

Collaborative optimization of truck appointment system and yard cranes allocation based on ship time window

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Abstract. With the rapid growth of the global container trade volume and the trend of large-scale container ships. The collection and distribution port efficiency and capacity of container terminals in various countries are facing huge challenges. Due to the randomness of most of the trucks entering the port, container terminals often face the problem of traffic congestion caused by the centralized arrival of trucks in the port and the load operation of the yard operation equipment. Therefore, terminal operators urgently need to manage and optimize all aspects of terminal collection and distribution operations. This paper proposes a truck appointment system that simultaneously considers the time window of the ships and the allocation plan of the yard crans, so as to reasonably allocate the arrival time of each truck and the amount of appointment quota. By means of shortening the time window of each ship's and rationally allocating the yard cranes operations in the blocks, human and material resources can be fully utilized, so as to alleviate the traffic pressure in the container terminal, shorten the waiting time of ships and trucks, and reduce the cost of terminal operators.

Keywords: Truck appointment system, Ship time window, Yard cranes allocation.

1 Introduction

With the increase in the world's container traffic and the introduction of giant ships, many port facilities are operating at or near full capacity. With limited resources and facilities, truck congestion at gates and yards has become a problem for various ports. And it has become a major challenge that needs to be addressed urgently. Terminal operators and academics are also demanding solutions to manage truck arrivals and ease terminal congestion. Such as Truck Appointment System (TAS), Vessel Dependent Time Window (VDTWs).

One of the main solutions for truck management arrivals is the Truck Appointment System (TAS), which has received many research results nowadays. And the first successful implementation of TAS in the Port of Vancouver is Morias(2006) [1]. However, Giulianoa

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(2007) [2] investigated the implementation results of the TAS in the ports of Los Angeles and Long Beach and found that the system had little improvement in terminal congestion. And it is clearly pointed out that only considering the queuing at the gate and ignoring the operation of the yard cannot significantly reduce the overall congestion of the terminal. Chen (2011) [3] proposed a two-stage model and analyzed the queuing behavior through the Point wise Stationary Fluid Flow Approximation (PSFFA) queuing model. Prior to this, most studies have used traditional stationary queuing networks to analyze. Based on the PSFFA method, Chen (2013) [4] developed an integration of the bisection method and the PSFFA method, called B-PSFFA. Compared with the stationary queuing model, it can be found that the non-stationary queuing model has higher accuracy.

Beside the TAS, Yang (2010) [5] first proposed another VDTWs method to manage truck arrivals and put it into practice in some container terminals in China. The control system it developed assigns two time windows to each vessel for container handover activities. It not only shortens the storage time of containers in the yard, but also improves the on-time arrival rate of trucks in the corresponding time window. However, the fixed time window length and appointment quota cannot be changed according to the busyness of the yard operations, which leads to the waste of some yard resources. Therefore, Chen and Yang (2011) [6] proposed the original idea of time window optimization, by developing a heuristic algorithm to find a near-optimal time window allocation, which was also used by Chen (2013) [4] to lay laid the foundation for further optimization of VDTWs. What is more, Guo (2013)[7] aims at the characteristics of container gathering port being limited by its arrival time, the concept of ship gathering time window is applied to the construction of the TAS model, and the time window and appointment quota are optimized at the same time to alleviate the problem. The terminal is reduced congestion and the utilization rate of the yard facilities is improved. Of course, the above research only discusses the impact of the time window on the arrival of trucks and the queuing behavior of trucks at the gate and yard, ignoring the various operation links inside the terminal, which does not necessarily improve the overall performance of the terminal. Therefore, some related studies on yard resource allocation and yard space should also be carried out at the same time, so that VDTWs can be seamlessly integrated with container terminal operations to ensure the smooth progress of the entire terminal operations.

