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Study on the optimization of imported container allocation of container terminals under the reservation system

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ABSTRACT

As an important part of container transport, the efficiency of container terminal directly affects the core competitiveness of the port. With the continuous increase of the number of containers, under the condition of limited space, reasonable container allocation becomes the key to improve efficiency. This paper takes the location allocation of imported container terminals at the entrance of container terminals under the reservation system as the research object, establishes the optimization model of the location allocation of imported container terminals at the entrance of container terminals, designs the solution strategy based on genetic algorithm, and conducts the practical verification of the calculation example. The calculation results show that this method can effectively reduce the volume of overturning containers and improve the efficiency of dock yard.

Key Words: Container Terminal, Import Container, Container Allocation, Genetic Algorithm

1. INTRODUCTION

With the continuous growth of the world container throughput in recent years, the performance indexes of the existing storage yard are relatively backward. In addition, the production of container terminal handling enterprises has the characteristics of cooperation, discontinuity and asymmetry. Therefore, in order to ensure the fast and efficient service of the port, yard management will be particularly important. It is very important to optimize the utilization rate of storage yard and improve the efficiency of pick-up operation.

In this paper, the management of the storage yard is studied only from the aspect of optimizing the allocation of boxes. Taking the import container of primary unloading as the decision-making object, based on the determined order of unloading and the order of picking up the container, the optimal container position is allocated for each arriving at the import container of the yard according to the order of unloading. The purpose of this study is that when the container is extracted, the total amount of container turnover generated by the rear yard during operation is the least.

For the wharf, reducing the turnover rate can improve the operation efficiency and thus enhance the comprehensive competitiveness of the port; For the customer, reducing the turnover rate enables him to reduce the waiting time when picking up the container, improve the turnover rate of goods and promote development. Therefore, both parties are eager to reduce the turnover rate of the container yard, which indicates that the study on the optimization of the container storage at the entrance of the container terminal is of great significance.

2. LITERATURE REVIEW

At present, many dock yards are faced with the problem of over-loading the containers when they are picked up, which not only wastes the resources of the wharf, but also reduces the satisfaction of the shippers. In order to reduce the volume of container turnover in the yard, enterprises and shipping scholars in various countries are committed to the study of this problem. The optimization of container position for imported containers can be divided into two stages: In the case delivery stage, it is preferred to choose the position of unloading box and stacking, so as to avoid the customer to take the box after pressing; In the case picking stage, if there is a case flipping operation when the client picks up the box, optimize the position of the case shifting and drop the box, and avoid the second and multiple cases. Relevant studies are as follows:

By analyzing the storage strategy of containers, it is considered that it is better to pile containers near the berth (Kozan&Preston,1999). By analyzing the cyclical and dynamic changes when the container arrival rate is constant, Kim and Kim (1999) studied how to allocate the storage position for the imported containers to achieve the minimum expected turnover total. The optimal allocation of container port system is discussed from the perspective of storage cost, cargo value and capacity constraint (Holguin-Veras&Jara-Diaz,1999). The arriving rules of the inlet box were set as random, and the time of the container was taken into account to build the coordinated scheduling model and solved by the iterative search algorithm (Holguin-Veras&Jara-Diaz,2006). A multi-objective and multi-stage mathematical programming model was constructed and a heuristic algorithm based on TLS was developed (Bish,2003). Ignoring the effect of customer pick-up time on the volume, the branch and bound method and heuristic algorithm were used to calculate the volume of all containers in the bay respectively (Kim K H, Park Y M, Ryu K R,2000). Aiming at minimizing the volume of unpacking in the process of pre-unpacking before loading, the corresponding integer programming model is proposed, and the position of unpacking box is optimized by using heuristic method (Lee Y & Hsu N Y,2007). Using integer programming model to optimize box allocation (Zhang,2000; Bazzazi,2009). Wan et al.(2009) and Tang et al.(2015) established the integer programming model with the goal of minimum volume turnover.

