A case study of heterogeneous fleet vehicle routing problem: Touristic distribution application in Alanya

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\textbf{Abstract.} In this study, Fleet Size and Mix Vehicle Routing Problem is considered in order to optimize the distribution of the tourists who have traveled between the airport and the hotels in the shortest distance by using the minimum cost. The initial solution space for the related methods are formed as a combination of Savings algorithm, Sweep algorithm and random permutation alignment. Then, two well-known solution methods named as Standard Genetic Algorithms and random search algorithms are used for changing the initial solutions. Computational power of the machine and heuristic algorithms are used instead of human experience and human intuition in order to solve the distribution problem of tourists coming to hotels in Alanya region from Antalya airport. For this case study, daily data of tourist distributions performed by an agency operating in Alanya region are considered. These distributions are then modeled as Vehicle Routing Problem to calculate the solutions for various applications. From the comparisons with the decision of a human expert, it is seen that the proposed methods produce better solutions with respect to human experience and insight. Random search method produces a solution more favorable in terms of time. As a conclusion, it is seen that, owing to the distribution plans offered by the obtained solutions, the agencies may reduce the costs by achieving savings up to 35%.

\textbf{Keywords} Tourism; tourist distribution; vehicle routing problem; fleet size and mix vehicle routing problem; heuristic algorithms.

\textbf{AMS Classification:} 90-08, 90B06, 90C27, 68W25.

\section{Introduction}

Transportation and logistics are in the center of interest of modern economies [1]. It is seen that the range between 11\% and 13\% of total production cost is constituted by transportation costs [1]. For instance, it is estimated that 15\% of the total expenditures are constituted by transportation expenditures in Canada and England [1]. The results of a research conducted in Europe show that among the cost items of the enterprises in terms of international trade, the amount of transfer, warehousing, stocking and administrative costs are 40\%, 26\%, 18\% and 16\%, respectively. The same study displays that more income in the amount of 30 billion dollars can be obtained by reducing the costs 10\% by efficiently using logistics and Supply Chain.
Management (SCM) in the food sector [2]. Another study shows that the typical working acquisition of integrated supply chain brings the 16%-18% increase in the distribution performance, 25%-60% decrease in stocking amounts, 30%-50% improvement in the cycle time, 25%-80% certainty in predictions and 10%-16% productivity raise in the facilities of enterprises [21].

Tourism is the most important service industry in which human transportation is a very sensitive subject in terms of countries’ economies. Important tourism centers such as Antalya and Alanya which desire to be a powerful brand as a tourism destination should give special importance to transportation facilities. Comfortable choices regarding air, sea, land and railway transportations should be presented to the tourists’ choices with the most reasonable prices [3]. Transportation has been rather important in tourism sector when its contributions to countries’ economies are considered. Savings in the transportation area can be obtained by qualitative and quantitative decision approaches. With these savings, service quality, efficiency, productivity and profitability can be increased and thus costs can be decreased. In addition to all these, improvements regarding environmental, ecological and historical assets will increase customer satisfaction and make a contribution to sustainable tourism.

In this study, Fleet Size and Mix Vehicle Routing Problem is considered in order to optimize the distribution of the tourists who have traveled between the airport and the hotels in the shortest distance by using the minimum cost. For this aim, two well-known solution methods named as Standard Genetic Algorithms and Random Search Algorithms are used. The initial solution space for the related methods are formed as a combination of Savings algorithm, Sweep algorithm and random permutation alignment. For the seeding, Savings and Sweep Algorithms are used to provide a single solution alternative for each vehicle type if the capacity of any vehicle is not exceeded for the demands of the customers. And for the routing, vehicle type with minimum cost of empty space is chosen. In the last section, real life applications of heterogeneous fleet VRP for Alanya destination are demonstrated.

2. Background

One of the most important variations of Vehicle Routing Problem (VRP) is the problem of determining fleet of vehicles characterized by various capacities and costs which can be used in various delivery activities. This special problem is known as Mixed VRP or Heterogeneous Fleet VRP [4]. The problem of Fleet Size and Mix VRP (FSMVRP) is a kind of VRP and may be defined as routing of a fleet of heterogeneous vehicles in order to make a service to a group of customers whose distribution requirements are known as and establishing a fleet composed of these vehicles [5]. VRP with heterogeneous fleet is a variation of classical VRP [6]. The fleet of heterogeneous vehicles has vehicles with different capacities, fixed costs for the vehicles and variable costs and that fleet serves to the customers with the given features [7] [8] [9]. Since, VRP with heterogeneous fleet is a generalized version of classical VRP, it is also known to be an NP-hard problem. The aim is to form a cluster of routes by minimizing the total value of the costs [10].

