Research on Vehicle Routing Optimization of Urban Logistics Distribution Based on Carbon Trading Mechanism
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**Keywords:** logistics distribution; cost; routing optimization; carbon trading; genetic algorithm.

**Abstract.** The study of vehicle routing problem under the carbon trading mechanism is essential for reducing carbon emissions in the process of logistics delivery and optimizing enterprise costs. To solve the vehicle routing problem under the carbon trading mechanism, this paper introduces the calculation method of carbon transaction cost, which integrates the time cost, fuel consumption cost, vehicle use cost and carbon transaction cost as the total cost. On the basis of the traditional vehicle routing problem, the objective function is constructed with the minimum total cost as the objective, and the research model is determined. Genetic algorithm is used to arrange the nodes on the distribution path, followed by simulation analysis. Using MATLAB simulation, the minimum cost of the delivery task is determined under the simulated scene of the completion of 10 delivery point tasks in several vehicles, and the number of the distribution vehicles and the route of the distribution vehicle are obtained.

1. Introduction

The so-called carbon trade is the commercialization of carbon dioxide emissions, a market mechanism to control carbon emissions. The national carbon trading market will start in 2017, and China will replace the EU as the world's largest carbon market, so carbon trading market more and more attention by our government. In this context, the study of how to choose the vehicle route of urban logistics distribution under the carbon trading mechanism can not only affect the optimization of enterprise cost, but also be essential to protect the ecological environment and promote green development.

In recent years, domestic and overseas scholars have taken up large-scale research on routing optimization and carbon emissions. Among them, Zhu Changzheng and others respectively with the shortest path or minimum fuel consumption or minimum carbon emissions as the goal, and have adopted different research methods to study the different vehicle routing problem\textsuperscript{[1,2,3]}; Zhou Cheng studied the vehicle routing decision problem of single-vehicle multi-task under three different low-carbon policies\textsuperscript{[4]}, and also conducted a similar cost study in other literatures. According to the constraints of time windows, the total cost consists of the economic costs of the four factors, vehicle, distance, time, and carbon emissions, in order to minimize total cost as the optimization objectives of vehicle routing\textsuperscript{[5, 6, 7]}. Bektas T. proposed a new algorithm to vehicle fuel consumption, vehicle speed and load as independent variables and the dependent variable as a function of fuel consumption\textsuperscript{[8]}. The above-mentioned literature is more detailed in the study of the traditional VRP (vehicle routing problem) and low-carbon research, but there are still imperfections. For example, the literature\textsuperscript{[1, 4]} and so on, all with the TSP model as the reference model; Most of the literature on carbon emissions in VRP is simply a cost that must be spent, without take into account the benefits of carbon trading mechanism. The cost is usually considered a single distance or time, or the sum of the cost of travel, time cost, start cost, carbon cost and fuel cost as the total cost, the total cost seems to be more comprehensive, but not reasonable, because the cost is extremely easy to repeat, will lead to research bias.

Therefore, combined with the current research and policy, this paper establishes a multi-vehicle multi-task vehicle routing optimization model, taking into account the impact of carbon trading...
mechanism and other costs. It is more scientific to consider time cost, fuel consumption cost, vehicle use cost and carbon transaction cost as the total cost.

2. Build models

2.1 Problem Description.

Discussion on multi-vehicle multi-task logistics distribution routing problem under carbon trading mechanism: a distribution center to undertake distribution services of multiple distribution points, a number of vehicles from the distribution center, traverse each delivery point once, and finally return to the distribution center. Assumptions are as follows:

(1) All delivery vehicles start from the distribution center, and then return to the distribution center immediately after completing the assigned tasks; (2) The vehicles are of the same type, and the loading capacity is known; (3) The demand for each distribution point is determined, and the loading amount of the distribution vehicle satisfies the customer demand; (4) All distribution points are served and can only be serviced once; (5) All distribution routes are road transport, and the road condition remain unchanged in the delivery task; (6) Vehicle carbon emissions depends on vehicle fuel consumption, fuel consumption is related to vehicle travel distance, load and speed; (7) The objective function considering the vehicle time cost, fuel consumption cost, vehicle use cost and carbon transaction cost.

2.2 Symbols and Decision Variables

\( G = (V, A) \) is the distribution network; \( V = \{V_0, V_1, V_2 \cdots V_n\} \) is a collection of all nodes, which \( V_0 \) said distribution center, the rest of the nodes indicate the distribution point; \( A = \{V_{ij} | i \neq j, i, j \in V\} \) is a set of directed arcs, the \( d_{ij} \) is the distance between the \( V_i \) and the \( V_j \); \( Q \) is the total demand for goods, the vehicle is set is \( K \), Node \( V_i \) corresponds to the demand for goods is \( Q_i \); \( x_{ijk} \) is a variable of 0-1, \( x_{ijk} = 1 \) indicates that vehicle \( k \) passes through \( V_{ij} \), otherwise \( x_{ijk} = 0 \); \( \mu_{ij} \) is the traffic damping factor for vehicles passing through \( V_{ij} \). The smaller \( \mu_{ij} \) indicates that the of higher the vehicle capacity of the road, \( \mu_{ij} \geq 0 \), When \( \mu_{ij} \) is valued at \(+\infty\), it is forbidden to travel on this road. \( t \) is the service time each customer needs, \( \delta \) is unit vehicle time cost, \( \lambda \) is unit fuel cost, \( \rho \) is unit vehicle use cost, \( \eta \) is carbon trading price, \( P \) is assigned carbon emissions.

