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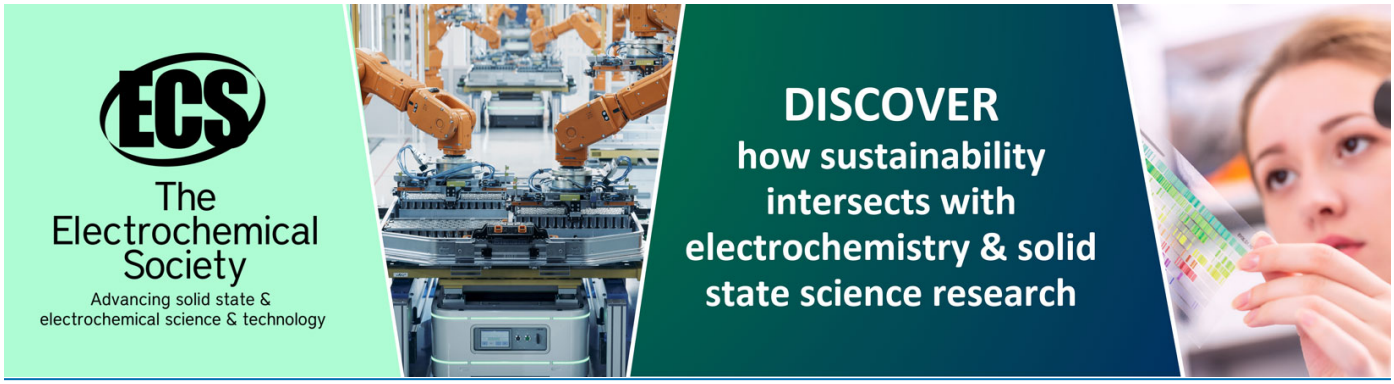

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The layout strategy of container yard and comparative analysis under double cycling process

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Abstract. In recent years, to adapt to the rapid growth of container throughput, the new loading and unloading technology of double cycling is beginning to be used in ports, because it can improve the loading and unloading efficiency of the terminal. However, the ports are currently lack of a corresponding and suitable container yard storage strategy, and according to the characteristics of the new loading and unloading process of double cycling, this paper proposes two strategies of the separate stacking strategy of import and export containers in the same vessel with different container areas and the mixed stacking strategy in the same vessel with the same container areas. The mixed stacking strategy of the same vessel with the same container area can be divided into two methods: the same vessel with the same ship-bay positions and the same vessel with different ship-bay positions, and the cost of the latter method is higher than the former, because the yard cranes and the trucks need to move back and forth frequently. Therefore, this paper focuses on the comparison and analysis of the two strategies of the same vessel with different container areas and the same vessel with the same ship-bay positions. The FlexTerm simulation modelling test shows that it is not easy to generate traffic congestion and the loading and unloading operation time is shorter if the strategy of the same vessel with different container areas is applied.

1. Introduction

Based on the characteristics of the full tank in the large container cabin, double cycling loading and unloading process is to carry out loading and unloading operations of the import and export containers at the same ship-bay position of a container ship at the same time, that is, it will start from the second column in the cabin after the unloading operation of the first container in the cabin is completed, and the quay crane completes a loading operation immediately after completing a ship unloading operation. That is, in a cycle, the export containers are loaded from the trucks to the ship, and the import containers are unloaded to the trucks and transported to the yard for storage in return process. The quay cranes move to other bays to continue the operations only after completing the operations of loading and unloading of all the import and export containers in the present bay position, thereby reducing the moving distances of the quay cranes and the empty loading rate of the trucks.

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Although the double cycling loading and unloading process can greatly improve the production efficiency of the yard cranes and the trucks, the process has high requirements for the rationality of the container yard storage strategy. At present, China's container terminals generally adopt the method of separately storing the import and export containers, that is, export containers are stacked near the front of the wharf, and import containers are stacked at the rear of the yard. Obviously, the traditional stacking method of import and export containers cannot meet the needs of the loading and unloading process, which will greatly reduce the application effect of this new process. Therefore, it is urgent to study an appropriate stacking method to make the connection between operations smoother and further improve the loading and unloading efficiency of the process.

The remainder of the paper is organized as follows. Section 2 provides a review of the existing literature. There are three stacking strategies are proposed in section 3, which is based on the characteristics of the double cycling process. According to the actual research results, two stacking strategies are selected in section 4 and section 5, to establish simulation models for experiments and carried out comparative analysis. And conclusions are given in Section 6.

