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## Yard Bay Allocation Method for Twin 40ft Container Terminal-Oriented

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### Abstract

*The efficiency of container handling has got great improvement with the usage of the 40ft quay crane and the twin 40 ft yard crane. Reasonable bay planning strategies is necessary to reach the high handing efficiency by the twin 40 ft yard crane. This paper studies both bay planning and row planning for yard bay allocation. The models of bay planning and row planning are created, and the discrete particle swarm optimization algorithm is used to obtain the optimum solution of the models. Finally, the numerical experiments show that the proposed approach can solve the yard bay allocation effectively.*

**Keywords:** automatic container terminal, twin 40ft, bay planning, row planning, discrete particle swarm optimization algorithm

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### 1. Introduction

In order to make full use of the twin 40ft high efficiency of loading and unloading, it must have a reasonable bay strategy. More and more researches have paid attentions to the studies on bay planning in global trade. Kim KH, Kim HB discussed the issue of imported container storage and turned the box [1]. Peter discussed the optimal stockpiling program in the container yard and established a mixed-integer linear programming model. The objective function was to minimize the time that the ship stay in the port by using genetic algorithm [2]. Peter Preston and Erhan Kozan proposed a container storage model. The objective function was to solve the shortest turnaround time in the port by using genetic algorithms and given the optimal container transportation plan with different mode of stockpiling [3]. Kim studied on regular liner and tramp times the imports of container storage space allocation problem. It focused on the imported ship continuous and uniform arrives, periodically arrives these three cases and established a mathematical model respectively. The model optimization variable was the container stacking height. But he assumed that only allowed within the same shell down box, only considered the circumstance of the operation of the quay crane [4]. Ebru studied on multi straddle carriers constraints operating plan, it considered the import yard space configuration issues in conjunction with the quay crane scheduling problem. The problem was divided into three sub-problems, that was as follows: (1) distributing container yard space for each unloading ship; (2) distributing haulage equipment for container; and (3) scheduling quay crane loading and unloading operations. The optimized goal was to make the shortest service time of the ship (fleet) [5]. De Castinho and Dagano studied the problem of stockpiling of imported container under the two strategies, one strategy was to pile up in accordance with the container size, another was to stack according to the time of arrival [6]. Kim et al considered the weight property of the container, yard shellfish stockpiling state and the weight distribution of the container, put forward a dynamic programming model by using the weighted method to calculate the expectations prone to overturn expectations minimize loading operation down box operations. And proposed decision tree generated from the optimal solution concentrated [7]. Kim and Lee used constraint technology to solve the box bit allocation of the export box under the premise of the meet the yard operating equipment set card operating efficiency constraints. It was try to improve the efficiency of the subsequent loading operation goals [8]. Yushi Wei et al built the quadratic programming thrust allocation and management system to solve the complex

thrust allocation problems of dynamic positioning ship with azimuth thrusters [9]. Nannan Yan et al established berth allocation and quay crane scheduling models of shore operating for a container terminal. Furthermore, the structure of the berth-quay crane scheduling agent was also given [10].

Based on above literature, this article researched though the handling system of twin 40ft container terminal bay planning. It studied on two levels: bay planning and row planning. Discrete particle swarm optimization algorithm was design in the model. It expected to reduce the level of the ship in port time and improve equipment utilization and port services, and ultimately improved the economic and social benefits of port enterprises.

## 2. Problem Description

Facing increased tough market competition and environmental pressures, the port uses twin 40ft quay crane and yard crane in order to improve competitiveness. To achieve twin 40ft loading and unloading operations, there must be a reasonable bay planning strategy. So twin 40ft container handling system bay planning and row planning have become the key issues in container transport development in the future. Therefore, this article combined with twin 40ft handling rules to build a twin 40ft container terminal bay planning multi-objective model. In order to simplify the complexity of the overall model, the overall model was decomposed into two step by step plan model, that is bay allocation model and row allocation model. The principles in bay planning: 1. box-bit centralized principle, 2. ship loading and unloading operations uncrossed principle, 3. empty containers bits not less than the container volume principle, 4. parallel distribution box principle. The principles in row planning: 1.the same row with the same port of discharge with the same tons principle, 2. far unload port with big tons set near the lane principle.

