Selection Of Multi-Distribution Center Location Based On Low Carbon

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Abstract

With the increasing of logistics activity, the influence of vehicle emissions for air quality is more and more serious. As the hub of logistics system, distribution center affects all aspects of the logistics vehicles directly. Such as vehicle number, road load, vehicle route and so on. As a result, Distribution center also plays a decisive role on carbon emissions. However, the traditional distribution center can rarely meet the needs of current low carbon society development, because they hardly consider energy conservation and emissions reduction when choose the location. Basing on the traditional distribution center location selection, this paper structures a location selection model of multiple distribution centers under the comprehensive consideration of low carbon, service optimization and cost saving. This paper also optimizes the distribution center location depending on economic cost minimization as the target, uses the improved genetic algorithm coding, and validates the feasibility and effectiveness by example verification model.

Keywords: low carbon; multi location selection; genetic algorithm.

1. INTRODUCTION

China, as the biggest developing country and world’s second largest economy, is the biggest carbon emitter in the world. The carbon emission in China presents the trend of big volume, high proportion and fast growth rate. According to the statistics issued in Global Carbon Project by BBC, the carbon emission of China exceeds the total of EU and America, reaching 10 billion tons and occupying 29% of Global carbon emissions (McGrath, 2014), while logistics activity is one the main contributor of carbon emission. Greenhouse gas emissions from transportation have increased by about 16% since 1990 (Ma et al., 2016). According to related researches by Chinese Academy of Sciences, the contribution rate of automobile exhaust to PM2.5 is 22.2% in Beijing (Fan, 2014), and this number may be even higher in Pearl River Delta and other coastal developed cities. With the development of logistics industry, the logistics activity has become more and more frequent and complicated, making it more and more difficult to mitigate the influence of carbon emission on air quality in the logistics activity. We should reverse the trend of the deterioration of environment from the source to make sure a favorable environment (Yao and Liao, 2016). From the perspective of government, we need to find out the balance point between ecological civilization construction and sustainable and steady economic growth; From the perspective of enterprise, we need to find out the balance point between sustainable development and cutting down operating costs with the improvement of carbon trading mechanism, making the carbon emission another big cost expenditure for enterprises. No matter from the macro and micro perspective, it is of great significance to take the factor of carbon emission into consideration when making decisions concerning logistics activity.
With the global warming and other environmental problems becoming severer and severer, environmental protection has drawn the attention of global community. The signing of Paris Agreement and the formulation of the 13th Five Year Plan of environmental protection also show that environmental protection has become the theme of the time, which is also one of the hot issues in the academic circle. The logistic activity is closely related to environmental protection and people have given more consideration to the environmental protection in related researches of logistics. The selection of multi-distribution center location is one the traditional but hot issue in logistics researches. CO$_2$-emitting companies should take their carbon capture, transportation and storage constrains into consideration in the selection of their new production sites (Yan and Charles, 2010); Measurement, evaluation and minimization of CO$_2$,NO$_x$, and CO emissions in the open time dependent vehicle routing problem, it can be applied to goods distribution in urban environments (Mansoureh and Mahdi, 2015); Facility location decisions play a critical role in strategic design of supply chain and hence have a long-term impact on its cost and environmental performance (Thiand Sun, 2016); In China, abundant researches have been done on distribution center location. However, these researches mostly focus on the improvement of method and general cost factor, lacking researches considering low carbon factor. Building distribution centers of different volume level for logistics enterprises under low carbon policy and logistics enterprises could achieve the balance between cost and environmental protection by reducing carbon emission (Yang and Lu, 2014); The optimization of network distribution under the background of low carbon and proved that the route arrangement considering low carbon was more economical and environmentally friendly (Zhang and Liu, 2015).

Although abundant researches have been done on low carbon logistics, still we can find some research space; This paper studies the selection of multi-distribution center location based on traditional distribution center location, sets up the objective function of the cost and adds the time function of the velocity and uncertain vehicle number to make the research closer to the actual conditions, and applies improved genetic algorithm to solve the multi-distribution center location at minimum total cost, genetic algorithm acquires its significance importance as it uses random search methods which are proved to be robust and capable of solving complicated search problems (Veni and Raju, 2016),finally, uses the example to verify the feasibility and effectiveness of the model and algorithm.