VRP is classified into two groups when the features such as the capacities of vehicles and their fixed and variable costs are considered. If all the vehicles have the same capacity, and the same fixed and variable cost values, this problem is called as Homogeneous VRP. Otherwise, if one or more features are different for the vehicles, this kind of problem is known as Heterogeneous VRP. Three models of Heterogeneous VRP are studied in the literature. The first one is based on the idea that variable cost is equal for all the vehicles and there is infinite number of ready to use vehicles of each type. This model is called Vehicle Fleet Mix (VFM), Fleet Size and Mix VRP or Fleet Size and Composition VRP. The second model takes into consideration the variable cost which differs depending on the vehicle type that is ignored within the first model. The third model is called VRP with a Heterogeneous Fleet of Vehicles or Heterogeneous Fixed Fleet VRP (HFFVRP). For instance, a visual interactive decision support system for the HFFVRP with and without backhauls is presented in the literature [11]. HFFVRP eliminates the assumption of unlimited number of vehicles regarding the second model and solves the same problem with a limited number of vehicles [8] [9] [4] [12].

However, heuristic methods are generally used as the solution of the problem regarding the heterogeneous fleet vehicles is not possible with exact methods. There are many studies in which heuristic methods are applied intensely in the literature [13] [8].
3. Application

3.1. Model formulation

Suppose that $G=(V, A)$ directed graph is provided, here $V = \{0, 1, 2, ..., n\}$ are $n+1$ vertices, $A$ is a set of arcs, $n=0$ shows the depot and the other $n$ vertices out of the depot equals the cluster $V' = V - \{0\}$ representing the customers. Each customer requires $q_i$ unit assets from $i \in V'$ depot (it is assumed that the requirement of the depot is $q_0 = 0$). The heterogeneous fleet of the vehicles is positioned in the depot and cares the claims of the customers. The vehicle fleet includes $k$ types of vehicles and the set of vehicles is shown as $\psi = \{1, 2, ..., k\}$. Each vehicle type of $k \in \psi$, $m_k$ vehicles are ready to use in the depot and each has the equal capacity of $Q_k$. Each type of vehicle is associated to a fixed cost of $f_k$ and this is defined with the cost of amortization or rent for this model. In addition, each model has the arc of $arc(i, j) \in A$ and each vehicle type has the cost of $c^k_{ij}$ routing which is not negative $k \in \psi$.

A route is defined as the couple $(R, k)$ and here while $R$ is defined as $R = \{i_1, i_2, ..., i_{|p|}\}$, $i_1 = i_{|p|} = 0$ and $\{i_2, i_3, ..., i_{|p|+1}\} \subseteq V'$, a simple $G$ cycle includes the depot and $k$ is the type of the vehicle which is assigned to the route. $R$ represents the visit path in a route and the set of the customers (including the depot). If the total demands of the visited customers on the route does not exceed the $Q_k$ capacity of vehicles (namely, if the constraint $\sum_{k=2}^{|p|+1} q_k \leq Q_k$ is provided), $(R, k)$ route is a feasible solution. The cost of the route is calculated adding the fixed cost of the assigned vehicle to the route to total cost of arc shaping the route and determined with the formula of:

$$TCL_p = \sum_{i=1}^{|p|+1} c^k_{i_{i+1}} + f_k$$

(1)

where $TCL_p$ is the total cost for $p^{th}$ route found by adding the fixed cost of the assigned vehicle to the total cost of arcs shaping the route. And the total cost function is expressed as the total cost of the route as follows:

$$\text{TotCost} = \sum TCL_p$$

(2)

The above equation is used to minimize both the distance of each route and total cost. The most common model of Heterogeneous VRP includes designing the suitable routes’ arc with the minimum total cost, namely:

- Each customer is certainly visited by a single vehicle;
- The number of the routes formed by the vehicle type which is signified by $k \in \psi$ cannot be more than $m_k$.

