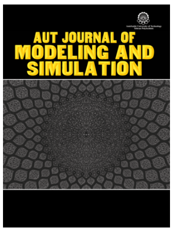

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Routing relief teams by introducing new urban congestion parameter and solving using GACD-MDVRP clustering through genetic algorithm

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ABSTRACT: Emergency disaster-relief activities could dramatically reduce injuries and casualties, while routing and scheduling of the relief teams is also considered an important factor in reducing the fatalities. For this reason, in this paper, a new model is proposed for routing rescue teams considering time windows, capacitated and multi-depot vehicles. In this model, additional factors such as availability of relief centers, congestion and service standard for the vehicles. A new parameter has been developed to denote the congestion of each path and id incorporated into the model using the concept of Social Network Analysis (SNA). Finally, the model is solved using a COREI5 8GB system. The model is also implemented using the data obtained from the Roads and Transport Organization and the Iranian Red Crescent Society. The average accuracy of this algorithm was 87% after solving 23 problem samples and improvement of the runtime was 74% in large problems. The model is then applied to the case study of the 2017 earthquake in Kermanshah, Iran. A rescue scenario is generated using the historical data of I.R. Iran Road Maintenance Transportation Organization and the I.R. Relief and Rescue Organization of Red Crescent Society of Iran. In this study, simulations are conducted based on a case study with actual locations.

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1- INTRODUCTION

In today's world, natural disasters such as earthquakes, floods, tsunamis, or crises such as the September 11 attacks and the protests of many people are threatening, because with the occurrence of these events, many people are injured or die. Since these events cannot be accurately predicted, improving rescue efforts can greatly reduce casualties and save more people. Careful planning to help and estimate potential needs can be very effective[1]. Operational research tools have been used to manage resources in natural disasters[2]. The issue of routing vehicles in predictable issues such as tornadoes, fires [3][4] and unpredictable conditions such as earthquakes and terrorist attacks [5][6].

One of the techniques of operation research for managing emergency is the use of mathematical modeling for routing. In this paper, a new mathematical model is presented with consideration of the time window, several depots and heterogeneous vehicles. In this model, the congestion parameter is added which is a necessary factor in routing.

Congestion parameter interference in routing issues can be a good factor for improving rescue services. Due to the fact under emergency conditions the main roads are facing disruptions about the crisis situation, it is very important for the rescue teams to choose the routes so that they can reach the scene as soon as possible.

In Fig. 1., it is clear that there is a significant difference in congestion levels in cities around the earthquake-affected areas, which can be considered an important factor in the routing discussion. These Figures are drafted using Google's fusion table traffic data from the Road Maintenance Transportation Organization of I.R. Iran [7].

Traffic congestion may occur frequently. Currently, some researchers focus on the routing optimizations [8] [9] [10] [11].

We extracted the congestion parameter using the network analysis concepts of the transport network and put it in the new mathematical model. Of course, in other articles, the congestion parameter was also used. But the current study assumes that the congestion parameter is affected by both the intrinsic property of the network and the actual traffic data at the network's edge. Using the extracted parameter, it can be seen from the network analysis of congestion on each edge as compared to other edges. Also, with data collected from Road Maintenance Transportation Organization of I.R. Iran, the amount of vehicle passing from every road, the average speed of vehicles, and the length of time of the work of the traffic system are also available. In the final parameter proposed, all effective and available factors in the network are interfered. The parameter, which will be introduced as a congestion

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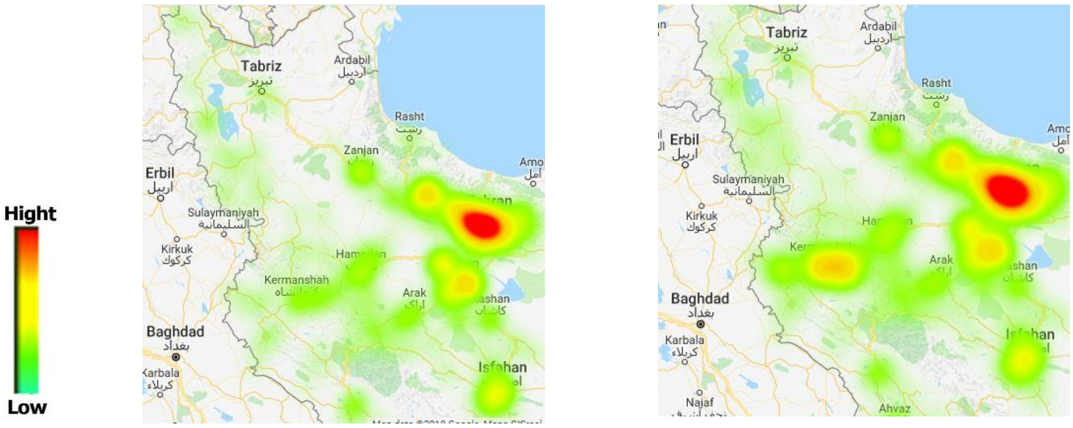

Average congestion parameter for each city from October 21 to November 3, 2017 (before the Kermanshah earthquake)

Average congestion parameter for each city from November 13 to November 21, 2017 (after the Kermanshah earthquake)

Fig. 1. Comparison of the congestion parameter before and after the earthquake

parameter, using network analysis has been defined in previous articles regarding its applications. Betweenness of any node in the network can be observed with the higher traffic capacity [12].