2. PROBLEM DESCRIPTION

Traditional researches on distribution center location simply consider minimum cost but neglects carbon emission. The objective function includes fixed cost, variable cost and distribution cost, and the distribution cost is the function of running route. The selection of multi-distribution center location based on low carbon is to add carbon emission into traditional distribution center location, it can be described that there exist several distribution sites within a region and several distribution centers are planned to be built in this region. The distribution adopts same type of vehicles; in the above-mentioned process, carbon emission is considered. The volume of carbon emission is associated with vehicle number, vehicle velocity, vehicle load and driving distance, etc. The objective function includes carbon emission cost, fuel cost, fixed cost of distribution center construction, variable cost of distribution center operation, and cost of service optimization and cost of vehicle purchase. Solve the objective function under the constraint condition and obtain the result of location optimization.

3.MODEL BUILDING

3.1 Fundamental assumption

The alternative points of distribution centers and the location of each distribution site are given. The volume of alternative distribution centers is limited and the quantity demanded by each distribution site is certain and given; all vehicles are of the same type and each
vehicle only belongs to one distribution center. All vehicles start from the distribution center for delivery to the distribution site and return to the distribution center. The cargo quantity of all distribution sites on each distribution route shall not exceed the upper limit of vehicle load; each distribution site is only served by one vehicle.

3.2 Correlation functional declaration

3.2.1 Estimation of vehicle number

The estimation of minimum vehicle number needed \( K_i \), can be obtained based on the sum of cargo volume of all distribution sites and the rated load of unit vehicle:

\[
K_i = \left[ \sum_{j=1}^{M} q_j / Q \right] + 1 \quad (1)
\]

[ ] represents to take the maximum integer no more than the numerical value in the bracket.

3.2.2 Formula of vehicle velocity

Based on the fitting results of fuzzy velocity membership function within urban areas, the membership distribution curve of fuzzy velocity within urban areas is presented as pseudo normal distribution (Cao et al., 2009). The vehicle velocity \( v \) at \( T \) moment is:

\[
v_T = \exp \left( - \left( \frac{\mu_T v - 1}{\sigma_T v} \right)^2 \right) \quad (2)
\]

\( \mu_T \) and \( \sigma_T \) are two parameters determining the shape of fuzzy velocity membership function at \( T \) moment.

3.2.3 Calculation formula of carbon emission

In logistics distribution activity, the carbon emission of vehicles is associated with vehicle type, vehicle load, velocity and driving distance. To make the research closer to the actual conditions on the basis of simplification, this paper selects three main factors influencing the carbon emission, which are driving distance, driving velocity and load. The carbon emission between \( I \) and \( j \) can be presented as the relationship between fuel consumption \( O_{ij} \) and fuel emissions factor \( f_e \) (Namseok et al., 2009):

\[
R_{ij} = O_{ij} \cdot f_e \quad (3)
\]

The fuel emissions factor \( f_e \) is the capacity of vehicles to convert fuel into carbon emission, which is connected with vehicle and fuel type. Combined with the current situation of logistics industry in our country, the logistics delivery vehicles mainly adopt the diesel engine, the value of \( f_e \) is taken 2.32kg/L (Ceo, 2005).

On the basis of previous researches, this paper conduct modification and optimization based on the concept that fuel consumption is only related to driving distance, this paper comprehensively considers the impact of driving distance, velocity and vehicle load, proposes the following fuel consumption formula (Demir et al., 2011):

\[\text{Fuel Consumption} = f_e \times \text{Driving Distance} \times \text{Velocity} \times \text{Vehicle Load} \]
\[ O_{ij} = [\alpha_{ij}(w_i + q_j) + \delta_{ij}^2]d_{ij} \quad (4) \]

\( \alpha_{ij} \) is the constant related to road traffic condition; \( w_i \) is the unloaded weight; \( q_j \) is the cargo weight of vehicles driving from \( i \) to \( j \); \( \delta \) is the constant related to vehicle rated power; \( v_{ij} \) the driving velocity of vehicles from \( i \) to \( j \); \( d_{ij} \) is the distance between \( i \) and \( j \).

