Optimization of Warehouse Layout Based on Genetic Algorithm and Simulation Technique

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Abstract: In order to improve the layout planning in warehouse, mathematical model and simulation model are built on the basis of traditional system layout planning (SLP) method. Because of the low efficiency of simulation calculation, this paper proposes a two-stage optimization method based on genetic algorithm and simulation method. Finally, this paper proposes reasonable layout planning of warehouse in the case study. According to the results, the two-stage optimization method avoids the interference of human factors that exists in the traditional SLP method, and with the advantages of mathematical model and simulation model, it can get more integrated and more logical layout planning. The satisfactory solution which is got in a certain time guarantees the efficiency of calculation.

Key Words: warehouse, layout planning, genetic algorithm, simulation

1 INTRODUCTION

1.1 Background

With the development of modern logistics and more and more fierce competition among enterprises, to improve the level of logistics service and to reduce logistics costs become the key means in the aspect of increasing core competitiveness of enterprises[1, 2]. Warehousing as one of the most important parts in logistics, rationality of warehouse planning has a direct influence on the operation efficiency of warehousing activities. Warehouse layout is a vital part in the stage of warehouse planning and construction, and a rational planning scheme can not only enhance operation efficiency and storage ability, but reduce the construction cost and management expenses to obtain the optimal allocation of resources. Owing to more specific function area and more complex operation procedure in warehouse, it is more and more difficult to do the layout planning. Therefore, the study of warehouse layout problem has great practical significance on the development of modern logistics[3, 4, 5].

1.2 Application status of warehouse layout planning method

Currently, layout planning methods are mainly focused on SLP method. Traditional SLP method can only get the location correlation graph of function regions, but not the specific location of function area, so it is easily influenced by human factors, also area constrains and actual factors are not considered in the SLP method[6, 7, 8, 9].

To improve SLP method, domestic and foreign scholars did a lot of research. The research was divided into two categories. One was to build mathematical model and used optimization algorithm to get the specific location of function areas, but it cannot obtain reasonable scheme of logistics line. The other was to build simulation model by logistics simulation technique, and the best scheme was chosen by the comparison of different schemes. This kind of method considered more actual constrains and got more rational design scheme of logistics line, but because of low calculation speed of simulation and high time cost, it was difficult to achieve large-scale solution search.

Therefore, based on the domestic and foreign research, this article absorbed the advantages of SLP method, mathematical model and system simulation technique, and applied genetic algorithm and simulation technique to design and optimized warehouse layout scheme. Considering more actual constrains, this method avoided human factors, guaranteed effectiveness of optimization method and improved integrity and rationality of layout scheme.

2 WAREHOUSE LAYOUT PLANNING MODEL

2.1 Problem description

The problem which was discussed in this article includes two sides, one is the location, length and width of function areas and the other is design logistics line Reasonable planning scheme had several characteristics as follows,

1) Minimize carrying cost and reduce dispensable mileage and volume.

2) Satisfy the needs of efficiency of out-put and in-put of warehouse.

3) Take actual constrains into consideration such as length-width ratio and minimum area factor.

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In the traditional mathematical methods, it was hard to describe the design of logistics line in warehouse, and to consider dynamics and randomness of warehousing activities. Because of the complexity of modeling when calculate the carrying mileage, the models were had to be simplified in the previous research, which resulted in unreasonable warehouse layout scheme. In order to solve this problem, this paper described the layout planning problems and designed algorithm with the combination of mathematical models and simulation models.

2.2 Assumptions

1) Do not consider multi-stores warehouse layout.
2) The division of warehouse function regions was known.
3) The area of warehouse regions and the whole area of warehouse were known.
4) The shape of every function region was rectangle.

2.3 Mathematical model

1) Objective function
The aim was to minimize logistics strength among warehouse function regions.

$$\min S = \sum_{i=1}^{N}\sum_{j=1}^{N} r_{ij} \times (|x_i - x_j| + |y_i - y_j|) \quad (1)$$

$(x_i, y_i)$was the central point of function region i, $r_{ij}$was the logistics volume between area i and area j, N was the number of function areas in warehouse.
2) Constraints
Non-overlapping constraints, function regions in the warehouse were not overlapping.

$$|x_i - x_j| \geq \frac{l_i + l_j}{2} \;\; or \;\; |y_i - y_j| \geq \frac{w_i + w_j}{2} \quad (2)$$

Boundary constraints, every function region must be in the warehouse.

$$X_l \leq x_i - \frac{l_i}{2} \leq X_R, X_l \leq x_i + \frac{l_i}{2} \leq X_R \quad (3)$$

$$Y_d \leq y_i - \frac{w_i}{2} \leq Y_u, Y_d \leq y_i + \frac{w_i}{2} \leq Y_u \quad (4)$$

$(l_i, w_i)$was the length and width of the function regions,$(X_l, Y_d)$was the coordinate of bottom left,$(X_R, Y_u)$was the coordinate of top right.
Length-width ratio constraints, function regions cannot be too long.

$$\lambda_i = \frac{l_i}{w_i} \in (\lambda_i^{\min}, \lambda_i^{\max}) \;\; \forall i \quad (5)$$

λ_i,$(X_R, Y_u)$was the length-width ratio,$(\lambda_i^{\min}, \lambda_i^{\max})$was the reasonable range of length-width ratio of regions.
Minimum area constraints, the area of every function regions cannot be smaller than minimum area.

$$l_i \times w_i \geq S_i^{\min} \;\; \forall i \quad (6)$$

$S_i^{\min}$,was the minimum area of function regions.