This factor is determined by the conditions of the edge located on the graph. The more betweenness of one edge leads the greater the congestion parameter and, it is predicted that this edge will have more traffic.

In 2002, Girvan and Newman defined the betweenness of the edges, which are as follows[13]:

"The intermediate center of edges is the sum of the number of shortest paths between two nodes passing all the shortest paths between two nodes"

This definition can be expressed in equation (1)[14]:

$$EB(e)=\sum_{v_i v_j \in v} \frac{\sigma_{v_i v_j}(e)}{\sigma_{v_i v_j}} \qquad (1)$$

In equation (1), which is used to compute the betweenness centrality of the edges e, the expression represents the number of shortest paths between the two nodes and $\sigma_{v_i v_j}(e)$ that passes through the edges. $\sigma_{v_i v_j}$ is also the total number of shortest paths between the two nodes v_i and v_j.

A summary of the use of congestion in routing problem is given in Table 1.

In this paper, considering the presuppositions of the routing problem and the state of emergency, we will introduce a new parameter and use it in the new vehicle routing model. A new congestion parameter is proposed based on the betweenness parameter, vehicle speed, number of vehicles, and the length of time traffic counter has worked.

In 1959, Danzig and Ramsar presented the first mathematical model of the vehicle routing problem[36]. Following from these two early studies in VRP literature, many researchers were interested in research in this field. The researchers' interest in these two reasons was twofold: matching with the real industry issues and its challenging complexity. In 1981 the complexity2 of the vehicle routing problem was examined, and the NP-hard of the issue was presented [37] .

The other study, the use of transport to evacuate people from a disaster, the accident is carried out by [38]. There are also articles that consider the use of public transport for relief [3].

The rest of the paper is organized as follows. Section 2 describes the new model of Multi-Depot Capacitated Vehicle Routing Problem with Time Window (MDCVRPTW). The proposed algorithm for MDCVRPTW is presented in Section 3. Section 4 shows the experimental setup, including the benchmark instances, the preparation and the performance evaluation. The application of the proposed model of the Kermanshah earthquake demonstrates in Section 5. The conclusion is provided at Section 6.

2- MODEL DESCRIPTION

The main purpose of the present paper is to provide a new mathematical model considering several multi-depot centers, a heterogeneous relief transport system, hard time window and the availability of rescue centers. The new congestion parameter is extracted from the road network using the network analysis and is applied to the model.

In the previous section, a litreature review was performed for the betweenness parameters to express congestion. The network was considered in which important urban are denoted as (V), and the paths between them are denoted as edges ($v_i, v_j \in v$). The weight, which considered for each edge, is the traffic of the edge. So, the betweenness of the edges was defined in the transport network as in equation. (2):

"The total mean of the weights of the shortest paths between the two nodes passing through the edge is divided by the average of all the shortest paths between the two nodes"

Table 1. Summary of the use of congestion parameter in routing problem with related papers.

Authors	year	environment	Objective function(minimum)					Congestion parameter
			cost	Time (distance)	congestion	delivery	Pollution	
Güner, Murat and Chinnam [15]	2012	just-in-time (JIT) manufacturing				*		Number of vehicles
Jabbarpour *et al.* [16]	2014	vehicular networks			*			Number of vehicles
He, Xu and Wang [17]	2015	complex networks	*					Use capacity of edges
Wen and Eglese [18]	2015	road network	*					Number of vehicles
Xiao and Konak [19]	2016	logistics systems					*	Number of vehicles
Angelelli *et al.* [20]	2016	road network			*			Number of vehicles
Abou-Senna [21]	2016	urban highway network			*			Number of vehicles
Rizet, Cruz and Vromant[22]	2016	Urban road network					*	Number of vehicles
Kaddoura and Nagel[23]	2016	road network	*					Number of vehicles
Le Vine and Polak[24]	2016	road network	*					Number of vehicles
Marufuzzaman and Ekşioğlu[25]	2017	supply chains	*					Number of vehicles
Angelelli, Morandi and Speranza[26]	2018	Transportation network			*			Number of vehicles
Echagüe, Cholvi and Kowalski[27]	2018	complex networks			*			Betweenness of edges in network
Farda and Balijepalli[28]	2018	city road network			*			Number of vehicles
Sabar *et al.*[29]	2018	road network	*					Number of vehicles
Wang and Niu[30]	2018	Urban road network		*				Number of vehicles
Wang *et al.*[31]	2019	urban distribution	*					Number of vehicles
Liu *et al.*[32]	2019	vehicular networks	*					Number of vehicles
Macrina *et al.*[33]	2019	Transportation network	*					Number of vehicles
Li *et al.*[34]	2020	urban distribution	*					Number of vehicles
Mohtashami, Aghsami and Jolai[35]	2020	supply chain networks	*					transportation fleets

$$H(e)=\sum_{v_i v_j \in v} \frac{\dfrac{w_{v_i v_j}(e)}{\sigma_{v_i v_j}(e)}}{\dfrac{w_{v_i v_j}}{\sigma_{v_i v_j}}} \tag{2}$$

