A partition design for a rotary shelf system based on ABC classification

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Abstract. On the basis of the traditional ABC classification method, this paper determines another standard to subdivide the goods, that is, hierarchical ABC classification method. The calculation shows that, based on the hierarchical ABC classification method, the efficiency of multi-layer horizontal rotating shelves is increased by 26.94% and vertical shelves by 37.25%. The partition design scheme is helpful to optimize the operation efficiency of the rotating shelf warehousing system and verifies the validity and rationality of the partition design.

1. Introduction

The efficiency of the warehousing system is determined by a combination of factors. Among them, an important factor is whether the goods are stored in the right place, that is, the problem of storage allocation. Optimizing the location of the goods can shorten the working time, reduce the handling cost, and improve the access efficiency of the goods, so that the entire storage system can be optimized. Depending on the relevant characteristics of the rotating rack, different storage strategies have different effects on the operating efficiency of the entire storage system. At present, relevant scholars at home and abroad have relatively important research significance for the research on the partition design of the rotary shelf storage system, same as above, the research on the location allocation problem.

2. Hierarchical ABC management methods

2.1. Hierarchical ABC Classification

Due to multiple indicators are often required as the classification standard in the designing process of the warehousing system, the hierarchical ABC classification method is introduced. The hierarchical ABC taxonomy is a scientific analytical method on the basis of the traditional ABC taxonomy, which has a fundamental principle, "key minority and minor majority".

The analysis factors can be divided into three categories: A, B, and C: Class A is called an important factor, Class B is called a secondary factor, and Class C is called a general factor.

The specific operation method is: firstly, the proportion of each factor is divided into three categories A, B, and C according to the same standard, and then another standard is applied, and each category is subdivided into a, b, c three levels, forming a layered decomposition of the structural model, as shown in Figure 1, and then according to the characteristics of each category for different ways of management.
Compared with the traditional ABC classification, the hierarchical ABC classification considers more factors and is therefore more practical. For example, in the pharmaceutical industry, the hierarchical ABC classification method is used for inventory management, which can effectively control the inventory quantity, shorten the access operation time, and improve the work of the storage system effectiveness.

2.2. Hierarchical ABC Classification of Goods

2.2.1. Classification of the First Tier Based on the Value of the Warehouse. Most warehouses are classified according to the value of goods in the warehouse, the traditional ABC classification. Specifically, the goods are classified according to the occupancy ratio of the funds in the warehouse and the occupancy ratio of the number of varieties in the warehouse. According to this classification method, the key objects of management can be quickly found, that is, the most valuable Class A goods. For important goods, effective measures must be taken to manage them in a focused manner, and for general goods, only proper management is required. In this way, scientific and effective management can be achieved.

| Category | Cumulative ratio of capital occupation | Species cumulative ratio | Management method |
|----------|---------------------------------------|--------------------------|-------------------|
| A        | 70%~80%                               | 5%~10%                   | Key management    |
| B        | 15%~20%                               | 15%~20%                  | Secondary management |
| C        | 5%~10%                                | 70%~80%                  | General management |

The specific classification method has been described in detail in the first section of this chapter. The data standards of the classification are shown in Table 1. In the ABC analysis, the ratio of the capital occupied by the warehouse and the ratio of the quantity in the warehouse are cumulative percentages.

2.2.2. The Second Layer Classification Based on the Frequency of the Inbound and Outbound. In order to perfect this method, optimization can be performed on the basis of the traditional ABC classification. Therefore, this paper carries out the second level of classification according to the frequency of goods entering and leaving the warehouse.

