This research attempts to solve both the multi-trip vehicle routing problem and the distribution center location problem at the same time. A mathematic model is developed first. The objective of this model is to minimize the total costs including the transportation costs and the activated vehicle costs. A heuristic algorithm is then developed for solving the problem which consists of three phases. The first phase is to find an initial location and routings. The second phase applies exchange algorithms to obtain better routings by using Simulated Annealing (SA) logic. The final phase is to improve the location which is controlled by the current temperatures of SA method. The results of numerical examples show that the proposed algorithm can effectively acquire a better distribution center location and the associated routings. Finally, the numerical experiments indicate that: (1) Using larger capacity of vehicle is better for reducing transportation distance. (2) Increasing service time can effectively reduce the number of vehicle required. Both results are useful for management decision in the multi-trip vehicle routing problem and distribution center location problem as well.

**Keywords:** Multi-Trip Vehicle Routing Problem, Location Routing Problem, Heuristic Algorithm.
and fixed destinations. Choosing a good location for distribution center is the second motivation of this research. A multi-trip vehicle routing policy can fully utilize all the working hours in a given period. It is also an efficient way to reduce the total number of vehicle to be activated, therefore, the fixed cost of vehicles can be saved. Figure 1 indicates a typical multi-trip routing for three vehicles. Based on the motivations mentioned above, this research provides an integrated approach to solve the multi-trip vehicle routing problem and location problem for distribution center simultaneously.

Figure 1  A Typical Multi-trip Routing for Three Vehicles

II. Literatures Review

The vehicle routing problem (VRP) is extended from traveler salesman problem with loading capacity of vehicle. Due to the complexity nation of VRP, it is one of NP-hard problems when the problem scale increases. Bodin and Golden suggested seven solution policies as follows: (1) Cluster first – Route second, (2) Route first – Cluster second, (3) Saving or insertion, (4) Improvement or exchange, (5) Exact procedures, (6) Interactive optimization, (7) Mathematical programming. This research will use the similar concept of saving or insertion to develop the initial solution. The heuristic algorithm will apply the concept of improvement or exchange.

The concept of multi-trip VRP is first developed by Fleischmann in 1990. Olivera and Viera (2007) found the single-trip VRP is not suitable for the lower vehicle capacity or longer delivery service time. For the solution approaches for the multi-trip vehicle routing problems, Taillard et. al. (1996), Brandao and Mercer (1997), Nabila et. al. (2010), Salhi and Petch (2007), Lin and Kwok (2006) suggest several heuristic algorithms including tabu search, branch and price, genetic algorithm, and simulated annealing. In this research, the logic of simulated annealing algorithm will be used in the routing improvement.

The location in this study belongs to a non-emergency and non-obnoxious facility, therefore, it is close to the P-media problem. The minimal distance will be used in the objective function. For the location vehicle routing problem, Tuzun and Bruke (1999) suggests the facility activated cost, vehicle activated cost, and routing cost in the objective function. The solution approach includes (1) activate depot randomly, (2) use saving approach to generate initial routings, and (3) use insertion and exchange approach to improve routings. Barreto et. al. (2007) suggests a procedure to decide location for each facility and service area. In this research, the location problem and vehicle routing problem are solved simultaneously by the simulated annealing procedure.
III. The Model and Solution Algorithm

3.1 Problem Statement and Assumptions

The problem discussed in this research focuses on two basic issues: (1) the multi-trip vehicle routing and (2) the facility location. Basically, the VRP is a typical short-term decision, however, the location problem is a typical long-term decision. To solve these contrary decisions, it is necessary to assume the data of flow quantities and locations for all demand points are collected by long-term statistics. The problem and mathematical model are based on the following assumptions:

(a) Single distribution center is considered in a given two-dimension plane. The distribution center is responsible for delivery goods to customers (demand points) and no pickup operations.

(b) Multi-trip deliveries for each vehicle are acceptable within a given and fixed service time in one period.

(c) No setup cost considered for the distribution center

(d) For each route, the vehicle starts from the distribution center (depot point) and the vehicle returns to the distribution center (ending point at the depot).

(e) Unlimited goods quantity in the distribution center, i.e. inventory shortage is not considered.

(f) Only one type of vehicle is considered. Loading capacity is given and fixed. Activated cost for each vehicle is given and fixed. Overloading vehicle is not acceptable.