Two models of the problem have an increasing importance naturally: The first one is symmetrical and the costs for each couple of $i, j$ customers are symmetrical as $c_{ij} = c_{ji}$ and for each vehicle type $k \in \psi$ is provided. The other model is the asymmetrical one. In addition, there are many variations of these general problems in literature in terms of interested cost type and applicable fleets. Especially, as a result of changing the features of the problem stated below, new VRP variations are formed. These features are the vehicle fleets including each vehicle type is infinite, that is to say $m_k = +\infty$, $\forall k \in \psi$; the fixed costs of the vehicles are not taken into consideration, namely $f_k = 0$, $\forall k \in \psi$; the routing costs are vehicle independent, namely $c_{ij} = c_{ji}$, $\forall k_1, k_2 \in \psi$, $k_1 \neq k_2$, and $\forall (i, j) \in A$.

Constructing the routes is another problem regarding the problems of Fleet Size and Mixed VRP (FSMFV). The routing structure is explained by a suggestion of Ochi et al. [14] about the route construction [14].

The following strategy has been suggested for the heterogeneous Fleet VRP. $\psi = \{1, 2, ..., k\}$ is the set of vehicle types. Under the circumstances of $Q_1 \leq Q_2 \leq ... \leq Q_k$ and $f_1 \leq f_2 \leq ... \leq f_k$, the capacity of $t_i$ type vehicle is $Q_i$ and $f_i$ is the fixed cost of the related vehicle. Each petal is structured as follows. Algorithm analyses the possibilities of the vehicles formed by $k$ type of the vehicles and chooses $t_i$ vehicle type which shows the minimum value for $(Q_i - D_{if})f_i$ and here $D_{if}$ defines the total demand of petal which is formed by using vehicle $t_i$. Obviously, the size of each petal will change depending on the assigned vehicle type. In the studies still being conducted by Ochi et al. [14], the logic of
choosing routes \((Q_i-D_i) f_i\) has been employed for heterogeneous fleet types \([15]\) \([16]\).

Moreover, while Ochi et al. \([14]\) use Petal Algorithm in order to form the solution space, Liu et al use Sweep Algorithm in order to form some parts of the solution space. In addition, they form the other part by using Savings Algorithm and the third part is formed in a random permutation way. Savings and Sweep Algorithms can provide solutions for a single vehicle type; thus, possible solution sets are formed by employing Sweep and Savings algorithms for each vehicle type of heterogeneous vehicle sets. Savings and Sweep Algorithms provide a single solution alternative for each vehicle type if the capacity of any vehicle is not exceeded for the demands of the customers. For this reason, if the number of the vehicle type is \(k\), both Savings and Sweep Algorithms provide set of solutions between 1 and \(k\). After the initial search space is formed as Liu et al. \([16]\), different solutions are obtained by using standard GA approach and random search.

3.2. The definition of the problem

Figure 1. A geographical distribution of some Alanya hotels. Source: \([17]\)

The 30\% of tourists visiting Turkey prefer Antalya region. Around 24\% of these tourists who prefer Antalya visit Alanya. The map above shows an example of geographical distribution for some of the hotels in Alanya. According to the statistics of 2011, the number of the foreign tourists who visited Alanya region is 2 million 500 thousand \([18]\). The tourists planning to visit this region are determined one year before their arrivals by the sales of the major tour operators in Europe that work with local agencies. These agencies give various logistic services to some of these tour operators such as seasonal renting of hotel rooms, transportation between airports and hotels and also the other required services. When the agencies in Alanya are analyzed, it has been determined that they have been using various computer programs having similar features in order to carry out these services. These programs have been effectively used by the agencies while meeting the needs of the enterprises, producing and controlling services. Moreover, these programs can carry out the services such as receiving and sending some data from the databases of the tour operators in Europe. However, when these task periods are analyzed, it has been seen that these programs cannot plan which type and what capacity of vehicles will be used and when the tourists will be collected or distributed while the tourists are being transported from the airport to the hotels or vice versa. This shortage in distribution plan is made up by the professional workers who know the situation of the region and hotels well. For the collection or distribution planning, generally human experiences and intuitions are used combined with some spread sheets and rule of thumb. It would be optimistic to expect obtaining an optimal or nearly optimal solution from a human expert each time.

