskin (33) in 1983.

Also in this period, the positioning-allocation models (34) were generated. The first review article which has produced classification was introduced by ReVelle. (35) Also, Matsutomi and Ishiiadopted the Fuzzy concept in modelling and solving the positioning of emergency facilities for the first time. The first model considering reliability was introduced in 1993 by Ball and Lin (37). Furthermore, in 1996, Marianov and Serra (38) used the Queueing theoretical concept in their models and since then, models with queueing theoretical concept found a particular position in modelling the emergency facilities positioning (39, 40).

Between the years 1990 to 2000, focusing on the existing models, scholars tried to develop these models. From 2000 on, focus was shifted to the solution and multiple objective models came under the researchers' attention. In 2004, the partial coverage model was introduced by the Karasakal brothers (41), which solved the main issue of the MCLP model. Erkut *et al.* (42) evaluated and developed the MCLP model in four different states. Berman[7]*et al*. (43) also adopted the transition point concept in their article for the first time. Moreover, Erkut *et al*. (44) developed the significant model of MSLP with its developments for troubleshooting the MCLP model. Considering the solution method caused the heuristic and metaheuristic algorithms to find a significant role in recent articles. For instance, in 2007, Rajagopalan *et al*. (45) attempted to compare the 4-heuristic method for solving the MEXCLP issue which was introduced by Daskin.

The emergency distribution and transportation issues are adopted in articles as follows:

Various models in the field of crisis are studied based on transportation and distribution in humanitarian logistic which we will describe it later. In the field of transportation, the basis of these models is established on cost, time, distance, and number.

The cost related models include preservation, maintenance and distance, and the resource choice cost considering the vehicles capacity and the covered regions and the amount of flow were evaluated (46-50).

With the purpose of minimizing the trip and loading times which include the route, and the time and amount of transportation capacity limitations, some models were developed that evaluated time also in term of traffic flow, so that they can identify more effective factors influencing decision making (50-53).

In terms of shortening the distance by limiting inquiries and trip time and route crashes, the third basis of these models were critically investigated (54, 55). Considering the fourth basis which is the number, models were developed for cases such as unfulfilled inquiries, the number of necessary emergency units, the sum of all covered inquiries, reducing risk and increasing individuals' longevity, reducing the injured individuals' waiting for aid and the traffic volume and shelters capacity based on the number of vehicles, inquiries, covered regions, and trip cost and duration (53-55).

In humanitarian logistic transportation with the purpose of minimizing the transportation duration which is considering the services presentation, emergency inquiries and budget, and is of its own resource limitation and some constraints in the flow volume in routes and servicing duration, positioning and allocation that were implemented in some models which can create an effective relationship in terms of distance and the amount of longevity increase is of a direct relationship with servicing duration. (56-61)

Based on distribution, humanitarian logistic models were also of purposes such as cost that include minimizing the trip cost, distribution cost and distance, and their possible space were created with the amount of supply, flow, covered areas and the transportation volume (49, 62-64).

Articles with the purpose of minimizing the transportation duration and the distribution duration and servicing duration were developed (62-64). Considering the number of vehicles, vehicle type and the material balance flow with Fulfillment of inquiries and the number of required emergency units created the number basis in logistic model distributions. (49, 62, 63).

Positioning and allocation can also be reviewed by cost, duration and number factors. Aiming to reduce trip duration, distribution cost, and shortening the distance were reviewed for the factors of duration, reduction of transportation and distribution duration and for the factor of increasing the inquiry fulfillment, which in these issues, limitations such as the volume of distribution, inquiry, covered areas and transportation capacity were investigated.

Facilities capacity is one of the important matters in these issues which considering this matter, inquiry fulfillment is conducted. Thus, matters such as supply capacity and the flow of resources and the number of injured individuals are considered as important matters of this kind (66-71).

Although, the concept which its absence is obvious in the mentioned matters is that the stability of the matter should be studied first, so that the decisions can have favourable and stable results. On the other hand, the integrated positioning model for emergency stations, allocation of ambulances and positioning for it can generate better and more accurate results which should be considered for closure to the reality of the uncertainty space in inquiry fulfillment and inquiry type variability

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should be considered based on various factors in the presented models.

Statement of the problem [8]

Ambulance planning which is one of the important concepts in relay logistics faces various challenges which complicates the decision making in this field. The solution algorithm presented in this article is illustrated in Figure-1 as following.

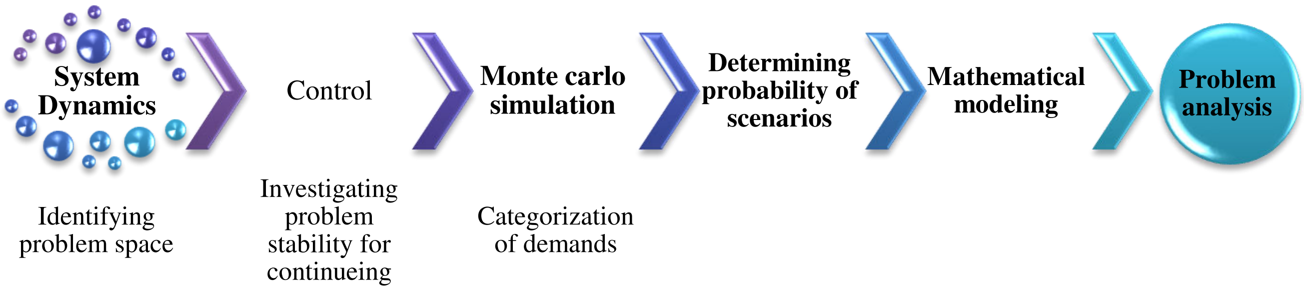

Figure-1. Suggested solution algorithm.

A and B) System dynamics and control system

The System Dynamics was introduced by J. W. Forrester[3] in MIT (72) as one of the first responses to the research disadvantages in operation and other management science techniques. Research modelling techniques in operation can only obtain a limited number factor in a system; on the other hand, there is a linear relationship between these factors. This approach is focused on the systematic and dynamic behaviours of systems and is developed according to the preceding research results of Tustin (73) about electrical and mechanical control systems.