With the continuous extensive and in-depth implementation and application of the tTAS, some scholars have begun to study the impact of accelerating the appointment system on the allocation of yard cranes resources. Huynh (2005) [8] firstly considered the turnaround time of the truck and the utilization rate of the yard cranes. And adopted the method of co-optimization of simulation and planning model to determine the maximum appointment quota of the terminal in a fixed time period. Guo (2011) [9] dynamically configures the yard cranes based on the predicted truck arrival information, which is a reasonable yard cranes management scheme for the container terminal system. Ma (2018) [10] carried out collaborative optimization of TAS and yard cranes resource allocation in the research. It adopts a two-layer planning method, which comprehensively considering the number of available yard cranes in the block and the time for each yard cranes to complete the operation, in order to reduce problems such as queue congestion of trucks during terminal operations. Considering the arrival information of ships and the reservation information of trucks, Yang (2019) [11] established a two-stage optimization model with the time of ship collection at the port as the research object. A reasonable stockpiling plan has been formulated to improve operational efficiency and shorten length of the port collection time window.

Compared with the above literature, this paper improves TAS in the following aspects:(1) Aiming at the problems of terminal traffic congestion caused by the random arrival of trucks to the port and shortage of yard cranes resources during peak hours, a collaborative optimization model of the TAS and yard cranes allocation plan is constructed, which effectively improves the utilization rate of limited yard cranes resources and reduces the cost

of yard bridge empty consumption.(2) On the basis of proposing and solving the above-mentioned collaborative optimization model, this paper adds the constraints of time window constraints on the relevant ships' collection ports. At the same time, the three factors of appointment quota, yard cranes allocation plan and ship gathering time window are considered and decided. It enables terminal operators to carry out overall management and precise management of the overall collection and distribution operations of container terminals.

2 Problem description

Aiming at the problems of terminal traffic congestion and uneven operation of yard cranes caused by random and irregular arrival of trucks, a two-stage model of collaborative optimization of the truck appointment system and yard crane allocation based on the ship's time window is constructed. In the first stage, the goal is to minimize the sum of the waiting cost of trucks at the gate and the difference between the appointment quota and the average reservation quota in each period, and allocate a reasonable time window for each ship in the decision-making period. In the second stage, on the basis of the known time window and the appointment quota for each block at each time period, minimizing the waiting cost of the truck in the yard, the operating cost of the yard cranes, the moving cost of the yard cranes and the empty consumption cost of the yard cranes are the goal. This model makes a yard cranes allocation plan and provides a reasonable gate and yard internal management scheme for terminal operators. This paper designs an adaptive genetic algorithm in the first stage and an adaptive large neighborhood search algorithm in the second stage to solve the established two-stage model. The general framework for this model can be described in Fig.1

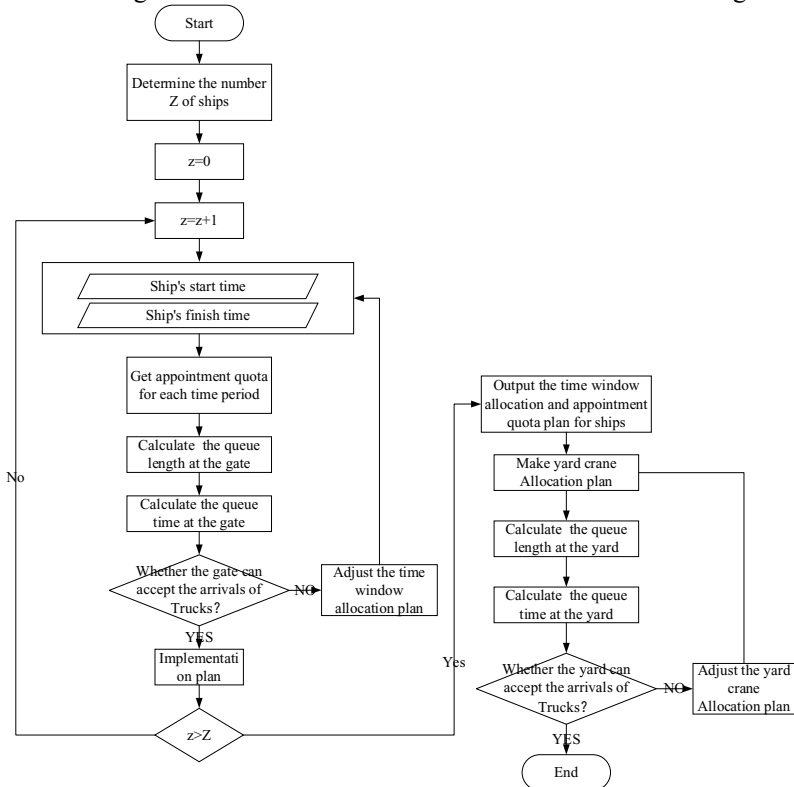


Fig. 1. The framework of optimizing time windows and yard cranes allocation plan.

