PRESENTATION OF A MULTI OBJECTIVE VEHICLE ROUTING MODEL FOR EMERGENCY SERVICES FACILITIES WITH META-HEURISTIC ALGORITHM SOLUTION APPROACH OF SIMULATED ANNEALING

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ABSTRACT
Today, using various instruments to reach destination and moving from the shortest and best path is a necessity. One of the scientific fields highly applied in recent decades and with high impact on improving transportation system operation is vehicles’ routing problem (VRP). In these problems, some vehicles in one or some stations should refer to a set of customers and present their service and each has definite demand. The present study attempts to design an integer planning model applied in emergency services and takes a scientific and practical step proposes the results analysis not only by a theoretical view but also by operational and executive view to be operated and implemented. The study modeling with a two-dimensional approach can optimize at least the sum of total paths and total trip time and minimizing the at most distances can be considered to create the justice-based approach to present timely services for all required sites. These problems are called NP-hard problems and its solution via linear planning and existing software is time consuming. Thus, meta-heuristic simulated annealing is used in solution.

KEYWORDS: Emergency services system, Simulated annealing algorithm, Multi-objective, Vehicle routing,

INTRODUCTION
Location–routing problems attempt to find the best location for facilities and also they attempt that by optimal relation via selecting the best paths, between the facilities present required sites with facilities. The term location-routing shouldn’t mistake us as this problem is not a well-defined unit as Travel Salesman Problem and should be defined as a set of theories and problems in location.

We prefer to think about location–routing problem as a trend for modeling and solving routing and location problems. According to Bruns (1998), location- routing can be considered as location- routing by considering tour planning aspects and they are in line with the study of Balakrishnan (1987) considering location- routing (LR) problems as the strategic decisions of facilities location. Each of these issues can be a topic of a study. Routing is composed of small issues and wide researches have been conducted annually in this regard (Montoya-Torres et al, 2015). Figure 1 depicts this variety and correlation between sub-problems as simply. We can easily find that vehicle routing problem is based on various factors and each considers various conditions. Each of them has specific objective function, possible space and mathematical model.

Thus, vehicle routing problem is one of the most important problems in the global industries and it has received much attention due to real applications in industrial issues. In this problem, some vehicles at the same time move from warehouse or parking and after visiting demand nodes as customers return to parking, on condition that first, each demand node is visited only by one of these vehicles and second, each vehicle doesn’t load more than its capacity in the route. Correct application of this problem saves about 5 to 20% of total transportation costs. One of the main applications of this problem is waste collection, food and drugs distribution, routing school and employees’ vehicle, post box distribution, ships scheduling, newspaper distribution, robots movement in factory (Musolino et al., 2013).

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Various objectives have been considered for this problem and some of them include:

- Minimization of taken route by all vehicles
- Minimization of total number of vehicles
- Minimization of function of delay or early time of service providing of vehicles to customers

Vehicle routing problem has some different limitations. Some of the limitations include: Number of service providing centers, limited or non-limited vehicles capacity, definite or probable demands, the existence or lack of limitation for route. Vehicle routing problem is one of the famous issues of integer problem included in NP-Hard problems (Montoya-Torres et al., 2015). The complexity of this problem is regarding two following problems:

a. Travel Salesman Problem
   If vehicle capacity is unlimited, vehicle routing problem is turned into multi Travel Salesman Problem (MTSP) (Balakrishnan, 1987).

b. Bin Packing Problem
   The question that is there one solution to VRP is bin packing problem.
   Based on the goals and restrictions for VRP and considering some factors as required time and costs to achieve solution and good accuracy, there are various methods to achieve routing problem solution of vehicles. These methods are divided into exact, heuristic and Meta heuristic methods. Exact methods have been applied in 1960 and 1970 to solve vehicle routing problem including dynamic planning, turning vehicle routing problem to Travel Salesman Problem and two-index formulating. Turning vehicle routing problem to Travel Salesman Problem is another method as by adding some nodes and edges, can be changed into another network and the network is as Travel Salesman Problem and we can determine the required routes and required vehicles by solving travel salesman problem (Burns, 1998). Also, an example of dynamic planning application in vehicle routing problem is presented by Eilon for m vehicles with definite capacity. By turning vehicle routing problem to m Travel Salesman Problem, the optimum solution is calculated (Burns, 1998). There is a third method and it is formulation based on 3-index variables. This formulation is presented by Fisher and Jcomar. The formulation covers the general allocation problem and Travel Salesman Problem with time constraints. This method at first solves a second degree main allocation problem to assign the points to vehicles and then the best route for each vehicle is achieved by solving a Travel Salesman Problem (Burns, 1998; Balakrishnan, 1987; Maranzana 1964).
Vehicle routing problem and Travel Salesman Problem are Np-hard or Np-complete problems (Rand, 1976). By increasing the dimensions and problem size, the calculation volume of recognized methods for their optimum solution has exponential growth and optimal solution of real problems with big size is impossible and we should use heuristic and meta heuristic methods to calculate the acceptable and optimal solution. Various Meta heuristic algorithms are used in vehicle routing problem as genetic algorithm. This algorithm in VRP solution is evaluated by many researchers including Perira, Tavares, Machada and Kasta (Montoya-Torres et al, 2015).

