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Location Allocation of Earthquake Relief Centers in Yazd City Based on Whale Optimization Algorithm

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ABSTRACT

Despite the fact that many governments try to set rules that guarantee having resistant buildings, there are many vulnerable structures in the world. Hence, establishing earthquake relief centers is an important issue in order to control the effect of an earthquake. Iran is a country in middle east which is severely vulnerable against earthquake. Yazd is a central city in Iran. Since there is no such a study for Yazd city, this city is considered in this study. The parcels' layer of the GIS map of Yazd city has been used as the input of the problem. Since the location allocation of relief centers is a problem with huge complexity and cannot be solved in polynomial time, Whale Optimization Algorithm (WOA) has been used to solve the problem. The Whale Optimization Algorithm or The WOA is a particle based heuristic algorithm which is suitable for solving hard problems. The main contributions of the research are modifying WOA function for the problem and designing a new method for creating whales. In order to reduce the time of reaching to the reasonable solution an innovative whale generating method has been designed. The results show that average distance of each parcel from its relief center is 1541 meters and the standard deviation of 114.

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1. INTRODUCTION

In order to mitigate the effects of natural disasters, governments and authorities must make plans and decisions in advance [1, 2]. Natural disasters, such as earthquake and flood, are inherently unpredictable and catastrophic. Lack of comprehensive plans along with low precautionary measures can have disastrous consequences for the region. Some of the serious consequences would be loss of properties, death tolls and injuries, contagious diseases and homeless people. Reducing these harsh events is the main mission in each relief and response process [3, 4]. The stronger logistic plans you have, the easier you can fulfill these goals [5]. In other words, the main part of a rescue mission is its logistic plans. At the time of any disaster, the level of our success is at the heart of decisions that we have already made [6, 7]. Moreover, when there is a detailed plan for logistics in advance, it would be easier to coordinate communication and commuting process with the delivery of commodities [8, 9]. As a result, we will have a better response time. With increasing the speed of delivery, we will be closer to our goals in rescue mission [10, 11]. Pre-locating of the relief centers is one of the most important initiatives in order to reduce the delivery time [12, 13]. This approach was used in WWII as a military strategy in order to increase the possibility of victory and also reduce the number of wounded soldiers [14]. The whole point of logistic strategy is proper location allocation of relief centers. Location of relief centers has a profound effect on rescuing process. There are many parcels on the map of a region which need to be rescued [15, 16]. If we have a closer relief center to each parcel we will deliver the food and medicine and other necessities in more reasonable time. Out of proportion distance between the parcels and the centers would decrease the quality of helping process. Helping injured people, delivering food and making a shelter for people in need would be

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accelerated if they are in short distance from the relief centers. Therefore, the ultimate vision of the decision makers is the relief centers to be in all people's fingertip [17, 18]. The size of the region which is affected by a natural disaster has direct effect on the complexity of the problem. When it comes to a metropolis there are many bottlenecks and congested areas on the map which can complicate the rescue process. Therefore, big cities with huge populations are exposed to more hazards and in order to decrease the risk we should have a more accurate plan and strategy [19, 20].

The logistic strategy in Yazd city in center of Iran has been addressed in this paper. This big city, like many parts of Iran, is vulnerable to earthquakes and should have an accurate plan to mitigate the effects of a possible disaster. Finding the best location for each relief center is the main goal of this research. Through decreasing the distance between centers and parcels and also balancing the load of work on each center, this research is aiming to present a solution for delivering the best service in shortest time for each person in need in Yazd city.

There is a classic problem named location allocation problem or LA which is referred to any kind of problem involved in finding suitable locations for bunch of entities. It is proved that LA is a NP-hard problem which does not have any polynomial solution. In a situation that we have a large number of objects, it is almost impossible to find the optimum solution in a reasonable time. In other words, it is true to say that solving this problem in general is not plausible [21, 22]. The most effective way to tackle this problem is using optimization methods. In this method we try to come up with an algorithm that can find a sensible solution which in close enough to the best solution to be accepted by the users. Despite the fact that these methods cannot find the optimal solution, they are useful because of their reasonable execution time. In fact, we sacrifice the best answer in order to reach a useful solution in a relatively short time [23]. One of the most famous optimization methods are particle based algorithms. These algorithms try to solve the problem by simulation of particle movements which has drawn the inspiration from natural phenomena [24, 25]. Recently a new particle based algorithm has been designed which optimize the problems by inspiration from whale's hunting process. This innovative algorithm which is called WOA (or Whale Optimization Algorithm) has added new characteristics to previous algorithms which seems to be promising to solve different types of NP-hard problems [26, 27].

There is no a comprehensive research about Location Allocation problem for Yazd city in center of Iran. Therefore, in this research a new heuristic algorithm based method has been proposed in order to tackle the problem. The WOA has been adjusted to solve the LA problem in Yazd city of Iran. The proposed method has been executed on GIS information of Yazd map in order to locate relief centers in the best places. The main aim of the paper is finding the best locations for earthquake relief centers by redesigning WOA.

To analyze the algorithm, all parcels are pulled out from a GIS map of Yazd city. In proposed algorithm, all of the locations in Yazd city could convert to a relief center. When we have some pre-defined candidate locations, the solution space will become smaller and solving the problem would be easier. The WOA has been redesigned and tuned to solve the Location Allocation problem in Yazd city. The proposed method has some parameters which are calibrated by means of a simple map. After that, the problem in Yazd city has been solved by means of proposed algorithm.

The rest of the paper is structured as follows. The second section reviews previous studies in this problem. In the third section, the proposed method has been presented completely and all of its phases have been clarified. In the fourth section, the proposed algorithm has been simulated and assessed thoroughly. In the fifth section, there is a summary, conclusion and some suggestions for future works.

2. PREVIOUS STUDIES

The Location Allocation problem or LA is a general problem which is involved in many aspects of human life. To some extent, improving the quality of life lays on solving different problems which can be boiled down to a LA problem. Therefore, in this section some solutions for various LA problems have been reviewed.

2. 1. Mathematical Model Approaches

One of the most famous and effective approaches to solve the location allocation problem is designing a mathematical model for the environment which the LA problem is supposed to be solved for it. All the parameters and their constraints can be embedded in the model. In order to reach the solution this model can be solved and optimized by different methods. Some of the recent papers which used this approach will be reviewed following.

