The Scheduling of quay cranes and truck in Container Port ——A Simulation-based method

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Abstract. In order to study the Scheduling of quay cranes and tractor in container port, this paper establishes the simulation model of container port's (un)loading operation by use of container port's simulation software FlexTerm. The mixed loading operation and independent (un)loading operation in different quantities of Trucks are simulated. The accomplished time of mission, crane utilization and truck travel distance in two different loading operation modes are compared. According to the simulation result, some suggestions on allocation of truck and (un)loading pattern are provided.

1. Introduction

With the economical development, modern container port has played an increasingly important role in the global comprehensive transport system. Therefore, it is of great significance to study the container dock's (un)loading procedure and resources scheduling. For the complexity of container dock production operation, it's hard to use a single analytic model to carry out global optimization. The commonest optimization method is to divide the port operation system into several subsystems and optimize them layer by layer. To be specific, the port operation system can be divided into berth allocation, quay crane dispatch, level handling equipment's dispatch configuration, yard crane's configuration etc. In the respect of truck route optimization, [1] considered the truck dispatch model within the limit of truck resources, set up an objective function model with the minimum weighted sum of truck transportation time and waiting time and design the improved algorithm to solve the model. In the respect of (un)loading optimal configuration, some researchers studied how to define scientifically the container dock construction scale and (un)loading equipment's allocated volume, reasonably and effectively manage the container dock's (un)loading resources and reduce the operation cost. Through modeling and simulating the different distribution, different equipment quantity's ratio and different truck speed, [2] ot the crane's different utilization ratios and proposed suggestion on equipment ratio and truck speed. [3] proposed the berth's crane scheduling problem within the limit of crane quantity and established the multi-objective programming model. L. Chen etc[4] and H. Y. K. Lau etc[5] studied the crane, yard crane and truck's comprehensive dispatch problem and set up a model targeted at the minimum of crane waiting time, truck raveling time and crane idle time. They also offered three equipments' collaborative scheduling scheme. Zhuo Sun [6] set up a micro port system and studied the problem of port's resource integration, evaluation of system handling capacity and improvement of port (un)loading equipment utilization rate. With the development of computer technology, computer simulation technology has been widely used in the port design and planning researches. Armando etc[7] modeled the port container (un)loading equipment's operation and discretely simulated the container port load and unload event. Agostino etc[8] carried out the simulation towards container dock (un)loading operation with TRAINPORTS emulator.

Based on the FlexTerm simulation software, this paper modeled and simulated the Scheduling of quay cranes and Tractor in Container Port, analyzed the simulation results, got the different trucks' configuration allocation and operation time comparison of mixed and independent (un)loading mode. Some advices on the truck configuration distribution and (un)loading mode are given.

2. Problem Description

2.1 The port (un)loading operation procedure

The container port's operation procedure is a type of operation mode which includes the technological process from unloading the ship to departing the port or from arriving at the port to loading the ship, the (un)loading handling machinery type and their interactive operation. After the ship arrives at the port, firstly the berth is allocated, then according to the ship (un)loading amount, the corresponding loading and unloading plan are developed, thus the quay crane, yard crane and the truck are allocated and scheduled. For the storage yard, the container's location is arranged based on the stacks strategy.

2.2 Analysis of different (un)loading mode

Independent (un)loading operation mode refers to the mode which equip a ship with a certain amount of trucks, quay cranes and yard cranes, which is illustrated by fig.1. In the unloading process, the truck at the berth transfers an imported container at the berth to the imported container storage yard, and then returned to the berth without load to unload another imported container; in the loading process, the truck transfers one container at the imported container storage yard to the berth and then returns to the storage yard without load to load another imported container.

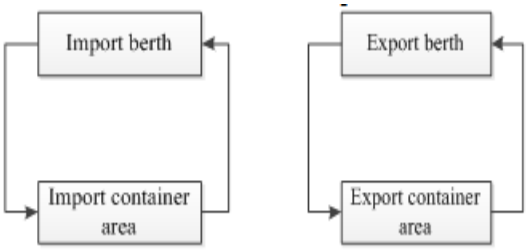

Fig.1 Independent operation mode

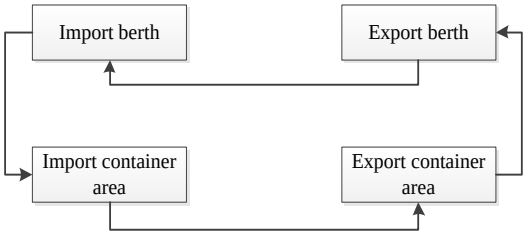

Fig.2 Mixed operation mode

Mixed (un)loading operation mode refers to the mode which the truck in the truck pool doesn't serve one ship solely, but to accomplish the container's loading and unloading mission based on the global optimization. The crane and the truck's (un)loading mode are illustrated in fig.2.