(g) Speed of vehicle is given and fixed. No traffic jam is considered.

(h) Transportation cost per unit distance is given and fixed.

(i) For each vehicle, the loading time in the distribution center is given and fixed.

(j) In each demand point, the unloading time per unit is given and fixed.

(k) Quantity required by each customer in one per period is given and fixed. This quantity should be satisfied in each period.

(l) In each time period (day), each demand point should be served once by one vehicle only.

(m) Euclidean distance is considered between any two transporting points.

3.2 The Mathematical Model

Based on the assumptions described in section 3.1, a mathematical model is then developed which focuses on the location vehicle routing problem with multi-trip operational policy. All the parameters and variables in this model are defined as follows:

\[ N \] : total number of demand point (customer)
\[ i, j \] : index of demand point, \( i, j = 0, 1, 2, 3, ..., N \)
\( i = 0 \) or \( j = 0 \) represents the distribution center (depot point).
\[ k \] : index of vehicle, \( k = 1, 2, 3, ..., K \) \( K \) is the total number of activated vehicle.
\[ r \] : index of trip, \( r = 1, 2, 3, ..., R \) \( R \) is the total number of trip.
\[ q_j \] : delivery quantity in one period for demand point \( j \), \( q_0 = 0 \)
\[ Q \] : maximal loading capacity of vehicle
\[ m \] : average speed of vehicle
\[ l \] : unit loading time in the distribution center
\( u \): unit unloading time in the demand point \\
\( VC \): vehicle activated cost per period (given) \\
\( TC \): vehicle transportation cost per unit distance \\
\( d_{ij} \): distance from demand point \( i \) to demand point \( j \), \\
\[ d_{ij} = \left[ (x_i - x_j)^2 + (y_i - y_j)^2 \right]^{1/2}, \text{ where } (x_f, y_f) \text{ is the coordinates of demand point } f. \]

\( U_k^r \): loading time for vehicle \( k \) in trip \( r \), \\
\[ U_k^r = l \cdot Q \cdot \sum_{j=1}^{N} X_{0jk}^r. \]

\( W_k^r \): total unloading times for vehicle \( k \) in trip \( r \), \\
\[ W_k^r = u \cdot \sum_{i=0}^{N} \sum_{j=0}^{N} q_j \cdot X_{ij}^r. \]

\( t_{ij} \): travel time from point \( i \) to point \( j \), \\
\[ t_{ij} = \frac{d_{ij}}{m}. \]

\( T \): service time in one period \\
\( M \): an arbitrarily large positive number

The decision variables are defined as follows:

\( X_{0jk}^r \): If vehicle \( k \) in trip \( r \) serves demand point \( i \) to demand point \( j \), then \( X_{0jk}^r = 1. \)

Otherwise, \( X_{0jk}^r = 0. \)

\( V_k \): If the vehicle \( k \) is activated, then \( V_k = 1. \) Otherwise, \( V_k = 0. \)

The mathematical model is constructed as the following objective function and constraints.

\[ \text{Minimize} \quad Z = \sum_{k=1}^{K} V_k \cdot VC + \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} \sum_{r=1}^{R} d_{ij} \cdot X_{ij}^r. \]

Subject to:

\[ \sum_{i=0}^{N} \sum_{j=1}^{R} X_{ij}^r = 1 \quad j = 1, 2, ..., N, \quad i \neq j \quad (2) \]

\[ \sum_{j=1}^{N} \sum_{k=1}^{K} \sum_{r=1}^{R} X_{ij}^r = 1 \quad i = 0, 1, ..., N, \quad i \neq j \quad (3) \]

\[ \sum_{i=1}^{N} X_{0jk}^r = \sum_{j=1}^{N} X_{j0k}^r \quad r = 1, 2, ..., R, \quad k = 1, 2, ..., K \quad (4) \]

\[ \sum_{i=0}^{N} X_{ijk}^r - \sum_{j=0}^{N} X_{hjk}^r = 0 \quad i \neq j \neq h \quad (5) \]

\[ \sum_{i=0}^{N} \sum_{j=0}^{N} q_j \cdot X_{ij}^r \leq Q \quad r = 1, 2, ..., R, \quad k = 1, 2, ..., K, \quad i \neq j \quad (6) \]