Rahmani [28] proposed a new method for blood supply chain management. Their method is an accurate algorithm which tries to reduce the delivery time and avoid shortages in blood. The approach is locating blood supply centers in appropriate point that causes delivery process to be conducted in time. Therefore, the objective function is minimizing the distance between blood centers and people in need. The algorithm behind the model is Lagrangian Relaxation. The results show that the cost of the system is in direct proportion with the level of demand. Salehi et al. [29] designed another method for blood delivery. In this paper authors considered the situation of after earthquake. They presented a sophisticated model which takes to account some important issues about the blood, such as compatibility of the blood group. Two important variables can be optimized in this model. First the location of each relief center and second the amount of blood which should be saved in each center. The simulation results for Tehran city prove the effectiveness of the proposed model. Fazli-Khalaf et al. [30] have presented a new model for relief management. This model has three different objective functions. Many involved parts in after earthquake rescue mission have been attached to the model. This research was aiming to find the best locations for permanent and temporary relief centers in order to reduce the delivery delay. The simulation results on Tehran city showed the positive effects of the proposed model.

Boonmee et al. [31] solved the LA problem for relief facilities before and after a disaster. In order to evaluate the method, different conditions have been tested (deterministic, stochastic, dynamic, robust). Before the disaster, location allocation of shelters and warehouses was carried out and after that, location allocation of healthcare and distribution centers was focused. The proposed method has been tested in all conditions through a case study. Mahootchi and Golmohammadi [32] designed a stochastic mathematical model which has two levels. This model is executed in two phases before and after disaster. The location allocation of relief centers and assigning each parcel to a single center are conducted in the first and second phases, respectively. The level of storage in each center and the total amount of goods are also specified. The simulation results showed that the cost of relief mission and the number of needed centers are in the direct proportion to intensity of the earthquake. The proposed method was tested on Tehran city in Iran. Sebatli et al. [33] proposed a new method which can allocate necessary goods to areas in need. Their algorithm is based on a mathematical model which has two phases. Their aim was reducing the distance and the cost of delivering necessary supplies. The Yildirim region of Turkey was used in order to evaluate and validate the model. Chu et al. [34] proposed an integer nonlinear programming in order to optimize the process of assigning medical and healthcare teams to each group in the rescue mission. Their innovation was taking to account the stochastic transition probability of triage levels. In order to find a solution, the stochastic Markov chain was used. Their main goal was increasing the number of wounded which have received emergency medical care. The results show that assigning the medical teams to the closest and worst affected areas causes more lives to be saved.

2. 2. Heuristic Approaches The papers which are reviewed so far were all based on mathematical models. There is another approach to address the location allocation problem. Since the LA problem is NP-hard one, the optimization algorithms which are based on heuristic methods are very useful to find a reasonable solution in a sensible time. The particle based algorithms and the genetic based algorithms are the famous heuristic methods which have been widely used to tackle the LA problem. Here some of the recent papers with this approach will be reviewed.

Golabi et al. [35] tried to find the optimal location of distribution centers in the large-scale disasters. They assumed that it was possible there would be a problem to reach to the intended points. For optimization phase they adjusted three different heuristic algorithms to be applied to the model. The GA or genetic algorithm was the first one. Another algorithm they used was Simulated annealing, and the third one was Memetic algorithm. They tested their method through a case study in Tehran. In another paper, authors designed a stochastic mathematical model in order to minimize the effects of natural disasters. Their new algorithm, which was designed for pre-disaster time, was capable of finding the best location for each center and finding the optimal capacity for each center. They also designed an objective function in order to minimize the rate of causality. They adjusted a particle based algorithm to optimize the solution [36]. In another research authors put forward a new method which tried to compare the effectiveness of the Genetic Algorithm (GA) and Bees Algorithm (BA) in location allocation of relief centers and assigning the parcels to them. The GIS data was used as the input of the algorithm. Then, each algorithm applied to the data separately for finding nine center location between the candidates and assigning the parcels to them. Before the main testing phase the algorithm was calibrated with a simple synthetic data. The simulation results indicated that the convergence of the BA was gradual to some extent, while the behavior GA was step by step. In terms of stability both algorithms were acceptable [37]. Saeidian et al. proposed a method in which the location allocation of relief centers is specified. They used Geospatial Information System (GIS), the Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) decision model, a simple clustering method and the two meta-heuristic algorithms of Particle Swarm Optimization (PSO) and Ant Colony Optimization (ACO). The authors compared PSO and ACO in different conditions. The simulation results indicate the efficiency of TOPSIS, the clustering method, and the particle based algorithms [38]. In another paper, the capacitated location-allocation problem with stochastic demand was addressed. They designed a mathematical model to find the best locations of the relief centers. A local search method was combined with genetic algorithm to tackle the problem [39]. In another research, various parameters including demand and flow of relief commodities, capacity of centers, transportation of injured people, capacity of vehicles for commodities and injured people, and back up centers were taken into account in different parts of planning. A real data from Tehran city in Iran was used to test the method. The modified multiple-objective particle swarm optimization (MMOPSO) and Non-Dominated Sorting Genetic Algorithm-II (NSGA-II) were the heuristic algorithms which were adjusted for the problem. The simulation results show that the MMOPSO has the best effectiveness [40].

Ghasemi et al. proposed a robust simulation-optimization method for planning before the disaster. Moreover, the amount of needed goods was one of the important parameters in this method. One of the stochastic parameters of the model was the demand pattern in the problem. Robust optimization approach was used to handle uncertainty. The proposed model could specify the location of each relief center and its parcels. The genetic algorithm has been modified and used in order to optimize the solution [41].

A multi-level facility location problem (FLP) is formulated to find the best number of relief centers and their locations in literature [42]. The authors assumed that the demand pattern was based on Poisson distribution. All demands are satisfied by the closest relief center. A hybrid genetic algorithm is developed to optimize the proposed model. The effectiveness of the proposed method is tested by means of a case study. The simulation results show that there was an increase in effectiveness of relief centers and also a significant decrease in response time [42]. Table 1. summorizes some of the most important reviewed papers.

