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Study on the Optimization of Cigarette Warehouse Storage Area in Tobacco Enterprises Based on Multi-objective Planning

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Abstract: In order to enhance the tobacco enterprise's complex raw material specifications, the current warehouse partitioning mainly relies on manual labor, resulting in the problem of low efficiency in and out of the warehouse, build a multi-objective function with the goal of optimal efficiency and the least number of cross-regional collection, combined with K-means clustering algorithm, solve the warehouse partitioning scheme, combined with the example to get the specific division of the tobacco enterprise warehouse storage area. Then, through the comparison of the inlet and outlet efficiency before and after the division, we can test the optimization scheme of the warehouse area and complete the optimization of the warehouse module from the division of the warehouse area to the guidance of the collection of goods.

1. Introduction

1.1. Research Status

China is a major producer and consumer of cigarettes and an important source of Chinese finance. Starting from 2020, China's tobacco industry is under the control of national policies, with an overall decline in cigarette production and sales, and a widening import/export trade deficit. This requires existing tobacco companies to reduce their production cost ratio through scientific and rational internal management optimization. This is reflected at the customer order level in the direction of "more products, less quantity, and more batches" [1]. The impact on the front-end of production is the increase in the combination of cigarette raw materials, how to plan the most efficient and lowest cost of raw materials collection program has become a new breakthrough in the current stage of cigarette enterprises to reduce costs and improve efficiency. At present, many tobacco enterprises' warehousing solutions are mainly designed by experience, and in actual operation, they may find defects in the design of raw material cargo space planning and unreasonable allocation of cargo collection resources. Using information technology to improve logistics efficiency is an optimization method that can be considered [2]. In this paper, a new solution idea is proposed for the optimization of warehouse storage area in tobacco enterprises.

Experts and scholars at home and abroad, after years of drilling and investigation, have made certain scientific research progress in how to improve warehouse storage efficiency, such as warehouse layout optimization, warehouse storage space optimization, etc. Various effective layout optimization studies have been conducted from different angles and in different directions, based on different theories and technologies. Numerous scholars have studied the problem of assigning storage space to products, MB Rosenwein [3] through statistical analysis and comparison of the data of order picking products in the warehouse, adopt the method of classification and clustering to analyze and optimize the hierarchical storage strategy, and finally obtained a considerable breakthrough in the optimization of warehouse product layout. TN Larson, A Kusiak [4] similarly thought about and analyzed the problem, combined with the study of warehouse space layout methods and strategies In the same year, Larson and Kusiak, in the same year, modeled and computationally solved the problem, obtained the required warehouse space layout ideas based on the model's calculation results, and then verified the ideas with practical examples. In the same year, Larson and Kusiak analyzed in depth the arrangement of the order of goods, proposed to analyze the optimization of warehouse layout by the problem of generalized transportation, and used examples to prove the idea. Yanning Jiang, Shuchi Hao [5], on the basis of analyzing the difference between the traditional aggregate coverage model and the aggregate coverage model under the cloud service model, construct the inventory allocation and dynamic site selection model based on aggregate coverage under the cloud service model.

Subanatarajan Subbiah [6] optimized the warehouse management system from the perspective of high level warehouse goods allocation. hooshang M [7] proposed a decision support system ABC inventory management model to facilitate managers to determine inventory policies as well as management decisions. Jing Wang [8] argued that the problem of unreasonable allocation of warehouse space in the current enterprise in warehouse management can be solved by applying the EIQ-ABC method demand. Xu Fatao [9] combined the traditional EIQ analysis method and ABC classification method to establish EIQ-ABC analysis method in order to realize the reasonable allocation of storage space, so as to achieve the goal of shortening the handling distance of goods and reducing the handling time. Hu Yujie [10] used EIQ analysis method to analyze the relevant data of its customers and order information, combined with ABC classification principle to find out the characteristics of customers and orders such as the number of orders, the number of orders and the operation rules of logistics business, so as to provide scientific management ideas and basis for the planning decision of finished goods warehouse. Bai Lu [11] takes a tobacco distribution center as an example, and uses the combination of EIQ-ABC method and spatial area division to design a reasonable layout of its goods, which reduces the walking time of operators and improves the efficiency of sorting operations. Tian Shixing [12] analyzed in detail the current situation of the development of warehouse group enterprises at home and abroad on the basis of in-depth demand analysis of warehouse group enterprises, proposed the use of GIS technology to achieve the management of warehouse group enterprises, discussed in depth the advantages and disadvantages of the three ways of GIS development, and selected an integrated secondary development method suitable for the construction of this system. In order to solve the problem of how to allocate the limited output of multi-warehouse tobacco enterprises to ensure the effective response of the warehouse to order execution, Zhang Zhihua et al [13] discussed the allocation of different warehouse sizes in multi-warehouse tobacco enterprises and proposed a specific algorithm for the allocation ratio of warehouse group response by combining the cyclical response factors. Yang Jun et al [14] constructed a tobacco transportation scheduling model based on mixed integer linear programming to address the shortcomings of low supply chain efficiency, high transportation cost, and poor logistics timeliness in tobacco industrial enterprises. On the premise of satisfying the production capacity, production plan and inventory capacity of multiple warehouses, we establish a theoretical model with the principle of matching supply and demand and the objective of minimizing cost, and solve the model optimally to obtain the cost-optimal shipment plan and the matching transportation scheduling plan.