Similarly, the frequency of the inbound and outbound warehouses is divided into three levels. The class A items have the highest frequency of entry and exit, the class B items have medium frequency, and the lowest frequency is class C items. In order to make reasonable arrangements for the storage location of different types of goods, the principle that “the frequency of the goods entering and leaving the warehouse is the same as the distance between the entrance and exit of the same category” should be followed. As shown in Figure 2, assuming that the entrance and exit are the center of the circle, the distance from the storage location of any type of cargo to the entrance and exit is a radius. According
to the above assumptions, class A items have the highest frequency of entering and leaving the 
warehouse, and frequently carry out the work of entering and leaving the warehouse, and should 
reduce the distance of transportation and arrange it to be placed near the entrance and exit. That is to 
say, the category A item is closest to the center of the circle, and its storage area has the smallest radius. 
In contrast, category C items have a lower frequency of access and are less frequently accessed, and 
can be placed in more remote locations. That is to say, the category C cargo is far from the center of 
the circle, and the radius of the storage area is large. Finally, class B goods should be somewhere in 
between because of their own characteristics.

Figure 2. Distribution diagram of the second layer classification

2.2.3. Comprehensive Classification Results. The two-layer analysis is combined, and the classification 
data standards for the scoreable layered ABC classification are shown in Table 2 below. We can clearly 
see that in the class A b and B class a, class A c and B b, B and c, b, in terms of the cumulative ratio of 
capital occupation and the cumulative ratio of species. The data standards are consistent, which is easy 
to lead to the problem of unclear standards when classifying goods. It also shows the importance of 
introducing the second level of classification criteria, that is, reclassification by frequency of entry and 
exit. After the division by the first layer standard, the second layer is subdivided by the level of the 
inbound and outbound frequency, as the final classification standard, and the partition design of the 
storage allocation according to the classification standard, according to the characteristics of different 
categories of goods. And it is key to optimize the combination of configuration, in order to improve 
the efficiency of the storage system access.

3. Zoning design of horizontal rotating shelves

Based on the hierarchical ABC classification of the goods in Chapter 2, the horizontal rotating 
shelves are partitioned. This paper chooses the H-type shelf for partition design research, a horizontal 
rotating shelf with the highest frequency of use in the current automated warehouse. At the same time, 
the H-shaped shelf belongs to a typical multi-layer horizontal rotating shelf.

3.1. Horizontal Rotary Shelf Model Hypothesis

Assume that this paper mainly studies a certain H-type rotary shelf storage system, which is mainly 
composed of five layers of shelves that can be independently rotated horizontally, and that single-layer 
shelves can be rotated clockwise or counterclockwise. The height of each layer of the shelf is set, and 
the width of each cargo space is 200. Each floor of the shelf is provided with 200 cargo spaces, which 
are sequentially numbered in a clockwise direction, and the cargo number is . A single picking station 
is arranged on the side of the storage system near the entrance and exit, and the picking station can be 
moved in the vertical direction to facilitate the staff to complete the picking operation.

The other parameters of the multi-layer horizontal rotary rack storage system are set as follows:
(1) Express each location in the system in the form of a coordinate set:
The abscissa is the unit of the position number and the ordinate is the number of layers. Among them, the coordinates (0, 0) indicate the initial position of the picking station. For example, (2w, 3h) indicates the second position of the third floor shelf.

(2) When performing an access operation, the single-layer shelf rotates horizontally at a rotation speed, and can be rotated clockwise or counterclockwise. At the same time, the picking station moves at a speed, which can be a vertical movement in the vertical direction. Both are moving at a constant speed and independent operation does not affect each other.

(3) Each shelf can rotate independently. When a certain shelf is rotated to the picking table, the direction of rotation is determined according to its abscissa. When $0 < x \leq 100w$, the single shelf rotates counterclockwise. When $100w < x < 200w$, the single shelf rotates clockwise. The shortest rotation path should always be taken as the basic principle to determine the rotation mode.

(4) When performing an access operation, the operator's required working time is constant, assuming it is T. Shortening shelf rotation time is the key to improve efficiency.