2. Literature review

A lot of researches have been done on the space allocation of container terminal yards under the single-cycle loading and unloading process. Most of them focus on the planning of the yard area, the formulation of the storage rules, the arrangement of the container area and the specific container position. This paper mainly focuses on the research on the relative position distribution of import and export containers. In the domestic and foreign literatures, there are many researches on the location selection of export containers in the separate storage mode of import and export containets, but few literatures on the space allocation of import containers.The position of export and import containers considered at the same time are mainly based on the condition of mixed stacking strategy.

The research on the space allocation of export container yard is generally aimed at minimizing the total transport distance of container trucks and the imbalance of the workload in each container area, as shown in literature [2-6]. Yang and Kim [7] first proposed a packet storage problem based on storage demand units (such as the same destination port, same size and weight, referred to as SDU). The SDU arrival and departure time is determined to be a static location problem firstly, and the dynamic location problem of SDU arrival time uncertainty is discussed. The distribution of the inlet containers is much simpler than the distribution of the outlet container. Generally, the goal is to minimize the total amount of the tumbling in the boxing process, as in the literature [8], [9].

Based on the research of the mixed mode, it is generally optimized in two stages. It solves the workload balance optimization problem of each container area in the first stage, and the transportation distance from berth to the yard is supposed to be minimized in the second stage. Representative studies: wang bin [10] explored the optimal allocation method when the quantity of export containers and the quantity of import containers are both random. Xie Chen, He Junliang and Chang Dao [11] adopted heuristic algorithm and distributed genetic algorithm to solve the problem. Tao Jinghui and Wang Min [12] also established the mathematical model of mixed container for import and export, which solved the problem of container group balance optimization in the second stage. MAO Jun, Li Na and Jin Zhihong [13] built a two-stage optimization model and solved it based on lingo. Sheng Yang et al. [14] considered the dynamic change of the capacity of the storage yard. Assume the mixed storage of import and export boxes and the task quantity of each work path were known, and it is required that the import boxes unloaded on each work path must be stacked in different container areas. The genetic algorithm is used to solve the problem, and the results show that the solution is better than Lingo.

As to the researches about double cycling, experts and scholars mainly focus on the improvement of demonstration efficiency [1-15-16], the optimization of loading and unloading operation sequence [17-22], scheduling and comprehensive optimization [23-29]. Liu Qin et al. proposed the stacking strategy of the same vessel with the same yard-bay position. The exported containers are located at the side of the bay position near the wharf, while the imported containers are located at the rear, which can be found in literature [30]. However, its research focuses on the use of simulation technology to study the

selection of equipment in the yard. Zhang Xiaoju, Zeng Qingcheng and Yang Zhongzhen proposed the mixed storage strategy in [31], which was the same as in the literature [30], but their paper focuses on the simultaneous loading and unloading scheduling problem of the same container. By optimizing the order of loading the export containers, the number of double-cycle operations of the yard cranes is increased. In the literature [32], they focused on the effect of the stacking strategy. The experiment showed that the use of the layout strategy in the double-cycle process greatly shortened the driving distance of the trucks, which reduced the demand of the required trucks and the operation time of the yard cranes by 16% and 26% respectively.

In this paper, based on the characteristics of the double-cycle loading and unloading process, three storage strategies suitable for this process are proposed. However, according to the actual investigations and interview results, one of the strategies is obviously more expensive than the others, so two stacking strategies are selected for comparative analysis through simulation experiments.

3. Container yard layout strategy

3.1. The Separate Stacking Strategy of Import and Export Containers in the Same Vessel with Different Container Areas

The separate stacking mode of the same vessel with different container areas specifically refers to the separate stacking of the import and outport containers of the same ship-bay position in a ship, but the separate stacking here is different from the traditional mode of import containers located the back yard arears and export containers located in the front yard arears. Instead of the “before out last in" stacking mode, the imported containers area is on the west side of the exported containers area. This is mainly based on the rule of counter-clockwise operation in wharf apron. The specific operational procedures are that the trucks first wait under the quay cranes, and the imported containers are unloaded from the ship into trucks. The trucks transport the imported containers to the import container area of the yard, and the yard cranes will immediately carry exported containers in export area of the yard to wharf apron after completing the unloading operation. As shown in Figure 1.