Chen and Lu (2012) constructed the mixed integer programming model and the mixed sequence superposition algorithm to determine the allocation of specific boxes. Rommert et al.(2007) simulated and analyzed the allocation rules of an automatic container terminal. By optimizing allocation rules, the amount of overturning was reduced.Leek(2010) proposed a three-stage heuristic box-picking optimization algorithm to reduce the overturning operation and operation time. This algorithm allows the overturning of boxes across shells, but in practice, most wharfs do not allow overturning of boxes across bay. De Castillo and Daganzo (1993) proposed two storage strategies for imported containers: the expected value of container turnover and the arrival time of the container to select the location of the target container. Cao and Uebe (1995) constructed nonlinear constraints for the allocation of container stacking positions in the yard, and optimized them with tabu algorithm. C.F.Daganz (1996) predicted the situation of containers, and established the optimization function between the height of the storage yard and the layout of the storage yard, in order to achieve balance between the height of the storage yard, the work efficiency of the storage yard and the utilization rate of the storage yard so as to maximize the efficiency of the storage yard. Munnichl (2012) studied the operation flow of container terminal yard, and established the cost mathematical model to solve the problem. Aydin(2012) proposed greedy heuristic algorithm and difference heuristic algorithm, which greatly improved the calculation speed. Zhao and Anne V et al.(2010) made a detailed classification of the information of the booking suitcase of foreign collection card according to different information quality, including complete arrival information of collection card, partial arrival information of collection card, and studied the impact of information quality at the arrival time of collection card and bended storage of storage on the rate of import box turnover based on the effective booking time.

We can see that the problem of container allocation in the storage yard has caused wide attention. However, the previous research on container location allocation in the container yard mainly focuses on the issue of export boxes, while there are few studies on import boxes, and a large part of the research only demonstrates the feasibility of the algorithm, which is not well combined with the actual operation in the container yard.

3. RESEARCH ON TURNING OUT PROBLEM

3.1 Analysis of The Reason of The Import Box's Relocation

The fundamental reason for relocation of imported containers when lifting containers is that the order of operation in the yard does not conform to that of the shipper. The order of pick-up depends on the shipper's scheduled pick-up time, but the allocation of container space for imported containers during unloading has already determined the order of operations in the yard, and both of them affect the change of the turnover volume.

1) The problem of turning over containers during unloading

When allocating container locations for containers, the ideal solution is for newly unloaded containers not to be loaded onto unpicked containers in the storage yard. However, in practice, it is necessary to ensure a high utilization rate of the yard, so the maximum probability in the yard is no suitable bay or empty stack when actually unloading the ship. So it can only be placed on the top of the box, which will undoubtedly increase the volume of relocation.

2) The problem of relocation when the owner takes up the containers

The reason why the containers' relocation when the foreign truck enters the yard to pick up the containers is that the order of the trucks to pick up the containers does not match that of the imported containers in the yard at the time of unloading. The more random the suitcase time, the more difficult to fully grasp form the dock side. In addition, if the arrangement of the position of the obstructed box is not reasonable in the case of unpacking, it will lead to the increase of unpacking again.

3.2 The Strategies of Reducing Relocation

1) Appointment booking mechanism

The mechanism requires the Shipping Co to provide the pre-departure time of containers as far as possible before the arrival of the container. Due to the large number of port shipping companies, the port side does not force shipping companies to provide case time. In addition, if the owner fails to pick up the container within the booking time, if the container is still within the free storage period, the Hong Kong side will not punish. It has brought adverse effects, seriously interfered with the box allocation plan, resulting in a lot of unnecessary turnover of the box. Therefore, a reward and punishment mechanism should be put forward to carry out the booking suitcase to make the owner comply on time.

2) Preferred removal of container

The situation of " One vote for multiple containers " generally exists in imported heavy container. However, multiple containers under the same bill of lading may be stacked in different locations. The method of preferred removal of container is aimed at this kind of box. Regardless of the order of container, the centralized stack exists at the top level, which can reduce the turnover of container.

4. MATHEMATICAL OPTIMIZATION MODEL

4.1 Booking Mechanism

In this paper, the strategy of mixed storage of import containers with different bills of lading and different cargo owners is adopted, and takes the pick-up time of import containers as the constraint condition to formulate the allocation plan of import carton allocation. It is assumed that all shippers have already made an appointment to take the container. In order to determine the order of container pick-up, the pick-up time will be converted into the pick-up priority when the pre-scheduled pick-up time is processed. The lower the number of priority, the higher the priority.

4.2 The Rule of Dropping Position

In order to reduce the second flip of the box, the position of the blocking box in this paper is to follow the following steps:

1) If there is an empty stack in the current storage state, the emptied box location selects the nearest empty stack from the blocking box.
2) If there is no empty stack in the storage state, locate the nearest lock box in the same bay and satisfy the priority of each imported container in the stack is higher than its stack.
3) If you do not have a stack in the two steps of speculations, the nearest and shortest stack is preferred.