\[ \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} X_{ij}^r \leq M \cdot V_k \quad k = 1, 2, ..., K, \quad i \neq j \quad (7) \]
\[ \sum_{j=1}^{N} X_{ijk}^r \geq \sum_{j=1}^{N} X_{ijk+1}^r \quad r = 1, 2, ..., R, \quad k = 1, 2, ..., K-1 \] (8)

\[ \sum_{j=1}^{N} X_{ijk}^r \geq \sum_{j=1}^{N} X_{ijk+1}^r \quad r = 1, 2, ..., R-1, \quad k = 1, 2, ..., K \] (9)

\[ \sum_{r=1}^{R} U_k^r + \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{r=1}^{R} f_{ij} \cdot X_{ijk}^r + \sum_{r=1}^{R} W_k^r \leq T \quad k = 1, 2, ..., K, \quad i \neq j \] (10)

\[ \sum_{i=1}^{N} \sum_{j=1}^{N} X_{ijk}^r = N - 1 \quad r = 1, 2, ..., R, \quad k = 1, 2, ..., K, \quad i \neq j \] (11)

\[ X_{ijk}^r \in \{0, 1\} \quad i, j = 1, 2, ..., N, \quad r = 1, 2, ..., R, \quad k = 1, 2, ..., K, \quad i \neq j \] (12)

\[ V_k^r \in \{0, 1\} \quad k = 1, 2, ..., K \] (13)

The objective function, as indicated in equation (1), is to minimize the overall cost which includes the vehicle activated costs and transportation costs. Equation (2) and (3) confirm that only one vehicle serves each demand point. For any activated vehicle in any trip, flow-in and flow-out travel frequency should be the same on the distribution center, as indicated in equation (4). In equation (5), the flow-in quantity should be the same as the flow-out quantity in any demand point. Equation (6) makes sure no overload for any vehicle in any route. Only the activated vehicle can deliver goods, which is represented in equation (7). Equation (8) makes sure the sequence of activated vehicle from \( k \) to \( k+1 \). Similarly, equation (9) confirms the sequence of activated trip from \( r \) to \( r+1 \). The overall operation time for any vehicle should be less than service time in one period, as indicated in equation (10). The operation time includes all loading times, travel times, and unloading times. Equation (11) confirms no sub-tour. Equation (12) and (13) define the decision variables to be 0 or 1.

3.3 Solution Algorithm

The location problem and multi-trip vehicle routing problem are all belong to the NP-hard problems. Based on the model developed in section 3.2, a heuristic algorithm using the simulated annealing logic is then constructed in this section. The structure of this algorithm includes three stages: Stage I builds an initial location for the distribution center and develops initial vehicle routings. Stage II improves the vehicle routings using simulated annealing algorithm. The stage III focuses on the location improvement using the current temperature in the simulated annealing to control the size of searching area. The overall logic of this solution algorithm is presented in Figure 2. The following paragraphs describe each stage in details.

In stage I, the initial location of distribution center is determined by finding an approximate center point in the area of demand points. The first vehicle in the first route starts at this point and the next service point is connected by the nearest demand point which is not been served. The process is repeating until the loading capacity of vehicle is reached. The second trip of this vehicle is then activated if the current time do not reach the end of service time. After one vehicle reach the service time, the second vehicle can be activated. This routing assignment procedure repeats until
all the demand points are assigned.

Figure 2  Flow Chart of the Proposed Solution Algorithm

In stage II, three basic approaches for routing improvement are used: (1) 1-1 internal route exchange, (2) 1-1 external route exchange, and (3)1-0 external route insertion. Due to the multi-trip nature in this study, the insertions and exchanges should include different vehicles and different trips. The basic logic of simulated annealing will be applied in this stage.

For the location improvement in stage III, the searching range of new location is based on the current temperature in the simulated annealing logic. Basically, we define a circle and the area within this circle is the “searching range”. When the temperature reduces and the radium of the searching circle will shorten. In another word, the searching area will gradually reduce through the entire searching process.

IV. Illustration Examples and Sensitivity Analysis

In this section, two typical examples are solved by the algorithm developed in section 3.3. The demand points of the first example are uniformly spread in the distribution area, whereas the second
example features one community which the demand points concentrate within a specific area. The basic data of examples and solution results are described in section 4.1. The second part of this section performs a sensitivity analysis which includes single/multi-trip, different loading capacities of vehicle, and different service times. Section 4.2 discusses results of this sensitivity analysis.