While some of the agencies have their own vehicle fleets, the others rent the vehicles from a firm. The collection or distribution operations are conducted by their vehicles and/or rented vehicles. The agency that the application data has been received does not have its own fleet; thus, they rent the vehicles to give a service. In accordance with the seasonal agreement between the agency and the vehicle supplier, the responsibility of the contractor firm is as follows: the vehicles having the required type and capacity by the agency will be provided by the vehicle supplier firm at the required time and quantity. In such a situation, unlimited number of required type of vehicles and their quantity are available for the agency. Being in conformity with the market, 4 types of vehicles are used intensively in Alanya. The renting costs and capacities of these vehicles are different and are given in Table 1. Thus, the encountered structure of the problem is determined as The Fleet Size with Fixed cost and Mixed VRP.
Table 1. The seasonal renting costs according to capacity and vehicle type

<table>
<thead>
<tr>
<th>SN</th>
<th>NV</th>
<th>VT</th>
<th>Q</th>
<th>VR</th>
<th>UC</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>BUS</td>
<td>$t_1$</td>
<td>46</td>
<td>320</td>
<td>6.95</td>
</tr>
<tr>
<td>2</td>
<td>TURKUAZ</td>
<td>$t_2$</td>
<td>25</td>
<td>245</td>
<td>9.80</td>
</tr>
<tr>
<td>3</td>
<td>MIDI</td>
<td>$t_3$</td>
<td>22</td>
<td>180</td>
<td>8.18</td>
</tr>
<tr>
<td>4</td>
<td>MINI</td>
<td>$t_4$</td>
<td>14</td>
<td>130</td>
<td>9.28</td>
</tr>
</tbody>
</table>

SN: Sequence Number; NV: Name of the vehicle; VT: Vehicle Type; Q: Vehicle Capacity (person); VR: Vehicle Rent (TL); UC: Unit Cost (TL/person)

Source: Renting costs of 2011 from the data regarding the relevant agency.

3.3. The pseudo code of the case study

The pseudo code of random search and GA HFVRP are given in the below algorithms. In these algorithms Matlog is used for obtaining some of the parameters and for obtaining Sweep and Savings algorithms for each vehicle type [19].

Algorithm 1—Random search algorithm Heterogeneous Fleet VRP

Begin
  Objective function $f(x) = (x_1, x_2, ..., x_d)$
  Initial Parameters
    $\{x_i, y_i\}, Q_k, q_i, f_k, BestSol = \infty, CurrentBestSol = \infty$
  MaxIteration
  Initial Calculation
    $C(Distance\ Matrix) \leftarrow Matlog(\ (x_i, y_i))$
    $TSP_{Sweep} \leftarrow Matlog(\ Sweep\ Algorithm) \leftarrow Q_k, C, q_i$
    $TSP_{Savings} \leftarrow Matlog(\ Sweep\ Algorithm) \leftarrow Q_k, C, q_i$
    $TSP_{Random} \leftarrow (Random\ Permutation)$
    $TSP_{Initial} \leftarrow [TSP_{Sweep}, TSP_{Savings}, TSP_{Random}]$

Begin
  RoutingFunction Select $\{Min(Q_k - D_k) * f_k\} \leftarrow TSP_{Initial}$

CurrentBestSol $\leftarrow Assign\ Best\ Solution \leftarrow [Routes, [TotCosts], [TCL_p]]$ (solution space)
  BestSol $\leftarrow CurrentBestSol$
  While (MaxIteration)
    $TSP_{New} \leftarrow (Random\ Permutation)$
    $TSP_{Initial} \leftarrow [TSP_{Sweep}, TSP_{Savings}, TSP_{Random}]$
  End

Begin
  RoutingFunction Select $\{Min(Q_k - D_k) * f_k\} \leftarrow TSP_{New}$
  CurrentBestSol $\leftarrow Assign\ Best\ Solution \leftarrow [Routes, [TotCosts], [TCL_p]]$ (solution space)
  BestSol $\leftarrow CurrentBestSol$
  End If

End While

Print Results: BestSol([Routes], [TotCosts], [TCL_p])