## 3. Yard Bay Allocation Model

Twin 40ft container terminal bay allocation overall model was decomposed into two parts: bay allocation model and row allocation model, which was a two-stage decomposition model. The decomposition corresponding objective function was also split into two parts.

### 3.1. Bay Allocation Model

Bay allocation model took the ordinary terminal yard plan and the rules of twin 40ft loading and unloading system into account. The bay allocation sub-model was created in the order of setting the distance and ensuring quay crane continuous hair box as the goal. The distance requirement in the model was to make the horizontal transport distance of the total ship to the box area the shortest, while ensuring the continuous distribution box of the quay crane, which made the distance the least when the carts moving. This goal at the operational level was to make the tank group number in the box area of the assigned number of times as far as possible continuous, so that an increase of the number of twin 40ft loading and unloading could be achieved. This sub-model determined the allocation of each box in group box area bay bit under the guidance of the box area plan. Each part of this model was as follows:

#### a. Notations

$N_{-20_v}$ : The 20ft export box quantity of i box area planning to v ship;

$N_{-40_v}$ : The 40ft export box quantity of i box area planning to v ship;

$N_{-20_{jv}}$ : The 20ft export box quantity of i box area j bay planning to v ship;

$N_{-40_{jv}}$ : The 40ft export box quantity of i box area j bay planning to v ship;

$S_{ij}$ : The loading start time of i box area j bay;

$E_{ij}$ : The loading end time of i box area j bay;

$QER_{ij}$ : In the current period, the number of the empty row in i box area j bay (Prediction according to the ship departure time and the statistical rules of picking up boxes);

$QEBR_{ij}$ : In the current period, the number of the empty row in i box area j bay;

$NOCG_m$ : The group number of  $m$  group;

$OP_{ij}$ : Judge whether  $i$  box area  $j$  bay and its adjacent bay belong to the same production line.

### b. Decision variable

The Objective function is to make twin 40ft shipment the most, the distance of RTG and cart is the shortest. Equation (1) is to ensure the total ship to each box area bay horizontal transport distance the shortest. Equation (2) is to ensure  $v$  ship to  $i$  box area adjacent box group sum the minimum. For 20ft containers at the same port of unloading, if the necessary bay is more than one, the planning bay should be adjacent, so that handling four 20ft container can be increased. The target can be converted into the adjacent bay planning box group sum the minimum. Due to the adjacent bay planning box group continuity is strongly, it reduces the movement of the carts to ensure carts total moving distance the shortest. Equation (3) is to ensure the number of 20ft containers in each  $i$  box area of  $v$  ship equal to the sum number of the ship assigned to the  $i$  box area. Equation (4) is to ensure the number of 40ft containers in each  $i$  box area of  $v$  ship equal to the sum number of the ship assigned to the  $i$  box area. Equation (5) is to ensure the empty row number in  $i$  box area  $j$  bay is not less than the amount of export box. Equation (6) is to ensure the empty row number in  $i$  box area  $j$  bay is not less than the amount of export box. Equation (7) is to ensure the whole of bays only has one size. Equation (8) is to ensure the box group in the same bay belongs to the same port of unloading. Equation (9) is to ensure a 40-foot box group occupies two adjacent bays. Equation (10) is to ensure the current periods  $v$  ship in  $i$  box area container volume more, and  $i$  box area has two quay crane, then there exists two adjacent times does not plan to the ship, i.e. there is an empty large bay in the middle of the box area to make two quay crane in  $i$  box area work at the same time. Equation (11) is to ensure the current  $i$  box area bay  $j$  and its adjacent does not belong to the same operating line and the operating time is not cross.