4.1 Illustration Examples and Solutions

There are 50 demand points in each example and all demand points are plotted in Figure 3. Figure 3(a) represents the “uniform” example and Figure 3(b) is called the “community” example. Other basic data used in both examples are indicated as follows.

The average vehicle speed is 60 unit distance per hour. Unit loading time and unit unloading time are 0.6 minute and 0.3 minute, respectively. The maximal loading capacity of vehicle is 55 and the service time in one period is 8 hours, \( i.e. \) 480 minutes. The vehicle activated cost is $300 per period and the transportation cost is $5 per unit distance.

An experimental design is also conducted for fine tuning the parameters used in the simulated annealing algorithm. These parameters are initial temperature \( T_0 \), temperature reduction rate \( R \), and iteration number under one temperature \( N \). By using the Taguchi method, these parameters are confirmed as follows: \( T_0 = 15, R = 0.95, \) and \( N = 100 \).

![The Uniform Example](image1.png) ![The Community Example](image2.png)

Figure 3  The Demand Points Plotted in the Planning Plane

The solution of the uniform example is summarized in Table 1 and the solution of the community example is presented in Table 2. Each example runs 5 times and each run takes about 7.3 hours. The data in Table 1 and Table 2 include the following information: the initial location of distribution center, the final location of distribution center (They are represented by coordinates), number of vehicle activated, total trips, total travel distance, and total cost which is the objective function value defined in equation (1). Figure 4 plots the initial and the final location of distribution center and all the demand points in each example.

By comparing results from the uniform example and community example, several observations can be summarized as follows: (a) The final location of uniform example is very close to the geography center of all demand points. (b) The final location of community example is close to the community which is also high density of demand points. (c) The numbers of vehicle activated and total trips are similar in each solution run. (d) The solutions in uniform example are more stable than those in community example, \( i.e. \) 2.2% VS. 45.0%.
Table 1  Solution Results for the Uniform Example

<table>
<thead>
<tr>
<th>Solution Runs</th>
<th>1</th>
<th>2**</th>
<th>3*</th>
<th>4</th>
<th>5</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Location</td>
<td>(34.0, 37.5)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Location</td>
<td>(38.75, 31.55)</td>
<td>(31.08, 30.12)</td>
<td>(38.35, 31.39)</td>
<td>(38.31, 31.21)</td>
<td>(38.06, 30.96)</td>
<td></td>
</tr>
<tr>
<td>Vehicle Activated</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Total Trips</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>1047.15</td>
<td>1075.17</td>
<td>1046.87</td>
<td>1048.02</td>
<td>1049.16</td>
<td>1053.27</td>
</tr>
<tr>
<td>Deviation**</td>
<td>0.03%</td>
<td>2.70%</td>
<td>–</td>
<td>0.11%</td>
<td>0.22%</td>
<td>0.77%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>6435.79</td>
<td>6575.85</td>
<td>6434.37</td>
<td>6440.11</td>
<td>6445.58</td>
<td>6466.34</td>
</tr>
<tr>
<td>Deviation***</td>
<td>0.02%</td>
<td>2.20%</td>
<td>–</td>
<td>0.09%</td>
<td>0.17%</td>
<td>0.62%</td>
</tr>
</tbody>
</table>

The Best Cost = 6434.37,  The Worst Cost = 6575.85,  The Average Cost = 6466.34

Remarks: *The best result, **The worst result, ***Deviation = \{[(Current value) – (Best value)] / (Best value)\}*100%