2.4 Simulation model

From the view of the structure of warehousing system, warehousing system can be divided into two parts, one was function region module, and the other was handling module. Space storage was done in the function region module, and space moving of goods was done in the handling module. Since there were no goods moving in the non-function regions, only function regions were considered in the simulation model.
In function region module, the capacity of every function region was limited, when the capacity did not come to upper limit, goods can be transported into the function region, otherwise cargoes would be put at the entrance of regions to wait for space. After entering regions and staying for certain time, logic graph can be got as follows,

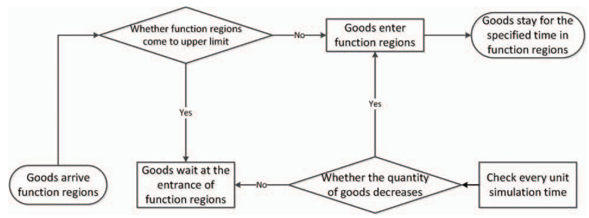

Figure 1: Logic graph of function region module

The main parameters of function regions were as follows,
1) Maximum capacity of function region, Maximum capacity of every function region was a determined value, and C_i was the maximum capacity of region i.
2) The staying time of goods in function regions was not a determined value, also it would be affected by the categories of goods, so the residence time was defined to follow randomness distribution, and function of randomness distribution can be obtained by historical data,

$$T_{ij} \sim f_{ij}(t) \quad (7)$$

T_ij was residence time of goods j in region i, $f_{ij}(t)$ was probability density of randomness distribution function of residence time of goods j in region i.
Handling module, space moving of goods was finished by specified handling tools, such as trucks, AGV and etc. Layout scheme affects travel path of handling tools, even the efficiency of handling. When there were handling activities, firstly we need to judge whether there were unoccupied handling tools, if there were, the distance between handling tools and handling goods should be calculated, and the handling tools that were closest to goods were chosen, otherwise unoccupied handling tools would be chosen. After the tasks were assigned, the cargoes would be transported to the appointed function regions. Dijkstra algorithm was used to calculate travel distance and path which were mentioned above, and logic graph about handling module was obtained as shown in figure 2,
The main parameters of handling module were as follows,
The speed of handling tools, since the travel paths were calculated by Dijkstra algorithm, speed of handling tools had a direct effect on handling time. The speed of handling tools was related to the categories of tools, so the speed was

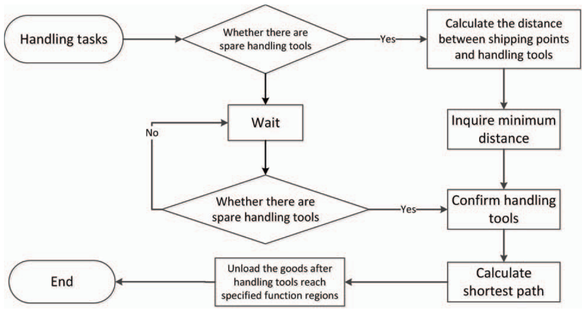

Figure 2: Logic graph of handling module

defined as v_m to describe m kinds of tools. The function of handling time was as follows,

$$t_{mpq} = \frac{D_{pq}}{v_m} \tag{8}$$

$t_m pq$ was handling time from function region p to region q by m kinds of tools. $D_p q$ was the Dijkstra distance from rejoin p to region q.

3 OPTIMIZATION ALGORITHMS

There were two difficulties in solving the problem of warehouse layout planning. Firstly, warehousing activities had great dynamic and randomness, so the analytical method cannot be used to solve the stochastic optimization problem that was discussed in this paper. Modern simulation technique and intelligent search algorithm were combined to solve this kind of problems. Secondly, how to guarantee the efficiency of algorithm in the process of algorithm design was another difficulty because of the low efficiency of simulation calculation compared with digital computation. Above all, this paper designed a two-stage optimization method based on genetic algorithm and simulation technique[10]. Genetic algorithm was a modern intelligent heuristic optimization algorithm, and it was widely used for optimization problems. The design procedure of algorithm was as follows.

3.1 Solve of the location and length and width of function regions with genetic algorithms

Step 1: Determine the parameters in algorithm, number of units N, crossover probability P_c , mutation probability P_m , current evolutionary algebra g , maximum number of iterations $MaxGen$.
Step 2: On the basis of initial scheme obtained by SLP method, initial population was generated in the neighborhood.
Step 3: The objective function took the negative value to calculate the individual fitness, and recorded the best chromosome as $Best$.
Step 4: According to individual fitness, this paper chose chromosome based on roulette strategy, and replaced the worst one with Best.
Step 5: Crossover operations were performed in accordance with the crossover probability, and two new individuals crossed into the new population, and no crossed chromosomes entered the new population directly.
Step 6: Mutation operations were performed according to the probability of mutation, and mutated chromosomes and non-mutated chromosomes formed a new population.
Step 7: Judge whether g is equal to $MaxGen$, if it is, stop the calculation and output the optimization results of locations of function regions and ratio of length and width, if not, make $g = g + 1$ and go back to step 3.