$$VTR_{ijqm} = \begin{cases} 1, & \text{The box group what } i \text{ box area } j \text{ bay } q \text{ row distributes to } m; \\ 0, & \text{The box group what } i \text{ box area } j \text{ bay } q \text{ row does not distribute to } m; \end{cases}$$

$$VTB_{ijv} = \begin{cases} 1, & \text{What } i \text{ box area } j \text{ bay distributes to } v \text{ ship}; \\ 0, & \text{What } i \text{ box area } j \text{ bay does not distribute to } v \text{ ship}; \end{cases}$$

$$VTB_{ijvm} = \begin{cases} 1, & \text{The box group what } i \text{ box area } j \text{ bay distributes to } v \text{ ship}; \\ 0, & \text{The box group what } i \text{ box area } j \text{ bay does not distribute to } v \text{ ship}; \end{cases}$$

$$Size_{ijqv} = \begin{cases} 1, & \text{The box group size between } i \text{ box area } j \text{ bay } k \text{ row and } k-1 \text{ row is not consistent}; \\ 0, & \text{The box group size between } i \text{ box area } j \text{ bay } k \text{ row and } k-1 \text{ row is consistent}; \end{cases}$$

$$LP_{ijqv} = \begin{cases} 1, & \text{The box group between } i \text{ box area } j \text{ bay } q \text{ row and } q-1 \text{ row belongs to the same unloading port}; \\ 0, & \text{The box group between } i \text{ box area } j \text{ bay } q \text{ row and } q-1 \text{ row does not belong to the same unloading port}; \end{cases}$$

### c. Objective functions

$$f_1 = \text{Min} \left( \sum_{i \in S_{B_{vm}20t}} N_{20_{ijv}} * VTB_{ijvt} * d_{ijv} + \sum_{i \in S_{B_{vm}40t}} N_{40_{ijv}} * VTB_{ijv} * d_{ijv} \right) \quad (1)$$

$$f_2 = \text{Min} \sum_{j=2}^{BNO_{vt}} \left| \sum_{q \in S_{BR_{jvt}}} VTR_{ijqm1} * NO_{CG_{m1v}} - \sum_{q \in S_{BR_{i(j-1)vt}}} VTR_{i(j-1)qm2} * NO_{CG_{m2}} \right| \quad (2)$$

$$i \in S_{OBL_{vt}}, v \in S_{VP_t}, m1, m2 \in S_{CG_{vt}}$$

#### d. Constraints

$$N_{-20}_{iv} = \sum_{j \in S_{-B_{ivm-20}_t}} VTB_{ijv} * N_{-20}_{ijv}, \quad i \in S_{-OBL}_{vt} \quad (3)$$

$$N_{-40}_{iv} = \sum_{j \in S_{-B_{ivm-40}_t}} VTB_{ijv} * N_{-40}_{ijv}, \quad i \in S_{-OBL}_{vt} \quad (4)$$

$$\lambda * \left( \sum_{v \in S_{-VP}_t} N_{20}_{ijv} + 2 * \sum_{v \in S_{-VP}_t} N_{40}_{ijv} \right) \leq \sum_{j \in S_{-B_{ivm-20}_t}} VTB_{ijv} * QER_{ij} * Tier_i \quad (5)$$

$$\lambda * \sum_{v \in S_{-VP}_t} N_{40}_{ijv} \leq \sum_{j \in S_{-B_{ivm-20}_t}} VTB_{ijv} * QER_{ij} * Tier_i, \quad \lambda * i \in S_{-OBL}_{vt} \quad (6)$$

$$\sum_{q=2}^{Row_i} \sum_{j \in S_{-VP}_t} S_{ize}_{ijqv} = 0, \quad i \in S_{-OBL}_{vt}, j \in S_{-B_{ivt}} \quad (7)$$

$$\sum_{q=2}^{Row_i} \sum_{j \in S_{-VP}_t} L_{P_{ijqv}} = 0, \quad i \in S_{-OBL}_{vt}, j \in S_{-B_{ivt}} \quad (8)$$

$$S_{m-40} * VTB_{ijv_m} * VTB_{ikv_m} * |BNO_{ij} - BNO_{ik}| = 2 \quad (9)$$

$$i \in S_{-OBL}_{vt}, j, k \in S_{-B_{ivt}}, v \in S_{-VP}_t, m \in S_{-CG}_{vt}$$

$$\text{If } N_{-20}_{iv} + 2 * N_{-40}_{iv} \geq N_{large}, \text{ and } QYC_{iv} = 2, v \in S_{-VP}_t, i \in S_{-OBL}_{vt}$$