Samples of studied dynamism systems are as following: systems engineering process, biology, social systems, psychology and ecological. Forrester published the books of “Principles of Systems[3]” (74), “Urban Dynamics” (75), and “World Dynamics” on in 1968, 1969 and 1971, respectively.

The System Dynamics checks the system in a vaster point of view as a set of feedback processes indicating an organized and defined structure. In fact, this is the cause and effect structure which causes the dynamic behaviours of system. The problem in studying complicated systems is variable because of the large number and the relationship between them is created through feedback loops.

The structure of a complicated system is not a simple feedback loop in a way the state of system determines the system behaviour. A complicated system is of various feedback loops. Its inner rates and levels are identified by nonlinear relationships. A complicated system is of a high rank which means that it has a lot of factors across it. These systems usually have positive loops showing the growth processes, and also, they have negative or goal seeking loops (72, 73)

In order to recognize the crisis problem which is going to be modelled, the cause and effect diagram of System Dynamics can be adopted. By having the cause and effect diagram and determining the factors and area, the crisis problem flow diagram can be obtained. The following diagram, is the crisis problem flow diagram which we have reviewed. As it can be seen in Figure-2, the problem is of two rates. The input rate corresponds with the service coverage rate and the cost rate is proportional to the emergency inquiry rate, and the surface here expresses the area and the number of patients. In other terms, this area shows the amount of unfulfilled inquiries. The service coverage rate is always hardly equal to the generated inquiry, though there is a response capacity for a percentage of inquiries. Response capacity also corresponds with a share of patients whose inquiries are unfulfilled, the minimum emergency capacity and the

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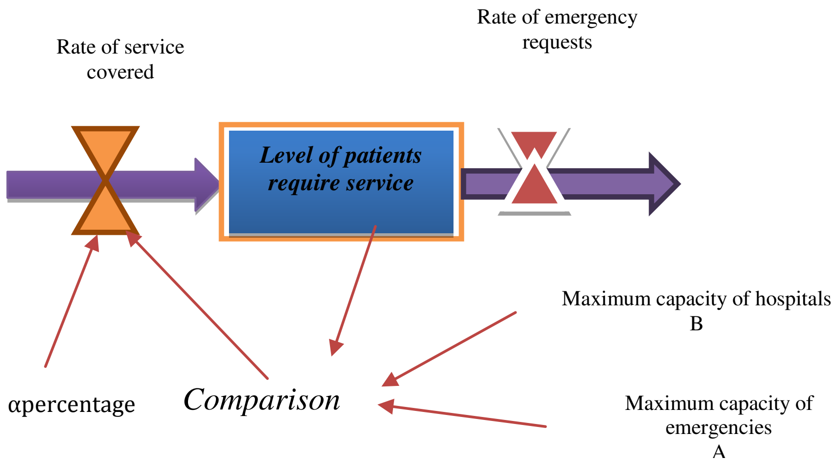
reception capacity of hospital. As constraints create the decision-making space, the minimum capacity of hospitals and emergency stations are considered as the baseline capacity.



Equation #1 $c' = Min(A, B)$

Figure-2. Flow diagram.

The following block diagram in Figure-3 is illustrated based on the cause and effect diagram:

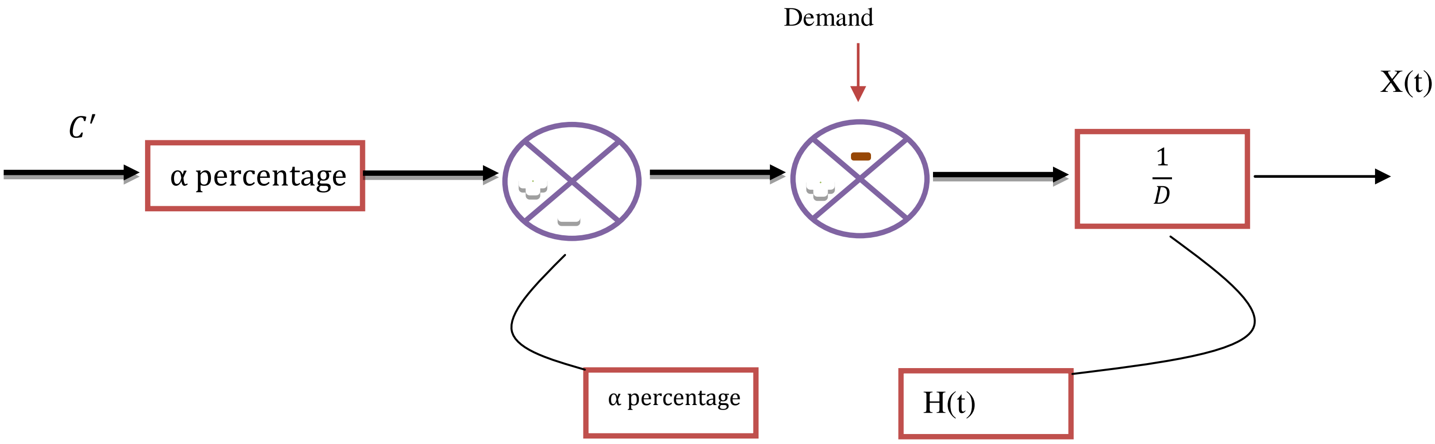


Figure-3. Block diagram.

And based on the above diagram, the signal diagram in Figure-4 is obtained:

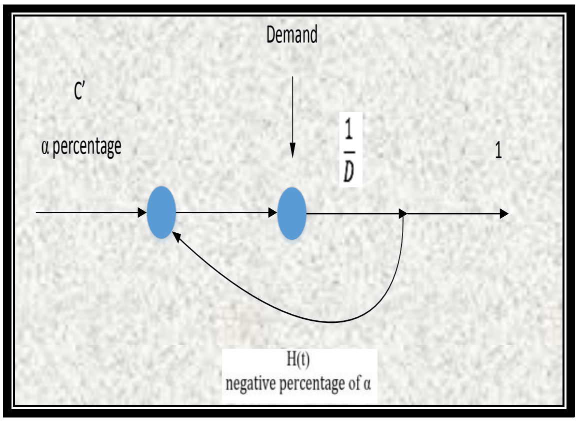


Figure-4. Signal diagram.