The following is a case study of table 1 to simulate the selection process of the location of the blocking box dropping when the box is turned. In the table, box 5 is the target box with a blocking box on it.

According to the above steps, box 7 should be placed at the location of the b$.

Table 1: The state of the yard at some point.

	①	17 (6)			
7 (13)	14 (16)	15 (24)	②	③	④
5 (4)	3 (17)	9 (19)	8 (8)	11 (16)	12 (21)
1 (15)	2 (22)	4 (23)	6 (9)	10 (10)	18 (7)

4.3 Model Assumption

There are many factors affecting the time of unloading. If all factors are taken into account, the model will become very complicated. In order to study the essence of ship unloading inventory problem, this paper selects a bay area, 4*6 size operation area(the actual number is 21, and three positions need to be reserved for turning the box),and make the following assumptions:

1) The containers are standard 20-foot-long containers, and if there is a case of over-loading, the over-loading will be carried out in the same bay.
2) The pick-up time of all import boxes has been booked and taken away within the specified time period.
3) The order of unloading has been known, and the storage bay reserved for this batch of boxes in the storage yard has been determined and the initial state is empty.
4) The bay involved in the unloading process do not carry out extraction container operation.
5) New boxes are not allowed in until all the boxes are taken.

4.4 Mathematical Modelling

1) Objective Function:

$$MinZ = \sum_{n=1}^{N} R_{nijk} \tag{1}$$

2) Constraint Condition:

$$R_{nijk} = H_{ij} - k \text{ if } c_n = c_{\min} \tag{2}$$

$$\sum_{i=1}^{I}\sum_{j=1}^{J}\sum_{k=1}^{K} X_{nijk} = 1 \forall n \tag{3}$$

$$\sum_{n=1}^{N} X_{nijk} \le 1 \qquad \forall i, j, k \tag{4}$$

$$\sum_{m=1}^{M} X_{mijk} - \sum_{n=1}^{N} X_{nijk'} \le 0 \qquad \forall i, j \qquad k > k' \tag{5}$$

$$M \times L_m \times X_{mijk} > L_n \times X_{nijk} \qquad k < k' \tag{6}$$

$$\begin{aligned} &if\ X_{mijk} = 1, \quad X_{nijk'} = 1, \quad k < k' \\ &then\ S_m < S_n \end{aligned} \tag{7}$$

3) Formula Interpretation

Formula (1) indicates that the total volume of the objective function is the smallest.

In constraint conditions: Formula (2) refers to the amount of over-turning in the storage yard when a container is extracted, and the lifting priority of the extracted container is minimal under the current state; Formula (3) specifies that a box can only be assigned to one position; Formula (4) means that a container can only be stacked one container at most; Formula (5) indicates that the container in the storage yard cannot be placed in suspension, that is, for the container on the same stack, the container below must be placed before the container above can be placed; Formula (6) indicates that the lower and middle containers of the same stack arrive earlier than the upper containers; Formula (7) means that only the top container can be operated when the container is operated.

The allocation problem of container position in container yard is a combinatorial optimization problem with a wide range of constraints. As the scale of the problem increases, the search space also expands rapidly. The allocation scheme based on experience will bring a high volume of container turnover, and sometimes

the global optimal solution cannot be obtained on the computer.

After years of research and practice, genetic algorithm has shown its superior performance in solving some NP uncertain problems. Therefore, this paper will try to use genetic algorithm to solve the container location allocation problem.

5. ALGORITHM SOLUTION

5.1 Overview of Genetic Algorithm

Genetic algorithm is based on the genetic evolution of natural organisms, that is, the solution of the problem is expressed into chromosomes through simple coding technology, and then the chromosome is selected based on fitness value. Genetic algorithm mainly uses selection operator, crossover operator and mutation operator to simulate biological evolution, so that the population can continue. The basic steps of the genetic algorithm are as follows:

1) Coding

The code determines the feasible solution of genetic algorithm on chromosome. The application of the genetic algorithm, the first to find the appropriate code will be mapped to the chromosome in the solution, which is a key step in designing the genetic algorithm. During the execution of the genetic algorithm, different problems are coded, and the code is directly affected by the genetic algorithm, such as selection, crossing, variation, etc. In theory, the purpose of coding is to better solve problems rather than simply explain them.