3 Mathematical model

3.1 Model assumptions

- (1) Select the port collection operations of ships arriving in the port within one week for research, and the decision-making period is 7 days
- (2) The service capacity of each gate is the same and the service capacity of each yard crane is the same
- (3) A maximum of two yard crane are allowed to be configured in each block in a single period
- (4) The gate queuing model is $M/M/1$ queuing models. The yard queuing model is $M/M/C$ queuing model.
- (5) One truck corresponds to one container, and the number of trucks participating in the operation in the model is equal to the number of containers.

3.2 Model parameters

Input variable:

- p : index of appointment periods;
- t : index of time intervals;
- n : gate number;
- i : block number;
- j : yard crane number;
- z : ship number;
- T_z^A : Ship z 's estimated time of arrival;
- T_z^D : estimated time of department;
- V_z : Ship z 's packing quantity in port;
- T^l : the length of the time window of the ship's collection port should be less than T^l hours;
- T^k : the time of starting to gather at the port is not earlier than the arrival time of the ship T^k hours;
- v^2 : variance of yard crane service time;
- e^g : service efficiency of gate;
- e^y : service efficiency of yard crane;
- $\alpha_{i,p}$: the number of trucks that have been picked up in the block i during the period p ;
- c^w : the waiting cost of the trucks at the port;
- c^y : the operating costs of the yard crane;
- c^s : the wasted cost of the yard crane;
- c_{ii} : the move cost of the yard crane;

Derived variable:

- $\alpha_{z,p}^g$: The appointment quotas related to the ship z in the period p ;
- $\alpha_{z,t}^g$: The number of trucks with ship z arriving at the gate at time t ;
- $\alpha_{n,t}^g$: The number of trucks arriving at gate n at time t ;
- $l_{n,t}^g$: The queue length of trucks arriving at gate n at time t ;
- $\beta_{n,t}^g$: The number of trucks departing at gate n at time t ;

- $\mu_{n,t}^g$: The utilization of gate n at time t ;
 - $w_{n,p}^g$: The waiting time of trucks arriving at gate n at time t ;
 - α_t^y : The number of trucks arriving at the yard at time t ;
 - $\alpha_{i,t}^y$: The number of trucks arriving at block i at time t ;
 - $\alpha_{z,i,p}^y$: The number of trucks associated with ship z that arrive at block i in time period p ;
 - $l_{i,t}^y$: The queue length of trucks arriving in the block i t time t ;
 - $\beta_{i,t}^y$: The number of trucks departing in the block i at time t ;
 - $\mu_{i,t}^y$: The utilization of yard crane in the block i at time t ;
 - $w_{i,p}^y$: The waiting time of trucks arriving in the block i at time t ;
 - $o_{i,t}$: The number of yard cranes allocated in the block i at time t ;
 - $o_{i,p}$: The number of yard cranes in the block i at the beginning of period p ;
 - r_y : The maximum workload of the yard cranes in a unit period;
 - S : A collection of yard cranes that can be transferred to other blocks;
 - $R^{\pm j}$: A collection of blocks that can be moved out/into j yard cranes at period p ;
 - $h_{i,p}$: The number of yard cranes configured in the block i at period p ;
 - n_z : Divide the arrival time window of the arriving ship z into n_z equal time slots
- Decision variables:
- T_z^S : Ship z 's starting time of the time window for ship i ;
 - T_z^E : Ship z 's finishing time of the time window for ship i ;
 - $h_{i,j,p}$: 0-1 variable,it equals to 1,if yard crane j works in block i at periodp p ,and 0 otherwise.