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In order to make decisions for identification and improvement of a problem, we should recognize that our decision-making space is stable, because decisions made in unknown and highly variable spaces would not produce favourable results. For this matter, the decision-making environment should be stable so that based on that, the uncertainty space can be implemented on the problem and the real-world circumstances are created as much as possible. Moreover, accurate identification of the problem space is resulted from its stability and consistency.

For checking the system stability, the transition function of the system should be found. Considering the flow, block and signal equations presented in the previous section, the Mason gain[3] should be calculated so that the transition function can be found:

$$\text{Mason gain} = \frac{\sum_i p_i \Delta_i}{\Delta} \quad (2)$$

Where p_i is the leading route from input to output in the signal diagram, Δ_i is the remaining route after passing the leading route, and Δ is the route without the even loops and with the odd loops, thus, we have:

$$p_1 = (\alpha\%C^1)(1)\left(\frac{1}{D}\right)(c) \quad (3)$$

$$\Delta_1 = 1 \quad (4)$$

$$\Delta = 1 + \left[\alpha\%H(t)\ \frac{1}{D}\right] \quad (5)$$

$$\text{Mason gain} = \frac{\alpha\%C^1 \times \frac{1}{D}}{1+\alpha\%\frac{H(t)}{D}} \quad (6)$$

The transition function is obtained as following:

$$G(s) = \frac{+\alpha\%\frac{1}{s}C'}{1+\frac{1+(s)}{}} = \frac{\alpha\%\ S^{-1}C'}{1+S^{-1}H(s)} \times S^2 = \frac{+\alpha\%SC^1}{S^2+H(s)S} \quad (7)$$

Considering the following equations:

$$\frac{1}{D} = \frac{1}{S}$$
$$x(t) = x(s)$$
$$H(t) = H(s) \quad (8, 9, 10)$$

The Equation of state is obtained as bellow:

$$a_1 = H(s)$$
$$a_2 = 0$$
$$a_0 = 1 \quad (11, 12, 13)$$

$$b_0 = 0$$
$$b_1 = \alpha\%C^1$$
$$b_2 = 0 \quad (14, 15, 16)$$

$$\beta_0 = 0$$
$$\beta_1 = b_1 = \alpha\%C^1$$
$$\beta_2 = b_2 - \alpha_1\beta_1 = (0 - H(s)\alpha\%C^1 = -\alpha\%CHS) \quad (17, 18, 19)$$

$$\dot{x}(t) = \begin{bmatrix} 0 & 1 \\ -H(t) & 0 \end{bmatrix} x(t) + \begin{bmatrix} +\alpha\% \\ -\alpha\%H(s) \end{bmatrix} u \quad (20)$$

Considering the state equation, the problem stability is studied:

$$1 \text{ row} \quad \begin{matrix} a_0 & a_2 \\ 1 & 0 \end{matrix} \quad (21)$$

$$2 \text{ row} \quad \begin{matrix} a_1 & a_2 \\ H(s) & 0 \end{matrix} \quad (22)$$

$$3 \text{ row} \quad b_1 = 0 \quad (23)$$

$$b_1 = \frac{a_1a_2 - a_0a_3}{a_1} \quad (24)$$

$$b_1 = 0 - 0 = 0 \quad (25)$$

In case decline is demolished unintentionally and solving is repeated again:

$$S^2 + H(s)S \overset{s=\frac{1}{p}}{\Longrightarrow} \frac{1}{p^2} + \frac{Hs}{p} = 0 \overset{xp^2}{\Longrightarrow} 1 + PH(s) = 0 \quad (26)$$

$$1 \text{ row} \quad p \quad 0 \quad (27)$$

$$2 \text{row} \quad 1 \quad 0 \quad (28)$$

$$3 \text{ row} \; 0 \quad (29)$$

Considering the results, both systems are stable (77).

Simulation

In the Monte Carlo simulation[3], first a random number is determined, then in the next step, the occurrence probability is compared with the amount of the generated random number, in a way that the generated number can satisfy the probability measure. In the next stage, a process or a set of process are created. This procedure can be repeated many times and for each iteration, a measurable output is generated. In the final stage, the set of experiments or the results of the output are statistically analysed and the induction of results is announced. The process or events sections can be simple or complicated and can include various cycles and algorithms and even contain various random generators. The quantitative data process or algorithm can be obtained by any point and they can be analysed as output variables. Using the Monte Carlo simulation technique, more studies can be possible

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in most engineering sciences and predicting the actual and virtual conference of systems and defining of scenarios (78-93).

In this article, inquiry is defined as a scalable and measurable item. As in the following 6 scenarios in Table-1, the inquiry degree is introduced as the inquiry probability.

Table-1. Probability amount and inquiry degree.

Probability	0/1	0/15	0/25	0/3	0/15	0/05	$\sum p_i = 1$
demand degree	0	1	2	3	4	5	

Using Monte Carlo simulation, the cumulative chart above is obtained and using random numbers contradicting with the scenarios, the uncertainty space is turned into a certain one and the results can be seen in Table-2:

Table-2. Final inquiry amounts [3].

generated random number	0/26	0/78	0/57	0/58	0/23
final demand amounts	2	3	3	3	1

The inquiry degree in Table-3 is illustrated with occurrence probability:

Table-3. Amounts of probability and inquiry.

Probability	0/05	0/05	0/1	0/1	0/2	0/25	0/15	0/1
demand	5	10	0/15	20	25	30	35	0/4

Using the Monte Carlo simulation, we obtained the final Table-4.

Table-4. The final amounts.

Random number	0/85	0/75	0/74	0/28	0/4	0/69	0/6	0/1	0/74	0/15	0/4	0/21
degree	2		3			3			3			1
demand	65		75			70			50			20

In this way, inquiries changed status into certainty.