2) Generation of Initial Population

Two issues need to be considered to generate the initial population: One is the selection of the generation method and the other is the determination of population size. In order to ensure the evolution of the population and find the global optimal solution, the initial population was selected randomly. However, the random selection of initial population increases the evolution algebra of population, and the selection method based on certain rules can reduce randomness. When the population size is determined, the fitness value will be increased to calculate, and the number of iterations will be increased, and the local minimum point is easy to fall into. Therefore, a reasonable population size needs to be determined according to practical problems.

3) Fitness Evaluation

Fitness of an individual or solution is expressed through fitness, which is usually proportional to the probability that the individual inherits to the next generation. The function of individual fitness is called fitness function. For different problems, the definition of fitness function is different. The fitness function is always non-negative. Anyway, the bigger the better.

4) Selection

Selection is the process of selecting individuals with strong vitality in a group to produce a new group. This process embodies Darwin's principle of survival. The purpose of selection is to select the individuals in the group to adapt to the environment and allow the selected individuals to reproduce the next generation. Generally, two strategies are adopted. The first is elite retention strategy and the second is roulette selection strategy. Use elite retention strategies when you want to pass on two better genes to the next generation. Select a roulette selection strategy when you want to randomly select two good individuals in a group, and process the next generation with a specific strategy.

5) Crossing

The so-called crossover in genetic algorithms is the exchange of two pairs of chromosomes, one way or the other, to form two new individuals. Crossover operation is an important feature of genetic algorithm, which is different from other evolutionary algorithms and plays a key role in genetic algorithm. The new individual method is mainly completed in the crossover operation, which determines the global search ability of genetic algorithm.

6) Variation

The mutation first randomly selects individuals in the population and then randomly changes the value of the gene in the chromosome to the selected individuals. As in biology, the chance of mutation in genetic algorithms is very low, often very small. The use of mutation operator in genetic algorithm has two main purposes: Improve the local search ability of genetic algorithm; Maintain the diversity of the group and prevent precocity. The crossover operator improves the global search ability and the mutation operator improves the local search ability.

5.2 Steps of Genetic Algorithm

1) Randomly generated population.

2) The strategy is used to determine the fitness of the individual and determine whether the individual conforms to the optimization criteria. If so, output the best individual and its optimal solution, and end. Otherwise, proceed to the next step.
3) Regeneration individuals were selected according to fitness, the individuals with high fitness were selected with high probability, and those with low fitness were eliminated.
4) According to a certain crossover probability and crossover method, new individuals are generated.
5) According to a certain mutation probability and mutation method, new individuals are generated.
6) A new generation of population is generated by crossover and mutation, returning to step 2.

The specific steps of genetic algorithm are shown in figure 1:

