Research on distribution center layout optimization based on genetic algorithm

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Abstract. As the core of logistics system, distribution center is not only beneficial to the construction of modern logistics environment, but also to the realization of the overall benefits of logistics system. In order to improve the operation efficiency and have no limitations, we need to design the distribution center as a whole. In this paper, the system layout planning (SLP) combined with genetic algorithm is used to optimize the distribution center. In the use of system layout planning to get the comprehensive relationship between the functional areas, combined with the relevant constraints, build the objective function model, using MATLAB to run the genetic algorithm. The feasibility and rationality of the model are verified by an example. In this paper, the distribution center function area layout problem is regarded as a mathematical optimization problem, and the application of genetic algorithm in the model improves the quantifiable accuracy.

Keywords: genetic algorithm, SLP, distribution centre, functional area layout.

1. Introduction
Distribution center layout planning is an important part of logistics system planning. It is a new type of network node. It plays a key role in reducing logistics cost and improving company efficiency. Its effective function is realized on the basis of reasonable functional area layout, and the optimization of functional area layout with appropriate methods is the basis of distribution center planning and construction.

In the 1960s, Richard Muther proposed the famous SLP method in the paper System layout design[1]. He combined the logistics relationship analysis with the non-logistics relationship analysis to solve the layout problem and regarded the minimal logistics cost as the goal. SLP method is widely used in production system and service system. Its application makes the method of facility planning change from qualitative analysis to quantitative analysis. The application of SLP in distribution center layout planning is also developing[2]. Wu (2012) combined SLP method with Flexism simulation software to plan and optimize the layout of logistics park, and obtained the optimization results and the final layout plan [3]. In this paper, the SLP method and genetic algorithm are combined to establish the distribution center layout model. The optimal configuration is taken as the objective function, and the genetic algorithm is used to find the optimal solution [4].
1.1. Functional area division and methods
Distribution center functional area layout planning is mainly through the cooperation between the functional areas to complete the logistics operation. Therefore, we should minimize the logistics cost and maximize the comprehensive relationship [5].

(1) The shape of distribution center is rectangle, and the length and width are known;
(2) All functional areas are laid out on the same plane, with rectangular or square shape, known length and width, and only arranged in two rows;
(3) Each functional area has a certain distance;
(4) There is no overlap between functional areas, and the functional area does not exceed the layout area.

The objective function expression is as follows:

\[
\begin{align*}
\min F_1 &= \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} c_{ij} d_{ij} \\
\max F_2 &= \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} b_{ij} v_{ij}
\end{align*}
\]  

Meet the constraints:
(1) There is no overlap between functional areas:

\[
|x_i - x_j| \geq \frac{w_i + w_j}{2}, \forall i, j \in V'
\]
\[
|y_i - y_j| \geq \frac{h_i + h_j}{2}, \forall i, j \in V'
\]
(2) The functional area does not exceed the layout area:

\[
\frac{w_i}{2} \leq x_i \leq W - \frac{w_i}{2}, \forall i \in V'
\]
\[
\frac{h_i}{2} \leq y_i \leq H - \frac{h_i}{2}, \forall i \in V'
\]

Set a penalty to handle the constraint. The expression is:

\[
P(x) = \lambda_1 k P_1 + \lambda_2 k P_2
\]

Combined with the penalty function term, the final objective function is as follows

\[
\min F_3 = w_1 F_1 + w_2 F_2 + p(x) = w_1 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} f_{ij} c_{ij} d_{ij} + w_2 \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} (V - b_{ij} v_{ij}) + \lambda_1 k P_1 + \lambda_2 k P_2
\]

In the formula:
\(F_1\) - Function of total transportation cost in functional area;
\(F_2\) - Functional interval adjacency correlation function;
\(f_{ij}\) - Number of material flows in functional area and functional area;
\(c_{ij}\) - Unit material handling cost from functional area to functional area;
\(d_{ij}\) - Distance from the center of the ribbon to the center of the ribbon,
\[d_{ij} = |x_i - x_j| + |y_i - y_j|\]
\(b_{ij}\) - Adjacency degree of function area i and function area j. See Table 1 for details.
\(v_{ij}\) - The correlation degree between function area i and function area j. See Table 1 for details.
\(F_3\) - The function with the minimum total transportation cost and the maximum adjacency correlation degree;
\(w_1, w_2\) - Cost item weight, weight value of correlation degree item;
\(w_1 + w_2 = 1\), This can be determined by experts;
\(V\) - The maximum adjacency correlation degree of function area i and function area j is 1.
\(\lambda_1\) - The number of the kth functional area that does not meet the constraint (1);
\(\lambda_2\) - The number of the kth functional area that does not meet the constraint (2);
\(P_1\) - Penalty for violation of constraint (1);
\(P_2\) - Penalty for violation of constraint (2).

2. The idea of genetic algorithm for functional area layout
(1) Chromosome coding mechanism
Coding is to transform the representation of the solution of the practical problem into the representation of the spatial solution of genetic algorithm. In this paper, The length and width of the
function area should start from the bottom operation. If the length exceeds the planning limit, a new length value should be set for the length.