(5) Partitioning on the basis of assuming that the shelves are used, and determining the number of available cargo spaces for each category of goods. According to the data standard of the hierarchical ABC classification method in the previous chapter, the number of reserved goods for various types of goods is as follows:

| Category | Aa | Ab | Ac | Ba | Bb | Be | Ca | Cb | Cc |
|----------|----|----|----|----|----|----|----|----|----|
| Number of cargo | 3~1 0 | 8~20 | 35~80 | 8~20 | 23~40 | 105~140 | 35~80 | 105~160 | 490~640 |

(6) After the shelf is partitioned, a random storage mode is adopted for a certain category of goods in a fixed area. If the total quantity of a certain type of goods exceeds the quantity of goods in its storage area, it stores it in the free space of the adjacent area, and it is analogized in turn.

### 3.2. Partition Design Principles

The main indicator chosen to evaluate efficiency is the time of accessing the goods. The total time off accessing the goods are affected by the rotation of the rack and the time at which the picking station operates. To minimize access time, following partitioning principles should be applied:

(1) For the first layer classification of A, B and C, the most important category A items should be stored in the lower level of the rotating shelves, reducing the up and down operation of the picking station to shorten the working time. Class C items should be placed on the shelves due to the low importance. High-level, Class B items are between Class A and Class C;

(2) For the second layer classification of a, b, and c, determine the distance between it and the picking station according to the frequency of its inbound and outbound frequency. For goods with the highest frequency of incoming and outgoing wares, the goods should be close to the picking station to shorten the distance that the single-story shelves need to be rotated each time, and reduce the time required for operations to improve efficiency;

(3) For the classification data standards are similar, such as Ab and Ba goods, the ratio of capital occupation to the number of goods is the same, and should be distributed in adjacent areas, so as to make use of each other when the storage space of the goods is insufficient;

(4) When designing the partition, since the category A items are the most important, the maximum number of goods required for the category A items should be given priority, followed by the category B, and the category C items must meet the basic number of items.

### 3.3. Partition Design Results

According to the above divisional design principle, the nine types of goods are sequentially divided into storage areas, and the top view structure of each layer of the following shelves can be obtained. First of all, the goods of category A are the key management goods. When the first layer of shelves is
used for access operations, the picking station does not need to carry out the lifting movement. The ratio of the capital occupied by the Class A cargo is very important, so the first shelf is mainly used for storage. For Class A cargo, the cargo number of the Class A cargo storage area should meet its maximum demand, namely 10 Aa cargo positions, 20 Ab cargo positions and 80 Ac cargo spaces. According to the frequency of the inbound and outbound goods in the Class A cargo, the distance between the different types of goods and the picking station is determined. The storage area of the goods in the Class A cargo is distributed as shown in the figure. The closer the distance is, the more it needs to be rotated during the access operation. The smaller the distance means, the shorter the time. The remaining space of the first shelf is used to store some of the B-type goods that are managed by the secondary management. In the same way, according to the number of the largest cargo demand, the Ba-type cargo space is 20, the Bb-type cargo space is 40, and the remaining Bc cargo space. For 30, the same reason is set according to the frequency of entering and leaving the warehouse. The partition design of the first floor of the shelf is shown in Figure 3.

The second layer of the shelf is mainly used to store Bc and Ca cargo. Since the cumulative capital of Ca cargo is higher than that of Bc cargo, and the quantity ratio is lower than that of Bc cargo, it is preferred to meet the Ca class when the location is allocated. For the maximum number of cargoes required for the goods, the number of Ca cargoes is 80 and the Bc cargo number is 120. Each layer of the shelf can be operated clockwise or counterclockwise. Therefore, the two types of cargo spaces are divided into two areas centered on the picking station. The partition design of the second floor of the shelf is shown in Figure 4.

The high-rise shelves should be used to store Cb and Cc goods. The minimum demand for cargo space should be met first. The number of CC cargoes is 490, and the remaining Cb cargoes are 110. According to the frequency of the warehousing and storage, in order to reduce the time required for the lifting and lowering of the picking station, the Cb cargo is stored in the third shelf, and the
remaining cargo space is used to store the Cc cargo space, and the partition design of the third floor of the shelf can be obtained. Figure 5 shows that the fourth and fifth layers of the shelf are all used to store Cc-type cargo locations, as shown in Figure 6.

