Abstract
With the minimum total fees of logistics center site selection as the target value, this paper analyzes key factors influencing the logistics distribution system, and builds the logistics distribution center site selection model. The particle swarm domain mean value method is introduced to overcome defects of the standard particle swarm optimization (PSO) algorithm in mutation operation, and improve the searching capability of the standard PSO algorithm. At last, different types of PSO algorithms are adopted to conduct simulation solution of the logistics center site selection model, respectively. Results suggest that the minimum total fees obtained by the PSO algorithm after the domain mean value optimization are lower than those obtained by other PSO algorithms by 3.5%. Besides, the model can achieve an optimal value through faster and more stable iteration. Besides, when the number of logistics demand points is huge, the model can still maintain its sound searching capability. Therefore, the PSO algorithm based on the domain field mean value optimization method can more efficiently solve problems facing the site selection of large-scale logistics distribution centers.

Key words: Logistics Distribution, Center Site Selection, Particle Swarm, Domain Mean Value, Simulation Solution

1. INTRODUCTION
Modern logistics is a direct and efficient way to expand competition advantages (Xiao and Ma, 2014). It can provide continuous driving force for sustainable development of the national economy. It is also an efficient way to increase enterprises’ competitiveness. With the deepening of economic globalization, logistics has exerted an increasing influence on enterprises. Since logistics centers are an important link and axis center of the whole logistics system, their site selection strategies are at the core of the logistics network system analysis. They usually decide the distribution mechanism and model of the whole logistics system. Therefore, how to reasonably choose the logistics distribution center and reach the optimal supply and demand balance to improve the operation efficiency of the whole logistics system is a research issue of both theoretical and practical significance.

Distribution centers receive the order information from users, sort out, process and assemble goods according to users’ requirements, and arrange delivery of these goods (Bian and Huang, 2013). As a terminal logistics facility, the distribution center functions to rationalize the good distribution and delivery process to achieve efficient allocation of resources. During the distribution process, it is based on optimization of labor distribution, so it is a comprehensive preparation process. Goods are generally transferred from manufacturers to wholesale or retail points, and then sold to consumers. During the process, goods are stored, classified and transferred through the distribution centers. Therefore, distribution centers are a core link connecting the manufacturers and retail points or consumers.

However, though many scholars have studied the logistics distribution center site selection and put forward corresponding solution models, the optimum-seeking results are not ideal and the error will increase when the scale of the problem to be solved is huge (Wu and Peng, 2014; Attaur Rahman, 2013; Yu and Zou, 2015; Lan, Peng and Chen, 2015). Concerning defects facing the solution of the logistics distribution center site selection model, this paper optimizes the standard PSO through the domain mean value. By doing so, the author attempts to overcome defects of the standard PSO algorithm, which is prone to be sunken in the partial optimal solution and is poor in searching. The idea of solving the logistics distribution center site selection based on the domain mean value optimization is put forward to further optimize the solution results of the logistics distribution center site selection model.

2. LOGISTICS DISTRIBUTION CENTER SITE SELECTION MODEL
In the logistics network system, the demand quantity of different demand points must be smaller than or equivalent to the scale capacity of the distribution center. Under the condition of meeting the distance restriction, it is necessary to seek the distribution center from the known demand points, and distribute corresponding goods to various demand points (Wang and Li, 2013). During the establishment process of the
whole logistics network, the ultimate goal is to minimize the total fees of logistics distribution. Therefore, this paper takes factors, including the fixed construction fees, the management fees and the maximum inventory capacity into consideration. The logistics distribution center site selection model thus obtained is shown in Eq. 1 below:

\[
\min T = \sum_{j=1}^{M} (h_j C_j) + \sum_{i=1}^{N} \sum_{j=1}^{M} (g_j W_{ij}) + \sum_{i=1}^{N} \sum_{j=1}^{M} (W_{ij} d_{ij} Z_{ij})
\]

\[
\sum_{j=1}^{M} W_{ij} \leq B_i, i = 1, 2, \ldots, N
\]

\[
\sum_{j=1}^{M} Z_{ij} = 1, i = 1, 2, \ldots, N
\]

\[
s.t. Z_{ij} \leq h_j, i = 1, 2, \ldots, N
\]

\[
\sum_{j=1}^{M} h_j = p
\]

\[
d_{ij} \leq l, i \in M, j \in N
\]

\[
h_j \in [0,1], Z_{ij} \in [0,1]
\]