3.3 Model building

(1) The first stage

Objective function

$$\min Z_1 = c^z \sum_{z=1}^Z (p_z^{end} - p_z^{start}) + c^w \sum_{t=1}^T \sum_{n=1}^N w_{n,t}^g \tag{1}$$

Time window constraints:

$$p_z^{end} - p_z^{start} \leq p^{\max}, \forall z \tag{2}$$

$$p_z^{end} - p_z^{start} = n_z p^l, \forall z \tag{3}$$

$$p_z^{end} + p^k \geq p_z^{arrive}, \forall z \tag{4}$$

$$p_z^{end} + p^b \leq p_z^{arrive}, \forall z \tag{5}$$

$$V_z = \sum_{i=1}^I V_{z,i}, \forall z \tag{6}$$

$$\alpha_{z,p} = \begin{cases} \frac{V_z}{p_z^{end} - p_z^{start}}, p \in \left(\frac{p_z^{start}}{p^l}, \frac{p_z^{end}}{p^l} \right) \\ 0, p \notin \left(\frac{p_z^{start}}{p^l}, \frac{p_z^{end}}{p^l} \right) \end{cases}, \alpha_{z,p} \geq 0, \forall z \quad (7)$$

Equation(1) aims to minimize the sum of the operating cost incurred by the terminal as the vessel collection port and the waiting cost of the trucks at the gate; Equation(2) indicates that the length of the time window of the ship's assembly port shall not be longer than p_{max} hours; Equation(3) indicates that the time window length of the port of the ship z must be an integer multiple of the length of the appointment period p ; Equation(4) indicates that the time when the port starts the ship z collection port shall not be earlier than p^k hours of the ship's arrival time; Equation(5) indicates that the relevant port work for ship z must be completed p^b hours before the ship arrives at the port; Equation(6) indicates that the total amount of the ship's scheduled operations in each container area is equal to its current container volume in the port; Equation(7) indicates that the appointment quota related to ship z is evenly distributed to each time slot in its port time window.
 gate queuing constraints:

$$\alpha_{z,p}^g = \alpha_{z,p}, \forall z, p \quad (8)$$

$$\alpha_{z,t}^g = \frac{\alpha_{z,p}^g}{\sigma}, t = \frac{p_z^{start} \sigma}{p^l}, \dots, \frac{p_z^{end} \sigma}{p^l}, \forall z, t, p \quad (9)$$

$$\alpha_{n,t}^g = \frac{\sum_{z=1}^Z \alpha_{z,t}^g}{N}, \forall z, n, t = \sigma(p-1)+1, \dots, \sigma p \quad (10)$$

$$l_{n,t+1}^g = \max\{l_{n,t}^g + \alpha_{n,t}^g - \beta_{n,t}^g, 0\}, \forall n, t \quad (11)$$

$$l_{n,t}^g = \frac{\mu_{n,t}^g}{1 - \mu_{n,t}^g}, \forall n, t \quad (12)$$

$$\beta_{n,t}^g = e^g * \mu_{n,t}^g, \forall n, t \quad (13)$$

$$\mu_{n,t}^g = \frac{l_{n,t}^g + 1 - \sqrt{(l_{n,t}^g)^2 + 2v^2 l_{n,t}^g + 1}}{1 - v^2}, \forall n, t \quad (14)$$

$$w_{n,p}^g = \frac{\sum_{t=\sigma(p-1)+1}^{\sigma p} l_{n,t}^g}{\sum_{t=\sigma(p-1)+1}^{\sigma p} \beta_{n,t}^g}, \forall n, p \quad (15)$$

Equation(8) indicates that it is assumed that the trucks can arrive at the gate on time during the appointment period; Equation (9) indicates the number of ship z related trucks arriving at the gate at time t ; Equation(10) indicates that the trucks arriving at the gate at time t are evenly

distributed to each gate n ;Equation(11) indicates the relationship between the queue length and the number of arrivals and departures of trucks at gate n at time $t + 1$;Equation(12) indicates the relationship between the queue length of trucks at the gate n at time t and the utilization rate of the gate ;Equation(13) indicates the amount of trucks departures at gate n at time t ;Equation(14) indicates the utilization rate of the gate n ;Equation(15) indicates the waiting time of the card at gate n during the appointment period of p .