In these studies, genetic algorithm application is evaluated in capacitated vehicle routing problem (CVRP) and vehicle routing problem with time windows (VRPTW). The calculation results show high efficiency of this method (Laporte, 1988; Laporte, 1989; Laporte et al., 1989). An example of the efforts to use tabu search algorithm and ant colony optimization system is shown in Reference 10, 11. These problems are widely applied and are important in scientific researches. Table 1 shows a summary of applied fields collected in the past studies and their details are also defined.

<table>
<thead>
<tr>
<th>Customers</th>
<th>Facilities</th>
<th>State/region</th>
<th>Applications</th>
<th>Authors and publication year</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>40</td>
<td>United Kingdom</td>
<td>Food and soft drink distribution</td>
<td>Watson-Gandy Dohn (1973)</td>
</tr>
<tr>
<td>50</td>
<td>3</td>
<td>Australia</td>
<td>Customers commodity distribution</td>
<td>Bednar and Strohmeier (1973)</td>
</tr>
<tr>
<td>117</td>
<td>3</td>
<td>US</td>
<td>Blood bank distribution</td>
<td>Or and Pierscalla (1973)</td>
</tr>
<tr>
<td>4510</td>
<td>42</td>
<td>Denmark</td>
<td>Newspaper distribution</td>
<td>Jacobsen and Madsen (1980)</td>
</tr>
<tr>
<td>300</td>
<td>15</td>
<td>Malaysia</td>
<td>Location-routing of rubber device</td>
<td>Nambiar et al., (1981)</td>
</tr>
<tr>
<td>318</td>
<td>4</td>
<td>US</td>
<td>Commodity distribution</td>
<td>Perl and Daskin (1984, 1985)</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>Belgium</td>
<td>Location-routing of post boxes</td>
<td>Labbe and Laporte (1986)</td>
</tr>
<tr>
<td>47</td>
<td>10</td>
<td>Malaysia</td>
<td>Location-routing of rubber device</td>
<td>Nambiar et al., (1989)</td>
</tr>
<tr>
<td>90</td>
<td>9</td>
<td>Switzerland</td>
<td>Beans distribution</td>
<td>Semet and Taillard (1993)</td>
</tr>
<tr>
<td>331</td>
<td>29</td>
<td>US</td>
<td>Location-routing of military equipment</td>
<td>Murty and Djang (1999)</td>
</tr>
<tr>
<td>3200</td>
<td>200</td>
<td>Switzerland</td>
<td>Package delivery</td>
<td>Bruns et al., (2000)</td>
</tr>
<tr>
<td>52</td>
<td>9</td>
<td>US</td>
<td>Drugs delivery</td>
<td>Chan et al., (2001)</td>
</tr>
<tr>
<td>27</td>
<td>4</td>
<td>Hong Kong</td>
<td>Bill delivery</td>
<td>Lin et al., (2002)</td>
</tr>
<tr>
<td>50</td>
<td>50</td>
<td>Korea</td>
<td>Fiber networks design</td>
<td>Lee et al., (2003)</td>
</tr>
<tr>
<td>2042</td>
<td>10</td>
<td>Australia</td>
<td>Package delivery</td>
<td>Wasner and Zapfel (2004)</td>
</tr>
<tr>
<td>70</td>
<td>6</td>
<td>France</td>
<td>Communication networks design</td>
<td>Billimmet et al., (2005)</td>
</tr>
<tr>
<td>300</td>
<td>24</td>
<td>Europe</td>
<td>Transportation industry</td>
<td>Gunnarsson et al.,</td>
</tr>
<tr>
<td>750</td>
<td>22</td>
<td>Poland</td>
<td>Package delivery</td>
<td>Lischak and Triesch</td>
</tr>
</tbody>
</table>