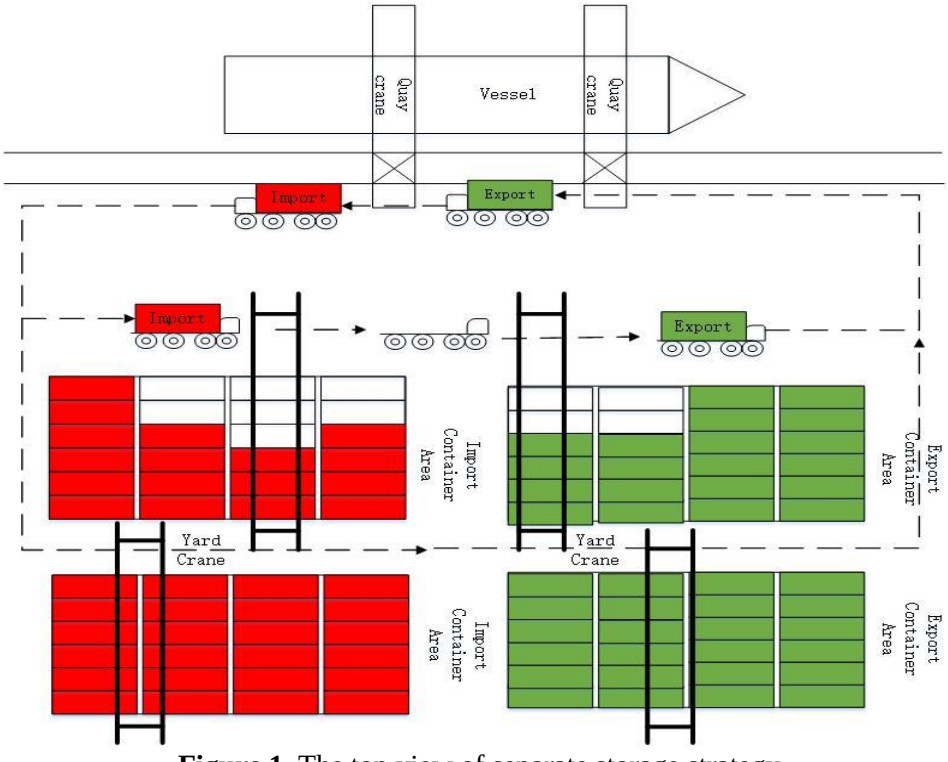

Figure 1. The top view of separate storage strategy

3.2. The Mixed Stacking Strategy of Import and Export Containers in the Same Vessel with the Same Container Areas

There are two kinds of this stacking strategy, one of which is the mixed stacking method of "same ship in the same bay" proposed in the literature [30-32]. It is different from these literatures andi in the actual dock operation, the outlet containers are stacked in three rows away from the lane, and the three rows close to the lane are used to store the inlet containers in this storage mode, as shown in Figure 2, which can reduce the vertical travel distance of yard cranes and improve the safety of yard operations. This kind of stacking strategy adopts the method of stacking by row when collecting the import and export containers.

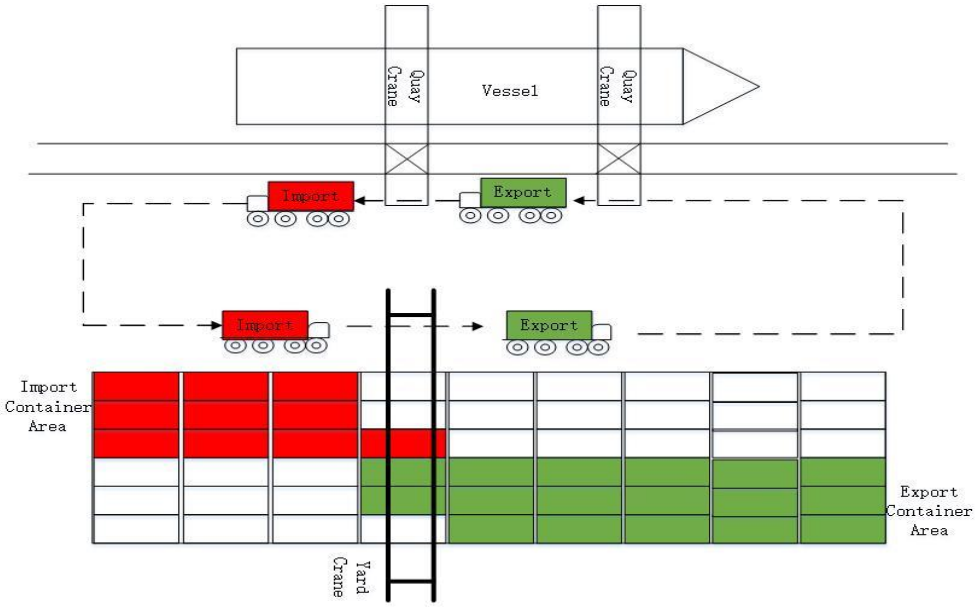

Figure 2. The top view of mixed storage strategy of the same vessel and ship-bay position