This inquiry is in district 1. As in this district, most occupational situations from morning until night is shown in five scenarios and as night arrives, movement toward district 3 increases, though occupational hazards of fewer than 60 percent of district one for district three are considered in the form of reverse time, and for district 2 where is considered as a linking bridge between the two other districts, the inquiry is identified by the average inquiry of districts one and three and rounding it upwards.

Determining the scenarios occurrence probability[14]

Scenarios were obtained based on two measures and considering the utilities (94,95):

In the presented model of three districts of the city, the two districts of one and three are playing as each other's opponents and their game chart is presented bellow according to two traffic and population density measures in terms of degrees, and in district 2, where is the transportation location, the total amounts of districts one and three is concluded.

The first measure which P1 and P2 are generated for the first and the second row, respectively:

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Table-5. The first measure of the Game chart.

$$\begin{bmatrix} 2 & -1 \\ -1 & 1 \end{bmatrix}$$

And for the second measure which P3 and P4 are driven from it, we express:

Table-6. The second measure of the Game chart.

$$\begin{bmatrix} 1 & -1 \\ -1 & 2 \end{bmatrix}$$

In this way, using the following mathematical model, Ps are calculated:

$$Max\ (p1, p2)\begin{bmatrix} 2+1 & -1-1 \\ -1-1 & 1+2 \end{bmatrix}\begin{pmatrix} p3 \\ p4 \end{pmatrix} - (\rho 1 + \rho 2)$$

St .

$$p1 + p2 = 1$$

$$p3 + p4 = 1$$

$$p1, p2, p3, p4, \rho 1, \rho 2 \geq 0$$

Where P2 and P1 are Lagrange multipliers for each measure and P5 corresponds to their sum. Solving this model, the following amounts are obtained:

Table-7. Amounts obtained from the model.

amounts obtained from the model	p
0.6	1
0.4	2
0.4	3
0.6	4
0.4	5

Presenting the model [15]

Limited financial ability for implementing and administrating ambulance bases justifies the necessity of programming in this field and also because of the dominance of uncertain conditions in the inquiry amounts for ambulance in different locations and the variable time of ambulance routes in different times of day, uncertain programming can present a more suitable solution. Integration in relief supply chain programming which includes positioning for bases and allocation of ambulances to them in order to aid patients in a standard time and with minimum cost is considered in designing the mathematical model for this article.

Some locations of the town are considered as candidates for ambulance maintenance bases that in these locations, bases can be implemented with various costs. The inception of ambulances are these centres and they can choose different routes in order to reach the inquiry points and from there to the hospitals. The traffic volume of these routes relies on time and so we cannot choose only one approach for all the times of the day. Thus, different scenarios corresponding to the simulation section are created. This traffic volume has a direct effect on the route passage duration. It is possible that a high amount of time is needed for a short route, and vice versa. So, it is better to consider the time between two points instead of the distance between them. Finally, the choice of the target hospital should be decided upon. The possibility of ambulance transportation for better utilization of available resources is considered. However, because of the uncertainty space in inquiries for the bases ambulances, inquiries are regarded according to different scenarios. The proposed model has multiple stages, in a way that in one stage, allocation is done with regard to fulfilling the inquiry points by the emergency bases. In the next stage, the final allocation for ambulance deployment in bases is done according to the scenario allocation and then, according to the final allocation, the necessary emergency facilities are established. And in the final stage, after establishing the emergency locations, suitable routes are determined regarding the location. Thus, the proposed model is a multi-stage model. In the following section, the components of this model are introduced.

Indexes [16]

i: inquirer
j: emergency bases
k: hospital
s: scenarios

Parameters

dis: inquiry amount of i in Scenario S
T: standard time
α.: minimum coverage percentage
t_{ijk}: the time scale from emergency base j to inquiry of i and transportation to the hospital k.
M: the large number
f_j: implementation cost for emergency base of j
g_j: cost of ambulance allocation to the emergency base of j
A: cost of route establishment from i to j to k
B: cost of especial route establishment from i to j to k
b_s: function ratio of allocation in each scenario
ω: possible space ratio
λ: scenarios effect ratio
M: the large number

Decision making variables

xj: if the location j is established as the emergency station, this variable is 1 or 0.
y_{ijs}: the number of required ambulances required by i in station j under the scenario S.
z_j: the number of ambulances allocated to the emergency station of j.
x_{ijk}: if the emergency route j to inquiry of i and to the hospital k is established, it is 1 or 0.
x'_{ijk}: if the emergency route j to inquiry of i and to the hospital k is especially established, it is 1 or 0.

A. The Robust model

In order to retrofit[17] the model for the final ambulance allocation based on the number of needed ambulances in each inquiry location, deviation from the possible space is considered. On the other hand, the amount of other scenarios effects on each scenario is considered as a factor for retrofitting the model in the objective function. In other words, how the amount of ambulances required for each inquiry location was different than the same index in other scenarios were considered so that the model is able to create the response while studying the effect of other scenarios on each scenario (96).

$$\text{Min} \quad \sum_j (f_j x_j + g_j z_j) + \sum_i \sum_j \sum_k \left(A X_{ijk} + B x'_{ijk}\right) + \sum_s \sum_i \sum_j p_s y_{ijs} + \lambda \sum_s p_s \left(\sum_i \sum_j y_{ijs} - \sum_{s'} p_{s'} \sum_i \sum_j y_{ijs} + 2\theta_s\right) + w \sum_s p_s(\delta_s + 2\Delta_s) \quad \text{(a)}$$

$$\text{St.} \quad -M x_j + z_j \le 0 \qquad \forall j \quad \text{(b)}$$

$$\sum_i y_{ijs} - b_s z_j + \delta_s = 0 \qquad \forall j, \forall s \quad \text{(c)}$$

$$\alpha \sum_i \sum_s d_{is} - \sum_i \sum_j \sum_s y_{ijs} \le 0 \quad \text{(d)}$$