3. A simulation model with FlexTerm

3.1 Introduction to FlexTerm

FlexTerm is a software which specializes in the container port simulation. Its modules include all kinds of port resources such as container port's commonest operation process, (un)loading operation equipment, horizontal transportation equipment and storage yard. By use of this simulation software's 3d graphics display function, user can set up container port's dynamic simulation model and simulate the container port's simple (un)loading procedure. FlexTerm 3D entity includes: quay crane, yard crane, empty-container forklift, truck, container ship, container storage yard, track, port gate and so on.

The purpose of using FlexTerm software is that through simulation user can optimize the operation procedure and achieve the implement effect before operation. The effects that the container port's simulation model can achieve are: increase the port's handling capacity; improve the port equipment's utilization and production efficiency; reduce the ship's waiting time; draw up container storage yard's stacks strategy; effectively allocate the resources and so on.

3.2 Simulation Objectives

This paper's simulation objective is to model the prototype of container dock operation procedure. Through the FlexTerm simulation software, we simulate the two berths' loading and unloading independent operation and two berths' joint operation, analyze the different trucks amount's effects on the task accomplishment time, compare in the two loading modes the crane's utilization and truck's operating range so as to get more reasonable (un)loading procedure and truck dispatch.

3.3 Simulation Setup

In the real container dock operating environment, all the operation links are rather tedious. When setting up simulation model, we need to simplify the complex problems and make specific problems abstract. In this paper, the model is constructed based on the following hypothesis:

(1) The truck can only load one container each time.

(2) The truck must operate independently and can't interfere with each other.

(3) For all the equipments, failure and maintenance are not considered and all the equipments must be in the continuous working state.

(4) The classification of container is not considered, regarding all the containers as the same.

3.4 Simulation Process

During the simulation of port's (un)loading operation, when the mission starts, the truck begins to work. When unloading, the truck drives to the quay crane to check whether the quay crane is free. It carries one container to the yard crane and checks whether the yard crane in the slot is free and then carries out the unloading operation. When loading, the truck drives to the yard crane to check whether the yard crane is free. It carries one container at the storage yard to the quay crane and checks whether the quay crane is free to receive the quay crane delivery. When the quay crane or yard crane are busy, the truck waits in line, simulates until all the imported cartons unload and all the exported cartons load. The specific simulation operation process is illustrated by fig.3.