$$\text{Then } \sum_{j=3}^{BNO_{ivt}-2} \left( \sum_{m \in CG_{pvt}} VTB_{ijv_m} + \sum_{m \in CG_{pvt}} VTB_{i(j+1)v_m} \right) = 0, i \in S_{-OBL}_{vt}, v \in S_{-VP}_t \quad (10)$$

$$VTB_{ijv} * VTB_{i(j+1)v} * (1 - OP_{ij}) * (S_{ij} - E_{ij+1}) * (E_{ij} - S_{ij+1}) \geq 0 \quad (11)$$

$$OP_{ij} = \begin{cases} 1 & i \text{ box area } j \text{ bay and its adjacent belong to the same production line;} \\ 0 & i \text{ box area } j \text{ bay and its adjacent does not belong to the same production line;} \end{cases}$$

The Objective function is to make twin 40ft shipment the most, the distance of RTG and cart is the shortest. Equation (1) is to ensure the total ship to each box area bay horizontal transport distance the shortest. Equation (2) is to ensure  $v$  ship to  $i$  box area adjacent box group sum the minimum. For 20ft containers at the same port of unloading, if the necessary bay is more than one, the planning bay should be adjacent, so that handling four 20ft container can be increased. The target can be converted into the adjacent bay planning box group sum the minimum. Due to the adjacent bay planning box group continuity is strongly, it reduces the movement of the carts to ensure carts total moving distance the shortest. Equation (3) is to ensure the number of 20ft containers in each  $i$  box area of  $v$  ship equal to the sum number of the ship assigned to the  $i$  box area. Equation (4) is to ensure the number of 40ft containers in each  $i$  box area of  $v$  ship equal to the sum number of the ship assigned to the  $i$  box area. Equation (5) is to ensure the empty row number in  $i$  box area  $j$  bay is not less than the amount of export box. Equation (6) is to ensure the empty row number in  $i$  box area  $j$  bay is not less than the amount of export box. Equation (7) is to ensure the whole of bays only has one size. Equation (8) is to ensure the box group in the same bay belongs to the same port of unloading. Equation (9) is to ensure a 40-foot box group occupies two adjacent bays. Equation (10) is to ensure the current periods  $v$  ship in  $i$  box area container volume more, and  $i$  box area has two quay crane, then there exists two adjacent times does not plan to the ship, i.e. there is an empty

large bay in the middle of the box area to make two quay crane in  $i$  box area work at the same time. Equation (11) is to ensure the current  $i$  box area bay  $j$  and its adjacent does not belong to the same operating line and the operating time is not cross.

### 3.2. Row Allocation Model

Row allocation model distributed each row of containers within the box area. It combined with the twin 40ft handling row allocation optimization rules. The row allocation sub-model was created in the order of setting the distance and ensuring the number of twin 40ft loading and unloading the most as the goal. It was to improve the efficiency of hair box. In order to reduce the moving distance of the car, the group number between row and row in the bay should be continuous and the box group number should be close to the lane following the order from big to small. At the same time for the big row, the number of twin 40ft handling was increased. This sub-model determined the allocation of each box in group box area row bit under the guidance of ensuring the number of each box group in each bay and the number of containers. Each part of this model was as follows:

#### a. Notations

$NOG_{ijq}$  : The number of box group in  $i$  box area  $j$  bay  $q$  row;

$NO_{CG_m}$  : The group number of  $m$  group;

$QCG_{ijqm}$  : The number of box group what  $m$  group distributes to  $i$  box area  $j$  bay  $q$  row.

#### b. Decision variable

$$VTR_{ijqm} = \begin{cases} 1, & \text{The box group what } i \text{ box area } j \text{ bay } q \text{ row distributes to } m; \\ 0, & \text{The box group what } i \text{ box area } j \text{ bay } q \text{ row does not distribute to } m; \end{cases}$$

$$S_{m\_40} = \begin{cases} 1, & \text{Box area } m \text{ is not 40ft;} \\ 0, & \text{Box area } m \text{ is not 40ft;} \end{cases}$$