3. PROPOSED METHOD

In this article a new method has been proposed based on Whale Optimization Algorithm (WOA) in order to optimize earthquake relief centers' location in Yazd city. Since the WOA is suitable for continuous problems, it has been adjusted for solving location allocation problem. All functions have been designed from scratch. Moreover, an innovative method has been proposed to speed up the convergence of the evolutionary algorithm. In this method first generation of whales is produced in a way that is more likely to be near the optimal solution. If the first generation whales are close to the best solution, the convergence of the algorithm will be faster. Figure 1 demonstrates the steps of the proposed method.

According to Figure 1 the input of the algorithm is the polygon data, extracted from GIS of Yazd city. At the beginning of the algorithm, first random solutions are produced. As it mentioned above, first whales creating is taken place by an innovative function. After this phase, there are some functions to move the whales. After each movement, the algorithm must update the fitness values. This steps will continue until we reach to exit criteria. Reporting optimal solution is the last phase of the proposed algorithm. In following, each step of the algorithm has been explained in detail.

3. 1. Whales' Structure

Each whale represents a random solution for the problem. In other word in each solution, location of relief centers in Yazd city can be found. Random whales are not optimal but they are supposed to be improved by moving functions. Every single whale is shown by an array. The length of the array is equal to number of relief centers. Each index of array represents a particular relief center and the value inside this index demonstrates the location of this relief center. Each location is determined by a couple of values (x and y). Table 2 shows an example of a whale that includes six relief centers.

TABLE 1. Previos works

Ref.	Problem	Method	Pros & cons
[28]	Blood supply	Math model	-Reasonable solution -Low scalabiity
[29]	Blood supply	Math model	-Low running time -Low scalability
[30]	Relief Management	Math model	-Multi objective -Complicated model
[31]	Location Allocation	Math model	-Optimal solution -Low scalability
[32]	Location Allocation	Heuristic	-Scalable -Computational overhead
[37]	Location Allocation	Heuristic	-Using GIS data -Computational overhead
[38]	Location Allocation	Heuristic	-Clustering -Using GIS data
[40]	Relief management	Heuristic	-Multi objective -Using GIS data

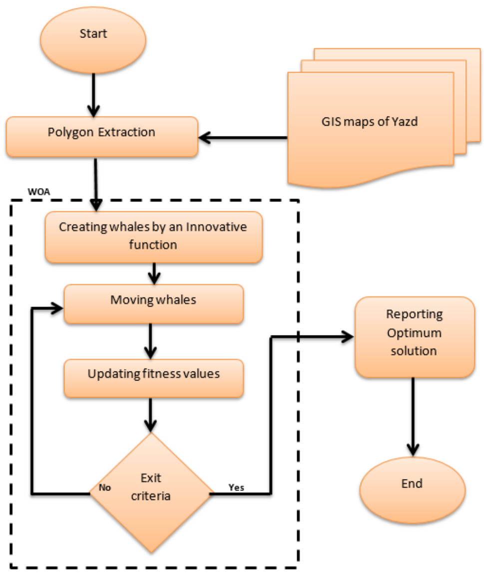


Figure 1. Steps in proposed algorithm

TABLE 2. A whale with 6 centers (meter)

Whale	$Center_1$	$Center_2$	$Center_3$	$Center_4$	$Center_5$	$Center_6$
(x , y)	(21,45)	(83,79)	(18,31)	(50,65)	(13,90)	(37,40)

3. 2. Creating Whales

In order to achieve better solution and as an aim to speed up the algorithm, initial whales are produced by an innovative function. This function has been designed in a way that tries to spread the first location of centers uniformly. Relief centers should be able to serve all parts of the region and this service should be fair. So if we spread the centers among the region it is more likely to have uniform services, however population distribution and more congested points of the map should be considered. For achieving this goal, a partitioning function has been proposed in Algorithm 1.

```
Algorithm1 : partition
Input : points of the map as (x,y)
output : lines
lineNum = ⌊√n⌋
pointNum = length(points)/lineNum;
Vline = 1;
for i = 1 to max(x)
        if (number of points with x ≥ Vline * pointNum) or (i = max(x))
                add a vertical line in this i position to lines;
                Vline = Vline + 1;
Hline = 1;
for j = 1 to max(y)
        if (number of points with y ≥ Hline * pointNum) or (i = max(y))
                add a horizontal line in this j position to lines;
                Hline = Hline + 1;
return lines
```

In Algorithm 1 *points* is an array that contains all points of the map. *LineNum* is a variable that determines the number of vertical and horizontal lines to partition the map. The number of vertical and horizontal lines are qual. *pointNum* is the number of points between each two lines. *Length(points)* is the number of points in the map. The output of the algorithm is an array, which is called *lines*, that contains all vertical and horizontal lines. The map could easily be partitioned by means of these lines. The partitioned map contains many rectangles that each one shows a particular partition of the map. Figure 2 shows output of this algorithm for two different maps. Comparing these two solutions shows that the proposed function not only considers the area of the map but brings the distribution of the points to play. In other word this algorithm tries to partition the map in a way that each part contains roughly equal number of points.

After partitioning it is time to create whales. In this step, for each whale we should select candidate points from different rectangles. Selecting candidate points from different rectangles helps us to distribute the centers among the map and make the random whales close to best solution. when number of rectangles are less than number of centers it is not a big problem to select multiple points from a single rectangle. Anyway, the number of selected points should be equal to number of centers.