Based on the investigations in review of literature, we found important researches have been conducted but considering vehicle routing of emergency services as emergency, fire fight, Red Crescent and etc. is of great importance during earthquake, flood, war and terroristic operations. We considered a model based on these conditions by considering limited capacity for facilities and solved it by simulated annealing Meta-heuristic algorithm as highly applied for routing problems in big dimensions. Thus, our share in improvement of this scientific field is summarized in three sections, at first presenting a capacitated integer programming model considering two goals at the same time and both of them have specific importance in crisis management. The first goal is minimizing total travelled distance as playing important role in facilitating service providing under critical times in which even seconds are of great importance. The second goal is for fair distribution of services in a definite distance and it is minimizing the maximum existing distance, second consistency and problem design as necessary for movement system of vehicles and final case is problem solution approach by simulated annealing meta-heuristic algorithm.

The present study is organized as follows, section 2 deals with the multi-objective model of integer programming of design problem and all its components. Based on multi-objective model, multi-criteria integration method is introduced
in section 3. Section 4 introduces the meta-heuristic solution approach. Section 5 applies data of Tehran town and analyzes the sensitivity and purposeful analysis of problem. Section 6 is about future recommendations and conclusion.

Integer programming model of routing capacitated facilities of emergency services

Before designing the model, the problem variables and parameters should be explained. The problem parameters can be explained as:

\( V \): Set of available vehicles
\( N \): Number of customers
\( C_i \): Capacity of \( v \)th vehicle as \( v \in V \)
\( D_{ij} \): Capacity of \( i \)th site as \( i \in N \) with \( j \)th site as \( j \in N \)

Problem variables include:

\( X_{ij}^v \): It is 1 if the \( v \)th vehicle as \( v \in V \) passes the route between \( i \)th location as \( i \in N \) and location \( j \)th as \( j \in N \), otherwise it is zero.

\( Y_i^v \): It is equal to 1, if \( i \)th location as \( i \in N \) is the first location as in movement route of \( v \)th vehicle as \( v \in V \), otherwise it is zero. Based on the mentioned items, we can define integer programming model of capacitated vehicle routing problem of emergency services.

Objective functions

Formula 1 attempts to minimize the total route and this leads to minimization of total travelled routes. The second section attempts that the initial demand site of route is located in the shortest distance from depot. Formula 2 attempts to identify the facility travelling highest distance and minimizes it. In other words, it presents justice based structure to reduce the time average of services and minimax approach is applied.

\[
Z_1 = \text{Min} \{ \sum_{v \in V} \sum_{i \in N} \sum_{j \in N} D_{ij} X_{ij}^v + \sum_{v \in V} \sum_{i \in N} D_{DCC} Y_i^v \} 
\]

\[
Z_2 = \text{Min} \{ \text{Max} \{ \sum_{i \in N} \sum_{j \in N} D_{ij} X_{ij}^v \} \} 
\]

\[
\sum_{v \in V} \sum_{i \in N} X_{ij}^v = 1 \quad \forall i \in N \tag{3}
\]

\[
\sum_{v \in V} \sum_{j \in N} X_{ij}^v = 1 \quad \forall j \in N \tag{4}
\]

\[
\sum_{i \in N} \sum_{j \in N} D_{ij} X_{ij}^v \leq C_i \quad \forall v \in V \tag{5}
\]

\[
\sum_{i \in N} X_{ik}^v - \sum_{j \in N} X_{kj}^v = 0 \quad \forall k \in N, v \in V \tag{6}
\]

\[
\sum_{j \in N} X_{ij}^v = 0 \quad \forall v \in V \tag{7}
\]

\[
\sum_{i \in N} X_{ij}^v = 0 \quad \forall v \in V \tag{8}
\]

\[
X_{ij}^v \in \{0,1\} \quad \forall i \in N, j \in N, v \in V \tag{9}
\]

\[
Y_i^v \in \{0,1\} \quad \forall i \in N, v \in V \tag{10}
\]
services exceeding its capacity. In other words, the sum of demand of customers allocated to a vehicle should be at most equal to vehicle capacity. Equations 6, 7, 8 are network balance constraints guaranteeing that the routes are continuous. These equations show the balance of entrance and exit of vehicles. In other words, the number of cards entering each node should be equal to the number of cards exiting them. Constraints 9, 10 are empowerment constraints of integer programming problem.