(1)The second stage
 Objective function:

$$\min Z_2 = c^w \sum_{t=1}^T \sum_{i=1}^I w_{i,t}^y + c^s \sum_{t=1}^T \sum_{i=1}^I o_{i,t} (1 - \mu_{i,t}^y) + c^y \sum_{t=1}^T \sum_{i=1}^I o_{i,t} \mu_{i,t}^y + \sum_{i=1}^I \sum_{j=1}^J \sum_{p=1}^P h_{i,j,p} c_{i,i} \quad (16)$$

Yard queuing constraints:

$$\alpha_t^y = \sum_{n=1}^N \beta_{n,t}^g, \forall t \quad (17)$$

$$\alpha_{z,i,t}^y = \alpha_t^y \frac{\alpha_{z,t}^g}{\sum_{n=1}^N \alpha_{n,t}^g}, \forall z, n, t \quad (18)$$

$$\alpha_{i,t}^y = \sum_{z=1}^Z \alpha_{z,i,t}^y, \forall i, t \quad (19)$$

$$l_{i,t+1}^y = \max\{l_{i,t}^y + \alpha_{i,t}^y - \beta_{i,t}^y, 0\}, \forall i, t \quad (20)$$

$$l_{i,t}^y = \begin{cases} l_{i,t-1}^y + \alpha_{i,t}^y, h_{i,p} = 0, \forall i, t \\ \frac{(\mu_{i,t}^y)^2 [1 + (e^y v)^2]}{2(1 - \mu_{i,t}^y)} + \mu_{i,t}^y, h_{i,p} \neq 0, \forall i, t \end{cases} \quad (21)$$

$$\beta_{i,t}^y = e^y * \mu_{i,t}^y * o_{i,t}, \forall i, t \quad (22)$$

$$\mu_{i,t}^y = \frac{l_{i,t}^y + 1 - \sqrt{(l_{i,t}^y)^2 + 2v^2 l_{i,t}^y + 1}}{1 - v^2}, \forall i, t \quad (23)$$

$$w_{i,p}^y = \frac{\sum_{t=\sigma(p-1)+1}^{\sigma p} l_{i,t}^y}{\sum_{t=\sigma(p-1)+1}^{\sigma p} \beta_{i,t}^y}, \forall i, p \quad (24)$$

Equation(16) is the objective function, and the goal is to minimize the sum of the waiting cost of the truck in the yard, the operating cost of the yard cranes, the moving cost of the yard cranes and the empty cost of the yard cranes; Equation (17) indicates the number of trucks arriving at the yard at time t ;Equation(18) indicates the number of trucks corresponding to ship z arriving at the yard during the time period represented by time t ;Equation(19) indicates the sum of the number of trucks arriving at the block at time t ;Equation(20) indicates the relationship between the queue length and the number of arrivals and departures of trucks at the block at time $t + 1$;Equation(21) indicates the relationship between the queue

length and the gate utilization rate at the block i at time t ; Equation(22) indicates that the amount of truck departures at block i at time t is related to the number of yard cranes allocated in the yard; Equation (23) indicates the utilization rate of the yard cranes allocated at block i at time t ; Equation (24) indicates the waiting time of the trucks at block i during the appointment period of p .

Yard crane allocation constraints:

$$r_y = \frac{24}{P} * e^y \tag{25}$$

$$o_{i,p} = h_{i,p-1}, \forall i, p \tag{26}$$

$$h_{i,p} = \begin{cases} o_{i,p} - 2, i \in R^2, \forall p \\ o_{i,p} - 1, i \in R^1, \forall p \\ o_{i,p}, i \in R^0, \forall p \\ o_{i,p} + 1, i \in R^1, \forall p \\ o_{i,p} + 2, i \in R^2, \forall p \end{cases} \tag{27}$$

$$h_{i,p} = \sum_{j=1}^J h_{i,j,p} \leq o_{\max}, \forall i, p \tag{28}$$

$$\sum_{i=1}^I h_{i,j,p} \leq 1, \forall j, p \tag{29}$$

$$x_{i,p} \geq 0, h_{i,j,p} \in \{0,1\} \tag{30}$$

Equation(25) indicates the relationship between the maximum workload of the yard cranes in the unit appointment period, the length of the time period and the operation efficiency of the yard cranes; Equation (26) indicates the relationship between the number of yard cranes at block i and the decision variable at the beginning of period p ; Equation(27) indicates the number of yard cranes allocated in the block i in the period p ; Equation(28) indicates the maximum number of yard cranes allowed to be allocated in each block within the unit appointment period; Equation (29) indicates that one yard crane can only operate in one block during the appointment period of the unit; Equation (30) indicates a range constraint on the decision variable.