Combined with (3) and (4), the carbon emission \( R_{ij} \) can be expressed as:

\[ R_{ij} = O_{ij} \cdot f_x = [\alpha_{ij}(w_i + q_j) + \delta_{ij}^2]d_{ij}f_x \quad (5) \]

### 3.2.4 Cost formula of service

As the hub of logistics system, it is of great significance to provide high quality service for the distribution center. Service efficiency and quality are important indexes measuring the service of distribution centers and directly reflected in whether customer requirements can be responded timely and quickly (Mansour, 2016). Therefore, to quantify service indexes, we convert the service into the function positively correlated with distance, as is shown in formula (6). \( S \) is the conversion coefficient of service.

\[ C_x = S\sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{dijk}d_{ij} \quad (6) \]

### 3.3 Location optimization model

This paper transforms the comprehensive problem of pursuing maximum economic benefit by enterprises and responding to the appeal of energy conservation and emission reduction into minimum cost problem, and proposes to take the comprehensive cost containing carbon emission cost and fuel cost, the fixed cost containing delivery center construction cost and maintenance cost, the variable cost related to the flow, service optimization cost and vehicle purchase cost and solves the optimal solution under the constraint condition.

Objective function:

\[ \text{Min} \left( C \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{dijk}R_{ij} + O \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{dijk}O_{ij} + \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{k=1}^{K} z_d f_x w_d^x + \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{k=1}^{K} z_d F_d + S \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{k=1}^{K} x_{dijk}d_{ij} + K \varphi \right) \quad (7) \]

Subject to:

\[ \sum_{d=1}^{N} \sum_{i=1}^{N+M} \sum_{k=1}^{K} x_{dijk} = 1, \forall i \in H \quad (8) \]

\[ \sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{dijk} = 1, \forall d \in D, i \in V \quad (9) \]

\[ \sum_{i=1}^{N+M} \sum_{k=1}^{K} x_{dijk} = 1, \forall d \in D, j \in V \quad (10) \]
\[
\sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{djk} = \sum_{j=1}^{N+M} \sum_{k=1}^{K} x_{djk} = 0, \forall d \in D, \forall i \in H
\] (11)

\[
\sum_{j=1}^{M} q_{dj} \leq c_d, d \in D
\] (12)

\[
\sum_{j=1}^{M} q_{j} \leq \sum_{d=1}^{N} \sum_{d} c_d
\] (13)

\[
\sum_{i=1}^{M} \sum_{j=1}^{M} q_{ij} x_{djk} \leq Q, \forall d \in D, \forall k \in K
\] (14)

\[
\sum_{j=1}^{M} q_{j} / Q \geq K_1
\] (15)

\[
\sum_{j=1}^{M} q_{j} / Q \leq K
\] (16)

\[
\sum_{d=1}^{N} z_d \leq P
\] (17)

\[
x_{djk} = [0, 1] , d \in D; i \in V; j \in V; k \in C
\] (18)

\[
z_d = [0, 1] , d \in D
\] (19)

Formula (7) is the objective function of distribution center location under the background of carbon emission, represents the minimum cost, including carbon emission cost, fuel cost, variable cost, fixed cost, service optimization cost and vehicle purchase cost. Formula (8) to formula (19) are constraint conditions and formula (8) represents each distribution site is visited and once only; formula (9) and formula (10) represent that vehicles start from the distribution center and return to the distribution center; formula (11) represents vehicles arrive at a certain node and leave from this node; formula (12) the capacity limitation of single alternative distribution center; formula (13) is the capacity limitation of distribution centers in the whole region; formula (14) is the load capacity of vehicles; formula (15) and formula (16) are the quantity limitation of distribution vehicles; formula (17) is the quantity limitation of distribution center location; formula (18) represents whether vehicles will pass \( i,j \) using 0 to 1 to rate. 0 means that vehicles will not pass \( i,j \) and 1 means that vehicles will pass \( i,j \); formula (19) represents whether the distribution center will be selected, using 0 to 1 to rate. 0 means that the alternative distribution center \( d \) will not be selected and 1 means that the alternative distribution center \( d \) will be selected. The Symbol description as shown in table 1.