(2) Population initialization

Random selection is the most common method of population initialization\cite{6}. In this paper, the initialization population is expressed by matrix to establish genetic algorithm.

(3) Fitness function

The purpose of building fitness function is to improve the adaptability of the final calculation results and the park\cite{7}.

The fitness function of this paper is as follows:

\[
Fitness = \frac{\max F_3 - F_3}{\max F_3 - \min F_3}
\]  

(10)

(4) Selection strategy

In this study, roulette selection method is used as the realization mode of selection. According to the basic principle of roulette selection method, the higher the probability of being selected, the higher the adaptability index of distribution center area.

(5) Crossover and Variation

Generally speaking, the crossover probability is between 0.9 and 0.97, which is 0.6 in this paper. Cross selection is the key to the behavior and performance of genetic algorithm. If the crossover probability is too high, the possibility of the genetic model being destroyed is also greater. If the crossover probability is too low, the search process will be slow and even stagnate. For genetic algorithm, because of the replacement and change of different chromosome codes, new gene codes are generated, which eventually form different algorithm results, and also improve the probability of obtaining the optimal solution. The variation probability is between 0.1 and 0.001, which is 0.05 in this paper.

3. Case study of distribution center

The existing distribution center of T mall supermarket is located in Hunnan District of Shenyang City. The distribution center is not directly close to the main roads of the city. The distribution center that needs to be arranged is 110 meters long and 70 meters wide. The length, width and area of each functional area are shown in Table 1.

| Number | Functional area            | Demand area /m² | length /m | width /m |
|-------|---------------------------|-----------------|-----------|----------|
| 1     | Temporary storage area     | 168             | 14        | 12       |
| 2     | Return processing area     | 160             | 10        | 16       |
| 3     | Food storage area          | 620             | 20        | 31       |
| 4     | Daily necessities storage area | 550           | 22        | 25       |
| 5     | Electrical storage area    | 209             | 11        | 19       |
| 6     | Outbound processing zone   | 96              | 8         | 12       |
| 7     | Outbound delivery area     | 500             | 20        | 25       |
| 8     | Self delivery area         | 84              | 12        | 7        |
| 9     | Defective product storage area | 216           | 12        | 18       |
| 10    | Pallet storage area        | 60              | 6         | 10       |
| 11    | Forklift storage area      | 65              | 5         | 13       |
| 12    | Administrative Area        | 160             | 10        | 16       |

SLP method is used to get the relationship between logistics and non logistics. In this paper, the weight of 4:1 is selected to get the comprehensive relationship between operation units, as shown in the figure. The comprehensive relationship of operation units is quantified, and the closeness formula is as follows.

\[
CR_{ij} = 0.8MR_{ij} + 0.8NR_{ij}
\]  

(11)
The closeness can be obtained by using the formula, as shown in Figure 1.

| Name of functional area | 1 | 4 | 3 | 2 |
|-------------------------|---|---|---|---|
| Temporary storage area  |   |   |   |   |
| Return processing area  |   |   |   |   |
| Food storage area       |   |   |   |   |
| Daily necessities area  | 0 | 0 | 2.2| 4 |
| Electrical storage area | 4 | 1 | 3.2| 2.2|
| Outbound processing zone| 2.2| 1.2| 0 | 0.4 |
| Outbound delivery area  | 3.4| 0 | 0 | 0.2 |
| Self delivery area      | 0 | 0 | 0 | 0.2 |
| Defective product area  | 0 | 0 | 0 | 0.2 |
| Pallet storage area     | 0 | 0 | 0.3| 0.3 |
| Forklift storage area   | 0 | -0.2| 0 | 0 |
| Administrative area     | -0.2|   |   |   |

**Figure 1.** Quantitative digital chart of comprehensive relationship.

Next, use matlab to solve the model, and you can get Figure 2 and Figure 3.

**Figure 2.** Iteration chart of genetic algorithm.  **Figure 3.** Functional area layout.

**Figure 4.** Operation results.
It can be seen from Figure 4 of the operation results that in this scheme, the functional areas in the logistics production area are closely arranged to shorten the logistics operation time and improve the production efficiency. The office area is far away from noisy distribution processing area and forklift storage area. At the same time, the office area is close to the comprehensive service area and leisure landscape green space, so the office environment is good. The distance between the return processing area and the defective product storage area is very close, which is convenient for goods return and storage. To sum up, the layout scheme obtained by genetic algorithm is reasonable.

4. Conclusion
This paper combines qualitative analysis with quantitative analysis, regards the distribution center functional area layout problem as a mathematical optimization problem, uses genetic algorithm to improve SLP method, establishes the layout optimization model through the objective function, and obtains the layout optimization scheme by solving the model. Compared with the SLP method, it reduces the layout uncertainty affected by subjective factors. At the same time, the application of genetic algorithm in the layout model greatly improves the quantifiable accuracy of the problem.

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