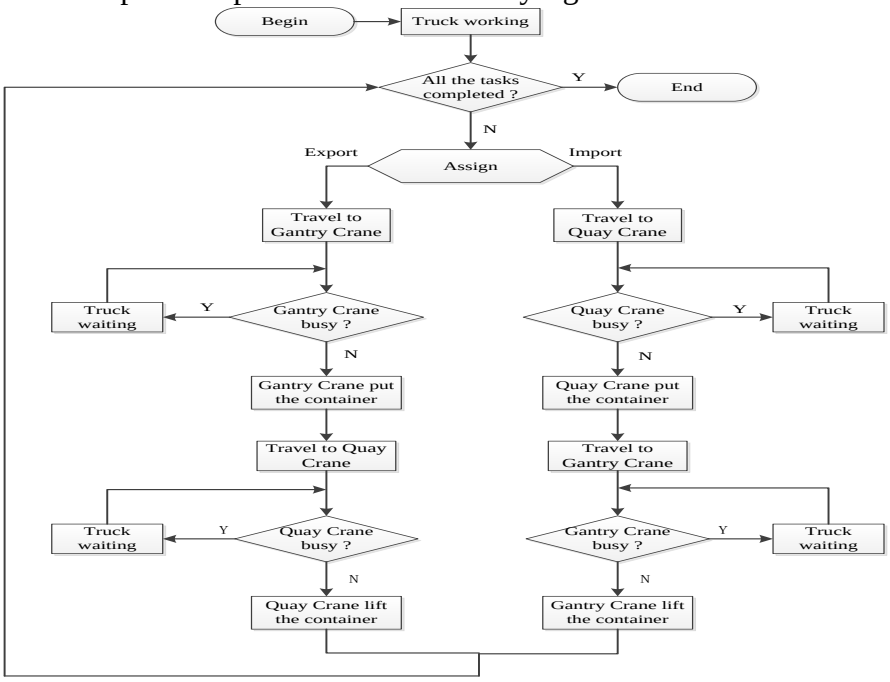

Fig.3 Truck operation handling simulation process

4. Analysis of the Simulation Results

4.1 Simulation parameters setup

Take an imported ship and an exported ship as the simulation objects. Suppose that the imported ship and the exported ship arrive at the same time. Continuously simulate the two boats' (un)loading operation from the ships' arrival to departure. There are 1400 TEU imported cartons to be unloaded and 1400 TEU exported cartons to be loaded. Suppose that there is only one carton type of 40FT. That is, there are 700 containers to be unloaded to the imported carton area and 700 containers to be loaded from the imported carton area. In this paper, 4 exported carton areas and 4 imported carton areas are involved.

The quay crane operation process includes loading, unloading and quay crane movement. The truck's movement process includes loading, unloading, waiting and truck transportation. The yard crane's operation process includes loading, unloading and movement. The model's initial state is that the truck awaits orders at the waiting areas and waits at the dock apron for the exported containers for shipment to be put at all the exported carton areas. In the operation process, all the imported

containers loaded from the ship are transported by the truck to the imported carton areas. All the exported containers for shipment are transported by the truck from the exported carton area to the imported ships.

The (un)loading equipment parameters involved in the model are shown in table 1.

Table1 Parameter list (unit: s)

Crane	Load time Discharge time Move speed	Obey triangular (60,180,100) distribution Obey triangular (60,180,100) distribution 2m/s
Truck	Max speed	5m/s
Gantry Crane	Load time Discharge time Move speed	Obey triangular (30,100,50) distribution Obey triangular (30,100,50) distribution 3m/s

4.2 Analysis of the Simulation Results

4.2.1 A comparative analysis of different truck amount to the operation accomplishment's overall time

By simulation, different trucks' collocations are got. The overall time accomplished by two boats' mixed (un)loading and independent (un)loading modes are shown in table 2.

Table 2 The effect of truck amount to the operation accomplishment's overall time

Truck quantity	Mixed operration time (min)	Independent operation Time (min)
4	2051	2168
5	1768	1898
6	1634	1648
7	1577	1596
8	1537	1555
9	1517	1527
10	1511	1518
11	1493	1512
12	1481	1510
13	1469	1507
14	1456	1492
15	1463	1510
16	1455	1511

The tendency of operation accomplishment time with the variation of the truck's number is shown in fig.4.

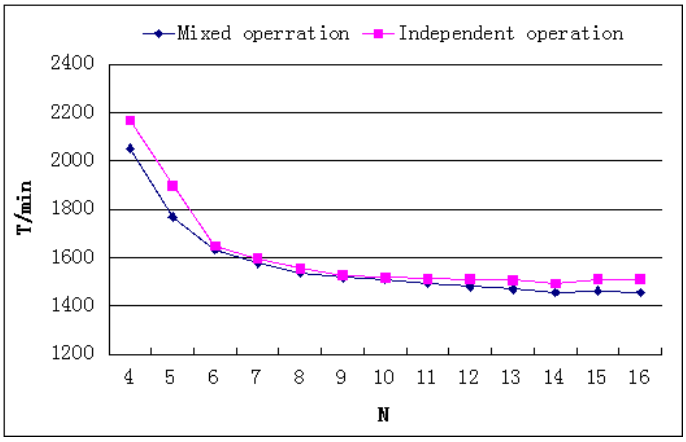

Fig.4 The variation of operation accomplishment time with truck's number

From table 2 and figure1, we can see that when the number of truck configuration is small, no matter whether it is mixed operation or independent operation, the (un)loading operation

accomplishment time is long. But when there are few truck resources, mixed operation accomplishes the (un)loading task much faster than the independent operation. With the increase of truck number, the (un)loading operation time declines rapidly. When there are 8 or 9 trucks, with the increase of trucks, the overall operation accomplishment time declines slowly. When there are 14 trucks, the overall operation time in the independent (un)loading mode doesn't decrease any more. Even because of the truck blocking, the dock's operation accomplishment time is affected. Therefore, as far as the (un)loading task, it is reasonable to have 8 or 9 truck configuration.

4.2.2 A comparative analysis of mixed (un)loading and independent (un)loading operation

In this mode, the port's (un)loading equipment configuration is: 4 quay cranes, 8 yard cranes and 8 trucks. The simulation models are constructed based on the imported ship and the exported ship's mixed operation and two boats' independent operations.