In summary, the research on the allocation of storage resources in the tobacco industry starts from the goal of achieving value-added, and applies modern theoretical tools in the field of storage and logistics to the actual management upgrade. As the research progresses, the theoretical system is constructed and modern technology is applied in parallel. From the basic geographic warehouse conditions to the upstream and downstream supply chain data, this process has been promoted from another point of view, requiring the theory of warehouse logistics optimization to be better combined with information technology, computer technology, artificial intelligence algorithms and other digital methods. Therefore, the process of theoretical development in this field is also a process of deep integration with information technology. In the face of the change from mass production to multi-species and small batch production, in order to cope with the diversity of market demand, the management of tobacco warehousing has become more refined, with subdivision of the storage area and the logic of the raw materials stored, supplemented by ERP, WMS and other management information systems to achieve the refinement of management.

1.2. Problem Description

In view of the many types of tobacco products and the complex composition of the raw materials involved in each product, the current tobacco warehouse is dependent on manual decisions for the division of storage areas and inbound and outbound storage solutions. The logistics section adopts the random allocation + experience allocation strategy, which can optimize the warehousing process and shorten the warehousing time in the short term, but there is much room for improvement in the long term.

First of all, the strategy of random allocation + experience allocation is not necessarily able to improve the efficiency of warehousing. The random allocation often appears to be the phenomenon of "stitching", which follows the "proximity principle" in the short term from the perspective of warehousing. The "proximity" perceived by the operator is only an empirical judgment, which may not be scientific. In the case of one truck transporting one grade, the reliability of relying on experience is higher, but when it comes to one truck transporting multiple grades of raw materials, such a problem is similar to the "traveler's problem", which is more complicated, and it is almost impossible to find the nearest and most suitable space in a short time by relying only on subjective experience.

Secondly, random allocation leads to the same level of raw materials stored in multiple warehouses and multiple storage areas, although according to the design requirements of mirror processing, the same level of raw materials need to be stored in different warehouses to reduce the impact of insecticide on the supply of raw materials, but a reasonable mirror processing of the same level of raw materials stored in the same storage area of 2-3 warehouses at most, random allocation of cargo space is easy to store the same level of Raw materials warehouse more than 3 cases, which leads to raw materials in the out of storage, it is likely to appear across the storage area, across multiple warehouses, directly reduce the efficiency of the out of storage, but also increase the human and material resources.

Finally, the strategy of random allocation + experience allocation is not conducive to the completion of the demand for outbound orders with the task of killing insects, or such a cargo space allocation strategy creates a lot of obstacles to the development of insecticide plans, especially in the full insecticide season of April-June and August-October each year. At this time, in order to improve the efficiency of pest control, the whole building is often used to kill pests, but in order to ensure the supply of raw materials, it is often necessary to move a lot of raw materials stored in the building to reverse storage, which makes it difficult to enhance the management and implementation, but if a single stack extermination, the efficiency of pest control can not be guaranteed, especially in the case of heavy pest control tasks. Ideally, the entire building of stored raw materials can be exterminated within a specific period of time without affecting the response to outbound orders, thus improving the efficiency of pest control and ensuring the response to outbound orders.