Based on the above analysis, according to the expression form of the cargo space coordinates in the model hypothesis, the storage area of different types of goods is described in the form of coordinate sets. The cargo space partition can be obtained by formula (1) as follows:

\[
\begin{align*}
A_a & : \{ (x, y) \mid 0 < x \leq 10w, y = h \} \\
A_b & : \{ (x, y) \mid 10w < x \leq 30w, y = h \} \\
A_c & : \{ (x, y) \mid 30w < x \leq 110w, y = h \} \\
B_a & : \{ (x, y) \mid 180w < x \leq 200w, y = h \} \\
B_b & : \{ (x, y) \mid 140w < x \leq 180w, y = h \} \\
B_c & : \{ (x, y) \mid 110w < x \leq 140w, y = h \} \cup \{ (x, y) \mid 0 < x \leq 120w, y = 2h \} \\
C_a & : \{ (x, y) \mid 120w < x \leq 200w, y = 2h \} \\
C_b & : \{ (x, y) \mid 0 < x \leq 110w, y = 3h \} \\
C_c & : \{ (x, y) \mid 110w < x \leq 200w, y = 3h \} \cup \{ (x, y) \mid 0 < x \leq 200w, 4h \leq y \leq 5h \}
\end{align*}
\]

3.4. Optimization Comparison Analysis

In the case of non-partitioned design, the general rotating shelf system will carry out random storage mode. After the partition design, the rotary shelves are partitioned and stored as a whole, but...
for a certain type of goods, random storage is still performed in the corresponding fixed area. The rotating shelf partition design is aimed at improving efficiency, and the scientific and effective design of the inspection partition is compared, and the designed partition classification storage is compared with the initial random storage. The design of the warehousing system is “to save for storage”. The appropriate storage strategy is chosen to improve the efficiency of the picking operation. Therefore, this paper chooses the total time of one picking operation as the objective function to make the total cost of a picking operation. The minimum time is set. The operating parameters of the rotating shelf are: single-layer cargo number $N = 200$, single-layer shelf height $h = 1m$, single-station width $w = 1m$, shelf horizontal rotation speed $V_x = 3m/s$, picking table vertical moving speed $V_y = 1m/s$, and constant time for picking personnel $T = 10s$.

(1) In the random storage mode, there is no fixed relationship between the goods and the cargo space, and the goods can be randomly stored in any cargo space, and the probability is the same. Therefore, for a single-storey shelf, when the goods on any location, the time expectation of a pick-up operation can be simply expressed as:

$$T_1 = T = \frac{1}{N} \sum_{i=1}^{N} t_i$$  \hspace{1cm} \text{Formula (2)}

Where $t_i$ represents the time required to rotate the location $i$ to the picking station on a single-layer shelf, calculated as:

$$t_i = \begin{cases} \frac{i \cdot w}{V_x}, & 0 < i \leq 100 \\ \frac{(200-i) \cdot w}{V_x}, & 100 < i \leq 200 \end{cases}$$  \hspace{1cm} \text{Formula (3)}

Therefore, from Equation (2) and Equation (3), it can be calculated that the time for a single picking operation on a single-layer shelf is:

$$T_2 = \frac{1}{5} \sum_{l=1}^{5} t_l$$  \hspace{1cm} \text{Formula (4)}

$$t_l = \frac{l \cdot h}{V_y}, \ l = 1, 2, ..., 5$$  \hspace{1cm} \text{Formula (5)}

From Equation (4) and Equation (5), the time expectation for picking up at any level can be calculated as:

$$T_3 = 2s$$

Therefore, the time expectation of a pick-up operation in random storage mode is:

$$T_R = T_1 + T_2 = 18.67s$$

(2) After partition classification storage, random storage is still used in the fixed category area. This paper is divided into 9 areas, namely $\lambda = 1, 2, ..., 9$. You can first calculate the time expectation of one picking operation in each area. The calculation method is the same as the calculation method in the random storage mode. Therefore, formula (4) and formula (6) can be calculated:

When $\lambda = 1$, for the area $A_a$, the time for picking up the job is expected to be:

$$T_\lambda = T_1 = \frac{1}{10} \sum_{i=1}^{10} t_i = 1.67s$$

When $\lambda = 2$, for the area $A_b$, the time for picking up a job is expected to be:

$$T_\lambda = T_2 = \frac{1}{20} \sum_{i=1}^{20} t_i = 6.67s$$

Therefore, the time expectation of the picking operation in each area can be calculated, in order:

$$T_3 = 22.92s, \ T_4 = 3.33s, \ T_5 = 13.33s, \ T_6 = 20.91s, \ T_7 = 14.33s, \ T_8 = 20.03s$$
When picking up a rotating shelf, the type of goods picked is also random. Therefore, for the entire rotary rack storage system, the time expectation for performing an access operation is:

\[ T_c = \frac{1}{\lambda} \sum_{k=1}^{C} \frac{T_k}{\lambda} \]  

Formula (6)

Substituting the values of the parameters in turn, the formula (6) can be used to calculate the time expectation of the model to perform a picking operation after the partition design: \( T_c = 13.64 \text{s} \)

By comparing the above calculation results, after the partition design, the pick-up time is shortened by about 5.03s in the random storage mode of the partition design, and the operating efficiency improvement expression of the system can be obtained.

\[ I_T = \left( \frac{T_{T}-T_c}{T_{T}} \right) \times 100\% \]  

Formula (7)

Therefore, from the above partial calculation results, the one pick-up time expectation under the two strategies can be compared, as shown in the table:

|                   | Random storage | Partitioned classification storage |
|-------------------|----------------|-----------------------------------|
| One time picking time expectation | 18.67s         | 13.64s                            |
| Efficiency change (IT)   | --             | 26.94%                            |

From Table 3, it can be stated that the partition design can effectively improve the working efficiency of the rotary rack storage system.

4. Partition Design of Vertical Rotating Shelves

Compared with the horizontal rotary shelf, the vertical rotary shelf has a small storage capacity, but its footprint is small, and the upper space can be better utilized, which is suitable for high-level automated warehouses. In view of the characteristics of this part, it is also necessary to carry out partition design research on the vertical rotary shelf storage system.

4.1. Vertical Rotary Shelf Model Hypothesis

Suppose a vertical rotating shelf has 5 columns, each column has 20 layers. The front and rear sides of the shelf are symmetrically distributed. There are 200 storage spaces. The height of each shelf is the width of each column. Counterclockwise from front to back. The direction numbers one row of goods, and the shelf also rotates clockwise or counterclockwise. Also, assuming that the single picking station is placed on one side of the shelf, it can be moved in the horizontal direction at the rotational speed. For the same reason, the other parameters of the vertical rotary shelf storage system are set, and some assumptions are the same as those of the horizontal rotating shelf, and the difference is:

1. Each location in the system can be expressed as a set of coordinates:

\[ \{ (x, y) | x = 0, w, 2w, ..., 5w; y = 0, h, 2h, ..., 200h \} \]  

Formula (8)

Indicates the number of columns, indicating the number of shipments, where the coordinates (0, 0) still indicate the initial position of the picking station. For example, the coordinates (2w, 3h) indicate the third position of the second column shelf.

2. The shelf can only perform the overall vertical rotation. When a certain cargo space needs to be rotated to the picking station, the rotation direction is determined according to its longitudinal direction: at that time, the shelf rotates clockwise vertically; at that time, the shelf rotates counterclockwise vertically. The shortest rotation path should be taken as the basic principle to determine the rotation mode.