#### c. Objective functions

$$f_1 = \text{Min} \sum_{q=2}^{Row_i} |VTR_{ijqm1} * NO_{CG_{m1}} - VTR_{ij(q-1)m2} * NO_{CG_{m2}}| \quad (12)$$

$$i \in S\_OBL_{vt}, j \in S\_B_{ivt}, q \in S\_BR_{ijvt}, m1, m2 \in S\_CG_{vt}$$

#### d. Constraints

$$VTR_{ij(q+1)m1} * NO_{CG_{m1}} \geq VTR_{ijqm2} * NO_{CG_{m2}} \quad (13)$$

$$i \in S\_OBL_{vt}, j \in S\_B_{ivt}, q \in S\_BR_{ijvt}, m1, m2 \in S\_CG_{vt}$$

$$NCG_{ijq} = 1, i \in S\_OBL_{vt}, j \in S\_B_{ivt}, q \in S\_BR_{ijvt}$$

Set

$$\text{mod}_{ijm} = \text{mod} \left[ \sum_{j \in S\_B_{ivt}} \sum_{q=1}^{Row_i} VTR_{ijqm} * QCG_{ijqm} * (1 - S_{m\_40}), 2 * Row_i * Tier_i - (Tier_i - 1) \right] \quad (14)$$

$$i \in S\_OBL_{vt}, m \in S\_CG_{vt}$$

$$\sum_{j \in S\_B_{ivt}} \sum_{q=1}^{Row_i} VTR_{i(j+1)qm} * QCG_{i(j+1)qm} * (1 - S_{m\_40}) =$$

$$\text{Then} \sum_{j \in S\_B_{ivt}} \sum_{q=1}^{Row_i} VTR_{ijqm} * QCG_{ijqm} * (1 - S_{m\_40}) = \text{mod}_{ijm} / 2 \quad (15)$$

The Objective function is to make twin 40ft shipment the most. That is to make the most number of rows at the same box area in the same row planning. The planning is made in the same bay adjacent row. It considers the quay crane minimum moving distance of the cart at the same time. The box group number should be continuous to ensure the distribution of the box easily. Equation (12) is to ensure  $v$  ship to  $i$  box area adjacent box group sum the minimum. Equation (13) is to ensure the small box group near to the lane to reduce the cart moving distance. Equation (14) is to ensure a row in a bay can be planed to a box group. Equation (15) is to ensure the number of distributing to  $i$  box area 20ft box group  $m$  is equal to the potential remainder box number divided by two bay sharing to the adjacent row. Other containers are planed according to the bay planning of the adjacent bay to facilitate the twin 40 operation.

#### 4. Algorithm for Bay Planning and Row Planning

##### 4.1. Bay Planning Algorithm

The container bay allocation model algorithm is mainly to solve the current plan of 20ft box and 40ft box on the ship within the period of time. The algorithm can work out the scheme of the distribution of the box in bays to the corresponding berth horizontal transport distance and the box group number in each box area bay, then through the comparison of the two indicators to determine the optimization scheme. This model designs the discrete particle swarm optimization algorithm to optimize the feasible solution. It gets the optimization scheme of twin 40ft container terminal bay allocation.

##### a. Encoding Representation

Because the container terminal yard space bay position is according to integer numbers and the distribution of the box quantity is discrete integer, so using the binary coding in the discrete particle swarm optimization algorithm to encode (Figure 1). Each 2 bits in particle coding is the bay of a particle. That is the bay number in box area. Even number is 40ft bays and odd number is 20ft bays. Such as "01 03 07 09 10 16 20", which represents 20ft box planning bay is 01. 03. 07. 09, represents 40ft box planning bay is 10. 16. 20. The particle in this model expresses a box area pile-up planning feasible solution. Each particle is a combination of four parts. There are ship numbers, the code box of distribution group, 20ft box quantity and 40ft box quantity respectively. Ship numbers expresses the order of to the port ship. That is  $V_1, V_2, \dots, V_n$ . Box group bay allocation is a combination of four parts.  $X_{12}$  2214 shows that the box area distributed to  $V_2$  ship was 22 box area and 14 bay in that period. The 20ft quantity was 0 and the 40ft quantity was 18.