Where

$w_{v_i v_j}(e)$: The sum of the weights of the edges is the shortest path between nodes v_i and v_j with the edge e located on it

$\sigma_{v_i v_j}(e)$: The number of the shortest paths is between nodes v_i and v_j with the edge e located on it

$w_{v_i v_j}$: The sum of the weights of the shortest paths between nodes v_i and v_j

$\sigma_{v_i v_j}$: The number of shortest path between nodes v_i and v_j

According to the data collected by Road Maintenance Transportation Organization of I.R. Iran, the average speed on each road and the number of vehicles passing through the time T on each road are available. So, the final congestion parameter, which is used in the model, will be given in equation (3).

$$CO_{ij=}H_{ij} \times \frac{N_{ij}}{T \times v_{ij}} \tag{3}$$

where CO_{ij} represents the congestion on road "ij" and other parameters, H_{ij} is betweenness of the road "ij", v_{ij} is average of speeds of vehicles on road "ij", T is the duration of the operation of the Traffic count and N_{ij} is the number of vehicles passing through road "ij".

The speed parameter increases as the road congestion is decreases. Also $\frac{N_{ij}}{T}$ is average number of passing vehicles per minute.

The model of Salhi et al. has been chosen as the basic model for development [39]. They presented the a new model with following assumptions.

· Each vehicle must start from a rescue center (depot) and return to the origin center.

· Every destination point for the rescue team (customer) must be visited exactly once and only by the same vehicle.

· Each customer service point must be visited only once and only by one vehicle.

· The capacity of the car is considered

· There is a time window for every demand point.

2.1. Model symbols

In this section, all the required symbols of the model including the parameters and decision variables are introduced. Table 2

2.2. Mathematical formulation

Mathematical programming formulation is presented as

Table 2. Notation

Symbol	Description
	sets
N	Set of demands (nodes call rescue) $N \in \{1,2,3,\dots,\lvert N\rvert\}$
M	Set of depots (nodes rescue centers) $M \in \{\lvert N\rvert+1, \lvert N\rvert+2, \dots, \lvert N\rvert+\lvert M\rvert\}$
K	Set of vehicles $K \in \{1,2,\dots,\lvert K\rvert\}$
	Index
k	Index for vehicle k
$i\,,j$	Nodes of operational points (demands) and relief centers (depots)
d	Index for depots (relief centers)
	parameters
q_i	is the demand of the ith node ($i \in N \cup M$) with $q_i = 0$ ($i \in M$) The demand value of the operating point i where $i = 1,\dots, n + m$
Q_k	Capacity of vehicle k ($k \in K$)
C_i	Capacity of rescue center (depot) i ($i \in M$)
V_k	Number of vehicles k available in each rescue center (depots) ($k \in K$)
FC_k	is the fixed cost of the vehicle of type k ($k \in K$)
γ_k	is the unit running cost of the vehicle of type k ($k \in K$)
Co_{ij}	is the congestion between nodes i and j ($i,j \in N \cup M$)
D_{ij}	is the distance between nodes i and j ($i,j \in N \cup M$)
B_{ik}	Number of vehicles k available in rescue center (depot) i ($k \in K\,, i \in M$)
t_{ij}	is the travel time between nodes i and j ($i,j \in N \cup M$)
ot_i	Service time at node i ($i \in N \cup M$)
et_i	Earliest time to start to service node i ($i \in N \cup M$)
lt_i	Latest time to start to service node i ($i \in N \cup M$)
A_d	1 if rescue center (depot) d available , 0 otherwise ($d \in M$)
M	Big number
n	Number of operational points (nodes requesting relief)
m	the number of depots (number of rescue centers)
	Decision variables
X_{ijkd}	$X_{ijkd} = 1$ if a vehicle of type k ($k \in K$) traveling along road (ij) ($i,j \in N \cup M$) and originating from depot d ($d \in M$) is selected, and $X_{ijkd} = 0$ otherwise.
Y_{ij}	is a non-negative continuous variable denoting the total load remaining in the vehicle before reaching node j while traveling along road (ij) ($i,j \in N \cup M$).
at_i	is a non-negative continuous variable denoting the arrival time to node i ($i \in N \cup M$)
S_k	1 if vehicle k is used, otherwise 0 ($k \in K$)

below based on [39]. This objective function aims to minimize total cost that includes both the vehicle fixed cost and the traveling cost. The objective function is formulated as follows:

$$Min\ Z = \sum_{k\in K} FC_k\, S_k + \sum_{d\in M}\sum_{k\in K}\sum_{i\in N\cup M}\sum_{j\in N\cup M} \gamma_k\, D_{ij}\, Co_{ij}\, X_{ijkd} \tag{4}$$