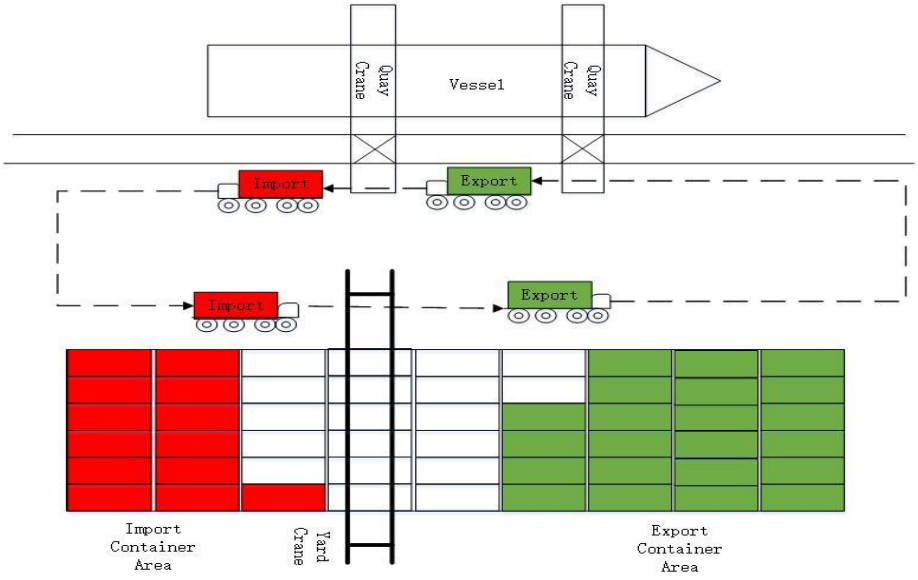

Figure 3. The top view of mixed storage strategy of the same vessel with different ship-bay position

The other method is the mixed storage strategy of the same vessel in different ship-bay positions. Compared with the mixed stacking strategy of the same vessel with the same ship-bay position above, the strategy is mainly to store the import and export containers in different ship-bay positions, which can be seen in Figure 3. However, the biggest disadvantage of this strategy is that the yard cranes and the trucks need to move back and forth frequently. After field research on the container terminal, the cost is relatively higher than that of the same ship-bay strategy. Therefore, the following paper mainly compares and analyses "separate storage strategy for different containers areas on the same vessel" and "mixed storage strategy for the same vessel and ship-bay position" under the double cycling process.

4. Construction of Simulation Model

4.1. Assumptions of the Simulation Test

There are two assumptions of the simulation model:

(1) It is assumed that at a certain bay position of a container ship, 170 import containers and 160 export containers need to be handled at the port. Meanwhile, the position of the containers to be unloaded in the ship and the containers to be loaded on the storage yard are known and fixed.

(2) This paper mainly studies the stacking strategy of import and export containers in the storage yard. Therefore, in the model, the storage yard is mainly composed of import and export container areas, and only 20 feet of ordinary containers are considered. Other special container types are not considered temporarily.

4.2. Simulation Parameters Setting

Based on the assumptions of the simulation model and the characteristics of FlexTerm software, the parameters of each entity were set in combination with the field investigation of the container terminal of Xiamen port. The specific Settings are as follows:

(1) The loading and unloading preparation time at the wharf front is 10 minutes;

(2) The speed of the quay cranes is 60m/min, and the car's speed of loading and unloading is 40move/h or 1.5min/move. At the same time, due to the situation of tumbling operation, the loading and unloading efficiency of the quay cranes is subject to triangular irregular distribution (1.0, 3,1.5) min;

(3) The capacity of the bay in the container yard is set to 24, that is, the number of rows stored is 6 rows, the height of the stack is 4, and the speed of the yard gantry crane is 180m/min, and its speed of loading and unloading is 25 move/h or 2.4 min/move. Due to the existence of the tumbling, the loading and unloading efficiency obeys the irregular distribution of triangular (0.5, 3, 2.4) min;

(4) According to the field survey of container terminals and relevant literatures, in order to reduce the waiting times of the quay cranes under the double cycling loading and unloading process. The number of the truck is 5, the no-load speed is set as 240m/min, and the speed at full load is 300m/min.