	Particle $X_1$					Particle $X_2$				
Position vector	$X_{11}$	$X_{12}$	$X_{13}$	$X_{14}$	$X_{15}$	$X_{21}$	$X_{22}$	$X_{23}$	$X_{24}$	$X_{25}$
Ship No.	$V_1$	$V_2$	$V_3$	$V_4$	$V_5$	$V_6$	$V_7$	$V_8$	$V_9$	$V_{10}$
Box area	1213	2214	2306	2305	2218	2214	2615	2115	2305	2114
Bay allocation	1214	.2123			2314					
20ft box	12 0	0	0 14	20	0	0 0	9	21	20	0
40ft box	0 21	18	10 0	0	8	4 16	0	0	0	8

Figure 1. The particle swarm algorithm code view of container terminal bay planning

##### b. Population Initialization

According to the yard plan model feasible solution algorithm generates first generation particle population randomly. The population size is  $m$ . The particle's initial velocity is 0. The value of  $m$  is 30~50 when the variable is small. The value of  $m$  is 100~200 when the variable is big.

### c. Fitness evaluation

Due to the bay allocation model is a multi-objective programming problem and the adaptive value function is the objective function, two objective functions must be normalized.

Normalized is made to equation (1). Setting the minimum distance is  $d_{\min}$ , the biggest distance is  $d_{\max}$  of each container transport to the berth. The target value is as follows:

$$f_1' = \frac{f_1 - \sum_{i \in S\_OBL_{vt}} \sum_{v \in S\_VP_i} (N_{-20_{iv}} + N_{-40_{iv}}) * d_{\min}}{\sum_{i \in S\_OBL_{vt}} \sum_{v \in S\_VP_i} (N_{-20_{iv}} + N_{-40_{iv}}) * d_{\max} - \sum_{i \in S\_OBL_{vt}} \sum_{v \in S\_VP_i} (N_{-20_{iv}} + N_{-40_{iv}}) * d_{\min}} \quad (16)$$

Normalized is made to equation (2). Setting the estimation minimum of the difference between box group in adjacent bay planning at any time. On the other hand, the maximum is  $NBQCG_{Max_{ivm}}$ . The target value is as follows:

$$f_2' = \sum_{v \in S\_VP_i} \frac{\sum_{m \in S\_CG_{vt}} \sum_{i \in S\_OBL_{vt}} (f_{2_{ivm}} - NBQCG_{Max_{ivm}})}{\sum_{m \in S\_CG_{vt}} \sum_{i \in S\_OBL_{vt}} (NBQCG_{Max_{ivm}} - NBQCG_{Min_{ivm}})} \quad (17)$$

The multi-objective function of the yard planning model after the normalized is  $f = \text{Min}(\omega_1 * f_1' + \omega_2 * f_2')$ . The fitness function for the algorithm is  $f(k) = \sum_{i=1}^2 \omega_i * f_i'$ ,  $\sum_{i=1}^2 \omega_i = 1$ ,  $\omega_i = 1 (i = 1 \dots 2)$  is the weight of different objective functions. The value of each weighting factor is 0.5.

### d. Other Parameter Settings

Twin 40ft container handling system bay allocation algorithm iterations sets to 60. The termination condition is designated iterative maximum algebra method to update the operation for the particle's velocity and position.

### e. Algorithm Process

The bay allocation in the decision cycle can be get after the algorithm is completed. According to the calculated results, the algorithm executives decision cycle current plan time box area bay allocation result.

## 4.2. Row Planning Algorithm

The algorithm of twin 40ft container terminal row allocation is made to determine the current decision cycle in each row distribution box group number and container number. The algorithm is based on twin 40ft handling number and quay crane moving distance minimization of adaptive value function. The algorithm can work out the scheme of the distribution of the box in rows to the corresponding berth level transport distance and the box group number in each box area row, then through the comparison of the two indicators to determine the optimization scheme. This model designs the discrete particle swarm optimization algorithm to optimize the feasible solution. It gets the optimization scheme of twin 40ft container terminal row allocation.