Table 2  Solution Results for the Community Example

<table>
<thead>
<tr>
<th>Solution Runs</th>
<th>1</th>
<th>2</th>
<th>3*</th>
<th>4</th>
<th>5**</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial Location</td>
<td>(38.5, 39.0)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final Location</td>
<td>(47.61, 67.18)</td>
<td>(54.07, 48.67)</td>
<td>(44.37, 55.59)</td>
<td>(43.57, 48.73)</td>
<td>(53.09, 47.08)</td>
<td></td>
</tr>
<tr>
<td>Vehicle Activated</td>
<td>5</td>
<td>4</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4.44</td>
</tr>
<tr>
<td>Total Trips</td>
<td>16</td>
<td>16</td>
<td>17</td>
<td>16</td>
<td>16</td>
<td>16.2</td>
</tr>
<tr>
<td>Travel Distance</td>
<td>500.07</td>
<td>489.88</td>
<td>384.15</td>
<td>575.50</td>
<td>752.05</td>
<td>540.33</td>
</tr>
<tr>
<td>Deviation**</td>
<td>30.18%</td>
<td>27.53%</td>
<td>–</td>
<td>49.81%</td>
<td>95.77%</td>
<td>50.82%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>4000.35</td>
<td>3649.42</td>
<td>3420.73</td>
<td>4077.48</td>
<td>4960.26</td>
<td>4021.65</td>
</tr>
<tr>
<td>Deviation***</td>
<td>16.94%</td>
<td>6.69%</td>
<td>–</td>
<td>19.20%</td>
<td>45.01%</td>
<td>21.96%</td>
</tr>
</tbody>
</table>

The Best Cost = 3420.73,  The Worst Cost = 4960.26,  The Average Cost = 4021.65

Remarks: *The best result, **The worst result, ***Deviation = \{[(Current value) – (Best value)] / (Best value)\}*100%

4.2 Sensitivity Analysis

The following analysis focuses on three topics: single trip and multi-trip, different vehicle loading capacities, and different service time in one period.

Table 3 summarizes the comparison results for single-trip and multi-trip vehicle routing problem. In Table 3, the data of single-trip is directly quoted from the international example E-n51-k5 and the data of multi-trip is averaged from 10 independent runs using the solution algorithm developed in this research. Several observations can be found as follows: (a) The single-
trip policy can shorten the finishing time, however, it requires more vehicles. (b) The multi-trip policy can effectively utilize service time in one period, i.e. 480 minutes in this case. (c) The multi-trip policy can save the vehicle activated cost, but it suffers from longer transportation cost (longer travel distance). In summary, the decision making depends on activated cost per vehicle and transportation cost per unit distance.

Table 3  Comparison of Single-trip and Multi-trip VRP

<table>
<thead>
<tr>
<th></th>
<th>Single-trip (A)</th>
<th>Multi-trip (B)</th>
<th>Deviation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Activated</td>
<td>5</td>
<td>3</td>
<td>-67.67%</td>
</tr>
<tr>
<td>Total Travel Distance</td>
<td>521</td>
<td>600</td>
<td>13.17%</td>
</tr>
<tr>
<td>Vehicle Activated Cost</td>
<td>1500</td>
<td>900</td>
<td>-67.67%</td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>2605</td>
<td>3000</td>
<td>13.17%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>4105</td>
<td>3900</td>
<td>-5.25%</td>
</tr>
<tr>
<td>Finishing Time</td>
<td>250.3</td>
<td>469.7</td>
<td>46.70%</td>
</tr>
<tr>
<td>Vehicle Idle Time**</td>
<td>1296.8</td>
<td>184.0</td>
<td>-604.65%</td>
</tr>
</tbody>
</table>

Remarks:  
* Deviation = \( \frac{(B) - (A)}{(B)} \times 100\% \)

** Vehicle Idle Time = (480) – (Finishing Time of the Vehicle)

The second analysis focuses on truck loading capacities. Theoretically, a bigger truck requires more activated cost and higher unit transportation cost. In this analysis, three different vehicles are considered and the loading capacities are 55, 75, and 100. The vehicle activated costs are 300, 400, and 550, respectively. The unit transportation cost are 5, 6, 8, and 9, respectively. The service time in one period is fixed on 480 minutes. Table 4 summarizes the comparison results for three different vehicles and each data in Table 4 is averaged from 5 independent runs.

Several observations can be found as follows: (a) Vehicle with higher loading capacity tends to reduce: total travel distance, total trip, average trip per vehicle, and total operation time. (b) Vehicle with lower loading capacity benefits from unit transportation cost and vehicle activated cost. (c) A trade-off decision should consider total cost and operation efficiency.