2. Mathematical Modeling

2.1. Model Assumptions

The tobacco warehouses do not differ in the physical conditions of storage, and the conditions of entry and exit and management and maintenance are the same. The insecticide process is mirrored in the tobacco warehouses to ensure that the tobacco warehouses will not be affected by the insecticide closure of the warehouses. The transfer of raw materials between tobacco warehouses is done by the logistics carrier of the warehouse. The efficiency of the inbound operation or collection operation is evaluated from the total freight cost at the time of operation completion.

2.2. Model Parameters

The model parameters and their meanings in this paper are listed in Table 1 below.

Table 1: Model parameters and meanings

Model Parameters	Meanings
$\{1, \ldots, m\}$	Central Warehouse
$V_n = \{m+1, \ldots, m+n\}$	Sub-warehouse collection
$K = \{1, \ldots, k\}$	Model set
V_k	Load volume of vehicle type k
C_k	Driving cost of car model k
$TYPE_k$	Cargo load category for vehicle type k
g_i	Weight requirement for order i
l_i, w_i, h_i	The length, width, height of goods for order i, respectively
a_i	The earliest start time for receiving service i
$type_i$	Type of goods for order i
WW_i^{kq}	Total weight of the qth vehicle of vehicle model k from node i to the next node
$V_m = \{1, \ldots, m\}$	Potential central warehouse collection
$V = \{0\} \cup \{V_m\} \cup \{V_n\}$	Node Collection
G_k	Load capacity of vehicle type k
L_k, W_k, H_k	The length, width, and height specifications of model k, respectively
S_k	Average travel speed of vehicle type k
R_i^{kq}	Time of arrival of the qth vehicle of vehicle type k at node i
v_i	Volume requirements for order i
s_i	Time of service for order i
b_i	The latest time to start receiving service i
d_{ij}	Distance between nodes i and j
VV_i^{kq}	Total volume of the qth vehicle of vehicle model k from node i to the next node

The layout logic of the warehouse cargo space: all cargo space is defined in the following format: $01-01-01-01$ (depot area - building - layer - cargo space, respectively, noted as A, B, C, D

features), in this project the range of values of each feature is: $A \in [1,3], B \in [1,118], C \in [1,5], D \in [1,30]$, where A, B, C, D are positive integers. In the case of unchanged conditions at the upper level the cargo level retrieval of each level is recorded as N_d, in the case of unchanged conditions at the upper level the level retrieval of each building is recorded as N_c, in the case of unchanged conditions at the upper level the warehouse building number retrieval of each storage area is recorded as N_b, and the retrieval between storage areas is recorded as N_a. When only the level search is conducted without finding the target location, only the target location is found in the change of level search, at this time the current level of the cargo location search is recorded as N_{cd}. Similarly there exists N_{bcd} for building change search, and change the warehouse partition retrieval of N_{abcd}. The sum of the number of retrieval weights is S. The parameters and their meanings in the model are shown in Table 1.

2.3. Model Construction

Two indicators are considered in the classification of the storage area, one is the optimal efficiency of the overall collection of goods, and the other is the optimal relevance of the storage of goods. The modeling involves problems such as complex parameter variables and many constraints [15], and when facing the first objective, the optimal efficiency of goods collection, and the optimal distribution cost. Facing the second goal, the optimal storage space correlation, so that each time the number of inbound and outbound cargo space retrieval to take the minimum value, because to design to avoid inbound and outbound cross-warehouse and cross-warehouse transfer, so the warehouse area, warehouse, floor respectively plus 10 of 5, 3, 2 times, so that in the process of comparison single space scheduling in the objective function of the results have more advantages. The value of $\sum S$ should be ensured to be minimum after the completion of cargo space and partitioning. The objective function is as follows.

$$minf = \sum_{i,j=0}^{V} \sum_{k=1}^{K} \sum_{q=1}^{Z^+} x_{ij}^{kq} d_{ij} C_k + \sum_{m=0}^{V_0+V_m} \sum_{i=m+1}^{V_n} \sum_{k=1}^{K} \sum_{q=1}^{Z^+} (P_{im} * U_m + y_{m0}^{max(k)q} d_{mo} C_{max(k)} [max(TW_m, TV_m)]) \quad (1)$$

$$minS = Na \times 10^5 + Nb \times 10^3 + Nc \times 10^2 + Nd + Ncd + Nbcd + Nabcd \quad (2)$$