4 Solving algorithm

The first stage of model research is to solve the decision-making problem of the time window of each arriving ship. The results of the model solution in this stage will directly affect the results of the field bridge configuration strategy in the second stage. Since the model established in the first stage of this paper is a nonlinear integer programming, it belongs to NP-hard problem. Therefore, it is necessary to design a heuristic algorithm to solve the problem. In this paper, an adaptive genetic algorithm is designed to solve the model. Because in the genetic algorithm, the selection of crossover and mutation probability is the most important thing that affects the behavior and performance of the genetic algorithm. In the

traditional genetic algorithm, the probability of crossover and mutation of individuals in the population is fixed, the convergence of the algorithm cannot be guaranteed, and it is easy to fall into local optimum. Therefore, this paper designs the adaptive adjustment rules for crossover probability and compilation probability, adjusts the crossover probability according to the individual fitness, and adjusts the mutation probability according to the evolutionary algebra. The specific algorithm steps are as follows Fig.2.:

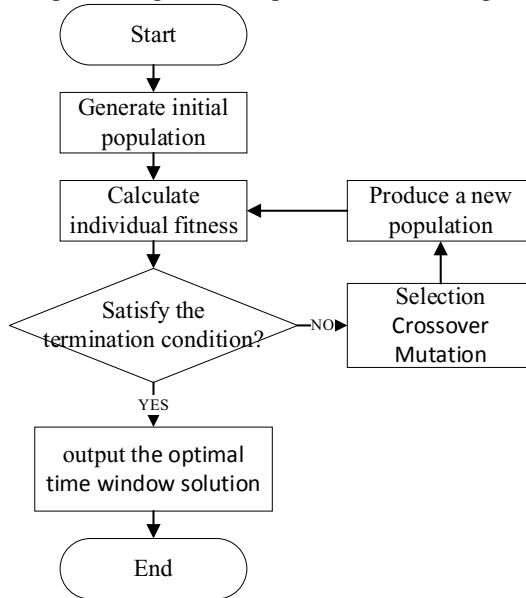


Fig. 2. Adaptive genetic algorithm flowchart.

The second stage of the two-stage model in this paper uses the adaptive large neighborhood search algorithm to solve the model on the basis that the time window for ship gathering and the reservation quota for each time period has been obtained in the first stage. The field bridge configuration scheme is preliminarily formulated through the set pre-classification rules, and then the neighborhood solution is generated through operations such as deletion and insertion. Simulated annealing algorithm is used to determine the acceptance rules of neighborhood solutions, and the selection probability of corresponding operators is updated according to the pros and cons of neighborhood solutions obtained in each iteration, so as to speed up the convergence speed of the algorithm. Repeat the large neighborhood search optimization steps until the preset maximum number of iterations is reached, and the best solution obtained in the iterative process is taken as the approximate optimal solution. The specific algorithm steps are as follows Fig.3.:

5 Case study

5.1 Case description

In this paper, an example analysis is carried out with the actual data of a container terminal, including: 4 port gate, 15 container blocks, 10 yard cranes participating in loading and unloading operations. And the decision-making period is set to 7 days, which is divided into $P = 56$ periods, and the period length is 3 h. The number of relevant ships is $Z = 25$

Assume that the other model-related parameters are as follows Table 1.:

Table 1. Inputs to the optimization model

Input variable	Value	Variable explanation
e^g	30 trucks/hours	gate service efficiency
e^y	15 trucks/hours	crane service efficiency
c^w	60yuan/hours	truck waiting cost
c^y	180 yuan/hours	Crane operation cost
c^s	50 yuan/hours	Crane empty cost