4.3. The Simulation Model of the Separate Stacking Strategy of Import and Export Containers in the Same Vessel with Different Container Areas

According to the operation process of loading and unloading of double cycling, the berth system, wharf front system, container yard system, horizontal transportation system and gate system of the FlexTerm platform are fully utilized for modelling respectively, to construct the model of double cycling process, and the separate storage strategy of import and export containers with different containers areas on the same ship is simulated. The simulation model was established on the FlexTerm 2.7.0 platform as shown in figure 4.

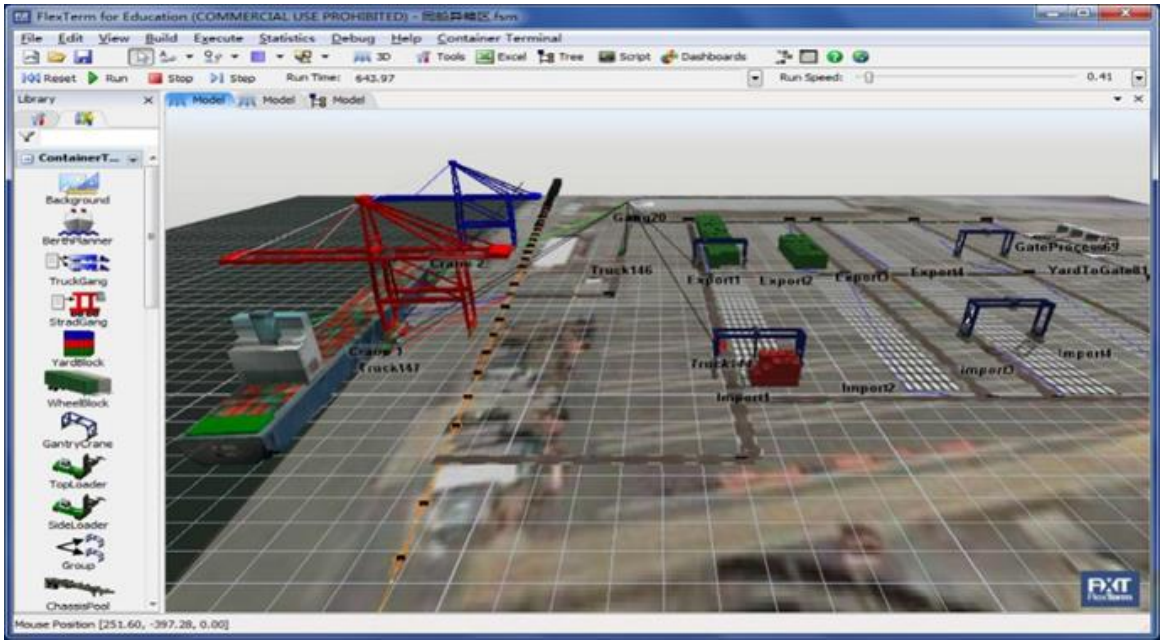

Figure 4. Simulation diagram of separate storage in the same vessel with different container areas

4.4. The Simulation Model of the Mixed Stacking Strategy of Import and Export Containers in the Same Vessel with the Same Bay Position

According to the analysis of the mixed storage strategy of the same vessel with the same bay positions, the simulation modelling on the FlexTerm simulation platform is mainly carried out in the Yard Planner area to store the import and export containers by bay positions, that is, the designated containers of the imported containers are located near the lane in three rows, and the export containers are designated to stacked in the other 3 rows away from the lane. In terms of stacking strategy, the method of arranging the storage is used to store and deliver the containers, and the simulation model is shown in figure 5.