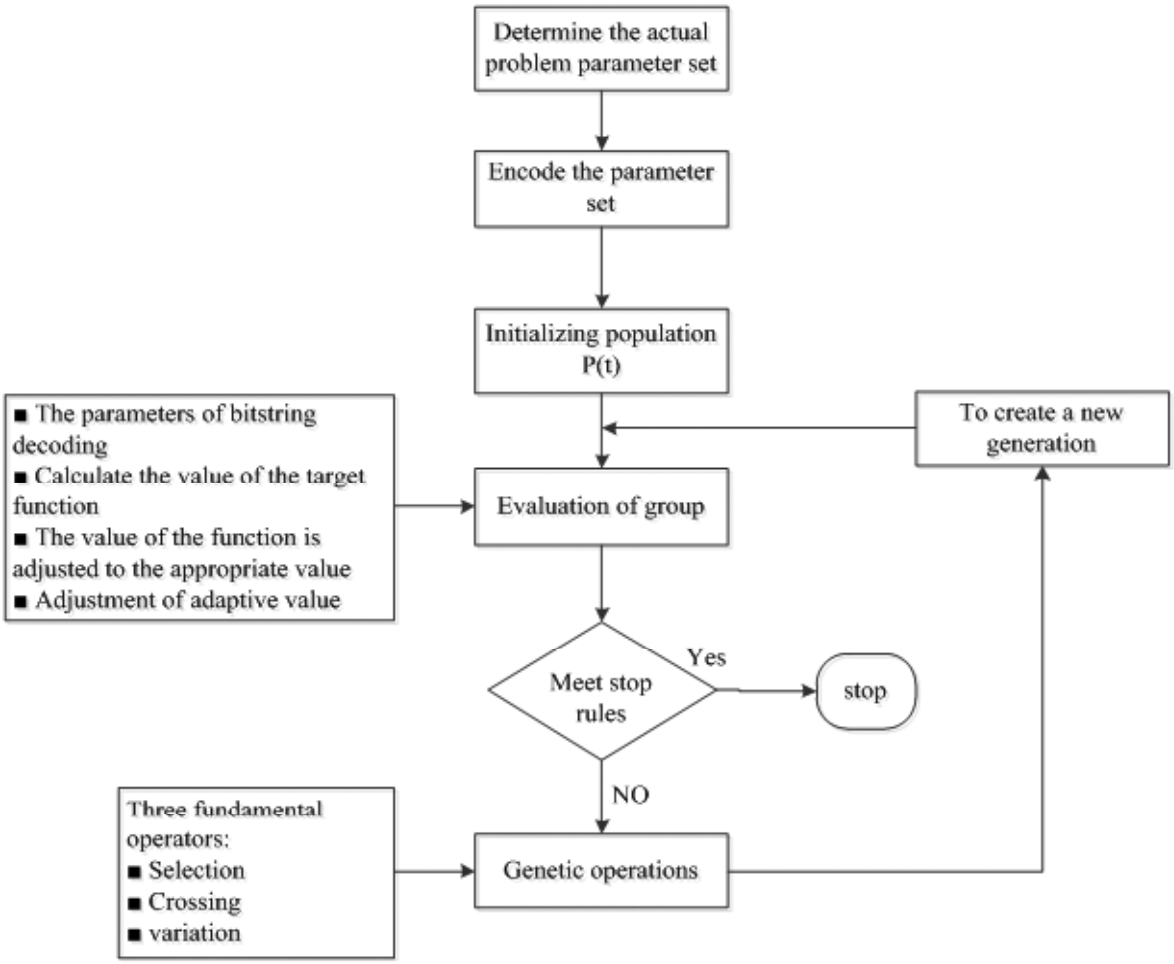

Figure 1: The specific steps of genetic algorithm.

5.3 Optimization Model Algorithm Design

5.3.1 Generation of Chromosome Coding and Initial Solution

Coding is the purpose of the transfer problem of feasible solutions in the search space of genetic algorithm. For practical problems, coding should take into account crossover and variation, and then consider the optimal solution of decoding. Binary encoding is commonly used in genetic algorithms, and each variable is represented in binary form. Such encoding and decoding operations are easy to carry out, and the genetic process of crossover and mutation is also convenient for subsequent implementation. However, the problem of courtyard space allocation in this paper needs to be solved due to special conditions. Using binary or floating point encode can make the problem more complicated. Using real code can not only be more image, express the problem, shorten the length of the code, and there is no decoding, easy to calculate.

Table 2: A sketch of a bay.

The layer						
4	41	42	43	44	45	46
3	31	32	33	34	35	36
2	21	22	23	24	25	26
1	11	12	13	14	15	16
The stack	**1**	**2**	**3**	**4**	**5**	**6**

The number of each container location is shown in table 2. The number of the ones represents the stack of containers and the number of the tens represents the layer of containers.

X(11, 21, 31, 41,12,13,14, 23), Means the first container goes to no. 11, the second container goes to no. 21, the third container goes to no. 31, and so on. In this paper, in order to avoid the overhanging container and simplify the representation of the container position, we use the following transformation: X(11, 21, 31, 41,12,13, 14, 23) '! X(1, 1, 1, 1, 2, 3, 4, 3). The transformed code X(1, 1, 1, 1, 2, 3, 4, 3) represents the first container on the first stack, and the second container on the first stack, Since the first container has been put in the box, the container number of the second container is 21, and the container number of the third container is 31. It can be seen from the analysis that the converted coding method can also represent the position of the container in the storage yard, and this coding method is also applicable to the case of multi-bay bit.

The generation of initial population is a random generation of M initial feasible solutions.

5.3.2 Design of Fitness Function

The fitness function solves the evaluation criteria and decides that the target function is used to distinguish the individual from the organization standard. Using genetic algorithm to solve the problem, fitness function will directly affect the convergence rate of genetic algorithm, can seek the optimal solution. Given that the objective function of the mathematical model in this paper is the minimum volume and non-negative, it can be used as an inverse objective function of fitness function. And in order to avoid the possibility that the denominator is zero, use $fitness = 1/(1+Z)$ to ensure that the optimal direction of the objective function corresponds to the direction of fitness value increase.

5.3.3 Determination of Genetic Operators

1) `The Determination of The Selection Operator

The operation of selecting good individuals from groups and eliminating bad ones is called selection. The goal of selection is survival of the fittest, which means that highly adaptable individuals have a greater chance of passing on directly to the next generation or to the next. In this paper, elite retention strategy is adopted, that is, those whose fitness is higher than the standard are retained.