This objective is subject to the following constraints:

$$\sum_{d\in M}\sum_{i\in N\cup M}\sum_{j\in N\cup M} X_{ijkd} \le M\, S_k \quad k \in K \tag{5}$$

$$\sum_{d\in M}\sum_{k\in K}\sum_{i\in N\cup M} X_{ijkd} = 1 \quad j \in N \tag{6}$$

$$\sum_{d\in M}\sum_{k\in K}\sum_{j\in N\cup M} X_{ijkd} = 1 \quad i \in N \tag{7}$$

$$\sum_{i\in N\cup M} X_{ijkd} = \sum_{i\in N\cup M} X_{jikd} \quad k \in K\,, j \in N\cup M\,, d \in M \tag{8}$$

$$\sum_{i\in M}\sum_{j\in N} Y_{ij} = \sum_{j\in N} q_j \tag{9}$$

$$\sum_{i\in N\cup M} Y_{ij} - \sum_{i\in N\cup M} Y_{ji} = q_j \quad j \in N \tag{10}$$

$$Y_{ij} \le \sum_{d=n+1}^{n+m}\sum_{k=1}^{K} Q_k X_{ijkd} \quad i \in N\cup M\,, j \in N \tag{11}$$

$$\sum_{i\in N\cup M}\sum_{j\in N\cup M}\sum_{k\in K} X_{ijkd} \le M \times A_d \quad d \in M \tag{12}$$

$$(at_i + ot_i + t_{ij}) \leq at_j + M \times (1 - X_{ijkd}) \quad i,j \in NUM, k \in K, d \in M \tag{13}$$

$$et_i \leq at_i \leq lt_i \quad i \in NUM \tag{14}$$

$$\sum_{k\in K}\sum_{j\in N} Y_{ij} \leq C_i \quad i \in NUM \tag{15}$$

$$\sum_{j\in N} X_{ijk} \leq B_{ik} \quad i \in M, k \in K \tag{16}$$

$$X_{d_1ikd_2} = 0 \quad i \in N, k \in K, d_1 \neq d_2, d_1,d_2 \in M \tag{17}$$

$$X_{id_1kd_2} = 0 \quad i \in N, k \in K, d_1 \neq d_2, d_1,d_2 \in M \tag{18}$$

$$X_{ijkd} \in \{0,1\} \quad i,j \in NUM, k \in K, d \in M \tag{19}$$

$$Y_{ij} \geq 0 \quad i,j \in NUM \tag{20}$$

$$at_i \geq 0 \quad i \in NUM \tag{21}$$

Constraint (5) the assignment of vehicle is allowed if it is used. Constraint (6) shows that each demand point is visited only once, Constraint (7) the assignment of the vehicle is allowed if it is used and creates. Creates the flow conservation which the vehicle enters a demand point site and then must be left. Constraint (8) guarantees that the maximum of the vehicle, which started from the rescue center, can be went from center i to center j. Constraint (9) shows that the total quantity leaving all depots is exactly the total demands and (10) guarantees that the quantity remaining after visiting customer j is exactly the load before visiting this customer minus its demand. Constraint (11) guarantees that the vehicle capacity of any vehicle type is not violated. Constraint (12) guarantees that if the depot is out of reach, it is disregarded. Constraint (13) sets a minimum time for beginning the demand point service j in a determined route and also guarantees that there will not be created the sub tours. The constant M is a large enough number. Constraint (14) is time windows and guarantees that total vehicle travel time does not exceed the total available service time window (15) guarantees that the depot capacity is not violated and (16) ensures that the number of vehicles of type k in each depot is not violated. Constraints (17) and (18) guarantee that there is no arc between depots or from a demand point to itself respectively using any type of vehicle. Constraint (19) refers to the binary of the decision variable respectively. Constraints (20) and (21) guarantee that the decision variables at_i and Y_{ij} are positive.

3- SOLUTION APPROACH

The proposed model is NP-hard. By reducing the dimensions of the proposed model and deleting some of the defaults, it can be converted into a classical VRP problem. Nevertheless, in this case, the solution to the larger scale will be much different from the optimal solution. The best way forward is to tackle this complex combinatorial problem by means of an appropriate design and an efficient implementation of one of the modern heuristics which are also commonly known as meta-heuristics [39].In the following section, we will introduce a heuristic algorithm, and in the next step, obtained results will be presented.

This section deals with solving the model with hypothetical data. Initially, it assumed a problem with 2 rescue centers and 8 on-demand points.

Given the interpolation (1) and the intermediate definition for the expression of edge congestion, a new parameter is presented in this section using existing traffic data. The disadvantage of the previous parameter is that it only considers the importance of the edge on the road and does not pay attention to the data and the weight of the traffic on the edge. Likewise, to fill the vacuum mentioned above, a new parameter according to relation (22) is presented:

$$EB(e) = \sum_{v_iv_j \in v} \frac{\dfrac{w_{v_iv_j}(e)}{\sigma_{v_iv_j}(e)}}{\dfrac{w_{v_iv_j}}{\sigma_{v_iv_j}}} \tag{22}$$