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Connotation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( D )</td>
<td>Set of alternative distribution centers, ( D={1, 2, 3, \ldots, N} )</td>
</tr>
<tr>
<td>( H )</td>
<td>Set of distribution sites, ( H={N+1, N+2, \ldots, N+M} )</td>
</tr>
</tbody>
</table>
4. ALGORITHM DESIGN

Genetic algorithm is the calculation model of simulating the natural selection of biological evolutionism and the biological evolution process of genetic mechanism. This algorithm achieves the purpose of searching the optimal solution through simulating the gene selection and genetic mechanism in the natural evolution process. Experiments have shown that using the genetic algorithm for optimal route has a high efficiency and good convergence (Hu, 2016). Therefore, this paper adopts improved genetic algorithm to solve the multi-distribution center location problem based on carbon emission.

4.1 Coding strategy

Considering the characteristics of the selection of multi-distribution center location based on low carbon, the coding scheme in traditional coding simply aims to distribution site and driving route and thus cannot solve the problems in this paper effectively. Therefore, this paper modifies traditional genetic algorithm based on the characteristics of this model and the concrete frame of thought is as follow: there are \(N\) alternative distribution centers and \(M\) distribution sites. This paper conducts assignment for each distribution centers with consecutive natural number. The serial number \([1, N]\) represents every alternative distribution center and the chromosome with length of \(M\) containing number\([1, N]\) is randomly generated. The \([1, M]\) gene-bit represents each distribution site respectively. In this way, the value of every gene-bit on the chromosome is the distribution center selected by the distribution site represented by this gene-bit. For example, there are six alternative distribution centers and 16 distribution sites and the chromosome is randomly generated as follow:

<table>
<thead>
<tr>
<th>V</th>
<th>Set of alternative distribution centers and distribution sites, (V = {1, 2, ..., N+M})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>Set of vehicle number, (C = {1, 2, 3, ..., k})</td>
</tr>
<tr>
<td>(x_{dijk})</td>
<td>When the (d)th alternative distribution center is selected, whether the (k)th vehicle will pass (i, j)</td>
</tr>
<tr>
<td>(R_{ij})</td>
<td>Carbon emission when vehicles pass (i, j)</td>
</tr>
<tr>
<td>(C_e)</td>
<td>Unit carbon emission cost</td>
</tr>
<tr>
<td>(O_{ij})</td>
<td>Fuel consumption when vehicles pass (i, j)</td>
</tr>
<tr>
<td>(O_f)</td>
<td>Unit fuel consumption cost</td>
</tr>
<tr>
<td>(Z_d)</td>
<td>whether the distribution center will be selected</td>
</tr>
<tr>
<td>(v_d)</td>
<td>Variable cost coefficient</td>
</tr>
<tr>
<td>(w_d^\theta)</td>
<td>Variable cost of the (d)th alternative distribution center, which is the power function of the flow, (\theta \in (0,1))</td>
</tr>
<tr>
<td>(F_d)</td>
<td>Fixed cost of building the (d)th distribution center</td>
</tr>
<tr>
<td>(\varphi)</td>
<td>Unit volume vehicle purchase expense</td>
</tr>
<tr>
<td>(q_{dj})</td>
<td>Cargo quantity of the (d)th distribution center to the (j)th distributions site</td>
</tr>
<tr>
<td>(c_d)</td>
<td>Volume of the (d)th distribution center</td>
</tr>
<tr>
<td>(q_j)</td>
<td>Cargo quantity of the (j)th distribution site</td>
</tr>
<tr>
<td>(q_{ij})</td>
<td>Cargo quantity of vehicles from (I) to (j)</td>
</tr>
<tr>
<td>(Q)</td>
<td>Rated loading capacity of vehicles</td>
</tr>
<tr>
<td>(P)</td>
<td>Upper limit of distribution center location</td>
</tr>
</tbody>
</table>