Repeatedly run the two (un)loading operation models, survey the task-accomplished time and the crane utilization, the author gets the following results: In the independent operation simulation model, the first berth's unloading ship's operation time is 778 minutes and the second berth's loading operation time is 777 minutes, thus the overall operation time is 1555 minutes. In the mixed operation simulation model, the first berth's unloading operation time is 761 minutes and the second berth's loading operation time is 776 minutes, thus the overall operation time is 1537 minutes. The crane's utilization in the independent operation and mixed operation models are shown in fig.5.

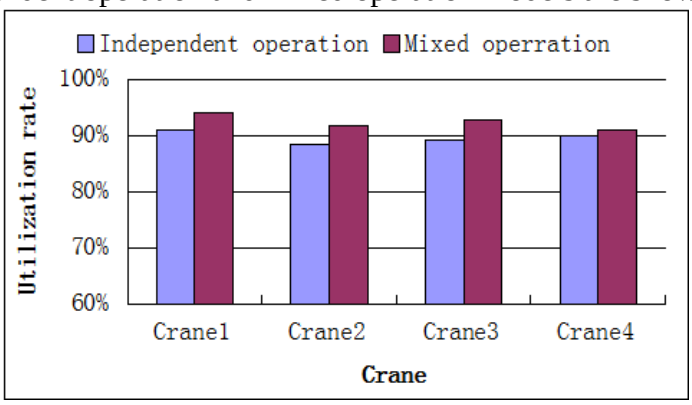

Fig.5 The crane's utilization in the independent operation and mixed operation models

In the independent operation simulation mode, the truck's overall travel distance is 499972 m. In the mixed operation simulation mode, the truck's overall travel distance is 357920 m. In this experiment, based on the two berths' mixed (un)loading modes, the truck dispatch's transportation route and transport containers' number are shown in table 3.

Table3 Mixed operation transport paths

Transport paths	Container quantity
Import berth→Import block 1→Export block 2→Export berth	7
Import berth→Import block 1→Export block 3→Export berth	104
Import berth→Import block 1→Export block 4→Export berth	52
Import berth→Import block 2→Export block 1→Export berth	12
Import berth→Import block 2→Export block 2→Export berth	116
Import berth→Import block 2→Export block 3→Export berth	112
Import berth→Import block 3→Export block 1→Export berth	153
Import berth→Import block 3→Export block 2→Export berth	79
Import berth→Import block 4→Export block 1→Export berth	36
Import berth→Import block 3	8
Import berth→Import block 4	21
Export block 1→Export berth	15
Export block 2→Export berth	12
Export block 3→Export berth	2

The mixed operation's mission accomplishment time slightly increases than that of the independent mission accomplishment time, but in a small range. From fig.2 we can see that in the model's equipment configuration, the mixed operation's quay crane utilization improved compared

with that of the independent operation. But in the mixed operation mode the truck's driving distance reduced by 28.4% compared with the independent operation mode. The simulation result shows that in the condition of definite (un)loading plan, the proposed model can reduce the truck's empty-loaded ratio, at the same time decrease the truck's driving distance so as to optimize the truck's transportation route.

In the mixed (un)loading operation simulation model, the truck no longer fixedly serves for a certain crane or a certain ship, but allocates dynamically according to the (un)loading block's actual location in the storage yard blocks. The dynamic scheduling mode increases the truck's utilization efficiency, enables the truck to bi-directionally drive with heavy-load, reduces the truck's empty-loaded driving distance thus reduces the truck's overall driving distance.

Although in the experiment the number of the loaded containers is the same with that of the unloaded container, the truck doesn't wholly bi-directionally drive with heavy-load because after the truck accomplishes one operation, the control system distributes next operation task based on the route optimization and order precedence principles, and dispatches comprehensively the truck's transportation process. The truck in random moment is chosen in multiple tasks according to the route distance's choices and shared by the quay crane and the yard crane. The object served by the truck dynamically matches with the whole dock's operation layer.

5. Conclusion

This paper studied the truck's dispatch in two berths' (un)loading modes, adopted the specialized simulation software FlexTerm for the container port to simulate the dock container load and unload process and concluded in different trucks' number, the operation accomplishment time and operating efficiency in mixed (un)loading and independent (un)loading modes. In the mixed (un)loading operation mode, by use of dynamic scheduling, the truck is operated between the awaiting unloading blocks and awaiting loading blocks, thus reduces the truck's empty-loaded ratio and the truck's overall driving distance when the mission is accomplished. In the dock's actual production process, drawing up reasonable scheduling scheme and resources configuration strategies can improve the operation efficiency and reduce the cost.

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