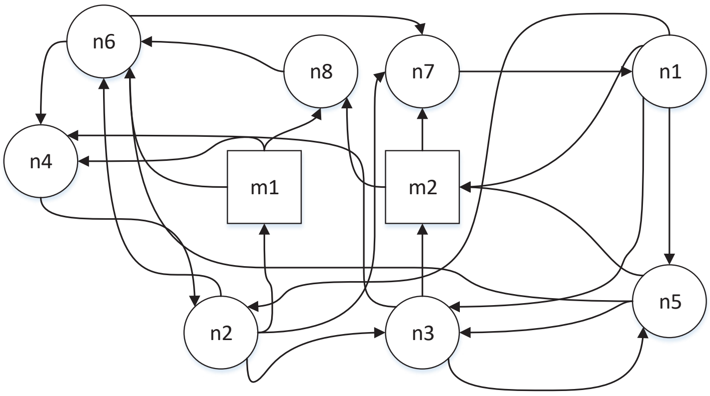

Fig. 2. Sample routing problem network with2 depots and 8 demand points

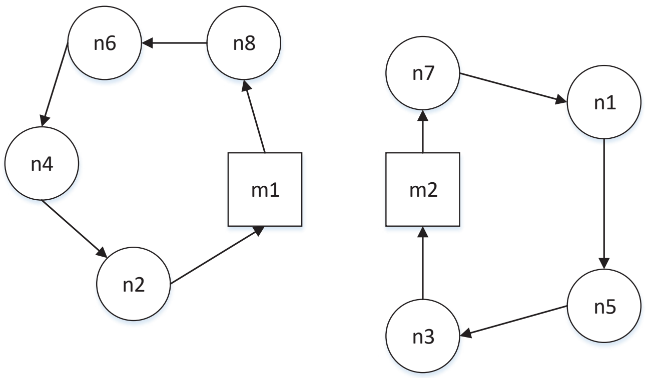

Fig. 3. Sample problem solving with 2 depots and 8 demand points

According to relation (22) in this paper, the interstitial in a weighted graph in the network is defined as follows:

((The sum of the weights of the shortest paths between two nodes passing through the edge to the mean of all the shortest paths between two nodes))

Using the concepts of network analysis, the interpolation of each edge is computed and the matrix H_{ij} is formed. The demand for each city is assumed to be between 50 and 100 and a car capacity of 380. After executing the schematic solution model it is as follows.

To solve this problem on a large scale one has to go to meta-heuristic and heuristic algorithms. Because the solution time in these algorithms and in large dimensions, is low. It should be noted, however, that the answer to the heuristic and meta-algorithm algorithms is worse than the exact solution. Lau introduces an innovative algorithm in this section and presents its results later. This problem is solved in various dimensions by a computer with an INTEL CORE i5 processor and 6GB of RAM.

3.1. Genetic Algorithm for Clustering Demands (GACD-MDVRP)

The MDVRP is a NP-hard problem that there are several ways to solve this problem at reasonable times. time. One way is to use a heuristic solution that transforms the problem into a few small problems. The usual heuristic used to approach MDVRP is to cluster the demand points into several sets where each set of demand points is served by exactly one depot. Ultimately, we need to solve several single-depot problems. If $\left(C=\{c_1,c_2,\ldots,c_n\}\right)$ is set of demands and $\left(D=\{D_1,D_2,\ldots,D_m\}\right)$ is a set of depots, the number of clusters should be equal as the number of depots. These clusters have nothing in common with each other$(C = C_1 \cup C_2 \cup \ldots \cup C_{|D|})$. Each depot is assigned to each cluster and set of demand point is served by exactly one depot. Some researchers have been used for this method to solve multi-depot routing issues [40], [41], [42].

The multi-depot vehicle routing problem (MDVRP) is examined. The task is divided into two subsidiary tasks. First, the demand points are clustered to determine the depot from which each demand point will be served. Then, the vehicle routing problem (VRP) with time window and capacity vehicles is applied and solved for each of the clusters.

In this paper, the genetic algorithm was used to cluster demand points, following the Libor Novak algorithm in 2015 [43]. Other articles have clustered the demand points based on the radius of service, the distance from the depot, and the minimization of the sum of the distances. But in this paper, clustering is done to minimize the sum of the internal traffic of the clusters and the results are examined.

In Novak's method each in the population is an assignment of the demand points to the depots, that is its chromosome is for example [1; 4; 2; 3; 3; 2; 4], where the position (locus) is the demand point index and the number at that position (gene) is the depot index to which the demand point is assigned.

He proposed a fitness function that uses the nearly exclusive pairing of the demand point assigned to each depot. The motivation behind it is to assimilate the routing process without actually solving it. Instead of taking into account the distance of the demand points to the cluster center, the distance between the demand points themselves was used in this paper. Instead of distance, a congestion path was substituted in the fitness function to create an algorithm for clusters in the number of depots in which the sum of the congestion of each cluster is minimized. Also, the total demand for each cluster should not be higher than the assigned depot capacity. This algorithm is effective in reducing the difference between the exact and heuristic answer as shown in Fig. 2.

In this section, a solution GACD-MDVRP algorithm was developed to solve the model as shown in Fig. 2:

4- Computational results

GACD-MDVRP algorithm is coded in MATLAB R2017b and executed on CORE I5 with 6 GB of RAM. To the best knowledge of the authors, the only data set that exists in the literature and which can be used in our testing was generated by Surekha and Sumanthi [44], and was derived from the commonly used MDVRP data set. Hence, the proposed heuristic will be compared with the result of exact solution coded by GAMS24.