### a. Encoding representation

Because the container terminal yard space row position is according to integer numbers and the distribution of the box quantity is discrete integer, so using the binary coding in the discrete particle swarm optimization algorithm to encode (Figure 2). The particle in this model expresses a box area pile-up planning feasible solution. Each particle is a combination of four parts. There are ship numbers, the code box of distribution group, 20ft box quantity and 40ft box quantity respectively. Ship numbers expresses the order of to the port ship. That is  $V_1, V_2, \dots, V_n$ . Box group bay allocation is a combination of four parts.  $X_{12}$  201404 shows that the box area distributed to  $V_2$  ship was 22 box area and 14 bay 04 row in that period. The 20ft

quantity was 0 and the 40ft quantity was 3. The sum container number in all the row allocation in the bay is no greater than the container number calculated in the bay allocation model.

Position vector	Particle $X_1$					Particle $X_2$				
	$X_{11}$	$X_{12}$	$X_{13}$	$X_{14}$	$X_{15}$	$X_{21}$	$X_{22}$	$X_{23}$	$X_{24}$	$X_{25}$
Ship No.	$V_1$	$V_2$	$V_3$	$V_4$	$V_5$	$V_6$	$V_7$	$V_8$	$V_9$	$V_{10}$
Box area	12130	22140	23060	23050	22180	22140	26150	21150	23050	21140
Row allocation	1	4	3	3	3	1	4	3	3	6
20ft box	11210	.	21230		22140					
40ft box	3	0	6	4	2	0	4	3	4	0
	4	0	0	4	0	0	4	3	4	0
	0	3	4	0	4	4	0	0	0	4

Figure 2. The particle swarm algorithm code view of container terminal row planning

### b. Population initialization

According to the yard plan model feasible solution algorithm generates first generation particle population randomly. The population size is  $m$ . The particle's initial velocity is 0. The value of  $m$  is 30~50 when the variable is small. The value of  $m$  is 100~200 when the variable is big.

### c. Fitness evaluation

Due to the row allocation model is a multi-objective programming problem, the adaptive value function must be normalized.

Normalized is made to equation (12). Setting the estimation minimum of the difference between box group in adjacent bay planning at any time. On the other hand, the maximum is  $NBQCG_{Max_{ijm}}$ . The target value is as follows:

$$f_1' = \sum_{m \in S_{CG_{vt}}} \frac{\sum_{i \in S_{OBL_{vt}}, j \in S_{OBL_{ivt}}} (f_{1ijm} - QCG_{Max_{ijm}})}{\sum_{i \in S_{OBL_{vt}}, j \in S_{B_{ivt}}} (QCG_{Max_{ijm}} - QCG_{Min_{ijm}})} \quad (18)$$

The multi-objective function of the yard planning model after the normalized is  $f = M$  in  $f_1'$ . That is the fitness function for the algorithm.

### d. Other parameter settings

Twin 40ft container handling system bay allocation algorithm iterations sets to 60. The termination condition is designated iterative maximum algebra method. Row allocation algorithm uses termination conditions is specified iterative maximum algebra method.

### e. Algorithm process

The row allocation in the decision cycle can be get after the algorithm is completed. According to the calculated results, the algorithm executives decision cycle current plan time box area row allocation result.

## 5. Numerical Experiments

### 5.1. Bay Planning

#### a. Initial data

Box area allocation planning determined the quantity of 20ft and 40ft and made bay planning for ship  $v01$  to determine the specific bay of the corresponding box area. The ship's bay allocation situation calculated through twin 40ft handling system. The case of  $v01$  distribution box area empty bay situation as was shown in Table 1.

### b. Control parameters

Bay allocation algorithm used discrete particle swarm optimization algorithm, Control parameters set are as follows:  $C_1$  and  $C_2$  were equal to 2, population scale was 100, iterations was 60.

Table 1.  $v01$  ship distribution of box area bay

Box area 2	Box area 3	Box area 4	Box area 5	Box area 7
1	3	1	1	5
3	5	3	3	7
5	7	5	7	9
7	9	7	9	11
9	13	9	11	13
13	15	15	15	15
15	17	17	17	17
17	19	19	21	19
19	21	21	23	21

### c. Operation results

Bay planning task was based on box area plan to calculate 20ft and 40ft export carton quantity of each ship distribution. In this way, bay allocation situations could be calculated. Take the ship for example, bay allocation of each box area could be calculated though bay allocation algorithm. Then calculate bay allocation according to the actual situation without using the bay planning optimization model and algorithm. That was planning the box group into bay according to the empty box sequence. The two operation results were shown in Table 2.