$$\sum_j y_{ijs} - d_{is} \le 0 \qquad \forall i, \forall s \quad \text{(e)}$$

$$t_{ijk} X_{ijk} - M x'_{ijk} - T \le 0 \qquad \forall i, \forall j, \forall k \quad \text{(f)}$$

$$x_j - \sum_i \sum_k X_{ijk} \le 0 \qquad \forall j \quad \text{(g)}$$

$$y_{ijs} - \sum_k X_{ijk} \le 0 \qquad \forall i, \forall j, \forall s \quad \text{(h)}$$

$$y_{ijs} \ge 0 \qquad \text{int}, \forall i, \forall j, \forall s \quad \text{(9)}$$

$$z_j \ge 0 \qquad \text{int}, , \forall j \quad \text{(10)}$$

$$x_j \in \{0,1\} \qquad \forall j \quad \text{(11)}$$

$$X_{ijk}, x'_{ijk} \in \{0,1\} \qquad \forall i, \forall j, \forall k \quad \text{(12)}$$

$$-\theta_s - \sum_i \sum_j y_{ijs} + \sum_{s'} p_{s'} \sum_i \sum_j y_{ijs} \le 0 \qquad \forall s \quad \text{(13)}$$

$$-\Delta_s - \delta_s \le 0 \qquad \forall s \quad \text{(14)}$$

$$\Delta_s, \theta_s \ge 0 \qquad \forall s \quad \text{(15)}$$

a) The objective function includes five components. The first one is minimizing the emergency facility establishment cost and the final ambulance allocation cost to the emergency station. The second component tries to minimize the cost of route and special route

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implementation. The third one tries to minimize the number of ambulances needed in each scenario. The fourth and fifth components are among the main components of Robust. The fourth component shows the effect of other scenarios on the studied one and the fifth component investigates the feasibility[18] of the problem.

b) When allocation of ambulances to the station location is done, there should be a location established there in the name of emergency station.

c) Final allocation to a location is done according to the number of ambulances required from that location in each scenario.

d) The sum of the ambulances required in each scenario to be established in each location should be at least α percentage of the total inquiry percentage.

e) The number of ambulances needed for each inquiry in each scenario is lower than the inquiry amount.

f) The total time of routes should be less than the standard time T, otherwise the route transforms into a special route. In other words, a special route is formed. Putting it simpler, we should say that whenever the total time an ambulance moves from the emergency station to the emergency inquired location and takes the injured individual to the hospital is more than the standard time calculated by the elites based on the injured individual longevity, a route is formed as an emergency route which is able to decrease time in terms of management or physical structure. In term of management based on the traffic control basis, and in term of structure, creating a special route can result in an emergency route.

g) A route is formed when the emergency station is surly established.

h) The route is formed for the number of the allocated ambulances.

The limitations 9 to 12 are the systemic obligations of the model.

13 and 14 are the robust linearization[19] obligations and 15 is the systemic obligation in robust.

B. DCP model

In this model, the inquiry amount of each location of emergencies are expressed in a tactile manner and on the other hand, the providing resources are uncertain in needs responding. In simpler words, each inquiry location tries to maximize its emergency inquiry fulfillment probability considering the resourcing it uses is indefinite (97 - 101).

$$\text{Max} \quad \bar{f} \qquad \text{(a)}$$

$$\text{St.} \quad -Mx_j + z_j \le 0 \qquad \forall j \qquad \text{(b)}$$

$$\sum_i y_{ijs} - b_s z_j + \delta_s = 0 \qquad \forall j, \forall s \qquad \text{(c)}$$

$$\alpha \sum_i \sum_s d_{is} - \sum_i \sum_j \sum_s y_{ijs} \le 0 \qquad \text{(d)}$$

$$\sum_j y_{ijs} - d_{is} \le 0 \qquad \forall i, \forall s \qquad \text{(e)}$$

$$t_{ijk} X_{ijk} - M x'_{ijk} - T \le 0 \qquad \forall i, \forall j, \forall k \qquad \text{(f)}$$

$$x_j - \sum_i \sum_k X_{ijk} \le 0 \qquad \forall j \qquad \text{(g)}$$

$$y_{ijs} - \sum_k X_{ijk} \le 0 \qquad \forall i, \forall j, \forall s \qquad \text{(h)}$$

$$\sum_j (f_j x_j + g_j z_j) + \sum_i \sum_j \sum_k (A x_{ijk} + B x\grave{}_{ijk}) + \sum_i \sum_j \sum_s y_{ijs} \le Bb \qquad \text{(i)}$$

$$\sum_j y_{ijs} \le \mu \bar{f} \qquad \forall i \forall s \qquad \text{(j)}$$

$$y_{ijs} \ge 0 \qquad \text{int}, \forall i, \forall j, \forall s \qquad \text{(11)}$$

$$z_j \ge 0 \qquad \text{int}, , \forall j \qquad \text{(12)}$$

$$x_j \in \{0,1\} \qquad \forall j \qquad \text{(13)}$$

$$X_{ijk}, x'_{ijk} \in \{0,1\} \qquad \forall i, \forall j, \forall k \qquad \text{(14)}$$

$$\bar{f} \ \textit{free variable} \qquad \text{(15)}$$

$$-\theta_s - \sum_i \sum_j y_{ijs} + \sum_{s\grave{}} p_{s\grave{}} \sum_i \sum_j y_{ijs} \le 0 \qquad \forall s \qquad \text{(16)}$$

$$-\Delta_s - \delta_s \le 0 \qquad \forall s \qquad \text{(17)}$$

$$\Delta_s, \theta_s \ge 0 \qquad \forall s \qquad \text{(18)}$$

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a) The objective function tries to increase the ambulance allocation probability in each scenario to places where inquiries are fulfilled.

b) When allocation of ambulances to the station location is done, there should be a location established there in the name of emergency station.

c) Final allocation to a location is done according to the number of ambulances required from that location in each scenario.

d) The sum of the ambulances required in each scenario to be established in each location should be at least α percentage of the total inquiry percentage.

e) The number of ambulances needed for each inquiry in each scenario is lower than the inquiry amount.

f) The total time of routes should be less than the standard time T, otherwise the route transforms into a special route. In other words, a special route is formed. Putting it simpler, we should say that whenever the total time an ambulance moves from the emergency station to the emergency inquired location and takes the injured individual to the hospital is more than the standard time calculated by the elites based on the injured individual longevity, a route is formed as an emergency route which is able to decrease time in terms of management or physical structure. In term of management based on the traffic control basis, and in term of structure, creating a special route can result in an emergency route.

g) A route is formed when the emergency station is surly established.

h) The route is formed for the number of the allocated ambulances.

i) This obligation indicates that financial resources that are the same as the budget are always static.

j) It shows that the sum of required ambulances in each scenario for each inquiry point observes a coherent distribution between zero to one hundred.