4.1. Data instances

The parameter values used in this implementation include

```
Step 0: Initialization
        Getting details
            *demands (quantity, coordinates, earliest time to start to service and latest time to start to service, service
              time),
            *depots (coordinates, capacity of car & rescue teams, if depot is available or not),
            *vehicles (capacity, fixed & variable cost),
            *roads (distances, congestions, time of travel).

Step 1: Clustering
    (a) Set parameters of the algorithm
    (b) Run genetic algorithm and get clusters of genetic algorithms($G=1,\dots,g$)
    (c) Calculate the center of each cluster

Step 2: Assign clusters to depots
    (a) Get the coordinates of demand points($Q=q_1,\dots,q_n$) and depots ($D=d_1,\dots,d_m$)
    (b) Construction of Distance Matrix (Depot-Cluster Center)
    (c) Assigning clusters to depots

Step 3: Solve multi CVRPTW
        Set $Z=0$
        for $i=1$ to $m$ :
          {
            Solve single depot problem with time window and capacity of vehicles
            compute the objective function ($z_i$)
            $Z=Z+z_i$
            }
Step 4: Display
        Display Z and run time
```

Fig. 4. The GACD-MDVRP algorithm

Table 3 . Data instance

parameters	value
q_i	Random number between [10,20]
C_i	100 persons
FC_k	Random between [70,80]
γ_k	Random between [0.4,0.6]
ot_i	10
et_i	For all demands set 0
lt_i	For all demands set 200
A_d	5% of depots are unavailable

Table 3:

4.2. Summary of the results

Table 2 displays the characteristics of the problems, the exact solution found by GAMS24, the solution costs and the RUN time (in seconds) found by GACD-MDVRP. The GAP of the heuristic solution and exact solution and the rate of improvement were shown at the Run Time (I.R.T) in equation (23) and (24), respectively:

$$GAP(\%)=\frac{(\text{Huristice}-\text{Exact})}{\text{Exact}}\times 100 \qquad (23)$$

$$I.R.T(\%)=\frac{(\text{run time exact method}-\text{run time heuristic method})}{\text{run time exact method}}\times 100 \qquad (24)$$

5- CASE STUDY – KERMANSHAH EARTHQUAKE – IRAN

This section demonstrated the application of the proposed model to the Kermanshah earthquake. The earthquake in Kermanshah, Iran, was reported on November 12, 2017. During the incident, 569 people were killed. This problem was solved with 35 demand points and 1308 rescue centers. Iran's road network was made using data from the Road Maintenance Transportation Organization of I.R. Iran. The matrix of distance and travel time between the two points was also plotted using the Google API.

For each road, the congestion parameter was calculated according to equation (2) and (3). Coordinate data, depot capacity and the number of vehicles in each depot were taken from the Rescue and Rescue Organization of Red Crescent Society of I.R. Iran. Time windows for each township were considered to be randomly generated with a range of ±25% of the actual recorded uniform distribution time window.

Fig. 5. shows the road network of Iran in the third week of November 2017, when road congestion is shown. The size of the city names depends on the total congestion of the entrance to that city.

Table 4 . Results for the GACD-MDVRP algorithm (K=5).

No.	details			Exact solution		Heuristic solution		GAP (%)	I.R.T[1]
	N. demands	N. depots	Capacity of vehicles	Run time (second)	Solution value	Run time (second)	Solution value		
1	25	2	80	10	1526.5	12	1648.62	8%	-15%
2	25	3	80	23	1575.2	24	1701.216	8%	-3%
3	55	4	80	62	2685.3	58	2926.977	9%	6%
4	55	3	80	54	2598.8	50	2806.704	8%	7%
5	85	3	160	101	3825.3	86	4131.324	8%	15%
6	85	4	160	114	4914.2	93	5405.62	10%	18%
7	100	4	160	131	5368.5	100	5905.35	10%	24%
8	100	5	160	139	5425.3	104	6022.083	11%	25%
9	100	5	80	104	5125.3	82	5791.589	13%	21%
10	150	5	120	174	6925.3	120	7756.336	12%	31%
11	150	6	120	186	7047.2	123	7963.336	13%	34%
12	210	5	120	201	7704.2	111	8782.788	14%	45%
13	250	4	160	221	7624.1	117	8767.715	15%	47%
14	250	6	160	275	7798.2	151	8889.948	14%	45%
15	250	6	200	320	7202.4	166	8354.784	16%	48%
16	360	6	200	412	8142.6	173	9526.842	17%	58%
17	360	6	250	492	7824.2	172	9232.556	18%	65%
18	360	10	250	526	8201.6	163	9759.904	19%	69%
19	500	10	250	631	9342.1	164	11584.2	24%	74%
20	500	12	300	_	_	192	11764.18	_	_
21	500	15	300	_	_	201	12272.4	_	_
22	750	15	300	_	_	209	12780.62	_	_
23	750	18	300	_	_	218	13288.83	_	_