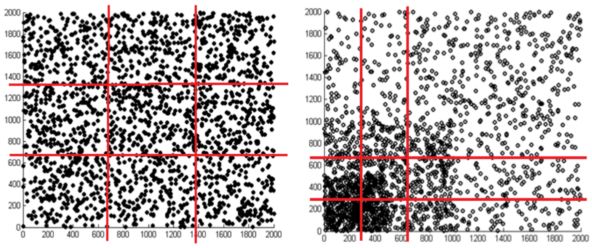
3. 3. Fitness Function

A new fitness function has been designed in order to achieve the best locations of relief centers in Yazd city. Two important issues have taken into account in calculating fitness value. Since the fitness function represents the objectives of the designers, this article has concentrated on two different aspects of the problem that are important for decision makers. The first aspect is they want to reduce the distance between centers and point as much as possible. And the second aspect is they want centers not to be over loaded. For the first goal, average distance between centers and points has been considered. The fitness function tries to reduce this value. For the second goal a penalty function has been designed. In the penalty function, finding a center that is responsible for more than average induces a negative effect on fitness value. Equation (1) shows the penalty function. The total penalty for a whale is equal the sum of the center penalties in the whale.

$$penalty(center_i) = \begin{cases} 1 & parcels_i > \frac{n}{k} \\ 0 & O.W. \end{cases} \tag{1}$$

Equation (2) shows the fitness function. The penalty value is in the denominator in order to have negative effect on the fitness value. The fitness function creates a value that represents the closeness of centers to the points and balancing of the centers' load simultaneously.

$$fitness(whale) = \frac{\sum_{i=1}^{n} distance(parcel_i, center_i)}{\sum_{j=1}^{k} penalty(center_j)} \tag{2}$$



a. Even map b. Uneven map

Figure 2. Partitioning example (meter)

3. 4. Move Functions The WOA has two functions to move the whales. These functions are Shrinking and Spiral respectively. Classic move functions of WOA are not useful in this problem, hence they should be redefined to meet constraints of the problem. Both of move functions use a particular concept which is called Distance. Distance value shows the difference between two given whale. In this article Distance of two whales is in the form of an array that contains the distance between nearest centers in two whales. Therefore, the length of Distance array is equal to Whale array. In following the detail of each move function has been presented.

3. 4. 1. Spiral The Spiral function tries to go toward the best answer (prey) through a spiral path. In other word in this function each whale tries to go near the best whale conservatively. So the whale spirals around the prey and approaching it. Figure 3 illustrates the rotation angle and moving toward the best answer. W wants to spiral around the Best. The rotation angle is $2\pi l$ where l is a random value in $[-1\ +1]$. The imaginary line between W and Best must be calculated by Distance function.

Algorithm 2 shows the details of Spiral. The direction of rotation is clockwise. The inputs of the function are W and Best. W is the whale that is supposed to be spiraled and Best is the prey location (best answer).

```
Algorithm2: Spiral
Input: w1: a whale for spiral , best: the best whale
Output: w: spiraled whale
l = a random number in [-1,+1];
θ = 2πl; // rotation angle
for i = 1 to len(w)
        point = a random location on line(w1, best);
        destination = θ sized roundClock rotation centered by best;
        w(i) = destination;
end
```

3. 4. 2. Shrinking The second move function is Shrinking. In Shrinking a random whale moves directly toward the prey (best answer). In this function, there is not any rotation, so in comparison with Spiral, the whales go faster toward the prey. Algorithm 3 shows the pseudo code of the Shrinking. The inputs of the function are W and Best. W is a random whale and Best is the prey.

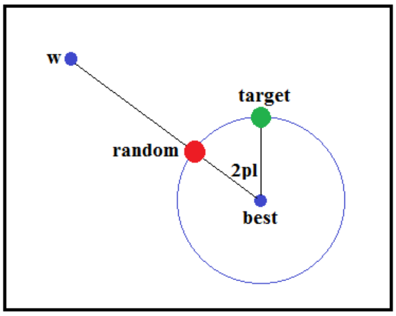


Figure 3. An example of Spiral

```
Algorithm3: Shrinking
Input: w1: a whale for spiral , best: the best whale
Output: w: shrinked whale
for i = 1 to len(w)
        destination = a random location on line(w1, best);
        w(i) = destination;
end
```

3. 4. 3. Search Apart from Shrinking and Spiral there is another useful function in proposed method which is called Search. The search function consist of three different functions. One of them is shrinking function that is used with different parameters. Instead of moving a whale toward the best, here, the shrinking function tries to move a whale toward another whale which is selected randomly. Join and random walk are two another function that are used in the search. These two functions in some extent act like crossover and mutation operators in Genetic Algorithm. All in all, the search function is used for exploring problem space. Algorithm 4 shows the pseudo code of this function.

```
Algorithm4: search
Input: w1: a whale for shrinking , w2: a randomly selected whale
Output: w: a new whale
distance = whaleDistance(w1, w2);
tmp = a random number in [0,1];
if tmp < 0.25
        w = shrinking(w1, w2);
elseif tmp < 0.25
        w = join(w1, w2);
else
        w = randomwalk(w1);
end
```

3. 5. Contributions Given the details of the proposed method which has been explained in this section, the following contributions can be considered as the novelties of this work:

- Using the WOA for the first time to solve the LA problem in Yazd city.
- Modifying the WOA functions in order to solve a discrete problem.
- Introducing an innovative Whale generating algorithm which can improve the method's efficiency.

4. EXPERIMENTAL RESULTS

After presenting the proposed method, it is time to implement and evaluate it. In order to analyze the effect of the algorithm on the Yazd maps, it has been implemented in Matlab software. The first step is calculating best parameters for the method and after that we can use the algorithm for solving the problem in Yazd city maps.

4. 1. Best Parameters of the Algorithm The proposed method has some parameters which determine its performance. In order to achieve better solutions, these parameters have to be calculated. Using a simple regular map is the best way to calculate these parameters. Since the optimal solution of this map is predefined, the effect of various parameters could easily be assessed. The number of whales and the number of movements are the parameters that must be calculated.

The outputs of the proposed method with different parameters have been listed in Table 3. According to the results it could be easily understood that the best parameters is the row number nine. So in the next sections all of the results are based on 40 whales and 100 movements. the pattern of parcel assignment has been shown in Figure 4 which is completely sensible and true.

To be more specific, the proposed method has been applied to a uniform map. The optimal parameters have been used to solve the problem. This hypothetical map has 2000 parcels which are distributed on the map uniformly. It is supposed to have six relief centers on the map. The size of the map is 2000 in 2000. The map has been shown in Figure 5.