Obligations 11 to 15 are the models' system obligations. 16 to 18 are the linearization constraints of Mulvey's robust model.

C. The robust model according to ambulance allocation probability in the uncertainty space

If the previous model is reviewed according to the feasibility space and the effects of other scenarios in each scenario, its robust model is as bellow:

$$\boldsymbol{Max\ \bar{f}} - \sum_i \sum_j \sum_s \boldsymbol{p_s y_{ijs}} - \boldsymbol{\lambda} \sum_s \boldsymbol{p_s} \left(\sum_i \sum_j \boldsymbol{y_{ijs}} - \sum_{s`} \boldsymbol{p_{s`}} \sum_i \sum_j \boldsymbol{y_{ijs`}} + \boldsymbol{2\theta s} \right) - \boldsymbol{w} \sum_s \boldsymbol{p_s} \left(\boldsymbol{\delta^2} + \boldsymbol{2\Delta s}\right) \quad \textbf{(a)}$$

$$-Mx_j + z_j \le 0 \qquad \forall j \quad \textbf{(b)}$$

$$\sum_i y_{ijs} - b_s z_j + \delta_s = 0 \qquad \forall j, \forall s \quad \textbf{(c)}$$

$$\alpha \sum_i \sum_s d_{is} - \sum_i \sum_j \sum_s y_{ijs} \le 0 \quad \textbf{(d)}$$

$$\sum_j y_{ijs} - d_{is} \le 0 \qquad \forall i, \forall s \quad \textbf{(e)}$$

$$t_{ijk} X_{ijk} - M x'_{ijk} - T \le 0 \qquad \forall i, \forall j, \quad \textbf{(f)}$$

$$x_j - \sum_i \sum_k X_{ijk} \le 0 \qquad \forall j \quad \textbf{(g)}$$

$$y_{ijs} - \sum_k X_{ijk} \le 0 \qquad \forall i, \forall j, \quad \textbf{(h)}$$

$$\sum_j (f_j x_j + g_j z_j) + \sum_i \sum_j \sum_k (A x_{ijk} + B x`_{ijk}) + \sum_i \sum_j \sum_s y_{ijs} \le Bb \quad \textbf{(i)}$$

$$\sum_j y_{ijs} \le \mu \bar{f} \qquad \forall i \forall s \quad \textbf{(j)}$$

$$y_{ijs} \ge 0 \qquad \text{int}, \forall i, \forall j, \quad \textbf{(11)}$$

$$z_j \ge 0 \qquad \text{int}, \forall j \quad \textbf{(12)}$$

$$x_j \in \{0,1\} \qquad \forall j \quad \textbf{(13)}$$

$$X_{ijk}, x'_{ijk} \in \{0,1\} \qquad \forall i, \forall j, \quad \textbf{(14)}$$

$$\bar{f}\ \textit{free variable} \quad \textbf{(15)}$$

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$$-\theta_s - \sum_i \sum_j y_{ijs} + \sum_{s`} p_{s`} \sum_i \sum_j y_{ijs} \leq 0 \quad \forall s \quad \textbf{(16)}$$

$$-\Delta_s - \delta_s \leq 0 \quad \forall s \quad \textbf{(17)}$$

$$\Delta_s, \theta_s \geq 0 \quad \forall s \quad \textbf{(18)}$$

a) The objective function is of four components. The first component tries to increase the ambulance allocation probability in each scenario to places that inquiries are satisfied. The second component tries to minimize the necessary ambulances of each scenario. The third and fourth components are of the main robust elements. The third component shows the effect of other scenarios on the one being studied. The fourth component shows the feasibility of the problem.

b) When allocation of ambulances to the station location is done, there should be a location established there in the name of emergency station.

c) Final allocation to a location is done according to the number of ambulances required from that location in each scenario.

d) The sum of the ambulances required in each scenario to be established in each location should be at least α percentage of the total inquiry percentage.

e) The number of ambulances needed for each inquiry in each scenario is lower than the inquiry amount.

f) The total time of routes should be less than the standard time T, otherwise the route transforms into a special route. In other words, a special route is formed. Putting it simpler, we should say that whenever the total time an ambulance moves from the emergency station to the emergency inquired location and takes the injured individual to the hospital is more than the standard time calculated by the elites based on the injured individual longevity, a route is formed as an emergency route which is able to decrease time in terms of management or physical structure. In term of management based on the traffic control basis, and in term of structure, creating a special route can result in an emergency route.

g) A route is formed when the emergency station is surly established.

h) The route is formed for the number of the allocated ambulances.

i) This obligation indicates that financial resources that are the same as the budget are always static.

j) It shows that the sum of required ambulances in each scenario for each inquiry point observes a coherent distribution between zero to one hundred.

Obligations 11 to 15 are the models' system obligations.

16 and 17 are the robust linearization obligations and 18 is the systemic obligation in robust.

Result analysis

Considering that the hessian matrix of the constitutive obligations of the feasible area and the semidefinite objective function are positive and that the problem is defined as linear, then the feasible space of the problem and the objective function are convex. Thus, in this kind of convex programming, the problem is of an optimum point which is obtained from solving the problem, in simpler words, the response to the optimum point is convex (102-103).