Where, \( N \) stands for the serial number set of all demand points; \( M \) stands for the demand point set of distribution centers; \( C_j \) stands for the construction fees of distribution centers; \( h_j \) means that point \( j \) is selected as the distribution center; \( g_j \) stands for the unit management fees for the goods transfer of the distribution center; \( W_{ij} \) stands for the demand quantity of the demand point, \( i \); \( d_{ij} \) stands for the distance from the demand point, \( i \), to the nearest distribution center, \( j \); \( Z_{ij} \) means that the demand quantity of point \( i \) is supplied by the distribution center, \( j \); \( l \) stands for the upper distance limit from the demand point to the distribution center; \( \sum_{j=1}^{M} W_{ij} \leq B_i \) means that the demand quantity of the demand point is smaller than or equivalent to the scale capacity of the distribution center; \( \sum_{j=1}^{M} Z_{ij} = 1 \) means that every demand point is served by its nearest distribution center; \( Z_{ij} \leq h_j \) means that there are no customers in places without distribution centers; \( \sum_{j=1}^{M} h_j = p \) means that there are \( p \) demand points are selected as distribution centers; \( d_{ij} \leq l \) means that the distribution center just supply the nearby demand points within the fixed scope.

3. DISTRIBUTION CENTER SITE SELECTION BASED ON THE OPTIMIZED PSO MODEL

3.1 Standard PSO algorithm

The PSO algorithm (Zhao W Q., 2014; Liu R, Ma C, Ma W., 2013) is an optimized heuristic calculation model. In terms of a PSO algorithm with set objective function, its solution and iteration process assumes that there is a particle swarm containing \( M \) particles, and that the searching space dimensionality of the particle swarm is \( D \). The state attribute value of the particle, \( i \), is shown in Eq. 2~Eq. 5 at the \( t \) calculation:

Position status:

\[
X_i^t = (X_{ix}^t, X_{i2}^t, X_{i3}^t, \ldots, X_{im}^t)^T
\]

\[
X_{in} \in [X_{mm}, X_{max}]
\]

Velocity status:

\[
V_i^t = (V_{ix}^t, V_{i2}^t, V_{i3}^t, \ldots, V_{im}^t)^T
\]

\[
V_{in} \in [V_{min}, V_{max}]
\]

Where, \( X_{in} \) stands for the lower limit of the coordinate position; \( X_{max} \) for the upper limit of the coordinate position.

Velocity status:

\[
P_i^t = (P_{ix}^t, P_{i2}^t, P_{i3}^t, \ldots, P_{im}^t)^T
\]

Global optimum position:
\[ P' = (P'_1, P'_2, P'_3, \ldots, P'_d) \]  

(5)

All the above is the status attribute value of the particle at the t moment; while the status property of the particle at the “t+1” moment can be updated and iterated through Eq. 6:

\[
\begin{align*}
V_{id}^{t+1} &= wV_{id}^t + c_1r_1(P'_{id} - X_{id}^t) + c_2r_2(P_{id}^t - X_{id}^t) \\
X_{id}^{t+1} &= X_{id}^t + V_{id}^{t+1}
\end{align*}
\]

(6)

Where, \( w \) stands for the inertia weight value of the PSO algorithm; \( c_1, c_2 \) for the acceleration constants of the PSO algorithm; \( r_1, r_2 \) for the random variables and obey the even distribution within the region (0, 1)

Based on the above standard PSO, it can be seen that, during the iteration process, \( w \) stands for the inertial weight value of the PSO algorithm. The higher the weight value is, the stronger the global searching capability is. When the weight value is relatively small, it has a relatively strong local searching capability. Therefore, in the standard PSO algorithm, \( w \) is set at a fixed value, and its algorithm convergence is relatively poor, which might fail to get the optimal solution. Therefore, in order to improve the convergence of the standard PSO algorithm and endow the algorithm with a good global searching capability in the early operation period and a good local searching capability in the latter operation period, \( w \) gradually changes with the model’s iteration number. The iteration equation of \( w \) is shown in Eq. 7:

\[ w(t) = w_1 + (w_2 - w_1) \frac{T - t}{T} \]

(7)

Where, \( w_1 \) stands for the initial inertial weight value; \( w_2 \) for the inertial weight value at the beginning and the end; \( T \) for the maximum iteration number.

Besides, from the standard PSO, it can be seen that, when \( c_1, c_2 \) are relatively small, the particle can partially adjusted within the optimal target region; when \( c_1, c_2 \) are relatively large, particles far away can move quickly to the target region. Therefore, proper adjustment of the value of \( c_1, c_2 \) can help the model stay close to the optimal value more easily. The iteration equation for the acceleration constants, \( c_1, c_2 \), is shown in Eq. 8:

\[
\begin{align*}
c_1(t) &= c_{1i} + (c_{1f} - c_{1i}) \frac{t}{T} \\
c_2(t) &= c_{2i} + (c_{2f} - c_{2i}) \frac{t}{T}
\end{align*}
\]

(8)

Where, \( c_{1i} \) and \( c_{2i} \) are initial acceleration constants; \( c_{1f} \) and \( c_{2f} \) are final acceleration constants; \( t \) is the iteration number; and \( T \) is the maximum iteration number.