In such a map, the sensible solution should be an assignment where number of parcels are equal in all centers. Figure 6 demonstrates the assignment pattern of the solution. As it could be seen the distance between centers are almost equal. The number of parcels for each center is roughly equal 330. Given the fact that the map has 2000 parcels and six centers, 330 parcel for each center is satisfactory (2000/6=333.33). In this problem, it has been assumed that relief centers can be located in each place of the map. If we have the limitation of locating centers just in pre-specified locations, there will no problem for the algorithm because we only have the problem space smaller, in other word, solving the problem will be easier.

4. 2. Yazd City In this section the proposed method has been applied to parcels of Yazd city in order to achieve the best locations of relief centers in the city. In this city there are roughly 8500 parcels. The parcels have been extracted from parcel layer of GIS maps. The GIS maps of the city has been acquired from the Ministry of Roads and Urban Development. According to optimal parameters, the algorithm has been executed with 40

TABLE 3. Results of the proposed method with different parameters (meter)

Row#	Whale#	Move#	Center1	Center2	Center3	Center4	Fitness	Time(minute)
1	20	60	512	580	669	739	21	2.5
2	20	80	643	599	572	686	19.5	4
3	20	100	602	535	711	652	19	5
4	30	60	699	605	614	582	19	6
5	30	80	615	641	610	634	18	7
6	30	100	637	620	618	625	16.5	8
7	40	60	621	625	630	624	16	5.5
8	40	80	621	625	630	624	16	7
9	40	100	625	625	625	625	12	9.5

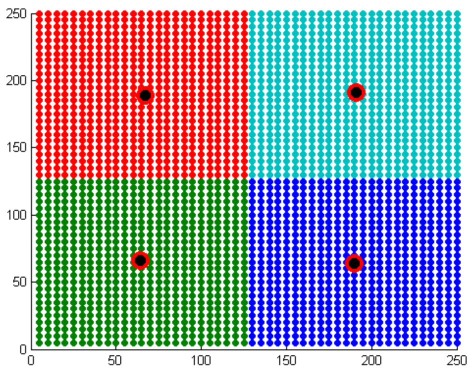


Figure 4. Optimal solution (meter)

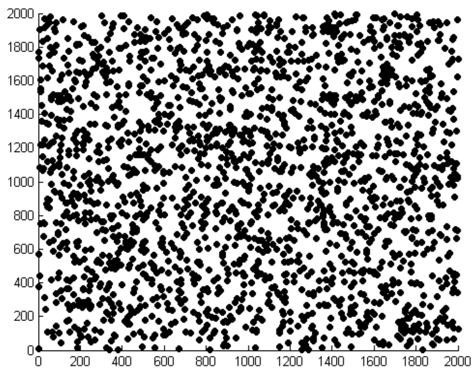


Figure 5. Sample map with 2000 parcels (meter)

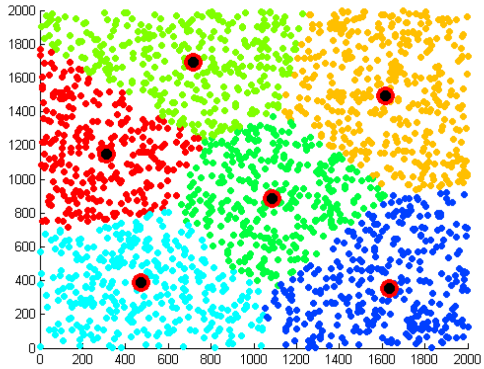


Figure 6. Location of relief centers on the map (meter)

whales and 100 movements. Figure 7 shows the results for Yazd city. In order to eliminate the mantissa, the numbers of the chart are 10000 times bigger than the real map. Figure 8 shows the process of optimization. The X axis shows the round of execution and the Y axis shows the fitness value.

4. 3. Effectiveness of Whale Creating Method

In this article a new method has been proposed in order to create effective whales at the beginning of the algorithm (section 3.2). The effectiveness of this algorithm has been analyzed in this section. For analyzing this method, map of Yazd city has been used. The best solutions, with and without whale creating method, have been compared. Three important metrics can indicate the effectiveness of the method. The first metric is convergence speed which should be shown with a chart. The second metric is average distance that shows the average distance between each parcel and its center. Finally, the third metric is standard deviation which shows that each parcel how fair could be rescued. Figure 9, demonstrates the optimization of objective function. The red line in Figure 8 shows the execution of the algorithm with random whales and blue line shows it with whales which created with proposed method. The speed of convergence and the final value in blue line in better than red line. Better solution in blue line is because of having better whales at the beginning of the algorithm. In fact, when we use the innovative whale generating method, due to having better whales at the begging of the algorithm, the final solution is slightly more optimized.

Table 4 shows the value of average distance and standard deviation for two executions. The first line shows the results for random whales and the second line shows them for whales which created by proposed method. The results show that by using whale creating method, both of metrics have more optimal values.

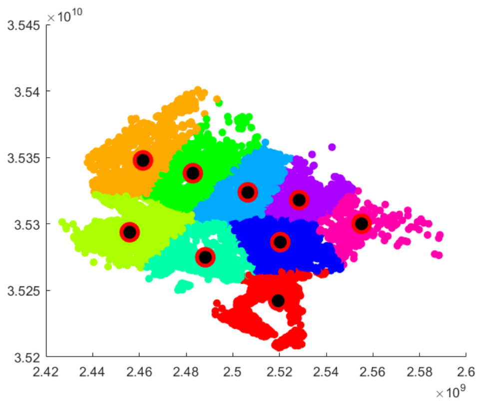


Figure 7. Location of relief centers in Yazd (meter*10000)

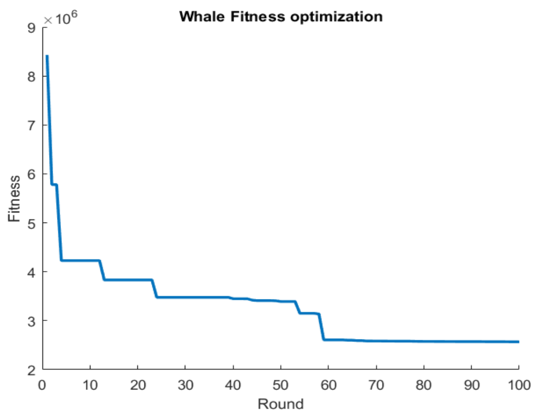


Figure 8. Optimization process for Yazd

4. 4. Stability of the Proposed Algorithm

The proposed algorithm tries to solve the problem by means of whale optimization algorithm. WOA is a kind of