Multi-criteria decision making method integrating objects
As it is introduced in the previous section of model, the problem is designed by two objectives. It is required to integrate these objectives with an approach of multi-criteria decisions. Thus, we can select simple additive weighting (saw) by which we can integrate objective functions easily.

Implementation stages of SAW
The following stages should be applied in this method:
First step: Normalization of decision making by linear transformation and the calculation method of value creation and costly criteria is as equations 11, 12. Table 4-28 shows normalization.

\[ X_{ij} = \frac{X_{ij}}{Max\{X_{ij}\}} \] (11)

\[ X_{ij} = \frac{X_{ij}}{Min\{X_{ij}\}} \] (12)

Second step: The calculation of scores by using defined weights of experts for his objective and for second objective and Formulation No. 13 and their descending order and finally final weights can be determined.

\[ W_j = \sum_{j=1}^{\lambda_2} w_j \cdot y_j \] (13)

In SAW method, the calculated utilities of normalized matrix are added together and as they are of utility nature, their adding is not problematic. Based on using this method, first objective weight is \( \lambda_1 = 68\% \) and second objective \( \lambda_2 = 32\% \).

Thus, final objective function of problem is calculated based on equation 14.

\[ Z_f = \lambda_1 (Min\{\sum_{v \in V} \sum_{j \in N} DCC_{ij} X_{ij} + \sum_{v \in V} \sum_{j \in N} DDC_{ij} Y_{ij}\}) + \lambda_2 (Min\{Max\{\sum_{v \in V} \sum_{j \in N} DCC_{ij} X_{ij}\}\}) \] (14)

Simulated Annealing metahuristic algorithm of problem
Simulated annealing algorithm is used to solve this problem in case of giving services to injures or survival of people. Simulated Annealing (SA) is a simple and effective metahuristic optimization algorithm in optimization problems solution. Kirkpatrick and Cerny et al. in 1983 and 1985 proposed simulated annealing algorithm (Kirkpatrick, 1983; and Cerny, 1985). Kirkpatrick et al., were statistical physic experts. They proposed annealing technique to solve optimization hard problems. Annealing technique is proposed by metallogists to achieve the phase in which solid is ordered well and its energy is minimized. This technique includes putting the material at high temperature and then gradual reduction of temperature. Figure 2 indicates the stages of this algorithm as in some phases.
General structure of simulated annealing algorithm

To solve an optimization problem, simulated annealing algorithm starts with an initial solution and then moves to neighbors’ solutions in a repetition loop. If the neighbor solution is better than current solution, its algorithm is used as current solution (moves toward it), otherwise, algorithm of the solution is accepted as current solution with probability \( \exp(-\Delta E/T) \). In this equation, \( \Delta E \) is the difference between objective function of current solution and neighbors’ solution and \( T \) is a temperature parameter. Some repetitions are performed in each temperature and then the temperature is reduced gradually. In the initial steps, the temperature is very high to have more probabilities to accept worst solutions. By gradual temperature reduction, in final steps, it is less probable to accept worst solutions and the algorithm is converged to a good solution. SA algorithm is a non-constraint algorithm applied for hard designs (Yaghini, Akhavan Kazemzade, 2014).

Repetition in inside loop of algorithm

In each phase, simulated annealing algorithm considers some states in neighborhood of current state \( S \) and decides to transfer the system from state \( s \) or not. These probabilities approach the system to the state with less energy.

Neighbors of a solution

Neighbors of a solution are new states of problem created by changing the present state and a pre-defined method. For example, in Travel Salesman Problem, each state is a specific permutation of the cities being visited. The neighbors of a solution are permutations created by selecting a pair of neighbor cities of total permutations and moving the two cities. The change of current solution and going to neighbor solutions is called “movement” and different “movements” achieve various neighbors.