2.3 Calculation of Carbon Emissions

Reference literature [2] [8] fuel consumption and carbon emissions measurement method. \( \beta_0 \) is the fuel consumption of the unit mileage when the vehicle is unloaded, \( \beta_1 \) is the influence of additional load on the fuel consumption of the vehicle per unit mileage, \( \beta_2 \) is the influence of vehicle speed on fuel consumption of the vehicle per unit mileage. Therefore, the fuel consumption of the vehicle unit mileage with load \( W \) is \( O \). The fuel consumption of the distribution vehicle through \( V_{ij} \) is \( E_{ij} \). \( \epsilon \) is carbon emission factor of unit fuel. The carbon emission of the distribution vehicle passing \( V_{ij} \) is \( C \).

\[
O = \beta_0 + \beta_1 W + \frac{\beta_2}{\nu^2}
\]
\[
E_{ij} = \left[ \beta_0 + \beta_1 W + \beta_2 \left( \frac{\mu_{ij}}{\nu} \right)^2 \right] d_{ij}
\]
\[
C = \epsilon \left[ \beta_0 + \beta_1 W + \beta_2 \left( \frac{\mu_{ij}}{\nu} \right)^2 \right] d_{ij}
\]

2.4 Model building

This paper aims to minimize the total cost of urban logistics distribution under the carbon trading mechanism. The total cost includes time cost, usage cost, fuel consumption cost, and carbon transaction cost. The model of urban logistics distribution route optimization is as follows:

Objective function:

\[
\min \left\{ \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} \frac{\mu_{ij} x_{ijk} d_{ij}}{\nu} + \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} x_{ijk} + \lambda E + \rho K + \eta (\epsilon E - P) \right\}
\]
\[
E = \sum_{i=0}^{N} \sum_{j=0}^{N} \sum_{k=1}^{K} x_{ijk} \left[ \beta_0 + \beta_1 W + \beta_2 \left( \frac{\mu_{ij}}{\nu} \right)^2 \right] d_{ij}
\]

Restrictions:

\[
\sum_{j=1}^{N} x_{ijk} = \sum_{j=1}^{N} x_{ijk} \leq 1, i = 0; k \in \{1,2,3 \cdots K\}
\]
\[
\begin{align*}
\sum_{i=1}^{N} \sum_{j=1}^{K} x_{ijk} &= 1, i \in \{1,2,3 \cdots N\} \\
\sum_{j=1}^{N} \sum_{k=1}^{K} x_{ijk} &= 1, j \in \{1,2,3 \cdots N\} \\
\sum_{i=0}^{N} x_{irk} - \sum_{j=0}^{N} x_{rjk} &= 0, r \in \{1,2,3 \cdots N\}, k \in \{1,2,3 \cdots K\} \\
\sum_{i=0}^{N} \sum_{j=0}^{K} x_{ijk} &\leq K, i = 0 \\
x_{ijk} &= [0,1], (i,j) \in A \\
\end{align*}
\]

Equation (4) is the objective function proposed in this paper, which means that the total cost of distribution is the least, including time cost, fuel cost, vehicle use cost and carbon transaction cost; Equation (5) indicates that the origin and end of the distribution line for each vehicle must be the distribution point; Equation (6) indicates that each distribution point is serviced and can only be serviced by a vehicle once; Equation (7) indicates that the vehicle must arrive from the point after reaching a distribution point; Equation (8) is the vehicle load limit; Equation (9) is the vehicle quantity limit; Equation (10) is a 0-1 constraint.

3. Simulation and analysis

3.1 Algorithm Design

Genetic algorithm is a computational model for simulating the natural selection and genetic mechanism of Darwin's biological evolution theory. Genetic algorithm has been successfully applied to classical vehicle routing problem research, and performed well. Therefore, this paper uses the genetic algorithm as the framework of the solution, the first arrangement of coding, and then follows the steps of the genetic algorithm.

3.2 Experimental Setup

This experiment assumes that there is a distribution center with ten delivery points, the demand for each distribution point as shown in Table 1, the distribution center vehicles are 20t load standard truck, plans to send a number of vehicles to complete the distribution task, the path parameters such as Table 2 shows.

<table>
<thead>
<tr>
<th>Distribution point</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>demand (ton)</td>
<td>4</td>
<td>7</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>8</td>
<td>9</td>
<td>11</td>
<td>4</td>
<td>15</td>
<td>75</td>
</tr>
</tbody>
</table>

Table 2. Path parameter table.