Where P_{im} is the $0-1$ decision variable of delivery from sub-warehouse i to potential central warehouse m, TW_m represents the total weight of pickups from warehouse m, TV_m represents the total volume of pickups from warehouse m, and U_m is the inbound cost of each shipment from warehouse m, $P_{im} * U_m$ is the inbound cost of potential central warehouse m

Where the constraints are set as follows.

$$\sum_{i=1}^{V_n} WW_i^{kq} \leq G_k, \forall k \in K, \forall q \in Z^+ \quad (3)$$

$$\sum_{i=1}^{V_n} VV_i^{kq} \leq V_k * 0.9, \forall k \in K, \forall q \in Z^+ \quad (4)$$

$$type_i \leq TYPE_k, \forall i \in V_n, \forall k \in K \quad (5)$$

$$a_j < R_i^{kq} + S_i + \frac{d_{ij}}{S_k} < b_j, \forall i,j \in V, \forall k \in K, \forall q \in Z^+ \quad (6)$$

$$l_i < L_k \& W_i < W_k \& h_i < H_k, \forall i \in V_n, \forall k \in K \quad (7)$$

$$x_{ij}^{kq} = \begin{cases} 1 & \text{, Denotes the qth vehicle of model k from node i to node j} \\ 0 & \text{, Others} \end{cases} \quad (8)$$

$$y_{m0}^{\max(k)q} = \begin{cases} 1 & \text{, Denotes the qth vehicle of model max(k) from the secondary warehouse m to the central warehouse} \\ 0 & \text{, Others} \end{cases} \quad (9)$$

Where equation (3) indicates that the total weight of the load of the qth vehicle of model k arriving at node i does not exceed the upper limit of that model, (4) indicates that the total volume of the load of the qth vehicle of model k arriving at node i does not exceed 90% of the upper limit of that model, (5) indicates that the cargo type of the customer satisfies the cargo type of pickup model k, (6) indicates that the time of the vehicle arriving at node j from the previous node i satisfies the hard time window of customer j, (7) indicates that the length, width and height of a single piece of cargo is less than the length, width and height of pickup model k, and (8) and (9) are decision variables.

3. Analysis of Calculation Cases

The distance in the objective function (1) uses the Euclidean distance as a measure of the similarity between warehouse objects, and the similarity is inversely proportional to the distance between warehouse objects; the greater the similarity, the smaller the distance. The algorithm needs to pre-specify the initial number of clusters K and K initial clustering centers. According to the similarity between warehouse objects and clustering centers, the positions of clustering centers are continuously updated, and the sum of squared error (SSE) of the class clusters is continuously reduced, and when the SSE no longer changes or the objective function converges, the clustering ends and the final result is obtained. First, K initial clustering centers $C_i(1 \leq \mathrm{i} \leq \mathrm{k})$ are randomly selected from the data set, and the Euclidean distance between the remaining data objects and the clustering center C_i is calculated to find the clustering center C_i closest to the target data object, and the data objects are assigned to the clusters corresponding to the clustering center C_i. Then the average value of data objects in each cluster is calculated as the new cluster center, and the next iteration is performed until the cluster center no longer changes or the maximum number of iterations is reached and stopped. The Euclidean distance between the data objects in the space and the cluster centers is calculated by the formula:

$$d(x, C_i) = \sqrt{\sum_{j=1}^{m}(x_i - C_{ij})^2} \tag{10}$$

Where x is the data object, C_i is the ith cluster center, m is the dimension of the data object, and x_j, C_{ij} are the jth attribute values of x and C_i.

The error sum of squares SSE for the entire data set is calculated as:

$$SSE = \sum_{I=1}^{K} \sum_{X \in C_i} |d(x, C_i)|^2 \tag{11}$$

Where the size of SSE indicates the goodness of the clustering result and k is the number of clusters.

3.1. Algorithm Design and Calculation Steps

The idea of the algorithm based on the above SSE characteristics is as follows:

(i) Calculating the sum of SSEs of all clustering centers under the depot division of K depots.

(ii) Selecting the reservoir allocation scheme at the inflection point when the sum of SSEs appears.

(iii) Re-calculating the objective function (1) according to the optimal number of depots and refining the division of each depot.