End

Algorithm 2—Genetic Algorithm Heterogeneous Fleet VRP

Begin
  Objective function $f(x) = (x_1, x_2, ..., x_d)$
  Initial Parameters
    $\{x_i, y_i\}, Q_k, q_i, f_k, BestSol = \infty, CurrentBestSol = \infty$
  MutRate, CrossRate, MaxIteration
  Initial Calculation
    $C(Distance\ Matrix) \leftarrow Matlog(\ (x_i, y_i))$
    $TSP_{Sweep} \leftarrow Matlog(\ Sweep\ Algorithm) \leftarrow Q_k, C, q_i$
    $TSP_{Savings} \leftarrow Matlog(\ Sweep\ Algorithm) \leftarrow Q_k, C, q_i$
    $TSP_{Random} \leftarrow (Random\ Permutation)$
    $TSP_{Initial} \leftarrow [TSP_{Sweep}, TSP_{Savings}, TSP_{Random}]$

Begin
  $[Routes, [TotCosts], [TCL_p]] \leftarrow RoutingFunction Select \{Min(Q_k - D_k) * f_k\} \leftarrow TSP_{Initial}$

CurrentBestSol $\leftarrow Assign\ Best\ Solution \leftarrow [Routes, [TotCosts], [TCL_p]]$ (solution space)
  BestSol $\leftarrow CurrentBestSol$
  Pop $\leftarrow TSP_{Initial}$
  While (MaxIteration)
    $TSP_{New} \leftarrow RandomGA$ 
    Clear Pop

Begin
  RoutingFunction Select $\{Min(Q_k - D_k) * f_k\} \leftarrow TSP_{New}$
  CurrentBestSol $\leftarrow Assign\ Best\ Solution \leftarrow [Routes, [TotCosts], [TCL_p]]$ (solution space)
  If BestSol > CurrentBestSol
    BestSol $\leftarrow CurrentBestSol$
  End If

End While

Print Results: BestSol([Routes], [TotCosts], [TCL_p])

End

3.4. The arrangement of the data according to the VRP structure

For the considered case study, it is assumed that there are $n$ tourists, 4 vehicle types. Thus the indices for the previously defined parameters can be given as follows:

$q_i$ The number of tourists to be transported to the $i^{th}$ hotel $(i = 2, ..., n)$

$Q_k$ The capacity of the $k^{th}$ vehicle type $(k = 1, 2, 3, 4)$

$m_k$ The number of $k^{th}$ type of vehicle $(m_k = \infty)$

$t_k$ $k^{th}$ type vehicle model $(k = 1, 2, 3, 4)$

An example distribution plan from the agents’ database is considered in which $n=183$ tourists coming from the airport, $p=4$ routes planned as $\{R_1, R_2, R_3, R_4\}$ and $k=4$ vehicles $\{t_1, t_2, t_3, t_4\}$ used in the each route and their capacities of the assigned vehicles have been determined as $\{46, 46, 46, 46\}$. The only missing data in this analysis is the cost of the analysis performed by
the agency. The cost of VRP analysis regarding Application Problem 1 has been shown in Table 2 in which the agency application solution has been found to be 2333.58.

Table 2. VRP analysis costs of application problem 1 in application

<table>
<thead>
<tr>
<th>AS</th>
<th>RN</th>
<th>VT</th>
<th>O</th>
<th>D</th>
<th>VR</th>
</tr>
</thead>
<tbody>
<tr>
<td>[1-2-3-1]</td>
<td>R₁</td>
<td>t₁</td>
<td>46</td>
<td>283.05</td>
<td>320</td>
</tr>
<tr>
<td>[1-4-5-6-7-1]</td>
<td>R₂</td>
<td>t₂</td>
<td>45</td>
<td>264.68</td>
<td>320</td>
</tr>
<tr>
<td>[1-8-9-10-11-1]</td>
<td>R₃</td>
<td>t₃</td>
<td>46</td>
<td>249.07</td>
<td>320</td>
</tr>
<tr>
<td>[1-12-14-15-16-17-18-1]</td>
<td>R₄</td>
<td>t₄</td>
<td>46</td>
<td>256.78</td>
<td>320</td>
</tr>
</tbody>
</table>

Total costs of routes / Total rent of the vehicles 1053 1280
Total cost of analysis 2333
AS: Application Solution; RN: Route Name; VT: Vehicle Type; O: Occupancy; D: Distance; VR: Vehicle Rent

From the agents’ database, total of 8 problems are considered and VRP analysis have been generated from the distribution plans. The problems derived have been named using the numbers between AppP1 and AppP8.