![Simulated annealing algorithm flowchart](image)
Stages of standard SA algorithm
0-Start and preparation: Entering the information of problem and regulating algorithm parameters (initial temperature, cooling rate, the stopping of initial and justified random answer and etc ).
1-Formation of a solution in neighborhood of current solution
2-Evaluation of neighborhood solution
2-1 Neighbor is better than current solution: moving to new solution
2-2Probability function is bigger than uniform random value: Moving to new solution, otherwise returning to step 1
3-Updating algorithm and problem parameters
4-We keep the best solution as it is not always the best and moving to step 1

Cooling function
Algorithm convergence speed is dependent upon cooling function and temperature reduction is as the temperature value (based on repetitions) in each repetition is reduced according to cooling function. Determining cooling rate function depends upon the problem structure and various functions are proposed for it. Very big cooling rate leads to early convergence and stopping in local optimum. Small cooling rate increases calculation time. Optimal rate and initial temperature are most important algorithm parameters. The temperature reduction in SA is very important. To reduce temperature, the current temperature is multiplied by a coefficient. α value is ranging 0, 1. In SA algorithm, the temperature is reduced slowly, and α value should be close to 1. Rapid temperature reduction causes that we stop in local minimum. In brief, searching method “simulated annealing” is a neighborhood searcher as applied widely in discrete problems optimization. Decision making of this algorithm is as in each movement, a new neighborhood is generated and evaluated randomly. The movement to this solution is done in each of two following stages:
1) New solution is better than current solution, 2) movement probability function [i] is bigger than random value of [0, 1] interval. Otherwise, the searcher generates and evaluates new answer. This gradual movement continues to satisfaction of algorithm stopping condition (number of repetitions, calculation time and etc). Movement probability function value is calculated in each time of equation. In this relation, difference of objective function is between current and new solution.

Proposed solution method
It is vehicle routing problem as it was said before its solution is in big dimensions Np-Hard and these problems need heuristic approaches. Our solution approach is simulated annealing being applied based on Monte Carlo model to study the relationship between atomic structure, entropy and temperature during cooling process of a matter. Physical process of cooling with the aim of reducing matter temperature to the lowest energy level is called thermal equilibrium. Cooling process starts with a matter in molten condition and then its temperature is reduced gradually. At any temperature, the matter can achieve thermal equilibrium. The temperature shouldn’t be reduced rapidly, namely in initial stages, otherwise some problems are in the matter and the matter doesn’t achieve minimum energy condition.

Temperature reduction is similar to reduction of objective function (in minimizing problems) as considered by a set of improving changes. To let the temperature reduce gradually, non-improvement changes of objective function should be selected by definite probability and when objective value is reduced, this probability is reduced. This causes that algorithm is not arrested in local improvement. Thus, in optimization issues, temperature acts as a control parameter. (A recommendation in Figure 3 is shown by introduction of basic algorithm steps. Before mentioning algorithm steps, problem input parameter algorithm is defined as:
Markov chain length is considered as the number of accepted answers in each temperature or criterion of exiting interior loop (LeAlgorithm), maximum temperature transfer is algorithm stopping criterion or criterion of exiting exterior loop (ɤ).
T=Initial temperature
α = Temperature reduction coefficient
X = Feasible solution
C(X) = X Objective function for solution
N = Counting the number of accepted solution in each temperature
r = Counting the number of temperature transfers
\[ r = 0, T = T_0, X_{\text{best}} = \emptyset \]
Generate \( X_0 \)
\( X_{\text{best}} = X_0 \)
Do (Out Side loop)
\( n = 0 \)
Do (In Side loop)
Select an Operator (1-Opt or 2-Opt) randomly and run over \( X_n \) as: Operator \( X_n \rightarrow X_{\text{new}} \)
\[ \Delta C = C(X_{\text{new}}) - C(X_{\text{best}}) \]
If \( \Delta C < 0 \) Then
\( X_{\text{best}} = X_{\text{new}} \) and \( n = n + 1 \) and \( X_n = X_{\text{new}} \)
Else
Generate \( y \rightarrow U(0,1) \) Randomly
\[ z = e^{-\frac{\Delta C}{r}} \]
Set \( y < z \) Then \( n = n + 1 \) and \( X_n = X_{\text{new}} \)
End if
Loop While (\( n < \text{LeAlgorithm} \))
\[ r = r + 1 \]
\[ T_r = T_{r-1} - \alpha \times T_{r-1} \]
Loop While (\( r < \gamma \) and \( T_r > 0 \))
Print \( X_{\text{best}} \)

**RESULTS**

In this section, it is attempted to have applied view of model analysis for emergency services. Thus, 22 districts of Tehran city are considered as demand centers and depot location is Azadi square, North West of district 10 and north east of district 9 and the reason is open space and operation of its underground space. As we assumed the problem is solved for 2, 3, 5 and 8 vehicles. Districts demand is integer random value ranging 50 to 100 and the distance between districts and districts to depot is estimated by map and website of Google. We considered vehicle capacity integer random values ranging 400 to 1000 units. Our main problem in using data is non-availability to them. Thus, we use simulation approach. Figure 4 shows districts in Tehran city in map.