(iv) Exhaustive method of cargo space arrangement so that the sum of function (2) is minimized.

(v) Export the storage area division scheme and material storage scheme.

The calculation steps of the algorithm are:

Step1: Calculate the value of the overall function (1) (2) under the existing layout.

Step2: Randomly adjust the layout to get the value of the recalculated function (1) (2), compared with the first better then replace the results.

Step3: iterate the result 1000 times according to cross-genetic.

Step4: Output the results.

3.2. Calculation Examples and Data Analysis Results

Now there are 120 warehouse coordinates data and the coordinates are summarized as shown in Table 2.

Table 2: Summary of coordinates of simulated warehouses

Serial number	Coordinates
1-6	(10,85), (11,83), (13,88), (13,78), (15,86), (15,81)
7-12	(15,73), (17,92), (17,88), (18,81), (19, 68), (19,93)
13-18	(19,76), (20,86), (21,65), (22,72), (22,79), (22,90)
19-24	(22,97), (24,68), (24,82), (24,94), (25,67), (25,75)
25-30	(25,87), (26,71), (26,90), (27,81), (27,94), (28,78)
31-36	(29,68), (30,74), (31,81), (37,12), (40,06), (40,11)
37-42	(40,17), (41,08), (43,22), (44,06), (44,14), (45,20)
43-48	(46,08), (47,12), (47,26), (48,21), (49,06), (49,15)
49-54	(50,09), (51,05), (51,27), (52,21), (53,04), (53,11)
55-60	(53,16), (53,20), (55,24), (56,07), (56,13), (57,04)
61-66	(57,29), (58,08), (59,11), (59,13), (59,19), (60,23)
67-72	(61,03), (61,17), (62,08), (63,21), (64,11), (65,16)
73-78	(66,07), (67,14), (68,02), (69,18), (70,08), (70,12)
79-84	(72,09), (59,75), (62,53), (64,72), (65,58), (65,78)
85-90	(67,60), (67,68), (68,74), (69,71), (70,63), (70,77)
91-96	(71,81), (72,68), (73,75), (73,79), (75,63), (76,73)
97-102	(77,69), (77,78), (77,83), (78,69), (78,78), (78,83)
103-108	(78,65), (78,74), (80,77), (81,72), (82,78), (83,67)
109-114	(83,82), (83,71), (86,75), (87,82), (88,70), (90,79)
115-120	(91,74), (93,77), (96,75), (98,76), (99,76), (99,77)

The partition map of the initial warehouse is shown in Figure 1, and the result of differentiation after conducting 1000 iterations is shown in Figure 2.

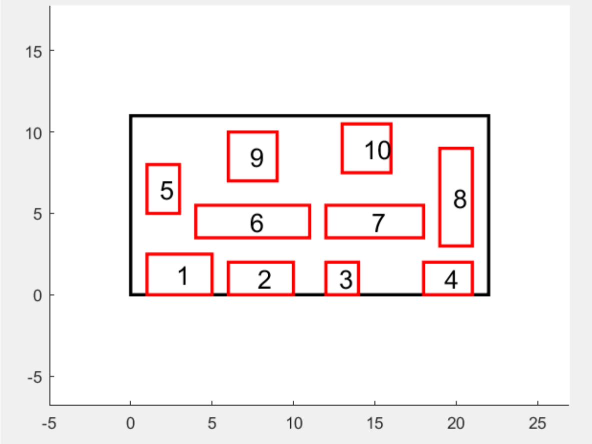

Figure 1: Initial partitioning of the warehouse

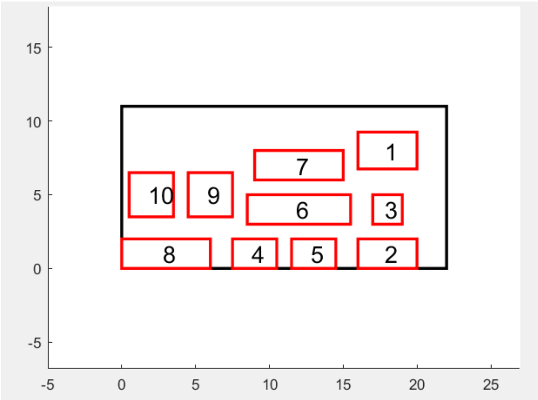

Figure 2: Optimized warehouse location distribution

The objective function changes as shown in Figure 3.

