Optimization Model of Storage Location Based on Minimum Logistics

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Abstract
The development of logistics is entering the stage of supply chain management. The warehouse, which was originally embodied with a simple "warehouse" function in the logistics chain, is evolving to a multifunctional logistics center. In the past, traditional warehouse management functions lacked dynamic management, and were often static warehouse management, with slow storage efficiency and lagging response speed. This article optimizes the overall warehouse logistics as the goal, selects the optimization model, through the research and analysis of the model, seeks a more suitable algorithm to solve and analyze it using MATLAB software.

Keywords
Storage space management; Storage space allocation; Three-dimensional warehouse; Total logistics.

1. Introduction
With the rapid development of economic globalization, e-commerce in China is also constantly following up. In today's society, the logistics industry is closely related to our lives, and the logistics industry plays an increasingly prominent role in my country's economic development. The warehousing function is one of the core business of logistics. Warehousing is well connected with all functional links of logistics, but simple storage and storage is difficult to meet the management requirements of modern warehousing systems. The cost of warehousing is valued by many managers. The optimization of cargo location should start from key factors, comprehensively consider factors such as market demand changes and warehousing equipment capabilities, reasonably allocate cargo locations, reduce storage and logistics costs, and reduce the possibility of accidental loss of goods due to handling [1].

Since the beginning of the 21st century, China's logistics industry has been developing vigorously, so the optimization of storage centers in my country has been more cherished. According to the characteristics of typical shipbuilding enterprises such as large amount of work in and out of warehouses, many types of products, and large differences in volume, Wenxian Tang proposed an automated three-dimensional warehouse partition storage strategy, and carried out research on cargo location optimization with multi-lane racks as the object [2]. Jiansheng Liu took the highest efficiency of goods in and out of the warehouse and the lowest center of gravity of goods as the optimization goals, and established a multi-objective optimization model of cargo location allocation, and adopted the genetic algorithm (GA) of the adaptive strategy and the particle swarm optimization (PSO) to solve the problem [3]. Aimin Deng constructed a time-based optimization of the three factors of taking medicine as an example, considering that the relevant data before and after the movement of goods in the automated three-dimensional warehouse can be effectively recorded, and the efficiency of goods in and out of the warehouse is high, similar goods are placed together, and the shortest
distance of goods movement. Multi-objective model [4]. Nava Pliskin and Eben-Chaime studied the operation management of complex mechanical automation systems, and concluded that the most reasonable path of warehousing operations is to improve the actual efficiency of warehousing operations [5]. Charles J Malmborg puts forward a method based on the Poisson distribution principle for the sorting of the storage and retrieval queues of goods, which relieves the pressure on the storage of goods in the entire warehouse and improves the storage and retrieval efficiency of goods [6]. Thonemann and Brandeau proposed the application of turnover rate and classification method for location allocation in a random environment, which can reasonably allocate existing shelves and goods according to the actual situation of the company’s storage [7]. When Gang Yu et al. studied the automated storage system, they classified the goods according to the frequency of the goods in and out of the warehouse, and on this basis, implemented the divisional storage of the goods [8]. Qian Feng builds a related mathematical model based on the analysis of the relationship between the number of times the warehoused goods enter and exits the warehouse and the variety of goods, and uses the genetic algorithm to calculate and solve it [9]. Shuo Chen and Lilin Lin experimented with simulation software, and the results showed that in the case of upgrading the existing shelf facilities, adopting a suitable shelf space allocation strategy can effectively improve the efficiency of storage operations [10]. The reasonable layout and distribution of warehouse space can effectively improve the efficiency of warehoused goods in and out of the warehouse, reduce the consumption of the operation process, reduce the number and cost of goods handling, and improve the efficiency of the entire logistics system [11].

In the process of studying the problem of storage location optimization, many outstanding domestic and foreign scholars have given different optimization methods. When optimizing the cargo location, it is generally improved from the following two aspects: one is to improve the warehouse in and out operations, and the other is to optimize the warehouse space and increase the inventory turnover rate. For the different optimization objects selected, the methods used are also different. The optimization of cargo location generally starts with quantitative analysis and qualitative analysis. Qualitative analysis methods are biased towards theoretical research, and cargo locations are allocated based on experience and visual inspection. When quantitative analysis is adopted, it is more inclined to the application of algorithms, and a mathematical model is constructed based on the large amount of data collected for planning and solving. Combining the opinions of domestic and foreign experts and scholars, a mathematical model is established and solved, the results are obtained, and corresponding optimization schemes are proposed.