Considering the four location candidates for emergency station, in order to satisfy three inquiry location by taking the injured individuals to three hospitals, the models were solved and analysed. The second problem is the analysis of a robust which relies on chance.

The ω, λ and α parameters of this problem are shifted in a range of 20 percent decrease to 20 percent increase so that the problem sensitivity to them is investigated. In the following tables and diagrams, their effectiveness on the objective function and the main variables of the problem are studied.

Table-8. ω changes.

objective function	solving the problem according to ω changes				
	0.8	0.9	1	1.1	1.2
the second problem objective	-92.280	-92.868	-93.456	-94.044	-94.632

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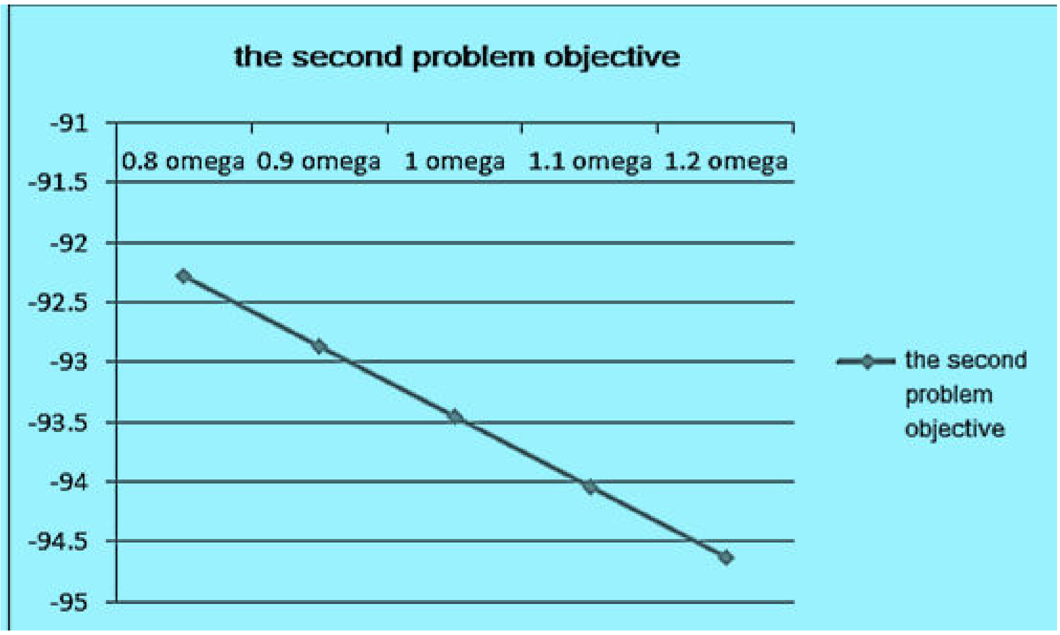

Figure-5. The second problem objective according to the feasible space changes.

As it is indicated from the diagram, in problem #2, y the increase of ω, the objective of the problem decreases, which this decrease is both in a relatively linear relationship with a negative gradient. Thus, the goal sensitivity is trivial for this parameter. In other words, in order to increase responsiveness by increasing the final number of allocated ambulances to emergency stations, costs are increased.

Table-9. λ changes.

objective function	solving the problem according to λ changes				
	0.1	0.9	1	1.2	1.9
the second problem objective	-92.290	-93.326	-93.456	-93.715	-94.622

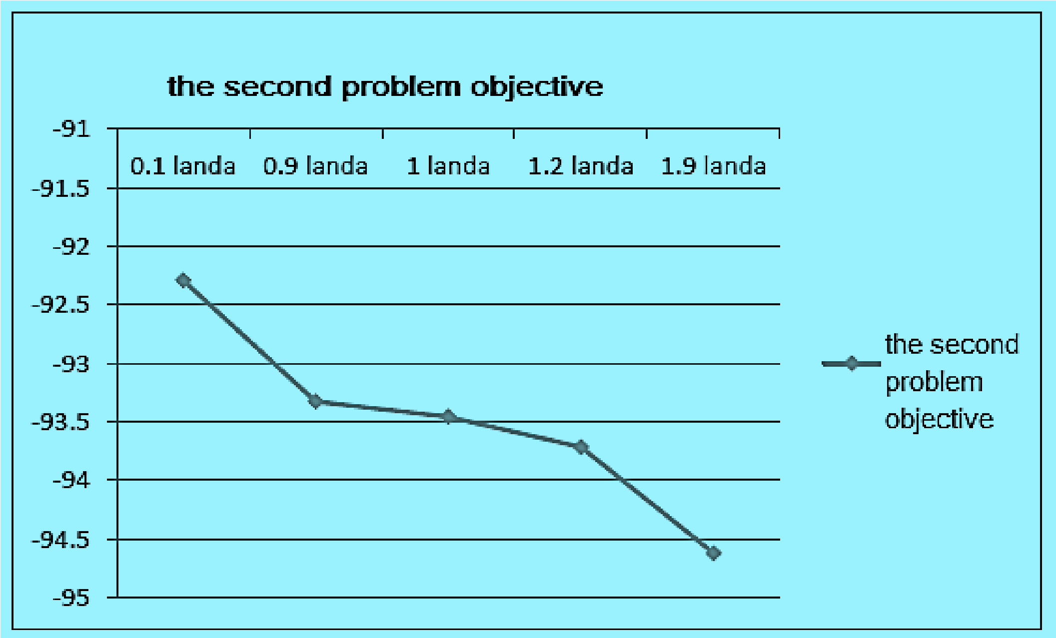

Figure-6. Cost of the first problem according to the effects of other scenarios.

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As it is indicated from the above diagram, in the second problem, as λ increases, the amount of total objective is reduced. Which these decreases follow a relatively constant amount considering the change ranges. For instance, for a 10 percent decrease, the λ parameter is reduced for 0.13 units and for a 10 percent increase; the λparameter is increased for 0.129 units. At the beginning and the end of this range of changes, the level of objective changes is higher than expected as well. By increasing control on other scenarios, in a way that the effects of other scenarios are controlled in each scenario, the cost level is increased.