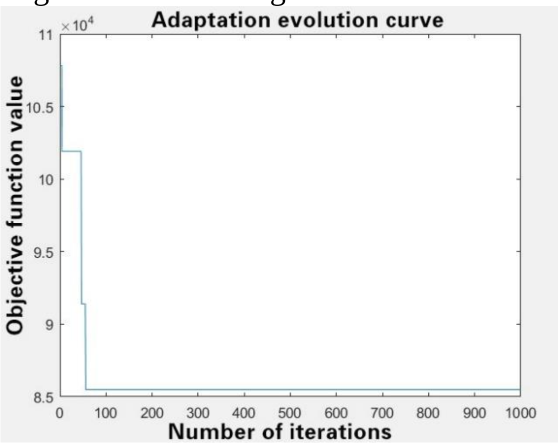

Figure 3: The change curve of the objective function for 1000 iterations

The efficiency indexes before and after optimization are compared, and the minimum distribution cost of the objective function (1) and the minimum cross-regional deployment of the objective function (2) are selected. The results of efficiency comparison before and after optimization are shown in Figure 4.

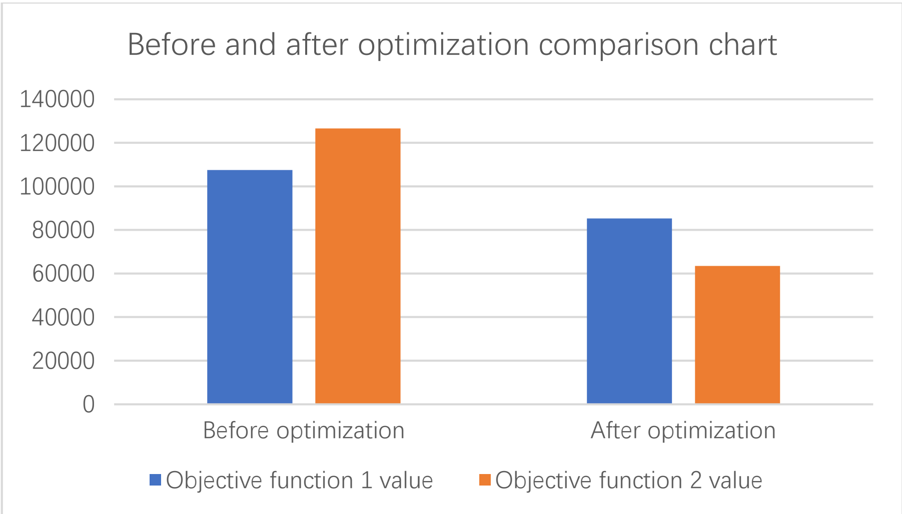

Figure 4: Comparison of the resultant values of the objective function before and after optimization

The efficiency improvement is 20.65% for objective function (1) and 49.83% for objective function (2).

4. Conclusion

This paper provides an idea of tobacco warehouse partitioning. The problem of inefficiency of inbound and outbound storage is caused by the fact that tobacco enterprises involve many types of raw materials in production and the warehouse partitioning arrangement mainly relies on manual arrangement. It is proposed to rely on the K-means algorithm as the basis for the selection of the number of partitions, set the objective function as multi-objective, solve for the combination of total cost of goods collection and storage convenience, and use it to test the rationality of the warehouse partitioning scheme. This warehouse optimization method first divides the area and then the cargo space. The validity, stability and parameter sensitivity of the model are verified by multiple operations, changing the problem size and changing the parameter values. The results show that the algorithm has high accuracy and good stability. It can be used for tobacco warehouse storage area division.

There are still some shortcomings in this warehouse optimization idea. When the production order is placed and raw materials are needed to be transported, the efficiency of goods collection is higher when the target raw materials come from the same partition, but the number of partitions also needs to consider the cost of management and maintenance after storage. When the number of partitions is too small, it will make the raw materials too scattered collection efficiency is low, too many partitions when the maintenance costs rise, and less storage space for warehousing put forward higher requirements, long-term inventory reached the upper limit of the need to adjust the partition situation. At the same time for the cost of distribution within the warehouse area only consider a single distribution conditions, when the distribution conditions of complex warehouses need to re-evaluate the validation program based on the actual situation.

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