Table 2.  $v01$  ship bay allocation results

Results	The general horizontal of transportation distance ( km)	The cart average moving distance ( m)	Computation time ( min)
Optimization	414.3	108.7	7.1
Actual	483.5	124.7	5.5

From this example, using twin 40ft container bay planning model and algorithm can reduce the container to corresponding berth total transport distance and box area quay crane cart average moving distance and further lessen the distance. Although the optimization time is long, space planning also belongs to offline optimization, so the influence of the actual production of terminal can be ignored. At the same time using bay planning optimization model and algorithm get the distribution of  $v01$  ship was shown in Table 3. The optimization bay planning results were the basic data of ship row planning, that is according to the data to determine the distribution position of the ship.

## 5.2. Row Planning

Determining on the  $v01$  ship bay allocation, the row planning example took  $v01$  ship as the object, made twin 40 handling number the most and cart moving distance the minimum.

### a. Control parameters

Bay allocation algorithm used discrete particle swarm optimization algorithm, Control parameters set are as follows:  $C_1$  and  $C_2$  were equal to 2, population scale was 100, iterations was 60.

### b. Operation results

Row planning task was based on bay area plan to calculate 20ft and 40ft export carton quantity of each ship distribution. In this way, row allocation situations could be calculated. Take the ship for example, row allocation of each ship could be calculated though row allocation algorithm. Then calculate row allocation according to the actual situation without using the row

planning optimization model and algorithm. That was planning the box group into bay according to the empty box sequence. The two operation results were shown in Table 4.

Table 3.  $v01$  ship row allocation situations

Box area 2		Box area 3		Box area 4		Box area 5		Box area 6	
Bay	Box quantity								
3	31	3	31	1	31	1	31	5	31
5	31	5	31	3	31	3	31	7	31
11	22	7	22	5	21	7	21	9	21
13	21	9	21	7	21	9	21	11	21
16	23	14	23	16	22	16	22	14	22
20	22	18	22	20	22	20	22	18	22

Table 4. Container row allocation numerical results

Results	The cart average moving distance (m)	Loading ratio	Best adaptive value	Computation time (min)
Optimization	5010.2	37%	0.22	8.5
Actual	7180.4	21.20%	0.401	5.2

From this example, using row planning model and algorithm can reduce the container to corresponding berth total transport distance and box area quay crane cart average moving distance and further lessen the distance. Although the optimization time is long, space planning also belongs to offline optimization, so the influence of the actual production of terminal can be ignored.

### c. Row allocation results

The row allocation results of  $v01$  ship using row planning optimization model and algorithm was shown in Table 5.

Table 5.  $v01$  ship row allocation results

	Bay	Row 1	Row 2	Row 3	Row 4	Row 5	Row 6	Row 7
Box area 2	3	5	5	5	5	5	5	1
	5	5	5	5	5	5	5	1
	11	5	5	5	5	2		
	13	5	5	5	5	1		
	16	5	5	5	5	3		
Box area 3	20	5	5	5	5	2		
	3	5	5	5	5	5	5	1
	5	5	5	5	5	5	5	1
	7	5	5	5	5	2		
	9	5	5	5	5	1		
Box area 4	14	5	5	5	5	3		
	18	5	5	5	5	2		
	1	5	5	5	5	5	5	1
	3	5	5	5	5	5	5	1
	5	5	5	5	5	2		
Box area 5	7	5	5	5	5	1		
	9	5	5	5	5	1		
	16	5	5	5	5	2		
	20	5	5	5	5	2		
	5	5	5	5	5	5	5	1
Box area 7	7	5	5	5	5	5	5	1
	9	5	5	5	5	2		
	11	5	5	5	5	1		
	14	5	5	5	5	2		
	18	5	5	5	5	2		

## 6. Conclusion

Based on the analysis of container terminal bay allocation and its principles, this article built a twin 40ft container terminal bay allocation overall multi-objective model. It solved the problem in stages: bay allocation model algorithm design and row allocation model algorithm design. Finally verify the correctness of the model and algorithm by a numerical example.

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