Table 4  Comparison for Three Loading Capacities

<table>
<thead>
<tr>
<th>Loading Capacity</th>
<th>55</th>
<th>75</th>
<th>100</th>
<th>Deviation*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Activated</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total Trip</td>
<td>16</td>
<td>12</td>
<td>9</td>
<td>77.78%</td>
</tr>
<tr>
<td>Average Trip per Vehicle**</td>
<td>4</td>
<td>3</td>
<td>2.25</td>
<td>77.78%</td>
</tr>
<tr>
<td>Total Operation Time</td>
<td>1821.26</td>
<td>1626.51</td>
<td>1499.38</td>
<td>21.47%</td>
</tr>
<tr>
<td>Total Idle Time***</td>
<td>98.74</td>
<td>293.49</td>
<td>420.62</td>
<td>325.99%</td>
</tr>
<tr>
<td>Total Travel Distance</td>
<td>1060.16</td>
<td>853.41</td>
<td>726.28</td>
<td>45.97%</td>
</tr>
<tr>
<td>Vehicle Activated Cost</td>
<td>1200.00</td>
<td>1600.00</td>
<td>2200.00</td>
<td>83.33%</td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>5300.79</td>
<td>5803.17</td>
<td>6536.51</td>
<td>23.31%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>6500.79</td>
<td>7403.17</td>
<td>8736.51</td>
<td>34.39%</td>
</tr>
</tbody>
</table>

Remarks:  
* Deviation = \( \frac{\text{((Worst value) - (Best value))}}{\text{(Best value)}} \times 100\% \)

** Trip per Vehicle = (Total Trip) / (Vehicle Activated)

*** Based on 480 minutes per period

The last analysis concentrates on the service times per period. In this study, we evaluate three
service times: 360, 480, and 600, respectively. The following data is fixed on each case: vehicle
loading capacity is 55, vehicle activated cost is 300, transportation cost per unit distance is 5. The
comparison results are summarized in Table 5 and each data in this table is averaged from 5
independent runs.

Several observations can be found as follows: (a) A longer service time can effectively reduce
the number of vehicle activated. (b) No significant difference in total operation time (2.5%) and
transportation cost (2.09%). (c) In this analysis, the longest service time, i.e. 600 minutes, spent
least money, however, the extra overtime cost for direct and indirect labor should be considered at
the same time.

Table 5  Comparison for Different Service Times

<table>
<thead>
<tr>
<th>Service Time</th>
<th>360</th>
<th>480</th>
<th>600</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle Activated</td>
<td>6</td>
<td>4</td>
<td>4</td>
<td>50.00%</td>
</tr>
<tr>
<td>Total Trip</td>
<td>15.2</td>
<td>16.0</td>
<td>15.8</td>
<td>5.26%</td>
</tr>
<tr>
<td>Average Trip per Vehicle</td>
<td>2.53</td>
<td>4.00</td>
<td>3.95</td>
<td>58.10%</td>
</tr>
<tr>
<td>Total Operation Time</td>
<td>1776.83</td>
<td>1821.26</td>
<td>1792.94</td>
<td>2.50%</td>
</tr>
<tr>
<td>Total Idle Time</td>
<td>383.17</td>
<td>98.74</td>
<td>607.06</td>
<td>514.81%</td>
</tr>
<tr>
<td>Total Travel Distance</td>
<td>1042.13</td>
<td>1060.16</td>
<td>1038.44</td>
<td>2.09%</td>
</tr>
<tr>
<td>Vehicle Activated Cost</td>
<td>1800.00</td>
<td>1200.00</td>
<td>1200.00</td>
<td>50.00%</td>
</tr>
<tr>
<td>Transportation Cost</td>
<td>5210.63</td>
<td>5300.79</td>
<td>5192.21</td>
<td>2.09%</td>
</tr>
<tr>
<td>Total Cost</td>
<td>7010.63</td>
<td>6500.79</td>
<td>6392.21</td>
<td>9.67%</td>
</tr>
</tbody>
</table>

Remarks: *Deviation = \{(Worst value) - (Best value)\} / (Best value) *100%
**Based on service time in each case

V. Conclusion

This paper investigates the location vehicle routing problem under the multi-trip operational
policy. A mathematical model and the associated solution algorithm are also proposed to solve this
problem. The proposed heuristic solution algorithm is based on the simulated annealing logic,
which is also confirmed to be an effective approach by several illustration examples. A sensitivity
analysis is also conducted and the results are useful for management decisions.

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References