\[\begin{array}{cccccccccccccccc}
1 & 2 & 3 & 4 & 5 & 6 & 7 & 8 & 9 & 10 & 11 & 12 & 13 & 14 & 15 & 16 \\
2 & 4 & 5 & 3 & 2 & 5 & 3 & 2 & 2 & 3 & 4 & 4 & 5 & 2 & 1 & 5 \\
\end{array}\]
Number 1, 2, 3, 4 and 5 alternative distribution centers on this chromosome are selected. And the alternative distribution center 1 is responsible for the distribution site 15; the alternative distribution center 2 is responsible for distribution site 1, 5, 8, 9 and 14; the alternative distribution center 3 is responsible for the distribution site 4, 11 and 12; the alternative distribution center 5 is responsible for the distribution site 3, 6, 13 and 16. This coding scheme can not only reflect which the alternative centers are selected from the chromosome, but also can let we know which distribution center is responsible for which distribution site. According to above-mentioned coding scheme of the chromosome, $N^m$ chromosome can be formed. In other words, the population size is $N^m$.

The driving route must be taken into consideration in terms of carbon emission, but the above-mentioned coding scheme of the chromosome cannot reflect the driving route of vehicles. Coupled with the uncertainty of vehicle number and load of each vehicle, it is impossible to complete the solution of the model with the help of the above-mentioned chromosome coding scheme. Therefore, we need to conduct another coding based on previous coding to solve the driving route of vehicles. The concrete method is as follow: for the $n$th distribution center selected, it is responsible for $i$ distribution sites, which are $m_1, m_2, ..., m_i$. Based on the practical situation of cargo at the distribution site, assume that the maximum vehicle number at the distribution site is $i$ and the sequence with the length of $2i-1$ is randomly generated. The sequence elements include $(m_1, m_2, ..., m_i, (i-1)0)$. The number 0 is taken as the splitting point. In other words, the delivery of the distribution site before 0 is completed by one vehicle and the delivery of the distribution site after 0 is completed by another vehicle. In this way, this code can represent the arrangement of route of one distribution center. For example, the second distribution center is responsible for distribution site 1, 5, 8, 9 and 14 and the sequence with length of nine is randomly generated as follow:

```
0 5 0 9 1 0 0 14 8
```

This sequence means that three vehicles participate in the distribution mission, which are:

Vehicle1: Distribution Center2 -Distribution Site5 -Distribution Center2

Vehicle2: Distribution Center2 -Distribution Site9 -Distribution Site1 -Distribution Center2

Vehicle3: Distribution Center2 -Distribution Site14 -Distribution Site8 -Distribution Center2

### 4.2 Fitness function

Fitness is the only basis of individual survival opportunity selection in the searching process of the optimal solution of genetic algorithm. To directly reflect the relationship between fitness function and degree of good or bad of species individual, the genetic algorithm sets the rule that the fitness is non-negative value and the higher value means that the individual is more likely to meet the demand. This paper seeks the minimum value of the objective function, and thus the fitness function $f(d,I,j,k)$ takes the reciprocal of the objective function.

### 4.3 Genetic operator

The genetic operator in the genetic algorithm include the selection operator, the crossover operator and the mutation operator, which are the core of strong searching capability of the genetic algorithm.
4.3.1 Selection operator

Calculate the fitness value of each chromosome to allow the chromosome with maximum fitness value to pass down to the next generation. Then, conduct the selection in the method of roulette to allow the chromosome with maximum fitness value in the parent species to pass down to the next generation. And the rest chromosomes conduct crossover based on crossover rate.

4.3.2 Crossover operator

Crossover operator is to simulate the process of genetic recombination in natural reproduction. This paper adopts one-point crossover and the crossover points are randomly generated; the crossover rate $P_c$ is a linear decreasing function, which facilitates the convergence in later period of algorithm.