**Figure 4-** Tehran map based on its separation as 22 districts

By considering the designed items in model and program development is solved by SA method and for each defined vehicle in problem, travelled route and demand locations allocated are defined and all relevant costs as trip costs, fleet costs and early and delay penalties are calculated. Also, service start time for each node and total trip time for each vehicle can be defined. Also, to prove solution method performance based on the presented model, its solution can be
made by algorithm in another section applied of random data. Demand location number are 40, 80 and the number of available vehicles is 8, 16. The districts demand is integer random value 50 to 100. The distance of district is integer random value ranging 10 to 200. The distance of districts to deport is estimated as integer random value ranging 5 to 100. The vehicle capacity is integer random value ranging 400 to 1000 units. In order to prevent non-justification by solution algorithm, a penalty value 100 units is considered and its value is added to objective function. The number of repetitions is considered as 200 units. Table 2 shows the problem output information based on the number of demand nodes, number of available vehicles in the form of total route traveled output, maximum travelled route, solution violation, solution time and integrated objective function of model. Also, Table 3 for each of three states 2, 3, 5 facilities of Tehran city data, a report is stated in the form of the fact that which vehicle passes which cities.

Figures 5, 6, 7 of convergence charts of solution are based on the number of repetitions for Tehran city. Also, Figures 8, 9, 10 of solution convergence are based on the number of repetitions for 40-node sample and figures 11, 12 and 13 depicted the solution convergence charts based on the number of repetitions for 80-node sample and all of them indicated the proposed algorithm considered true trend in improvement of solution.

Table 2- The results of model output for three samples with the volume of 22, 40 and 80 data

<table>
<thead>
<tr>
<th>Solution time (s)</th>
<th>Objective function value</th>
<th>Penalty</th>
<th>Maximum travelled route</th>
<th>Total travelled route</th>
<th>Number of vehicle facilities</th>
<th>The number of demand nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>11.7057</td>
<td>74712.76</td>
<td>741</td>
<td>370</td>
<td>727</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>11.9917</td>
<td>695.84</td>
<td>0</td>
<td>381</td>
<td>844</td>
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<td>3</td>
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<tr>
<td>12.4967</td>
<td>800.6</td>
<td>0</td>
<td>515</td>
<td>935</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>13.4876</td>
<td>808.92</td>
<td>0</td>
<td>371</td>
<td>1015</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>12.8145</td>
<td>24235.68</td>
<td>228</td>
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<td>1876</td>
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<tr>
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<td>1869</td>
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<tr>
<td>16.4626</td>
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<td>0</td>
<td>376</td>
<td>3810</td>
<td>16</td>
<td>16</td>
</tr>
</tbody>
</table>

Figure 5-Converagence chart of Tehran city solution with 2 facilities
Figure 6-Converagence chart of Tehran city solution with 5 facilities
Figure 7-Converagence chart of Tehran city solution with 8 facilities
However, for better report of service providing system performance in Tehran city, model output is depicted as graphic and the results of routes output for this sample in states 2, 5 facilities are observed in figures 14, 15, respectively.

Figure 14- The map of output routes of model for Tehran city with 2 facilities
As shown in the maps in Figure 14, 15, using more than 3 facilities for Tehran city have the required adequacy with these conditions and there is no need to increasing facilities. The important point in two images of similar paths in the east is green and the route extended from southeast to southwest as introducing a definite model.

CONCLUSION AND SUMMARY
The present study presents a three-index model for vehicle routing problem in emergency services and can consider facilities capacity and continuity of model route as unique and based on its applied view, it can be implemented in Tehran metropolis. Also, simulated annealing meta heuristic solution is presented for the problem and it is a big aid for problem solution in big sizes. To test the validity of meta heuristic solution method at big dimensions, two random data samples with 40, 80 nodes are simulated and the valuable results are presented. We can develop present study and it is comparison of the other solution methods with the present study to separate the most efficient method for the set of these problems.

REFERENCES