3.2 Determine logistics line based on simulation technique

Step 1: There were n categories of design of logistics lines, and n is positive integer.
Step 2: On the basis of the location and length and width of function regions, which were obtained by genetic algorithm, n alternative simulation schemes were formed in accordance with the categories of logistics lines.
$Plan = \{Layout_1, Layout_2, ...Layout_n\}$
Step 3: Count travelling distance of the handling tools and calculate the total mileage in every scheme.

$$Dis_{total} = \sum_{m=1}^{M} \sum_{n=1}^{N_m} Dis_{mn} \tag{9}$$

$Dis_{mn}$is total mileage of nth tool in m category, M is the number of kinds of carrying tools, and N_m is the number of carrying tools in m category.
Step 4: Minimize total mileage as objective $\min Dis_{total}$, and choose the best layout scheme $Layout_{best}$.

4 CASE STUDY

4.1 Parameters

Based on the two-stage optimization method which is combined with genetic algorithm and simulation technique, warehouse layout is designed under the background of warehouse construction in a power transmission project. The total area of the warehouse was 4400 square meters, and there were 10 function regions. They were receiving space, inspection space, precious metal area, electrical components area, accessories area, standard parts area, imperfection space, sorting area, shipping space and office area respectively, and minimum areas of each function region were shown in table 1. According to correlation graph got by SLP method, initial scheme was formed. Logistics lines had three kinds, linear type, double-lined type and U-type. Genetic algorithm had 40 populations, 100 iterations, 0.4 crossover probabilities and 0.05 mutation probabilities. And the handling tool in the warehouse was track, the speed of which was 1m/s.

Table 1: The minimum area of each function region

regions	area	regions	area
receiving	720	standard parts	125
inspection	125	imperfection	50
precious metal	390	sorting	275
electrical components	2158	shipping	194
accessories	69	office	169

4.2 Results and analysis

Based on the two-stage method referred to genetic algorithm and simulation technique, the location and the length and width of each function region was calculated using GA. The first stage used 1.2s and the result was shown in table 2.

Table 2: The location and length and width of each function region obtained by genetic algorithm

regions	x	y	Length	Width
receiving	79	17	22	33
inspection	42	37	18	10
precious metal	104	7	28	14
electrical components	34	15	68	32
accessories	57	36	10	7
standard parts	111	19	14	9
imperfection	112	27	10	5
sorting	83	39	37	9
shipping	97	27	13	15
office	114	37	12	15

According to table 2, simulation model was built in FlexSim platform on the basis of the type of logistics lines. The logic of simulation units is shown in figure 3.

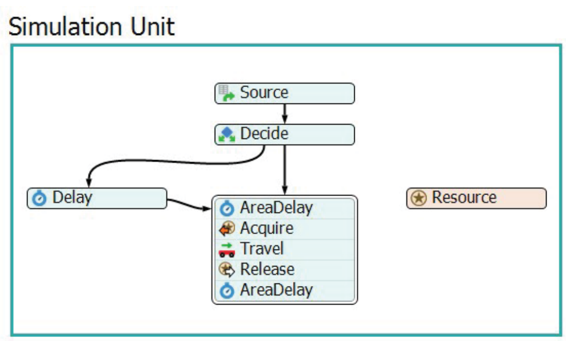

Figure 3: Sketch map of simulation units

Every simulation unit operated one day and 5 times repeatedly. The second stage used 485s and the total mileage of tracks was as follows in table 3.

Table 3: Results of simulation

	Linear type	Double-lined type	U type
Total mileage	34439	20675	22682

It is clear that the mileage of double-lined logistics line is shortest, so it is the best scheme. If the GA was only used to solve the problem, it is difficult to perform quantitative calculation for determination of logistics line. But the computational efficiency optimization of GA is not the research scope of this paper.

5 CONCLUSION

Based on traditional SLP method, this paper does deep research on warehouse layout planning problems, combines mathematical models and simulation models, uses genetic algorithm and simulation technique, and obtains comprehensive warehouse layout schemes. The results show that the two-stage optimization method on the basis of genetic and simulation techniques solves the design problems of logistics lines, considering several actual constraints, which cannot be solved in mathematical models. Since the small scale of design schemes of logistics lines, simulation methods avoid the disadvantages of low calculation speed. As for the performance of calculation methods, the efficiency of simulation methods is lower than single intelligent optimization algorithm, but the calculation time can be accepted, so this kind of method has great significance on reasonable warehouse layout planning. In this paper, the research still has weak points. There are some hypotheses to some extent during the construction of models. The design of the form and width of warehouse channel should be taken careful consideration in future research.

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