4.3.3 Mutation operator

Mutation operation is in favor of the improvement of local searching capability. To add the diversity of solutions, new chromosomes are randomly generated based on mutation rate $P_m$ for chromosomes satisfying mutation condition. The method of new chromosome generation is to replace the selected distribution centers with other distribution centers. Then accelerate the solution obtained to make convergence to the optimal solution.

4.4 Process of constraint violation

Because there are many constraint conditions, the non-feasible solutions in species formed by the adopted coding scheme holds high proportion. Therefore, we need to introduce punishment mechanism. For the non-feasible solutions breaching the constraint, the fitness function corresponding to this non-feasible solution will be set as infinitesimal and thus achieve the purpose of elimination this non-feasible solution.

5. EXAMPLE ANALYSIS

To verify the validity and effectiveness of the model and the algorithm, this paper adopts the following to conduct verification.

5.1 Known conditions

A large logistics company named DB has 16 distribution sites in A city and now plans to build several distribution centers. There are 6 alternative distribution centers and the position relationship between each distribution site and alternative distribution center is shown in Figure 1; the cargo volume of each distribution site and alternative distribution center is shown in Table 2; the fixed cost, variable cost coefficient and capacity limitation of each alternative distribution center are shown in Table 3. The variable cost of each alternative distribution site is related to the flow, which can be expressed as $v_d w_d$. $v_d$ is the variable cost coefficient; $w_d$ is the flow of the $d$th distribution center; $w_d = \sum_{j=1}^{M} x_{dj}, d \in D$. The variable cost of the distribution center conforms to the law of diminishing marginal cost. The index $\theta$ is taken as $\frac{1}{2}$ (Wu and Shi, 2004); and the value of other parameters is shown in Table 4.
Figure 1. Relationship between position and distance of each point.

Table 2 Cargo volume of each distribution site

<table>
<thead>
<tr>
<th>Distribution</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>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cargo volume (ton)</td>
<td>14</td>
<td>10</td>
<td>25</td>
<td>11</td>
<td>10</td>
<td>25</td>
<td>13</td>
<td>8</td>
<td>12</td>
<td>7</td>
<td>11</td>
<td>10</td>
<td>24</td>
<td>13</td>
<td>23</td>
<td>25</td>
</tr>
</tbody>
</table>

Table 3 Fixed cost and capacity limitation of each alternative distribution center

<table>
<thead>
<tr>
<th>Alternative distribution center</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed cost (ten thousand yuan)</td>
<td>40</td>
<td>55</td>
<td>30</td>
<td>60</td>
<td>35</td>
<td>30</td>
</tr>
<tr>
<td>Variable cost coefficient $v_i$</td>
<td>65</td>
<td>70</td>
<td>65</td>
<td>75</td>
<td>70</td>
<td>65</td>
</tr>
<tr>
<td>Capacity (ton)</td>
<td>80</td>
<td>80</td>
<td>60</td>
<td>100</td>
<td>80</td>
<td>60</td>
</tr>
</tbody>
</table>
Table 4 Parameter value

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Connotation (unit)</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_e$</td>
<td>Per unit carbon emission cost (Yuan/ton)</td>
<td>27.15</td>
</tr>
<tr>
<td>$O_c$</td>
<td>Per unit fuel consumption cost(Yuan/L)</td>
<td>6</td>
</tr>
<tr>
<td>$\alpha_{ij}$</td>
<td>Constant related to traffic situation</td>
<td>0.02</td>
</tr>
<tr>
<td>$\delta$</td>
<td>Constant related to vehicle power</td>
<td>3.4</td>
</tr>
<tr>
<td>$w_k$</td>
<td>Unloaded weight (6.8m van) (ton)</td>
<td>5</td>
</tr>
<tr>
<td>$f_e$</td>
<td>Conversion factor of fuel (kg/L)</td>
<td>2.32</td>
</tr>
<tr>
<td>$Q$</td>
<td>Vehicle rated loading capacity (ton)</td>
<td>25</td>
</tr>
<tr>
<td>$\varphi$</td>
<td>Per unit vehicle purchase expense (ten thousand yuan)</td>
<td>20</td>
</tr>
</tbody>
</table>

To simplify the time-varying velocity change during the distribution process, the velocity of typical sections from 6:00 to 20:00 is fitted out based on formula (2) and related research results, as is shown in Figure 2; the longest stay time at the distribution site of each vehicle is 2 hours.