1. I.R.T is Improve the Run Time

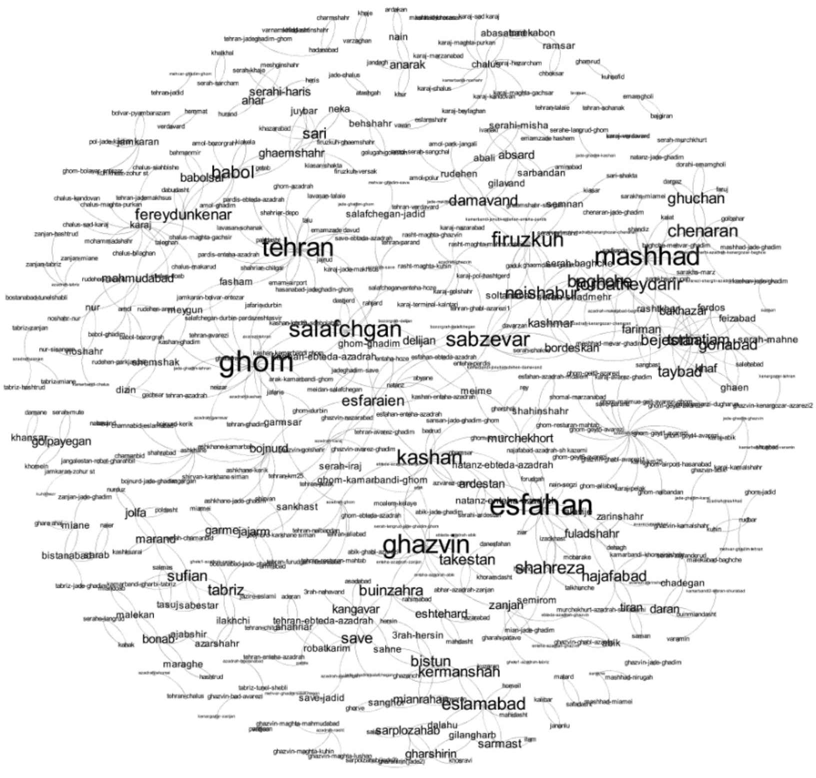

Fig. 5. road network of Iran in the third week of November 2017

. 50 percent of the depots were considered unavailable and solve the problem by the heuristic algorithm proposed. In this case, some demands may be larger than the capacity of the depots. For this case, demands more than 5 will be broken down to a smaller demand 5 and resolved.

Fig. 6. indicates the location of the depots and the demand points.

Table 5. shows the result of solving vehicle routing problem for rescue teams using in Kermanshah earthquake.

6- CONCLUSIONS AND SUGGESTIONS

The main purpose of the present paper was to provide a new multi-depot model for routing heterogeneous vehicles, taking into account the time window. In addition to the availability of depots, congestion was also considered. The new congestion parameter was calculated using network analysis for each network edge. To solve the proposed model, a heuristic algorithm was considered that reduced

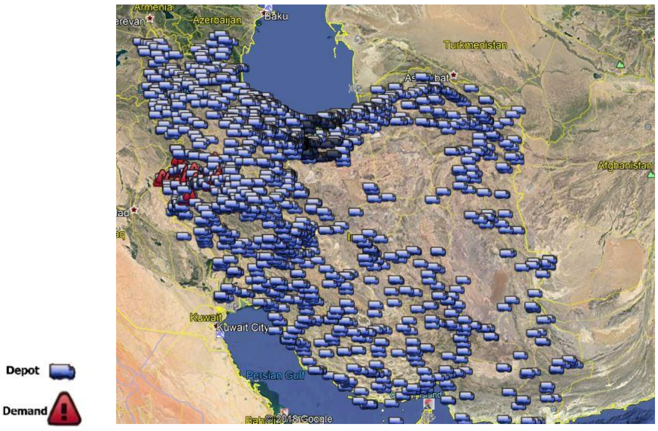

Fig. 6. The location of the depots and the demand points

Table 5 . The result of solving vehicle routing problem for rescue team using in Kermanshah earthquake

NO.	demand	Quantity of demand	Depot assigned	(lat. ,long) of depots	Distance between demand and depot assigned(km)	Travel time between demand and depot assigned(min)
1	Khosravi	5	Ghasr shirin markazi	(34.5276-45.6079)	24	28
2	Gilan-gharb	4	Naser dayere	(34.3191-45.8923)	42	43
3	Eslam Abad gharb	5	Gilan-gharb	(33.97-46.3575)	8.38	37
		3	Chardavol	(33.6818-47.0555)	4.71	57
4	Ilam	4	Eyvan_e gharb	(46.353-33.78)	34	36
		5	Mehran	(33.575-46.2795)	21	25
		5	Eyvan_e gharb-mrkazi	(33.5-46.184)	35	34
5	Homeil	4	Kuhdasht	(33.5528-47.306)	93	98
6	Serahi Harsin	3	Sinun	(34.34-47.36)	29	30
7	Harsin	4	Nurabad	(34.157-47.9241)	4.39	36
8	Sarmast	3	Sahne	(34.4792-47.8091)	24.1	12
9	Sahne	5	Sahne-markazi	(34.4656-47.6746)	9.14	14
		3	Kangavar	(34.47.26-47.7356)	6.8	10
10	Kangavar	5	Nahavand	(34.3801-48.0894)	5.25	35
		2	Malekshahi	(34.6394-47.8647)	5.24	31
11	Nahavand	5	Malayer	(35.2753-48.5373)	2.22	25
		5	Nahavand	(34.1051-48.4384)	2.13	22
12	Gasr_e Shirin	5	Gasr_e Shirin	(34.5276-45.6.79)	6.3	6
		4	Ghasr shirin markazi	(34.5276-45.6079)	7.3	6
13	Gasr_e Shirin-52th	5	Mehran	(33.32-46.11)	310	249
		1	Eyvan_e gharb	(33.7877-46.3395)	148	134
14	Sarpolzahab	5	KhorramAbad	(33.6583-48.56273)	301	232
		5	Mehran	(33.32-46.11)	280	226
		5	Malekshahi	(33.2654-46.6232)	253	206
15	Sarpolzahab-52th	3	Eyvan_e gharb	(33.5-46.18)	229	180