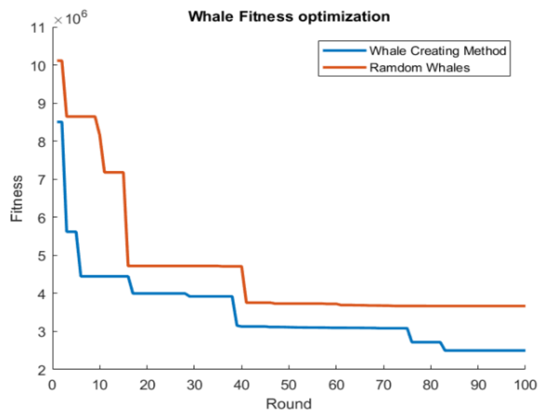
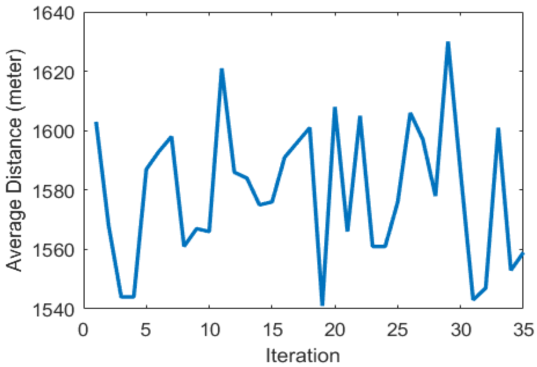


Figure 9. Effect of whale creating method

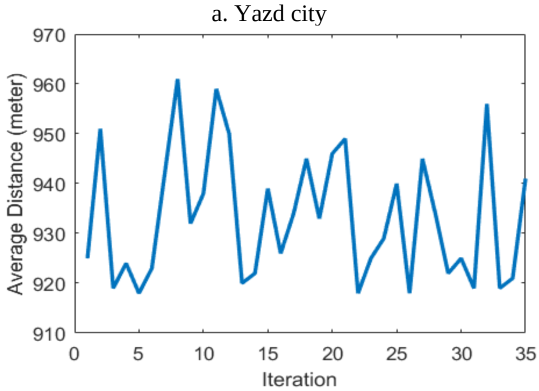
TABLE 4. Value of average distance and standard deviation for two executions

Whale creating method	Avg_dis (meter)	Standard Deviation
random	1590	155
proposed	1541	114

algorithm that solves problem heuristically. These kind of algorithms produce a different solution in each execution. Hence, the proposed method should be analyzed in terms of stability. In order to assess the stability of the algorithm it has been executed 35 times for Yazd city. The results show that the average distance is equal 1580 and the standard deviation is 20, whereas the best solution is 1541. For better assessment, the proposed algorithm has been applied to a hypothetical map as well. The results for 35 execution show that the average distance is equal 933 and the standard deviation is 13, whereas the best solution is 918. For both maps the results are satisfactory. Figure 10 shows the details of the results. Figure 10(a) is for Yazd city and Figure 10(b) is for hypothetical map.



a. Yazd city



b. Hypothetical map

Figure 10. Stability of the proposed method (by 35 executions)

5. CONCLUSION

In this paper, a new algorithm has been proposed in order to find the best locations for earthquake relief centres in Yazd city. The Whale optimization algorithm or WOA has been modified for using in this problem. Redesigning functions of WOA by means of some innovative concepts is one of the most important contributions in this article. Another contribution is introducing a new method for creating better whales at the beginning of the algorithm. By means of better whales the algorithm could be converged faster and produce better solutions. Some hypothetical maps have been used to calculate the best parameters of the algorithm. Moreover, results of the problem for Yazd city has been reported thoroughly. The best average distance for each relief centre is 1541m and the standard deviation is 114. After evaluating the stability of the algorithm it can be understood that the results of the algorithm are reliable. For future works, parameters like vulnerability of the buildings in Yazd city, Level of relief centres can be considered in designing algorithm.

6. REFERENCES

1. Bozorgi-Amiri, A., Jabalameli, M. S., Alinaghian, M., and Heydari, M., "A modified particle swarm optimization for disaster relief logistics under uncertain environment", ***The International Journal of Advanced Manufacturing Technology***, Vol. 60, Nos. 1–4, (2012), 357–371. doi:10.1007/s00170-011-3596-8
2. Beiki, H., Seyedhosseini, S. M., Ghezavati, V. R., and Seyedaliakbar, S. M., "Multi-objective optimization of multi-vehicle relief logistics considering satisfaction levels under uncertainty", ***International Journal of Engineering, Transactions B: Applications***, Vol. 33, No. 5, (2020), 814–824. doi:10.5829/IJE.2020.33.05B.13
3. Every, D., and Richardson, J., "A framework for disaster resilience education with homeless communities", ***Disaster Prevention and Management: An International Journal***, Vol. 27, No. 2, (2018), 146–158. doi:10.1108/DPM-08-2017-0196
4. Beiki, H., Seyedhosseini, S. M., Ghezavati, V. R., and Seyedaliakbar, S. M., "A location-routing model for assessment of the injured people and relief distribution under uncertainty", ***International Journal of Engineering, Transactions A: Basics***, Vol. 33, No. 7, (2020), 1274–1284. doi:10.5829/ije.2020.33.07a.14
5. Liberatore, F., Pizarro, C., de Blas, C. S., Ortuño, M. T., and Vitoriano, B., "Uncertainty in Humanitarian Logistics for Disaster Management. A Review", ***Decision Aid Models for Disaster Management and Emergencies***, (2013), 45–74 Atlantis Press, Paris. doi:10.2991/978-94-91216-74-9_3
6. Maharjan, R., and Hanaoka, S., "A multi-actor multi-objective optimization approach for locating temporary logistics hubs during disaster response", ***Journal of Humanitarian Logistics and Supply Chain Management***, Vol. 8, No. 1, (2018), 2–21. doi:10.1108/JHLSCM-08-2017-0040
7. Kaviyani-Charati, M., Souraki, F. H., and Hajiaghaei-Keshteli, M., "A Robust Optimization Methodology for Multi-objective Location-transportation Problem in Disaster Response Phase under Uncertainty", ***International Journal of Engineering, Transactions B: Applications***, Vol. 31, No. 11, (2018), 1953–1961. doi:10.5829/ije.2018.31.11b.20
8. Fazelabdolabadi, B., and Golestan, M. H., "Towards Bayesian Quantification of Permeability in Micro-scale Porous Structures – The Database of Micro Networks", ***HighTech and Innovation Journal***, Vol. 1, No. 4, (2020), 148–160. doi:10.28991/HIJ-2020-01-04-02
9. Bozorgi-Amiri, A., Jabalameli, M. S., and Mirzapour Al-e-Hashem, S. M. J., "A multi-objective robust stochastic programming model for disaster relief logistics under uncertainty", ***OR Spectrum***, Vol. 35, No. 4, (2013), 905–933. doi:10.1007/s00291-011-0268-x