3. Zoning on the basis of assuming that the shelves are used, and determining the number of available cargo for each category of goods. According to the data standard of the hierarchical ABC
classification method in the previous section, it can be concluded that the number of reserved goods for various types of goods is as shown in Table 4 below:

| category | Aa | Ab | Ac | Ba | Bb | Be | Ca | Cb | Cc |
|----------|----|----|----|----|----|----|----|----|----|
| Number of cargo | 1~2 | 2~4 | 7~16 | 2~4 | 5~8 | 21~32 | 7~16 | 21~32 | 98~128 |

4.2. Partition Design Principles

The principle of partition design for vertical rotating shelves is basically the same as that of horizontal rotating shelves. The difference lies in:

1. The shelf makes full use of the upper space, so its height is more than double that of the horizontal rotating shelf. For the three categories A, B and C, the A-type items should be placed on the bottom of the shelf to reduce the need for the shelf when performing the access operation. The distance of rotation, Class C items should be placed on the upper shelf of the shelf due to low importance, and Class B items are between Class A and Class C;

2. The vertically rotating shelves are symmetrically distributed, and the shelves can be rotated clockwise or counterclockwise, but it is more convenient to perform access operations on the side of the picking station, and is preferentially used for storing important materials;

3. Due to the limited storage space, it is necessary to make close arrangements for full use, and the classification data standards are similar. For example, Ab and Ba goods are distributed in adjacent areas, and a certain type of goods can be used for each other when the storage space is insufficient.

4.3. Partition Design Results

According to the above divisional design principles, the first consideration is AA cargo, which has the least number and the highest frequency of entering and leaving the warehouse. It is distributed in the area closest to the picking station. The Aa class has 2 reserved cargo spaces to meet its maximum demand. It is known that the Ab class is the same as the Ba class classification data standard. The reserved number of goods in this category is four. The storage areas of the two can be used by each other, while the goods of the Ba class have a higher frequency of entry and exit, and priority is given to all the goods. Stored in the same layer, and then store the Ab-type goods in adjacent areas. Similarly, the ratio of the capital ratio of the Ac and Ca goods is the same as the quantity ratio of the types, and they are sequentially stored in the area closest to the picking station on the back side of the shelf, and the number of cargo spaces is 15 respectively. Considering the Cb and Bc goods, according to the frequency of the two inbound and outbound, the Cb class has a high frequency of entry and exit, and the storage area is preferentially allocated. The storage location is 27, the Bc is the second, and the storage location is 25. The high-rise parts of the shelves are all used to store Cc goods. The structural diagram of the available shelves is as follows, wherein Figure 7 is the front view and Figure 8 is the reverse view.
Figure 7. Front structure of shelf

Figure 8. Shelf reverse structure
In the same way, based on the above analysis, according to the expression form of the cargo space coordinates in the model hypothesis, the storage area of different types of goods is described in the form of coordinate sets. The cargo space partition can be obtained by formula (8) as follows:

\[ A_a: \{ (x, y) \mid 0 < x \leq 2w, y = h \} \]
\[ A_b: \{ (x, y) \mid 2w < x \leq 5w, y = h \} \cup \{ (x, y) \mid x = 5w, y = 2h \} \]
\[ A_c: \{ (x, y) \mid 0 < x \leq 4w, y = 2h \} \]
\[ B_a: \{ (x, y) \mid 0 < x \leq 5w, y = 3h \} \cup \{ (x, y) \mid 0 < x \leq 3w, y = 4h \} \]
\[ B_c: \{ (x, y) \mid 0 < x \leq 5w, 3h < y \leq 14h \} \]
\[ C_a: \{ (x, y) \mid 0 < x \leq 5w, 37h < y \leq 40h \} \]
\[ C_b: \{ (x, y) \mid 3w < x \leq 5w, y = 4h \} \cup \{ (x, y) \mid 0 < x \leq 5w, 4h < y \leq 9h \} \]
\[ C_c: \{ (x, y) \mid 0 < x \leq 5w, 14h < y \leq 34h \} \]

4.4. Optimization Comparison Analysis

Compared with horizontal rotating shelves, the known vertical rotating shelves are basically the same as the principle, except that the direction of rotation is opposite. Therefore, the comparison analysis can be carried out according to the method described in the previous section. The operating parameters of the shelf are set as follows: single row cargo number is \( N = 40 \), single row shelf height is \( h = 1m \), single row shelf width is \( w = 1m \), shelf vertical rotation speed is \( V_y = 1m/s \), and picking station horizontal motion speed is \( V_x = 1m/s \).