2) The Determination of The Crossover Operator

A single point crossing means to select a point and then divide it into left and right parts, where the left and right parts of the two genes exchange their sequences with each other. Due to its simple operation, this paper mainly uses the single point crossing method for chromosome hybridization.

The following example is a single point of intersection:

Parent Q:11112 ↓ 343 → 11112 241(filial Q)

Parent P: 12143 ↑ 241 → 12143 343(filial P)

If the resulting ultra-high case (like five 1 in the filial Q) is present, the alternative is discarded and the alternative is re-crossed.

3) Determination of Mutation Operator

The mutation operation in genetic algorithm is an indispensable method to generate new individuals. This paper adopts the proportion of 5% for selection. The method of mutation is to randomly select two genes from one chromosome (the actual stack position) and exchange them if the stack position is different.

6. ALGORITHM VERIFICATION AND COMPARATIVE ANALYSIS

6.1 Case Background

Assume that one of the bay positions of a storage yard is empty, and 21 standard boxes are arranged in this bay. According to the unloading sequence of these 21 boxes and the pick-up priority based on the reservation system, a reasonable allocation scheme of boxes is required to make the overall volume of containers

minimum. Here the loading sequence is reasonably equivalent to the container number.

Table 3: The order of unloading of containers and priority of picking up containers.

Sequence of ship unloaded	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Extract container box priority	7	20	11	10	9	13	2	19	14	17	3
Sequence of ship unloaded	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	
Extract container box priority	15	4	16	1	18	21	8	5	12	6	

6.2 Case Solution

A concrete example is used to verify the effectiveness of the genetic algorithm. Data as shown in the table 3. In this paper, the initial population size is 100 and the genetic algebra is 500 generations. Design the computer solution program of genetic algorithm. And through MATLAB software programming. The optimal solution results are shown in table 4 and 5:

Table 4: The optimal solution for 21 containers.

Enter order	1-2-3-4-5-6-7-8-9-10-11-12-13-14-15-16-17-18-19-20-21
Extract container box priority	7-20-11-10-9-13-2-19-14-17-3-15-4-16-1-18-21-8-5-12-6
Storage location	1-6-5-2-3-3-5-2-6-2-6-4-6-1-3-1-5-5-1-4-4
Extract container box order	15-7-11-13-19-21-1-18-5-4-3-20-6-9-12-14-10-16-8-2-17

Table 5: Optimal allocation of 21 containers.

19				18	13
16	10	15	21	17	11
14	8	6	20	7	9
1	4	5	12	3	2

6.3 Compare with The Conventional Box Allocation Plan

The following is a comparison between the conventional box location distribution scheme and it. The information such as pick-up priority is consistent with that shown in table 4, as shown in table 6:

Table 6: The conventional box allocation plan.

19	20	21			
13	14	15	16	17	18
7	8	9	10	11	12
1	2	3	4	5	6

According to the program, the optimized number of rear cases turning is 37, and the optimization degree of the conventional box location distribution scheme is 56.8%, which can reduce the number of rear cases turning by 21 times.

It can be seen from the above results that, in the case of the unloading sequence and the time for the owner to pick up the container, the box location distribution

result obtained by genetic algorithm can greatly reduce the volume of turning over the container and improve the efficiency of the dock yard, which also proves the validity of the algorithm in this paper.

7. CONCLUSION

The problem of space allocation of container yard is an important part of dock management. However, in the actual unloading process, relevant managers may also mainly rely on personal experience, which not only wastes space resources, but also fails to give full play to the efficiency of port machinery. This paper comprehensively analyzes the research status of container spatial distribution at home and abroad. In view of the existing problems, a genetic algorithm is proposed to optimize the allocation of imported containers.

This paper uses the method of dynamic calculation of volume turnover, and gives the specific rules of the location of the specific location of the volume turnover. With the objective of minimizing the turnover of suitcases, a mathematical model based on genetic algorithm for the allocation of specific box positions in the rear yard entrance box is established. According to the model, the corresponding solving program is compiled. Through a specific example, the feasibility and validity of the genetic algorithm for solving the allocation scheme of container location are verified when the unloading sequence and the time of the cargo owner's suitcase are known. Comparing with the conventional scheme, it can be seen that the allocation result of box location obtained by genetic algorithm can greatly reduce the turnover of box and improve the efficiency of dock yard.

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