3.5. Analysing the application problems by Genetic Algorithm

The application problems have been analyzed first by the standard GA method. For GA analysis, simple crossover and mutation have been applied. An elitist approach has been employed while choosing the generations. Total cost has been estimated as fitness value of the population for each generation. 50% of the population having the minimum fitness value has been transferred to the next generation. The left part of the population has been produced again by crossover. The crossover ratio has been applied as 0.5 and the mutation ratio has been applied as 0.1. The population includes 500 individuals and 10 generations. The software codes have been developed in Matlab interface. There is no study regarding code optimization. Savings Algorithm, Sweep Algorithm have been calculated by using the functions of the distance matrix and the route costs Matlab⁴ [19].

The initial population has been applied as it is suggested by Liu et al. Some of the solution space has been formed by Sweep Algorithm, the other part has been formed by Savings Algorithm and the left part has been formed random permutation. Savings and Sweep Algorithms can provide solutions for only single type of vehicles, so possible sets are formed by employing Sweep and Savings Algorithms individually for each vehicle in the set of heterogeneous vehicle. Savings and Sweep Algorithms provide a single solution for each vehicle if any demands of the customers do not exceed any capacity of the vehicle. Thus, if there are k vehicles, Sweep Algorithm provides minimum 1 and maximum k set of solutions, and similarly, Savings Algorithms produce set of solutions between 1 and k. After the initial population has been formed, solutions have been produced by using GA approach.

By using the Heterogeneous Fleet VRP method for tourist collecting or distribution plan, it is aimed to suggest better solutions than the solutions of the human expert working for the local tourist agency (Application Solution: AS). Therefore, the term “deviation” between the Suggested Solution (SS) of the Heterogeneous Fleet VRP method and AS has been defined below as:

\[ \text{Deviation} \% = \frac{(\text{AS} - \text{SS})}{\text{AS}} \times 100 \quad (3) \]

The deviation (%) may have three different values. If it is negative, the solution of the suggested method is worse than the application solution; if it is positive it is better than the application solution; if it is zero; there is no deviation.

The cost of AS, the cost of SS provided by GA, the solution time of GA and deviation values have been shown in Table 3. It can be from the table that minimum 0% and maximum 35.16% positive savings have been gained by GA. The minimum and maximum solution times are 845 and 2228 seconds, respectively.

Table 3. Solution results of application problems by GA

<table>
<thead>
<tr>
<th></th>
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<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>ST</td>
<td>2079</td>
<td>2000</td>
<td>1478</td>
<td>1223</td>
<td>2228</td>
<td>1131</td>
<td>1816</td>
</tr>
<tr>
<td>AS</td>
<td>2333</td>
<td>2310</td>
<td>1801</td>
<td>1453</td>
<td>3126</td>
<td>1453</td>
<td>2967</td>
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<td>GA</td>
<td>2333</td>
<td>2609</td>
<td>1771</td>
<td>1371</td>
<td>2952</td>
<td>1193</td>
<td>1924</td>
</tr>
<tr>
<td>%</td>
<td>0</td>
<td>11.47</td>
<td>1.70</td>
<td>5.63</td>
<td>5.57</td>
<td>20.26</td>
<td>35.16</td>
</tr>
</tbody>
</table>

ST: Solution time (second); AS: Application Solution; GA: Genetic Algorithm; %: Deviation

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⁴Matlab: Logistics Engineering MATLAB Toolbox has been developed in North Carolina State University by Michael G. Kay.
3.6. The solution of the application problems by random search

The random search has been tested by forming a search space in two dimensions. Initial solution space has been formed with the same approach in the GA solution method. The populations have been created as 40 individuals and 500 individuals. While creating the search space, the seeding has been employed. Seeding process is defined as the sets created from Sweep and Savings Algorithms and these sets are also used in GA method.