To sum up, the PSO velocity and position update equation based on the linear declination of the velocity iteration is shown below: (See Eq. 9)

\[
\begin{align*}
V_{id}^{t+1} &= wV_{id}^t + c_1(t)(P'_{id} - X_{id}^t) + c_2(t)(P_{id}^t - X_{id}^t) \\
X_{id}^{t+1} &= X_{id}^t + V_{id}^{t+1}
\end{align*}
\]

(9)

From the standard PSO, it can be seen that all particles stay close to the optimal position, \( P'_x \). When the optimal position becomes a local optimal point, the standard PSO cannot re-search in the solution space and becomes trapped in the local optimal solution. Therefore, it is necessary to conduct variation operation of the global optimal position, \( P'_x \), change the forward direction of parameters during the iteration process, and enter the other regions to keep on searching for the global optimal solution. Certain dimension is randomly chosen for the variation operation. The variation probability, \( p \), is shown in Eq. 10 below:

\[ p = \begin{cases} 
  k & \sigma^2 < \sigma_d^2 f(P'_x) > f_d \\
  0 & \text{otherwise}
\end{cases} \]

(10)

Where, \( k \) is a random value within the section of \([0.1, 0.3] \); \( \sigma^2 \) for the group fitness variance; \( f_d \) for the optimal target solution. The particle’s position variation is shown in Fig. 15 below, where \( \eta \) is a random variable within the section of gauss (0,1).
3.2. The PSO algorithm based on the domain mean value optimization

In the above PSO algorithm, though the particle variation operation is introduced to balance the error caused by the individual optimal value and the swarm optimal value, the variation operation also has some defects. For example, after the particle after the variation operation seriously deviates from the swarm, the content added into the speed update equation cannot optimize the particle speed. On the contrary, it will destroy the correct flying path of the particle swarm. Besides, every variation operation is random. Therefore, the solution results are not stable enough to meet the high-precision model calculation requirements. Therefore, this paper introduces the particle domain mean value to overcome defects caused by the mutation operation. The domain mean value method is shown below:

When the individual optimal value of the particle, i, in the t iteration is the individual is \( P_{id}(t) \), and the global optimal value of all particles is \( P_{gd}(t) \), the domain radius of the particle is R (See Eq. 12 below):

\[
R = \left\| P_{id}(t) - P_{gd}(t) \right\| = \sqrt{\sum_{i=1}^{D} \left( P_{id}(t) - P_{gd}(t) \right)^2 } 
\]

Where, D stands for the number of space dimensions of the PSO:

It can be assumed that, when \( N_i \) stands for the number of all neighboring particles of the particle, i, within the domain radius, R, it means that "\( N_i + 1 \)" included in the particle, i, can be expressed as \( \{ P_1, P_2, ..., P_{N_i+1} \} \), and the domain means value of the particle, i, is shown in Eq. 13 below:

\[
T_{ui}(t) = \frac{1}{N_i + 1} \sum_{i=1}^{N_i+1} P_{ui} 
\]

Through the introduction of the above domain radius, the speed and position update formula of PSO is shown in Eq. 14 below:

\[
V_{id}^{t+1} = wV_{id} + c_1r_1(P_{id} - X_{id}) + c_2r_2(P_{gd} - X_{id}) + c_3r_3(T_{ui} - X_{id}) \\
X_{id}^{t+1} = X_{id} + V_{id}^{t+1} 
\]

3.3. Solution steps for the logistics distribution center site selection

Below are steps to solve the logistics distribution center site selection model:

Step 1: Initialize the PSO and relevant PSO model parameters, including the PSO scale, the particle initial position, the particle speed, the inertia weight, w, the accelerator factors, c1, c2 and c3, and the maximum iterations;

Step 2: Calculate the fitness of all particles, certify the individual optimal value and the swarm optimal value, and use Eq. 12 and 13 to calculate the domain radius and the domain mean value;

Step 3: Update the speed and position of all particles through Eq. 14, and update the individual optimal value, the swarm optimal value and the domain mean value of all particles;

Step 4: Judge whether the maximum iterations meet the condition to end the optimum-seeking process. If such conditions are met, the optimal results are output. If not, return to Step 2.