![Figure 1 Warehousing space distribution](image_url)
2. Model Establishment

2.1. Layout Structure
Before optimizing the location of the company’s warehouse, we first express and explain some data in the warehouse storage area. Assume that there are a total of M rows of shelves in the storage area of the warehouse, and each row has storage positions in the C-layer and D-row. The length, width, and height of the grid of each storage area are a, b, and h respectively, the total volume of the storage area is a*b*h, and the distance between the shelf and the shelf (i.e., the width of the lane) is L. The distance from each storage area grid to the outbound place is S, the frequency of sorting goods is N, and the distance from the first row, 1st, and 1st floor to the outbound place is S0. The floor plan is shown in Figure 1.

2.2. Parameter Description
- X: Represents the xth row of shelves
- Y: Represents the yth column shelf
- Z: Represents the z-th shelf
- $S_0$: Indicates the distance from the first floor of the first row of the first row to the warehouse
- S: Indicates the distance from any cargo space grid in the storage space area to the warehouse
- L: Indicates the distance between each row of shelves in the warehouse
- a: Indicates the length of the storage shelf grid
- d: Indicates the width of the storage shelf grid
- h: Indicates the height of the storage shelf grid
- T: Indicates total logistics
- $N_i$: Indicates the number of picks for the goods with the goods code i
- $S_j$: Indicates the number of picks on the goods position in the M row, R column and P layer
- $c_{ij}$: When it is 1, it means that the goods category i is stored on the cargo location grid j, otherwise it is 0.

The length and height mentioned above are all in meters.

2.3. Warehousing Location Optimization Model
The goal of this article for the construction of the model is to minimize the overall logistics volume of the warehouse. Here, the value of the overall logistics volume T is set as the number N of the picking frequency at the location area and the storage staff from the location area to the delivery of the goods. The product of the distance S of the goods out, namely $T=N*S$. Then the number of picks N at the storage area is a known quantity, which can be obtained from the past data, and the distance between the staff from the storage area and the warehouse can also be obtained by measurement. The distance can be represented by L. In this study, the entire warehouse area can be approximated as a three-dimensional rectangular coordinate system with the origin of the warehouse, and the rows, columns, and layers of the shelves are used as the X, Y, and Z axes to introduce the coordinates (X,Y,Z) indicate that the shelves and the shelves are unobstructed, without any obstructions, and the second row can go directly to the warehouse without passing through the first row and so on. The distance from the shelf grid of the first row of the first row of the first row to the outbound place is S0, and the distance from row X (X=2,3..M) to the first row is equal to the distance between the laneway L and the storage. The product of the number of workers passing through the lanes, the distance from row 1 of row X (X=1,2..M) to the outbound place can be expressed as:

$$\sqrt{S_0^2 + [(X - 1)*L]^2} \quad X=1.2.3..M$$

(1)
Then find the distance from the Yth (Y=1,..R) column to the first column in each row. With a geometric relationship, we can easily get that the distance value is the length \(a\) of the cargo area grid and the distance passed. The product of the number of storage grids can be expressed as:

\[
a(Y-1)
\]  

(2)

There are a total of \(P\) layers in the storage area of the warehouse. The distance to get the goods from the \(Z\)th (\(Z=1,..P\)) layer to the first layer is the height \(h\) of each shelf grid and the passing distance. The product of the number of grids can be expressed as:

\[
h(Z-1)
\]  

(3)

Therefore, from equations (1), (2), and (3), it can be concluded that the distance \(S\) from any one of the storage areas of the warehouse to the outgoing place can be expressed as:

\[
S = \sqrt{S_0^2 + [(X_1)^2]} + a(Y-1) + h(Z-1)
\]  

(4)

2.4. Optimize the Objective Function of the Model

The various variables in the storage have been defined above, then we can establish the objective function of the overall logistics in the storage according to some of the variables above, and the function can be expressed as follows:

\[
T = \min_{i=1}^{M*R*P} \sum_{j=1}^{M*R*P} N_i * S_j * c_{ij}
\]  

(5)

\[
\begin{align*}
S & = 1, j = 1,2..M * R * P \\
\end{align*}
\]  

(6)

\[
\begin{align*}
\gamma & = 1, i = 1,2..M * R * P \\
\end{align*}
\]  

(7)

\[
\gamma = 0,1
\]  

(8)

The objective function (5) indicates that the overall logistics flow is the smallest, and the formula (6) indicates that the goods with the item code \(i\) are stored in a certain position of the \(M*R*P\) position grid, and the formula (7) indicates the position code \(j\). Only one of the \(M*R*P\) types of goods can be stored in the location, and the value of \(X_{ij}\) is 1, otherwise it is 0.