Among them, the line parameters \((d_{ij}, h_{ij})\) represents the distance (in km) between the nodes i and j and road conditions, there is a different path between each node, the path parameters have been minimized screening, the rest of parameters shown in Table 3.
Table 3. Parameter setting.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service time per customer</td>
<td>0.2h</td>
</tr>
<tr>
<td>Time cost per unit vehicle</td>
<td>50Yuan/h</td>
</tr>
<tr>
<td>Unit fuel cost</td>
<td>7Yuan/kg</td>
</tr>
<tr>
<td>Unit vehicle use cost</td>
<td>150Yuan/vehicle</td>
</tr>
<tr>
<td>The standard speed of the vehicle</td>
<td>60km/h</td>
</tr>
<tr>
<td>Carbon trading price</td>
<td>2Yuan/kg</td>
</tr>
<tr>
<td>Carbon emission coefficient</td>
<td>3kg-co2/kg</td>
</tr>
<tr>
<td>Parameter</td>
<td>0.3</td>
</tr>
<tr>
<td>Parameter</td>
<td>$8 \times 10^{-5}$</td>
</tr>
<tr>
<td>Parameter</td>
<td>$2 \times 10^{-2}$</td>
</tr>
<tr>
<td>Assigned carbon emissions</td>
<td>160kg</td>
</tr>
</tbody>
</table>

Among them, the unit fuel cost is taken from the average annual 0# diesel fuel price in China and converted to 7 Yuan / kg, the carbon trading prices from China's carbon trading market, the carbon emissions factor is taken from the China Energy Network, the assigned carbon emissions is a single delivery task estimate.

3.3 Simulation Result

Based on the genetic algorithm, this paper uses MATLAB software to solve the function of this paper, which aims at the minimum cost of the total cost. Set the evolution algebra 1000, population size is 500, the crossover probability is 0.8, the probability of mutation is 0.1, and the operation is 50 times, we get the minimum total cost path corresponding to the example, as shown in Table 4 and Table 5.

Table 4. Path table.

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Optimal path</th>
<th>Distance (km)</th>
<th>Carbon emission (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-3-5-1-0</td>
<td>39</td>
<td>39.73</td>
</tr>
<tr>
<td>2</td>
<td>0-10-2-7-0</td>
<td>43</td>
<td>38.98</td>
</tr>
<tr>
<td>3</td>
<td>0-8-4-0</td>
<td>38</td>
<td>35.58</td>
</tr>
<tr>
<td>4</td>
<td>0-6-9-0</td>
<td>39</td>
<td>35.15</td>
</tr>
<tr>
<td>Total</td>
<td>159</td>
<td>149.44</td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Cost table(Yuan).

<table>
<thead>
<tr>
<th>Vehicle</th>
<th>Optimal path</th>
<th>Time cost</th>
<th>Fuel consumption cost</th>
<th>Use cost</th>
<th>Carbon transaction costs</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0-3-5-1-0</td>
<td>97.50</td>
<td>92.71</td>
<td>100.00</td>
<td>100.00</td>
<td>348.7</td>
</tr>
<tr>
<td>2</td>
<td>0-10-2-7-0</td>
<td>98.00</td>
<td>90.96</td>
<td>100.00</td>
<td>100.00</td>
<td>348.7</td>
</tr>
<tr>
<td>3</td>
<td>0-8-4-0</td>
<td>83.50</td>
<td>83.02</td>
<td>100.00</td>
<td>100.00</td>
<td>348.7</td>
</tr>
<tr>
<td>4</td>
<td>0-6-9-0</td>
<td>85.50</td>
<td>82.01</td>
<td>100.00</td>
<td>100.00</td>
<td>348.7</td>
</tr>
<tr>
<td>Total</td>
<td>364.50</td>
<td>348.7</td>
<td>400.00</td>
<td>1092.08</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

From tables 4 and 5 can be obtained in the numerical experiment, need 4 delivery vehicles to participate in the distribution of 10 distribution points. The total cost of the smallest path are 0-3-5-1-0; 0-10-2-7-0; 0-8-4-0; 0-6-9-0, the total distance of the distribution path is 159km, Carbon emissions of 149.44kg, the time cost of 149.44 Yuan, fuel consumption costs 348.7 Yuan, the vehicle cost of 300 Yuan, carbon trading costs of -21.12 Yuan, the total cost of 1092.08 Yuan.

4. Conclusion

Because of the diversity of urban logistics distribution path and the antinomies phenomenon prevalent in logistics activities, although the time cost, fuel consumption cost, operating cost and carbon transaction cost of the above distribution route are not necessarily the minimum, the overall cost of the four items, the distribution path 0-3-5-1-0; 0-10-2-7-0; 0-8-4-0; 0-6-9-0 in a number of distribution routes in the integrated cost of the least.

This paper is limited by the author's research level and the length of the thesis, there are still many directions for further research, for example, this calculation example using genetic algorithm to calculate the results, and has not been verified by other algorithms. The results can be compared with other algorithms in the future; and discuss the impact of carbon trading price fluctuations on the results of the study. The above questions can be used as the following research contents.
5. References