4. MODEL SIMULATION AND RESULTS

How to verify the feasibility and validity of the algorithm put forward in this paper to solve logistics distribution center site selection, this paper adopts 30 simulation coordinates and the corresponding goods demand quantity as the research object. The coordinate of the 30 cities and the corresponding goods demand quantity are shown in Table 1 below:

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Coordinate</th>
<th>Demand quantity</th>
<th>Serial number</th>
<th>Coordinate</th>
<th>Demand quantity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>(1304,2312)</td>
<td>20</td>
<td>16</td>
<td>(3715,1678)</td>
<td>80</td>
</tr>
<tr>
<td>2</td>
<td>(3639,1315)</td>
<td>90</td>
<td>17</td>
<td>(3918,2179)</td>
<td>90</td>
</tr>
<tr>
<td>3</td>
<td>(4177,2244)</td>
<td>90</td>
<td>18</td>
<td>(4061,2370)</td>
<td>70</td>
</tr>
<tr>
<td>4</td>
<td>(3712,1399)</td>
<td>60</td>
<td>19</td>
<td>(3780,2212)</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>(3488,1535)</td>
<td>70</td>
<td>20</td>
<td>(3676,2578)</td>
<td>50</td>
</tr>
<tr>
<td>6</td>
<td>(3326,1556)</td>
<td>70</td>
<td>21</td>
<td>(4029,2838)</td>
<td>50</td>
</tr>
</tbody>
</table>
In order to reflect differences of optimized PSO algorithm and the ordinary PSO algorithms, several models are adopted during the simulation process for the simulation calculation. The simulation parameters of various models are shown in Table 2 below:

<table>
<thead>
<tr>
<th></th>
<th>Standard PSO</th>
<th>Speed update+self-adaptive mutation</th>
<th>Domain mean+speed update+self-adaptive mutation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initial inertial weight, $w_i$</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Final inertia weight, $w_f$</td>
<td>1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Initial acceleration constant, $c_{1i}$ and $c_{2i}$</td>
<td>1, 1</td>
<td>1, 1</td>
<td>1, 1</td>
</tr>
<tr>
<td>Final acceleration constant, $c_{1f}$ and $c_{2f}$</td>
<td>1, 1</td>
<td>2.5, 2.5</td>
<td>2.5, 2.5</td>
</tr>
<tr>
<td>$c_3$</td>
<td>--</td>
<td>--</td>
<td>1.5</td>
</tr>
<tr>
<td>Maximum iterations</td>
<td>200</td>
<td>200</td>
<td>200</td>
</tr>
<tr>
<td>Mutation probability, $k$</td>
<td>0</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>Particle scale</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
</tbody>
</table>

Conduct simulation calculation of model simulation parameters in Table 2, respectively. The curve iteration process of the optimal fitness and the average fitness of various models is shown in Fig. 1 below. The site selection and the distribution results of various logistics distribution centers are shown in Fig. 2 below, and the detailed convergence results of various models are shown in Table 3 below:

**Figure 1.** Model iteration fitness variation value (Fig. a stands for the standard PSO algorithm; Fig. b stands for “the speed variation update+the self-adaptive mutation”; Fig. c stands for the “the domain mean value+the speed update+the self-adaptive mutation”)}
The standard PSO algorithm is adopted for detailed induction. In order to overcome its shortcomings, this paper overcomes defects of the standard PSO algorithm, this paper overcomes defects of the standard PSO algorithm in terms of mutation operation through the introduction of the domain mean value optimization method. In this way, the searching capability of the standard PSO algorithm can be greatly improved. At last, different types of the PSO algorithms are adopted to solve the logistics distribution center site selection model. Results suggest that the PSO model based on the domain mean value optimization is superior to the other PSO algorithms. According to simulation analysis results of this paper, the minimum target fees are reduced by 3.5%. Besides, the algorithm can achieve the optimal value faster and more stably in terms of the iteration speed. Therefore, the PSO model based on the domain mean value optimization has a better optimum-seeking capability.

### CONCLUSIONS

This paper first introduces key factors influencing the logistics distribution center site selection. The total fees for site selection of logistics centers are adopted as the target value to build the logistics distribution center site selection model. The standard PSO algorithm is adopted for detailed induction. In order to overcome shortages of the standard PSO algorithm, this paper overcomes defects of the standard PSO algorithm in terms of mutation operation through the introduction of the domain mean value optimization method. In this way, the searching capability of the standard PSO algorithm can be greatly improved. At last, different types of the PSO algorithms are adopted to solve the logistics distribution center site selection model. Results suggest that the PSO model based on the domain mean value optimization is superior to the other PSO algorithms. According to simulation analysis results of this paper, the minimum target fees are reduced by 3.5%. Besides, the algorithm can achieve the optimal value faster and more stably in terms of the iteration speed. Therefore, the PSO model based on the domain mean value optimization has a better optimum-seeking capability.
REFERENCES