3. Numerical Simulation

3.1. Case Analysis

This paper designs the following calculation example. The warehouse has 5 rows of shelves in the storage area, and each row of shelves has four layers, and each layer has 10 storage grids, so there are a total of 200 storage spaces, and each storage grid. The length is \(a=2.3\) m, the width is \(d=0.6\) m, the height is \(h=1.9\) m (that is, the specification is: \(2.3\) m*\(0.6\) m*\(1.9\) m), the distance
between the shelf and the shelf is 3m, and the first row The distance from the cargo space grid on the 1st row and 1st floor to the outgoing point is 15m. Therefore, the value of each parameter can be obtained, M=5 rows, R=10 columns, P=4 floors, S0=15m, L=3m, and the storage location distance comparison table is shown in the following table:

Table 1 Comparison table of warehouse space distance

<table>
<thead>
<tr>
<th>Cargo location code</th>
<th>Row</th>
<th>Column</th>
<th>Floor</th>
<th>Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>15.00</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>17.30</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>19.60</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>178</td>
<td>5</td>
<td>8</td>
<td>2</td>
<td>37.21</td>
</tr>
<tr>
<td>179</td>
<td>5</td>
<td>9</td>
<td>2</td>
<td>39.51</td>
</tr>
<tr>
<td>180</td>
<td>5</td>
<td>10</td>
<td>2</td>
<td>41.81</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>199</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>43.31</td>
</tr>
<tr>
<td>200</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>45.61</td>
</tr>
</tbody>
</table>

As shown in the above table, the distance from picking to the outgoing place with the cargo location code 3 is 19.6m, and the distance from picking to the outgoing place with cargo location code 178 is 37.21m.

The research purpose of this article is to optimize the existing storage space. The storage and picking times of the existing goods in the warehouse are shown in the following table:

Table 2 Distribution of existing goods in warehousing (partial)

<table>
<thead>
<tr>
<th>Product name</th>
<th>Item number</th>
<th>Row</th>
<th>Column</th>
<th>Floor</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9</td>
</tr>
<tr>
<td>Goods2</td>
<td>2</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>Goods3</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>Goods4</td>
<td>4</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>20</td>
</tr>
<tr>
<td>Goods5</td>
<td>5</td>
<td>1</td>
<td>5</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td>Goods6</td>
<td>6</td>
<td>1</td>
<td>6</td>
<td>1</td>
<td>11</td>
</tr>
<tr>
<td>...</td>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td>...</td>
</tr>
<tr>
<td>Goods198</td>
<td>198</td>
<td>5</td>
<td>8</td>
<td>4</td>
<td>19</td>
</tr>
<tr>
<td>Goods199</td>
<td>199</td>
<td>5</td>
<td>9</td>
<td>4</td>
<td>42</td>
</tr>
<tr>
<td>Goods 200</td>
<td>200</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>17</td>
</tr>
</tbody>
</table>

3.2. Simulation Results

What this article establishes is an integer plan. The above data is analyzed by using Matlab_R2017b software to write a program to obtain the optimal solution. The following intercepts the results of recombination of 1-10 goods positions and goods:
The meaning of each number in the result of the above operation is expressed as item number, position number, row, column and layer. For example, \((1,40,1,10,4)\) means that the goods with the item number 1 are stored on the shelf number 40, and the specific location is in the first row, 10 columns, and 4 floors. According to the above solution, it can be concluded that the combination of the goods and the goods positions after the optimization of the 200 goods positions, and the comparison before and after the optimization of the goods positions, as shown in the following table:

<table>
<thead>
<tr>
<th>product name</th>
<th>Cargo location code</th>
<th>Specific location</th>
<th>Distance</th>
<th>Number of picks</th>
<th>Logistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goods 1</td>
<td>Before optimization</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Optimized</td>
<td>40</td>
<td>10</td>
<td>4</td>
<td>41.4</td>
</tr>
<tr>
<td></td>
<td>Difference</td>
<td>39</td>
<td></td>
<td></td>
<td>26.4</td>
</tr>
<tr>
<td>Goods 170</td>
<td>Before optimization</td>
<td>170</td>
<td>10</td>
<td>1</td>
<td>39.91</td>
</tr>
<tr>
<td></td>
<td>Optimized</td>
<td>89</td>
<td>9</td>
<td>1</td>
<td>34.56</td>
</tr>
<tr>
<td></td>
<td>Difference</td>
<td>-81</td>
<td></td>
<td></td>
<td>-5.35</td>
</tr>
</tbody>
</table>

### 3.3. Result Analysis

Unreasonable distribution of material flow in various lanes will result in low efficiency of warehousing goods in and out of the warehouse, increase the work intensity of warehousing operators, and result in excessively high costs of warehousing operations. The table is the new storage location and difference value of the goods before and after the optimization of the cargo location. Based on the results of the above operation, we can obtain the logistics volume of each row of shelves in the entire warehouse before and after optimization according to formula (5), as follows The table shows:

<table>
<thead>
<tr>
<th>Logistics</th>
<th>Number of rows of shelves</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>first row</td>
</tr>
<tr>
<td>Before optimization</td>
<td>23389.500</td>
</tr>
<tr>
<td>Optimized</td>
<td>30837.100</td>
</tr>
</tbody>
</table>

Table 4 Comparison before and after logistics optimization
It can be seen from Table 3 that the optimized results have a tendency for goods to be stored close to the outbound platform with frequent outbound goods. This way, the walking distance of outbound operators can be greatly reduced during the sorting process. The table shows that the total logistics volume of the optimized warehouse is smaller than that of the warehouse before optimization. It can be seen from the broken line chart in Figure 7 that the fluctuation range of the broken line before optimization is relatively large, indicating that the distribution of the logistics volume of each row of the warehouse is extremely unreasonable. The logistics volume of the first row close to the warehouse is at least 23389.5, The logistics of the next few rows of shelves are generally high, which will cause the accumulation of goods when the goods are in and out of the warehouse, and the high cost of in and out of the warehouse.

Table 5 Comparison of total logistics volume before and after optimization

<table>
<thead>
<tr>
<th>optimize the target</th>
<th>Before optimization</th>
<th>Optimized</th>
<th>Difference</th>
<th>Increase ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total logistics</td>
<td>166883.89</td>
<td>147622</td>
<td>19261.887</td>
<td>11.54%</td>
</tr>
</tbody>
</table>

It can be calculated from Table 3 above that the total logistics volume formed when the existing 200 cargo spaces in the warehouse are in and out of the warehouse is $T_1 = \sum_{i=1}^{200} \sum_{j=1}^{200} N_i S_j = 166883.887$ (Keep 3 decimal places). After optimizing its cargo location, it can be calculated from the above table that the optimized overall logistics volume is $T_2 = \sum_{i=1}^{200} \sum_{j=1}^{200} N_i S_j = 147622.000$ (Keep 3 decimal places). From the above data analysis, it is obvious that $T_2 < T_1$. After optimizing the location of the warehouse, some logistics have decreased, and some logistics have increased, but the overall logistics has shown a downward trend. Therefore, based on the data known above, we can find $\text{△}T = T_1 - T_2 = 166883.887 - 147622.000 = 19261.887$. It can be concluded that the overall logistics volume is reduced by 11.54% after the optimization of the cargo location.

4. Summary

In the process of warehousing location optimization studied in this paper, the frequency of picking by warehousing operators and the distance traveled by the goods are optimized. At the same time, based on real warehousing operation and maintenance data, this paper uses different dimensions, the scenarios were tested and analyzed on the performance of the coordinated optimization algorithm of the cargo location path. The experimental results showed that the intelligent warehouse collaborative optimization algorithm proposed in this paper has significant advantages in the effectiveness and stability of the algorithm. The algorithm can effectively improve the shipping efficiency of the warehouse, Reduce transportation costs [12]. Greatly reduce the overall logistics of the warehouse, improve the actual efficiency of warehousing operations, improve the warehouse's response to the market, increase customer satisfaction, and thus shape a good image of the company, Improve the competitiveness of enterprises in the market, and create a lot of benefits for enterprises.

References