(1) In the random storage mode, the time expectation for one picking operation for any cargo space on a single row of shelves is expected, and the calculation method is similarly obtained by formula (2):

\[ T_1 = \bar{t} = \frac{1}{N} \sum_{i=1}^{N} t_i \]  

Formula (9)

The difference is that this means the time required to rotate the location vertically to the picking station on a single-row shelf, expressed as:

\[ t_i = \begin{cases} 
0 & 0 < i \leq 20 \\
\frac{(40 - i) \cdot h}{V_y} & 20 < i \leq 40 
\end{cases} \]  

Formula (10)

It can be calculated from formula (2) and formula (3) that the time for picking up a single row of shelves is expected to be:

Similarly, the total number of shelves is 5 columns, and the time for accessing the operation in any column is expected. The calculation method is obtained by formula (4):

\[ T_2 = \bar{t} = \frac{1}{5} \sum_{l=1}^{5} t_i \]  

Formula (11)

At this time, \( t_i \) is different, expressed as:

\[ t_i = \frac{l \cdot h}{V_x}, l = 1,2,3,4,5 \]  

Formula (12)

It can be calculated by formula (4) and formula (5): \( T_2 = 2s \)

Therefore, the time expectation of the model to perform a picking operation in random storage
The mode is: $T_h = T_1 + T_2 = 12s$

(2) After partition classification storage, it is also divided into 9 regions, namely $\mu=1, 2, ..., 9$. The calculation method is consistent with the previous section and is calculated by formula (9) and formula (10), which can be obtained in sequence: $T_1 = 1.5s$, $T_2 = 4.5s$, $T_3 = 22.92s$, $T_4 = 3.33s$, $T_5 = 13.33s$, $T_6 = 20.91s$, $T_7 = 14.33s$, $T_8 = 20.03s$, $T_9 = 19.59s$

After the same partitioning, the calculation method for the operation time of picking up a kind of goods arbitrarily is:

$$T_C = \frac{1}{\mu} \sum_{\mu=1}^{\mu} T_\mu$$

Formula (13)

The value of each area is taken in turn, and the time expectation of a picking operation after partitioning can be calculated by formula (13): $T_C = 7.53s$

(3) By comparing the above calculation results, after the partition design, the pick-up time is shortened by about 4.47s in the random storage mode of the partition design, and the calculation efficiency of the system can be improved by the formula (6). Get the following table:

| Table 5. Comparison of the two strategies |
|------------------------------------------|
| Strategy | Random storage | Partitioned classification storage |
|----------|----------------|-----------------------------------|
| One time picking time expectation       | 12s            | 7.53s                             |
| Efficiency change (IT)                  | --             | 37.25%                            |

Therefore, from Table 5., it can be explained that the partition design can effectively improve the working efficiency of the vertical rotary rack storage system.

5. Conclusions
This paper mainly studies the partition design of rotating shelf warehousing system. Two kinds of models are established, multi-storey horizontal rotating shelf and vertical rotating shelf. On the basis of hierarchical ABC classification of goods, two different zoning design results are obtained according to the different characteristics of the two models. Finally, use one-time pickup operation time as the objective function, comparing the partition classification storage strategy with random storage strategy. Therefore, this paper can draw the following conclusions: (1) Using multiple indicators to classify goods will help to achieve deeper subdivision and accurate management. (2) The rotating shelf has a high storage density; only reasonable cargo allocation can improve its operational efficiency. In another word, the efficiency of the system can be improved through the effective designing of the random storage and classified partition storage, which means after zoning area of goods confirmed, it should applied random storage in the corresponding fixed area. (3) The expectancy time of one pick-up operation is shortened and the efficiency is obviously improved by using two modes of zone designing in this paper. But the two models are different, so the degree of efficiency improvement is also different. Therefore, it is necessary to design the warehouse system according to the specific situation, so as to maximize the operational efficiency of the system.

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