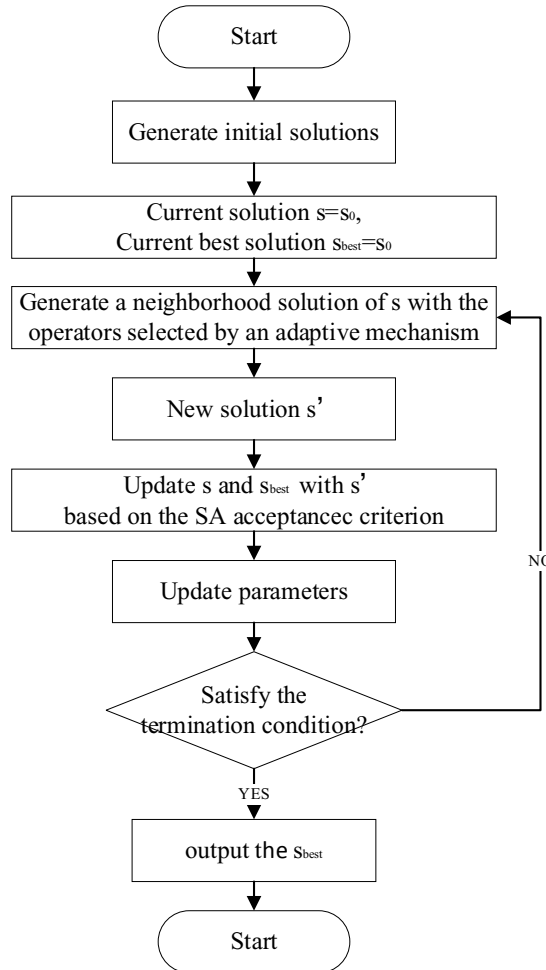


Fig. 3. Adaptive large neighborhood search algorithm flowchart.

5.2 Operation result

Figure 4 shows the time window allocation plan for the ship gathering port obtained in this chapter, the yard crans allocation plan is shown in Table 5, and the queuing length of the container before and after optimization is shown in Figure 6.

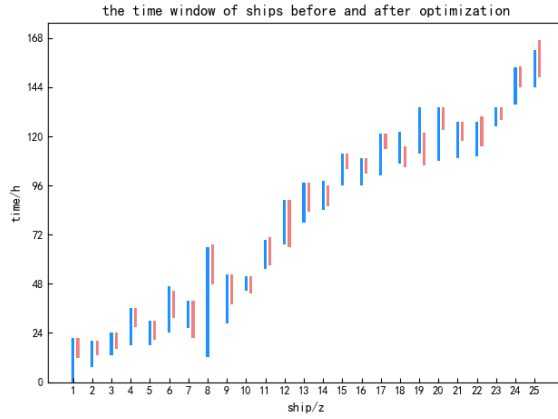


Fig. 4. Comparison figure of time window for ship gathering before and after optimization.

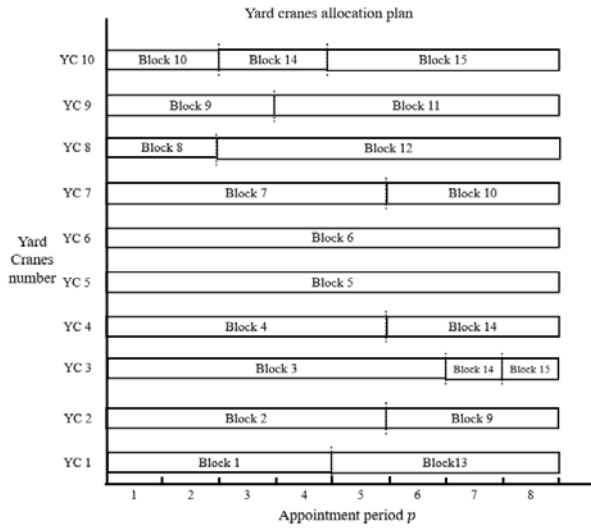


Fig. 5. The yard cranes allocation plan.

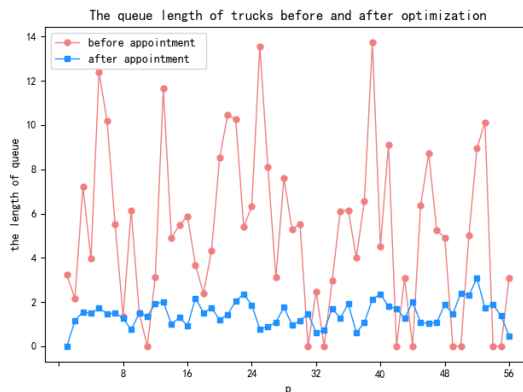


Fig. 6. Comparison figure of the queue length before and after optimization.