Table 4. The solution of the application problems by random search

<table>
<thead>
<tr>
<th>App</th>
<th>Pop :40</th>
<th>Pop :500</th>
<th>SI</th>
<th>AS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% Cost</td>
<td>Period</td>
<td>% Cost</td>
<td>Period</td>
</tr>
<tr>
<td>App1</td>
<td>0</td>
<td>2333</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>App4</td>
<td>6.11</td>
<td>1364</td>
<td>2</td>
<td>14.53</td>
</tr>
<tr>
<td>App8</td>
<td>25.22</td>
<td>959</td>
<td>2</td>
<td>27.31</td>
</tr>
<tr>
<td>App3</td>
<td>1.70</td>
<td>1771</td>
<td>2</td>
<td>1.70</td>
</tr>
<tr>
<td>App5</td>
<td>5.57</td>
<td>2952</td>
<td>8</td>
<td>5.57</td>
</tr>
<tr>
<td>App6</td>
<td>20.26</td>
<td>1193</td>
<td>1</td>
<td>20.26</td>
</tr>
<tr>
<td>App2</td>
<td>11.47</td>
<td>2310</td>
<td>4</td>
<td>11.47</td>
</tr>
<tr>
<td>App7</td>
<td>35.16</td>
<td>1924</td>
<td>5</td>
<td>35.16</td>
</tr>
</tbody>
</table>

SI: Solution Individual; %: Deviation; AS: Application Solution

Each population has been operated ten times for each application problem. The codes of the software have been developed in Matlab interface. There is no study about the code optimization. Savings and Sweep algorithms, the distance matrix and the route costs have been calculated by using the functions of Matlog\(^2\) [19].

The solutions in Table 4 have been classified according to the individual that the solution is attained. The solutions of the application problems 1, 4 and 8 are attained by random individuals here. The solutions of the application problems 3, 5 and 6 have been attained by Sweep Algorithm individuals formed by the seeding. On the other hand, the solutions of the application problems 2 and 7 have been attained by the derived individuals from Savings Algorithm depending on the seed.

3.7. The comparison of the suggested solutions with the agency solutions

The problem of distributing or collecting the tourists to and from the hotels and the airports is a challenging problem in terms of NP-Hard class from the theoretical point of view. Namely, the solution space exponentially grows up. Therefore, heterogeneous fleet VRP will be quite advantageous for this issue.

The comparative table developed by the agency which is defined as AS is below with the data regarding GA, Random Search for 40 individuals and Random Search for 500 individuals.

When the solutions are analyzed, there is not a great deviation between the solutions of GA and random search. Only problem 4 is worse in terms of GA solution quality according to random search method. Furthermore, there is no deviation between the solutions in terms of solution quality. When the solution periods are analyzed, GA solution periods seem longer. However, when it is taken into consideration that 10 generations have been operated in GA method the solution period will be shorter although 10 operations are assessed for random search with 500 individuals. As a result, random search solution is a more effective method in terms of cost and speed for the tourist distribution problem.

\(^2\)Matlog: Logistics Engineering MATLAB Toolbox has been developed in North Carolina State University by Michael G. Kay.
Another important thing is that some of the individuals are produced by Savings and Sweep algorithms and the remaining part of the individuals are produced randomly while forming the seeding, in other words, structuring the search space. When these eight application problems have been analyzed, it is seen that the solutions of 3 problems are obtained from random individuals and of 3 problems from Sweep and of 2 problems from seed of Savings algorithm. With the combination of random search, Savings and Sweep algorithms based on seeding, better performance and less solution time than the human expert have been attained. This means that the populations which started by the given seeding may guarantee a fast and high quality solution for many problems. Also, it is always possible to derive better solutions from random individuals by using larger populations or longer simulation times.

**4. Conclusion**

When logistic sector has been analyzed, it is seen that transportation business is an issue having quite high costs. The improvements to be performed in this area will not only have important contributions in terms of local and national economy, but also provide cost advantages in terms of companies.

Distribution or collection of tourists to or from hotels and from or to airports is basically a transportation problem. The solutions for this problem developed by operations research methods will provide important contributions to the companies, regional economy and countries’ economy.