Table-10. αchanges.

objective function	solving the problem according to α changes						
	0.1	0.6	0.8	0.9	1	1.2	1.4
the second problem objective	-31.292	-62.584	-62.584	-93.456	-93.456	-93.456	invalid

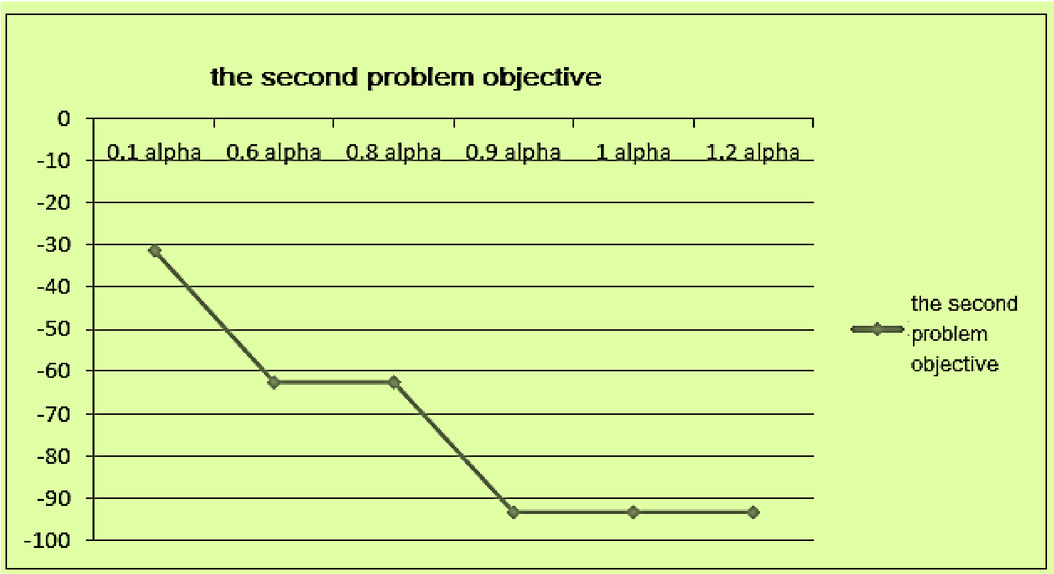

Figure-7. Cost of the first problem according to the effects of the increase of inquiry satisfaction.

As it is indicated from the above diagram, in problem 2, for increasing the amount of α, the total objective is relatively reduced, except in some change ranges where it does not change. For the range of 10 to 30 percent increases of the αparameter, the objective does not change, which finally for a 40 percent increase range, this problem becomes invalid. For a 10 percent decrease of this parameter, as it is seen from the results, objective did not change. Though for a 20 percent decrease, objective is increased significantly. Finally, from the 20 percent decrease point to 40 percent decrease point (0.6 alpha), the objective did not change as well, but for increases more than 40 to 90 percent, the objective is increased in a linear manner, this is in a way that by increasing the amount of inquiry satisfaction, costs are generally increased. In some domains, facilities are able to satisfy the virtual tolerance of inquiry changes with no changes in costs.

Considering the results, it can be expressed that by increasing the inquiry satisfaction, more ambulances should be allocated to emergency stations, so that in this way, different events of each scenario are controlled and respond is of more strength against changes. In some diagrams, gradient is static, elevating or decreasing. In terms of analysis, we sometime need to make decisions that are executed effectively immediately and have favourable results. By adapting the above analysis, we can adjust the direction and amount of these decisions according to this matter. But, on the other hand, some of the limiting factors also may influence the response and decision making. Thus, it is necessary to achieve favourable results during time, and we can choose the points with less steep gradient on the analysed diagrams, though sometimes the made decisions are not effective in the end. Thus, considering the analysis diagrams that fit the conditions, investments in such cases can be prevented. Thus, in general, in order to reach favourable results, the problem space should be perfectly identified and reach the objective through defined steps. Extremely recommended to read base papers of this paper that are written by Ardavan Babaei & Kamran Shanaghi.

Suggestions

Some suggestions are presented bellow for future studies:

- Dynamic positioning of emergency centers be studied in different periods
- Ambulance classification be conducted according to provided services.
- Ambulances be considered as supporting service for problems. By analysing the sensitiveness of the supporting ambulance numbers in each location, emergency be determined with regard of the requested inquiry, so that response is made with a higher confidence level.
- The distribution of ambulances be determined, so that the emergency centers can lend their ambulances to more demanding areas when they are idle.
- Maintenance and reparation of ambulances, and routes be studied in a way that the access level of these resources be identified.
- In order to have a more justified distribution, objective functions be determined in order to lower the unsatisfied inquiry level.

CONCLUSIONS

Relief[20] at the time incidents to humans are of great significance as it endangers their lives. In order to reduce the dangers and increase the longevity of the injured individuals, relief should be delivered within a standard time. On one hand, there is a budget limit for creating an integrated relief system. On the other hand, in order to have a better confrontation with this problem of relief delivery, this problem should be investigated in an uncertainty space, so that the results are closer to the real world. In this article, the relief crisis and logistics were investigated during six phases. In the first phase, using the System Dynamics, the relief problem space is illustrated. In the second phase, the existing cause and effect space is studied in a control point of view and considering the defined problem, its reliability is identified. In the third phase, using an inquiry for ambulances simulation, the occurred inquiries are obtained. In the fourth phase, different occurrence probability scenarios are obtained considering the games theory and with regard to the traffic and population density. In the fifth phase, multiphase integrated modelling for emergency station location, allocation and routing of ambulances is conducted considering the fuzzy and probable inquiries and considering the minimization of the fuzzy cost of allocation based on the scenario and using a robust planning. In the sixth phase, the problem is analysed in terms of the obtained results. It was realized from the results of this problem that as much as we may need the response to be stronger and the ambulances allocation be in a way that creates a suitable favourability in each scenario, more costs should be bore, which sometimes leads to a change in the feasibility space.

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