![Velocity fitting results of each period from 6:00 to 20:00.](image)

**Figure 2.** Velocity fitting results of each period from 6:00 to 20:00.

5.2 Operation results

Set the initial population scale as 500 and the evolutionary generation as 500. Crossover rate $P_r$ is a linear decreasing function. $P_r=-0.001X+0.9$ and the mutation rate is 0.1. After 100 operations, the optimal results are shown as follow.

Table 5 Operation results 1

<table>
<thead>
<tr>
<th>Distribution center</th>
<th>Vehicle number</th>
<th>Arrangement of route</th>
<th>Volume of carbon emission (g)</th>
<th>Cost (Yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>① - 1 - 2 - ①</td>
<td>145,000</td>
<td>1,004,692</td>
</tr>
<tr>
<td></td>
<td></td>
<td>① - 6 - ①</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>① - 4 - 7 - ①</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 6 Operation results 2

<table>
<thead>
<tr>
<th>Distribution center</th>
<th>Vehicle number</th>
<th>Arrangement of route</th>
<th>Volume of carbon emission (g)</th>
<th>Cost (Yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
<td>③ - 3 - ③</td>
<td>75,586</td>
<td>702,754</td>
</tr>
<tr>
<td></td>
<td></td>
<td>③ - 5 - 10 - 8 - ③</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 7 Operation results 3

<table>
<thead>
<tr>
<th>Distribution center</th>
<th>Vehicle number</th>
<th>Arrangement of route</th>
<th>Volume of carbon emission (g)</th>
<th>Cost (Yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>3</td>
<td>⑤ - 9 - 11 - ⑤</td>
<td>125,698</td>
<td>954,402</td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑤ - 13 - ⑤</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑤ - 15 - ⑤</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 8 Operation results 4

<table>
<thead>
<tr>
<th>Distribution center</th>
<th>Vehicle number</th>
<th>Arrangement of route</th>
<th>Volume of carbon emission (g)</th>
<th>Cost (Yuan)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>2</td>
<td>⑥ - 14 - 12 - ⑥</td>
<td>48,302</td>
<td>701,920</td>
</tr>
<tr>
<td></td>
<td></td>
<td>⑥ - 16 - ⑥</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The operation results are shown in Table 5 to Table 8. Four distribution centers are planned to be built, which is 1, 3, 5 and 6. Altogether 10 vehicles will carry out the distribution mission to 16 distribution sites. The total investment is 3,364,038 Yuan and the total volume of carbon emission in a single day is 394,586 g.

6. CONCLUSION

The selection of multi-distribution center location based on low carbon is of great significance for the energy conservation and emission reduction in the logistics industry. This paper considers the carbon emission on the basis of traditional distribution center location. Under the background of uncertain distribution center location and number and uncertain vehicle number, this paper establishes the multi object mathematical model of cost optimization and service optimization containing carbon emission cost, fuel consumption cost, and distribution center construction fixed cost and operation variable cost, service cost and vehicle purchase cost. This paper seeks solution to the model through improved genetic algorithm and verifies the feasibility and effectiveness of the model and the algorithm.

Under the trend of energy conservation and emission reduction and constructing environment-friendly society, this model and algorithm design can provide theoretical foundation for the distribution center location, vehicle scheduling and route arrangement of logistics enterprises. This paper provides decision support for related government departments in improving the carbon trading mechanism to lead enterprises to optimize organizational behavior.

7. REFERENCES


Li Z.H. (2012). Research on the transportation decision-making in A Co. Ltd based on carbon emission reduction, Beijing JiaoTong University, China.