Continued Table 5 . The result of solving vehicle routing problem for rescue team using in Kermanshah earthquake

NO.	demand	Quantity of demand	Depot assigned	(lat. ,long) of depots	Distance between demand and depot assigned(km)	Travel time between demand and depot assigned(min)
16	Karand_e ghaeb	5	Dare shahr	(32.2-46.59)	255	223
		2	Kuhdasht	(32.2687-47.5747)	183	145
17	Mahidasht	5	Chardavol	(33.6818-47.0555)	118	107
		3	Kuhdasht	(33.4552-47.4283)	185	145
18	Sarabele	1	Chardavol	(33.7928-46.6648)	5.19	22
19	Kamyaran	5	Kermanshah-markazi	(34.6753-46.8996)	6.15	18
		3	Kamyaran	(34.8661-46.9536)	8.8	11
20	Ghazanchi	5	Paveh	(34.6668-46.9027)	28	20
		2	Kuhdasht	(33.5528-47.306)	158	154
21	Kermanshah	5	Kermanshah - markazi	(34.394-47.1277)	4.1	20
		5	Kermanshah	(34.3941-47.126)	6.1	22
		4	Sanandaj	(35.3005-46.9549)	144	152
22	Mianrahan	5	Sanghor	(34.5257-47.4008)	3.7	6
		4	Nur Abad	(34.0705-47.9728)	112	91
23	Sanghor	5	Sanghor	(34.7832-47.6301)	7.3	11
		1	Sanghor	(34.9613-47.789)	5.31	29
24	Asad Abad	5	Tuysekan	(34.5322-48.2753)	2.38	47
		2	Tuysekan	(34.4669-48.565)	125	99
25	Salas	5	Kamyaran	(34.6668-46.9027)	128	140
		4	Eyvan_e gharb	(33.5-46.8)	253	239
26	Salas_e babajan	5	Poldokhtar	(33.1406-47.7322)	353	343
		5	Khoram Abad	(33.47-47.9358)	279	273
27	Ghorve	5	Bahar	(34.115-48.3524)	64	52
		4	Hamadan	(34.9769-48.5926)	99	120
28	Javanrud	2	Sanandaj	(35.3216-47.044)	133	136
29	Se rahi biashush	3	Sanandaj	(35.3842-46.7985)	164	179
30	Ravansar-Siahpush	2	Divandare	(35.673-47.1234)	176	160
31	Ravansar-Noruzabad	5	Sanandaj-markazi	(35.3532-46.9955)	115	121
32	Kuzran	1	Chardavol	(33.45-46.37)	199	170
33	Nosud	2	Baneh	(35.9949-45.8847)	227	296
34	Javanrud	4	Saghez	(36.2547-46.2747)	327	298
35	Paveh	3	Dehgolan	(35.2752-47.4156)	181	184

the solving time. This algorithm first clustered the demand points using the genetic algorithm, and solved a single-depot routing problem with a time window and capacity vehicles in each cluster. The average accuracy of this algorithm was 87% after solving 23 problem samples and improvement of the runtime was 74% in a large problem. Rescue problem in the earthquake of Iran's Kermanshah in 2017 is also solved using the mathematical model and the proposed solution, and the last point of demands will be met 6 hours after the occurrence of an emergency, which will be very effective in case of implementation in the real environment. It would be useful to evaluate how the proposed model may be able to be adapted for potential use in other propagating natural disasters, such as hurricanes and bushfires. It has also identified ways that have significantly increased congestion compared to pre-earthquakes and has identified governments as susceptible to congestion to take appropriate action. The unavailability of depots is also an important issue that should be taken into consideration. It is recommended that depots be placed in higher grade nodes. Because the number of edges is more selectable and easier to do in the event of a crisis. By solving the proposed model, we can identify the provinces that should be ready to serve in each city during the crisis. In the scenario presented, the provinces that are to come to a crisis in Kermanshah are Kurdistan, Ilam, Lorestan and Hamadan. This model can be applied to other provinces and the provinces that should be ready to serve are introduced to the I.R. Relief and Rescue Organization of Red Crescent

Society of Iran.

For future studies, it is suggested that the uncertainty of demand and the availability of roads between cities considered. In emergency condition, the vulnerability of roads might lead to the closure of roads.

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