10. Kılcı, F., Kara, B. Y., and Bozkaya, B., "Locating temporary shelter areas after an earthquake: A case for Turkey", ***European Journal of Operational Research***, Vol. 243, No. 1, (2015), 323–332. doi:10.1016/j.ejor.2014.11.035
11. Karimi, B., Bashiri, M., and Nikzad, E., "Multi-commodity Multimodal Splittable Logistics Hub Location Problem with Stochastic Demands", ***International Journal of Engineering, Transactions B: Applications***, Vol. 31, No. 11, (2018), 1935–1942
12. Vahdani, B., Veysmoradi, D., Noori, F., and Mansour, F., "Two-stage multi-objective location-routing-inventory model for humanitarian logistics network design under uncertainty", ***International Journal of Disaster Risk Reduction***, Vol. 27, (2018), 290–306. doi:10.1016/j.ijdrr.2017.10.015
13. Borowski, P. F., "New Technologies and Innovative Solutions in the Development Strategies of Energy Enterprises", ***HighTech and Innovation Journal***, Vol. 1, No. 2, (2020), 39–58. doi:10.28991/HIJ-2020-01-02-01
14. Das, R., "Disaster preparedness for better response: Logistics perspectives", ***International Journal of Disaster Risk Reduction***, Vol. 31, (2018), 153–159. doi:10.1016/j.ijdrr.2018.05.005
15. Sadidi, J., Fakourirad, E., and Zeaieanfirouzabadi, P., "Designing a spatial cloud computing system for disaster (earthquake) management, a case study for Tehran", ***Applied Geomatics***, Vol. 10, No. 2, (2018), 99–111. doi:10.1007/s12518-018-0203-9
16. Haji Gholam Saryazdi, A., and Poursarrajian, D., "Qualitative System Dynamics Model for Analyzing of Behavior Patterns of SMEs", ***HighTech and Innovation Journal***, Vol. 2, No. 1, (2021), 9–19. doi:10.28991/HIJ-2021-02-01-02
17. Tavana, M., Abtahi, A.-R., Di Caprio, D., Hashemi, R., and Yousefi-Zenouz, R., "An integrated location-inventory-routing humanitarian supply chain network with pre- and post-disaster management considerations", ***Socio-Economic Planning Sciences***, Vol. 64, (2018), 21–37. doi:10.1016/j.seps.2017.12.004
18. Wedawatta, G., Kulatunga, U., Amaratunga, D., and Parvez, A., "Disaster risk reduction infrastructure requirements for South-Western Bangladesh", ***Built Environment Project and Asset Management***, Vol. 6, No. 4, (2016), 379–390. doi:10.1108/BEPAM-06-2015-0022
19. Noyan, N., and Kahvecioğlu, G., "Stochastic last mile relief network design with resource reallocation", ***OR Spectrum***, Vol. 40, No. 1, (2018), 187–231. doi:10.1007/s00291-017-0498-7
20. Baylan, E. B., "A Novel Project Risk Assessment Method Development via AHP-TOPSIS Hybrid Algorithm", ***Emerging Science Journal***, Vol. 4, No. 5, (2020), 390–410. doi:10.28991/esj-2020-01239
21. Allahbakhsh, M., Arbabi, S., Galavii, M., Daniel, F., and Benatallah, B., "Crowdsourcing planar facility location allocation problems", ***Computing***, Vol. 101, No. 3, (2019), 237–261. doi:10.1007/s00607-018-0670-1
22. Mihajlović, G., and Živković, M., "Sieving Extremely Wet Earth Mass by Means of Oscillatory Transporting Platform", ***Emerging Science Journal***, Vol. 4, No. 3, (2020), 172–182. doi:10.28991/esj-2020-01221
23. Babicz, D., Tihanyi, A., Koller, M., Rekeczky, C., and Horvath, A., "Simulation of an Analogue Circuit Solving NP-Hard Optimization Problems", In 2019 IEEE International Symposium on Circuits and Systems (ISCAS), (2019), 1–5. doi:10.1109/ISCAS.2019.8702694
24. Ozturk, B., "Preliminary seismic microzonation and seismic vulnerability assessment of existing buildings at the city of nigde, turkey", In 14th World Conference on Earthquake Engineering, Beijing, China, (2008), 1–7.
25. Ozturk, B., "Application of preliminary microzonation and seismic vulnerability assessment in a city of medium seismic risk in turkey", In 5th International Conference on Earthquake Geotechnical Engineering, Santiago, Chile, (2011), 1–11.
26. Mirjalili, S., and Lewis, A., "The Whale Optimization Algorithm", ***Advances in Engineering Software***, Vol. 95, (2016), 51–67. doi:10.1016/j.advengsoft.2016.01.008
27. Mehranfar, N., Hajiaghaei-Keshteli, M., and Fathollahi-Fard, A. M., "A Novel Hybrid Whale Optimization Algorithm to Solve a Production-Distribution Network Problem Considering Carbon Emissions", ***International Journal of Engineering, Transactions C: Aspects***, Vol. 32, No. 12, (2019), 1781–1789. doi:10.5829/ije.2019.32.12c.11
28. Rahmani, D., "Designing a robust and dynamic network for the emergency blood supply chain with the risk of disruptions", ***Annals of Operations Research***, Vol. 283, Nos. 1–2, (2019), 613–641. doi:10.1007/s10479-018-2960-6
29. Salehi, F., Mahootchi, M., and Husseini, S. M. M., "Developing a robust stochastic model for designing a blood supply chain network in a crisis: a possible earthquake in Tehran", ***Annals of Operations Research***, Vol. 283, Nos. 1–2, (2019), 679–703. doi:10.1007/s10479-017-2533-0
30. Fazli-Khalaf, M., Khalilpourazari, S., and Mohammadi, M., "Mixed robust possibilistic flexible chance constraint optimization model for emergency blood supply chain network design", ***Annals of Operations Research***, Vol. 283, Nos. 1–2, (2019), 1079–1109. doi:10.1007/s10479-017-2729-3
31. Boonmee, C., Arimura, M., and Asada, T., "Facility location optimization model for emergency humanitarian logistics", ***International Journal of Disaster Risk Reduction***, Vol. 24, (2017), 485–498. doi:10.1016/j.ijdrr.2017.01.017
32. Mahootchi, M., and Golmohammadi, S., "Developing a new stochastic model considering bi-directional relations in a natural disaster: a possible earthquake in Tehran (the Capital of Islamic Republic of Iran)", ***Annals of Operations Research***, Vol. 269, Nos. 1–2, (2018), 439–473. doi:10.1007/s10479-017-2596-y
33. Sebatli, A., Cavdur, F., and Kose-Kucuk, M., "Determination of relief supplies demands and allocation of temporary disaster response facilities", ***Transportation Research Procedia***, Vol. 22, (2017), 245–254. doi:10.1016/j.trpro.2017.03.031
34. Chu, X., and Zhong, Q., "Post-earthquake allocation approach of medical rescue teams", ***Natural Hazards***, Vol. 79, No. 3, (2015), 1809–1824. doi:10.1007/s11069-015-1928-y
35. Golabi, M., Shavarani, S. M., and Izbirak, G., "An edge-based stochastic facility location problem in UAV-supported humanitarian relief logistics: a case study of Tehran earthquake", ***Natural Hazards***, Vol. 87, No. 3, (2017), 1545–1565. doi:10.1007/s11069-017-2832-4
36. Paul, J. A., and MacDonald, L., "Location and capacity allocations decisions to mitigate the impacts of unexpected disasters", ***European Journal of Operational Research***, Vol. 251, No. 1, (2016), 252–263. doi:10.1016/j.ejor.2015.10.028
37. Saeidian, B., Mesgari, M. S., and Ghodousi, M., "Evaluation and comparison of Genetic Algorithm and Bees Algorithm for location–allocation of earthquake relief centers", ***International Journal of Disaster Risk Reduction***, Vol. 15, (2016), 94–107. doi:10.1016/j.ijdrr.2016.01.002
38. Saeidian, B., Mesgari, M., Pradhan, B., and Ghodousi, M., "Optimized Location-Allocation of Earthquake Relief Centers Using PSO and ACO, Complemented by GIS, Clustering, and TOPSIS", ***ISPRS International Journal of Geo-Information***, Vol. 7, No. 292, (2018), 1–25. doi:10.3390/ijgi7080292
39. Thumronglaohapun, S., "Heuristic Methods for the Capacitated Location- Allocation Problem with Stochastic Demand", ***International Journal of Industrial and Systems Engineering***, Vol. 14, No. 6, (2020), 452–457
40. Ghasemi, P., Khalili-Damghani, K., Hafezalkotob, A., and Raissi,