The results in Table 2 show that before and after the optimization, the time window for the relevant ships to gather at the port is reduced from an average of 18.43h to 11.85h, and the optimization rate reaches 35.70%. The queue length after the trucks arrive at the container terminal is also reduced from 5.18 before optimization to 1.47. Over the entire 7-day decision period, the total cost incurred dropped from 378,448 to 265,083. Significantly reduces the operating costs of truck companies and terminal operators, and improves economic benefits. It can be seen that the two-stage model designed in this paper can not only effectively shorten the time window for ships to gather at the port, but also significantly improve the problem of terminal congestion. So as to reflect the effectiveness of the model algorithm.

Table 2. Comparison table before and after optimization.

Optimization Results	Time window length	Queue length	Total cost
Before optimization	18.43	5.18	378448
After optimization	11.85	1.47	265083

6 Conclusions

In this paper, a two-stage optimization model for the synergistic optimization of the truck appointment system based on the ship's time window and the yard cranes allocation is constructed to deal with the uneven operation of the yard cranes caused by the random arrival of trucks, the shortage of yard cranes resources during peak hours, and the congestion of container terminals. The adaptive genetic algorithm and the adaptive large neighborhood search algorithm are designed in two stages. Taking a container terminal in my country as an example, the correctness of the proposed model and the effectiveness of the algorithm are verified. The test results show that the length of the time window before and after optimization is shortened by 6.85h, and the queue length after the truck arrives at the wharf is reduced by 3.71 units. It can be seen that the model constructed in this paper can not only reduce the operating cost of the truck fleet, but also reduce the operating cost of the terminal operator by shortening the time window and improving the utilization rate of the yard cranes.

However, according to the research, it is found that due to the current capacity of the container terminal gate is far greater than the operating capacity of the yard cranes, the speed of handling containers at the gate does not match the operating speed of the yard cranes, resulting in a large number of trucks still waiting in the yard after entering the gate. It is easy to cause the phenomenon that the trucks are pressed in the terminal yard, which affects the implementation effect of the port operation plan. In order to further consolidate the implementation effect of the port operation plan, on the basis of the joint decision-making of the yard cranes allocation in the yard and the ship time window, the sub-regional balance planning method can also be used for site planning, that is, when multiple yard cranes are in a container block operates at the same time, this site planning method can better solve the problem of container space allocation and coordinated optimization of multi-yard crane allocation, thereby improving the operation efficiency of the yard cranes and making the yard operation speed and the gate operation speed more matched, avoiding the phenomenon of car pressing in the yard.

References

1. Morais P, Lord E. Terminal Appointment System Study. Canada Csa Final Report Copy(2006)

2. GIULIANO G, O'BRIEN T. Reducing port-related truck emissions: The terminal gate appointment system at the Ports of Los Angeles and Long Beach. *Transportation Research Part D Transport & Environment*, 12(7), 460-473(2007)
3. CHEN X, ZHOU X, LIST G F. Using time-varying tolls to optimize truck arrivals at ports. *Transportation Research Part E*, 47(6): 965-982(2011)
4. CHEN G, GOVINDAN K, YANG Z. Managing truck arrivals with time windows to alleviate gate congestion at container terminal. *International Journal of Production Economics*(2013)
5. YANG Z, GANG C. Optimizing time windows for managing export container arrivals at Chinese container terminals. *Maritime Economics & Logistics*, 12(1): 111-426(2010)
6. CHEN G, GOVINDAN K, YANG Z Z, et al. Terminal appointment system design by non-stationary $M(t)/Ek/c(t)$ queueing model and genetic algorithm. *International Journal of Production Economics*, 146(2), 694-703(2013)
7. GUO Z F, FAN H M, MA M Z, et al. Optimization model of container delivery appointment based on ship collection port time window. *Industrial Engineering and Management*, 22(3),7(2017)
8. HUYNH N. Methodologies for reducing truck turn time at marine container terminals; The University of Texas at Austin(2005)
9. GUO X, HUANG S Y, HSU W J, et al. Dynamic yard crane dispatching in container terminals with predicted vehicle arrival information. *Advanced Engineering Informatics*(2011)
10. Ma M Z, Fan H M, Ji M J, et al. Coordinated optimization of container terminal delivery truck reservation and yard crane scheduling. *Transportation Systems Engineering and Information*, 18(3) 8(2018)
11. YANG H, WANG L, XU Q, et al. Collaborative optimization of container allocation and yard crane deployment based on truck appointment system. *Journal of Physics Conference*, 1074(2018)