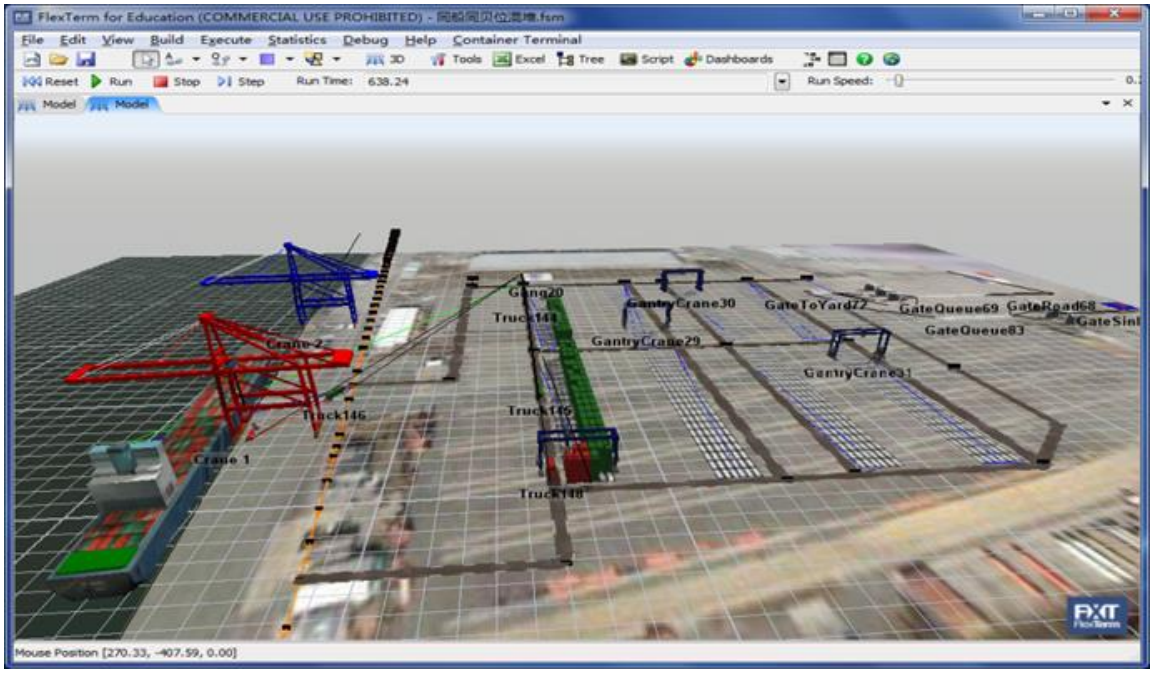

Figure 5. The Simulation diagram of separate storage in the same vessel with the same bay position

5. Simulation Results and Data Analysis

Data collection was carried out on comparative indicators for two types of stacking strategies, such as the utilization rate of quay cranes, the utilization rate of yard cranes, the utilization rate of trucks, etc. In this paper, 50 simulation experiments are carried out for each strategy, and the running data is summarized and averaged, which can be found in Table 1.

Table 1. The summary of simulation data collection for two types of storage strategy.

Name of index	The separate storage strategy of the same vessel with different container area	The mixed storage strategy of the same vessel with the same bay position
The utilization rate of quay cranes (%)	76.05	75.08
The utilization rate of tyred gantry crane (%)	39.45	67.90
The utilization rate of inner trucks (%)	71.88	75.95
The traffic jam rate of container terminal (%)	-	3.4
The port time of ship(h)	8.5	8.7

It can be seen from Table 1 that the data of the separate storage strategy in the same vessel with different container areas and mixed storage strategy in the same vessel with the same bay position are similar. The main difference is that in the utilization rate of the tired gantry crane, the utilization rate of the tired gantry crane in the separate storage strategy is 39.45% while and the utilization rate of the tired gantry crane of the mixed storage strategy is 67.90 %, this is mainly because the import and export containers in the same gantry crane for the storage operations in the condition of the same vessel with the same bay position, so that the gantry cranes have been fully loaded. In contrast, there are two gantry cranes working at the same time in the separate stacking strategy of the same vessel with different container areas, so the gantry crane will be idle for a part of the time. However, during the simulation, it was found that due to the same gantry crane mixed storage strategy, the trucks in the yard need to wait in line to complete the loading and unloading operations, which caused traffic jams and affected the loading and unloading operations smoothly, and thus increasing the time of the ship in port. By comprehensive comparison, it is not easy to generate traffic congestion and the loading and unloading operation time is shorter when the separate storage strategy of the same vessel was applied, so the port time of the ship is also shorter.

6. Conclusion

A storage strategy for container yard based on double cycling loading and unloading technology was introduced in this paper. Separate stacking strategy of the same ship with different container areas was introduced, simulation model as well as corresponding simulation experiment of mixed storage strategy of the same vessel with the same ship-bay position was established. Based on the analysis of the utilization rate of quay cranes, the utilization rate of tired gantry crane, the utilization rate of inner trucks, the traffic jam rate of container terminal, the port time of the ship and other parameters, the comparison and validation show that the separate stacking strategy of the same vessel with different container areas is more suitable for the double cycling loading and unloading process, providing a reference for selecting the storage strategy of container yard in the actual container terminal.

Acknowledgments

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