S., "Uncertain multi-objective multi-commodity multi-period multi-vehicle location-allocation model for earthquake evacuation planning", ***Applied Mathematics and Computation***, Vol. 350, (2019), 105–132. doi:10.1016/j.amc.2018.12.061

41. Ghasemi, P., and Khalili-Damghani, K., "A robust simulation-optimization approach for pre-disaster multi-period location–allocation–inventory planning", ***Mathematics and Computers in Simulation***, Vol. 179, (2021), 69–95. doi:10.1016/j.matcom.2020.07.022

42. Shavarani, S. M., "Multi-level facility location-allocation problem for post-disaster humanitarian relief distribution", ***Journal of Humanitarian Logistics and Supply Chain Management***, Vol. 9, No. 1, (2019), 70–81. doi:10.1108/JHLSCM-05-2018-0036

Persian Abstract

چکیده

علیرغم اینکه دولت‌ها قوانین سختگیرانه¬ای را برای تضمین استحکام ساختمان¬ها وضع می¬کنند؛ همچنان ساختمان¬های زیادی وجود دارد که در برابر زلزله آسیب¬پذیر است. ازاین رو ایجاد مراکز امداد زلزله جهت کنترل اثرات آن بسیار ضروری است. ایران یکی از کشورهای خاورمیانه است که آسیب¬پذیری زیادی در برابر زلزله دارد. شهر یزد در مرکز ایران قرار گرفته است. از آنجایی که چنین تحقیقی برای شهر یزد وجود ندارد، این شهر در این تحقیق مورد بررسی قرار گرفته است. لایه پارسل از نقشه جی آی اس شهر یزد بعنوان ورودی مساله در نظر گرفته شده است. از آنجایی که مکان¬یابی مراکز زلزله یک مساله پیچیده بوده و در زمان چندجمله¬ای قابل حل نیست؛ از الگوریتم اکتشافی بهینه¬سازی نهنگ برای حل مساله استفاده شده است. الگوریتم بهینه¬سازی نهنگ یک روش مبتنی بر ذره است که کاربرد زیادی در حل مسائل سخت دارد. نوآوری اصلی این مقاله تنظیم توابع نهنگ برای استفاده در مساله مکان¬یابی و همچنین معرفی روش جدیدی برای ایجاد نهنگ است. جهت رسیدن سریع‌تر به جواب منطقی یک روش مبتکرانه برای تولید نهنگ طراحی شده است. بررسی نتایج الگوریتم نشان می¬دهد که میانگین فاصله هر ذره تا نزدیکترین مرکز ۱۸۵۰ متر و انحراف از معیار اجراهای مختلف نیز برابر ۲۰ است.