In order to visualize the economic aspect of the problem, Table 6 is acquired. In this table, the number of tourists who visited Turkey, Antalya and Alanya in 2011 have been taken from statistics [20]. The assumptions considered while forming Table 6 are as follows:

- All the transportation operations have been assumed to be performed with the vehicles for 46 seats.
- The rental cost for a 46 seated vehicle in 2011 is 320 TL.
- The average cost of 1 USA Dollar in 2011 is 1.820 TL.

**Table 2. The comparative table of the agency, GA and random search solutions**

<table>
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<tr>
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<td>1</td>
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<td>20.26</td>
<td>35.16</td>
<td>27.31</td>
</tr>
</tbody>
</table>

ST: Solution time (second); AS: Application Solution; RS(PopSize):Random Search(1:40;2:500); %: Deviation

The deviations between the solutions obtained by the algorithm of Fleet Size and Mixed VRP, and the solutions obtained by human expert for the agency have been shown in Table 7.

**Table 3. The economic aspect of tourist distribution**

<table>
<thead>
<tr>
<th>Tourist numbers</th>
<th>Required Cost</th>
<th>Cost (TL)</th>
<th>Cost ($)</th>
<th>%10 Savings ($)</th>
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<tr>
<td>Turkey</td>
<td>31.456.076</td>
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<td>218.824.640</td>
<td>120.233.318</td>
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<td>Antalya</td>
<td>10.464.425</td>
<td>227.487</td>
<td>72.796.000</td>
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<tr>
<td>Alanya</td>
<td>2.500.000</td>
<td>54.347</td>
<td>17.391.304</td>
<td>9.555.661</td>
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</tbody>
</table>

The provided rental cost for a 46 seated vehicle for 1 USA Dollar in 2011 is 1.820 TL.

**Table 7. Savings obtained by optimization technique**

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>%</td>
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<td>11.47</td>
<td>1.70</td>
<td>14.53</td>
<td>5.57</td>
<td>20.26</td>
<td>35.16</td>
<td>27.31</td>
</tr>
</tbody>
</table>

As it can be seen in Table 7, it has been found that the minimum value of the results of the savings obtained from Equation (3) at the end of the optimization is 0% while the maximum saving is 35.16%. The provided average savings of the proposed methods for 8 applications of the local agency will be approximately 15%. When the saving is supposed to be 10% with a risk aversion point of view, instead of solving the problem of distribution using the account tables depending on human experience and intuition, the problem should be solved by using random search algorithm which has been developed for Fleet Size and Mixed VRP. This practice will provide the expected benefits in terms of an economic aspect such as:

- About 12 million dollar annual savings for Turkey
- About 4 million dollar annual savings for Antalya

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(Notes and references should be included for complete understanding of the content.)
Turkey and all around the world, applications are applied to all the destinations in developing potenti, solving the problem as a whole for tourism issue will help increasing employment. Using operations research methods can offer service to the firms directly. Such kind of tourist distribution and increasing economic savings appreciably. Tourism has positive effects on the economy and development of countries. Moreover it is an important industry as it contributes to the employment. Using operations research methods for tourism issue will help increasing the service quality, improving effectiveness and productivity and increasing economic savings appreciably.

This is a study which provides practical results in a fast and effective way in application. User friendly computer programs may be developed that can offer service to the firms directly. Such kind of tourist distribution planning program not only helps to solve a difficult problem theoretically in an effective and fast way, but also eliminates the need of expertise. The same application may be solved with a broader planning organization from a single center for all Alanya agencies. In such a situation, solving the problem as a whole for Alanya will provide contributions depending on the scale economies and it will provide a bigger developing potential for the region. If these applications are applied to all the destinations in Turkey and all around the world, there will be quite important cost reductions and the pleasure of the tourists may increase.

Acknowledgments
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References
[9] Choi E., Tcha, D. W., A column generation approach to the heterogeneous fleet vehicle


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Ibrahim Gungor studied production management for his BSc and econometrics for MSc and PhD degrees. He is a professor of operations research at the econometrics department at Akdeniz University and he is also the dean of Alanya Business Administration Faculty. His field of study includes operations research both in theory and application. Tourism is one of the subjects he is interested in regarding the application of operations research. He was awarded as a supervisor of the best PhD thesis on Graduate Tourism Students Congress in Belek (2008) and in Antalya (2012) and Kuşadası (2014).