Comparison between Two Different Handling Modes of Gantry Cranes in Railway Container Terminals

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Abstract. Railway container terminals are important hubs of hinterland logistics transportation. Gantry cranes, the main handling equipment of it, are the key to promote its efficiency. According to the operating area, simultaneity of loading and unloading and operating track number, the scheduling problem could be categorized into different modes. This article compared two of them: mode I (single-track, fixed-area, single cycle handling mode) and mode II (multi-track, fixed-area, hybrid handling mode), consequently pointing out their strengths and weaknesses.

1. Introduction

Playing an important role in transportation, railway container transportation combines the advantages of both containers and railway which are safe, convenient, energy-efficient and environment-friendly. Logistics’ booming in China make container transportation very trendy lately. Recently, railway container terminals that serve as the key substantial hubs of hinterland logistics transportation have successively been built in China.

Ever since container transportation came into being, scholars kept studying and experimenting it no matter home and abroad. Daganzo[1] first put forward the scheduling problem of cranes, assuming that ships are divided into holds and that (usually) only one crane can work on a hold at a time. Cranes can be moved freely from hold to hold, to turn around (serve) all the ships, while minimizing their aggregate cost of delay. A tabu search heuristic for the Quay Crane Scheduling Problem (QCSP) was proposed by Sammarra[2] in order to figure out the minimum completion time, considering precedence and non-simultaneity constraints between tasks. A genetic algorithm that is fast, robust and efficient for solving the problem of scheduling two quay cranes with non-interference constraints at Narvik container terminal was developed by Hakam[3]. A genetic algorithm and a tabu search algorithm are proposed by Lu Chen[4] to obtain near-optimal solutions to scheduling multiple yard cranes in loading operations considering potential interferences between them.

Obviously, most of them concentrated on the crane scheduling problem of maritime terminal. With railway transportation prospering in China, it is necessary that we cut deeper on advancing the efficiency of gantry crane of railway container terminals.

2. Functions and Layout of Railway Container Terminals

Railway container terminals, where gantry cranes are responsible for loading and unloading containers between freight trains and yards, are important hubs of hinterland logistics transportation. Its functions and layout are fundamental for subsequent work.
2.1. Functions
Main functions of railway container terminal are as followed:
(1) It is capable of receiving and setting out both freight trains and district transfer trains. At the same time, containers and handling machinery could be repaired, washed, maintained etc. here.
(2) Thorough Logistics service is provided, as it has functions including modern information processing, storage and distribution.
(3) It is also equipped with management information system. By strengthening the management and transmission of information such as containers, vehicles and goods, the dynamic tracking and management of containers can be realized. It has the functions of inquiring, consulting and accepting business for the whole process of multi-modal container transport

2.2. Layout
According to the functional layout of the terminal, the central station can be divided into three areas: main operation area, auxiliary storage area and service area.
(1) Main operation area
Main operation area is composed of facilities and equipment including gantry cranes, truck operation lane, main container yard and rail handling track. It is mainly responsible for accepting and sending container trains, handling and storing containers. Main operation area is the core area of railway container terminals. Main operation area is shown in Figure 1.

![Figure 1. Main operation area](image1)

(2) Auxiliary storage area
Auxiliary storage area is a container storage area outside the main operation area. It is mainly composed of special container yard, refrigerated container yard and empty container yard. The handling equipment in the auxiliary storage area mainly includes reach stackers and forklifts. Auxiliary storage area is simply depicted in Figure 2.

![Figure 2. Auxiliary storage area](image2)
(3) Service area

The service area is composed of facilities and equipment outside the main operation area and auxiliary storage area, which is mainly responsible for handling container-related business, dispatch management, cleaning, repairing, loading and unloading vehicles, parking center station access, card management, and container inspection.

2.3. Handling equipment resources

Handling equipment resources mainly includes gantry cranes, reach stackers, forklifts and container trucks etc. Most of container terminals built and put into use adopt gantry crane as handling equipment in the main operation area.

Gantry cranes, in the main operation area, are responsible to handle all the containers arrived or to be launched. Besides, the vast majority of heavy containers are piled and lifted by gantry cranes. As the only handling machinery in main operation area, the scheduling problem of gantry cranes is now the choke point of improving the capability and efficiency of the terminals. So we need a high-efficiency scheduling strategy to lift up the level of gantry cranes’ utilization, thus speeding up turnover velocity of containers and shortening the waiting time of trains and container truck.

3. Comparison of Two Modes

According to the operating procedure and working state of cranes, the handling mode could be divided into various kinds. The following content and compared two of them: Mode I (single-track, fixed-area, single cycle handling mode), Mode II (multi-track, fixed-area, hybrid handling mode).

3.1. Operating procedure

The operation procedure of this system can be divided into, arriving-container procedure, sending-container procedure and transferring-container procedure.

(1) Arriving-container procedure

Arriving container refer to the containers that are transported into the terminal by the container train and waiting to be picked up. After container train entering handling track, corresponding cranes will be dispatched to unloading containers according to its position. Most of the arriving container will be unloaded by the gantry cranes and stored in the main container yard temporarily, waiting for being picked up to the container truck.

(2) Sending-container procedure

Sending containers refers to the containers transported into the terminal by container truck waiting for loading. Most sending containers are directly shipped to the terminal and unloaded by gantry crane then stored temporarily in main container yard.

(3) Transferring-container procedure

Transferring container refers to the containers that are transported to the terminals, unloaded and transferred to another train. Most transferring containers are unloaded by gantry cranes and stored in main container yard temporarily.

3.2. Different Handling Modes

The handling mode can be classified according to the following three aspects:

(1) The operating area of gantry cranes

According to the restricted scope when cranes are working, the handling mode could be divided into fixed-area handling mode and flexible-area handling mode.

At present, most railway terminals adopt the former one. In this kind of mode, operating track is divided into holds in the light of the amount of cranes that are included. Each crane serves trains in one hold. Applying this mode make it easy to schedule and directly avoid the interference between cranes. Yet it holds down the utilization level of gantry cranes. The latter one is excluded from this study.

(2) Simultaneity of loading and unloading

According to the simultaneity of the loading and unloading operations, the handling mode can be divided into two kinds: single cycle handling mode and dual cycle handling mode. At present, most of
railway terminals use the former one. This method separates the loading and unloading operations. It is easy to manipulate, because it avoids the interference between the loading and unloading operations. However, the travel distance when crane is carrying nothing is increased. The dual cycle handling mode is a more efficient method when it comes to lift up the level of crane utilization. The unloading operation will be closely followed by loading operation, so the travel distance of crane carrying nothing is going to be shortened sharply. And naturally, it’s complex than the former mode. Below (Figure 3) is a simple demonstration of these two modes.

Figure 3. Single cycle handling mode and dual cycle handling mode

Beside above modes, this article brings about a hybrid-handling mode. The hybrid handling mode, the combination of the above two, does not specify the type of subsequent operations, but dynamically selects a superior plan. Special algorithm should be studied subsequently to realize this mode.

(3) Handling track number

According to how many trains are operated simultaneously, the handling mode can be divided into single-track handling mode and multi-track handling mode. Among them, single-track handling mode is ubiquitously adopted, while multi-track handling mode is usually accompanied by dual cycle handling mode.

3.3. Comparison

Everything has two sides. We should consider thoroughly when putting forward a new mode. An old mode should be analyzed thoroughly too.

As a most widely used and sophisticated mode currently, Mode I is more suitable for those small terminals. As we all know, in this current stage, not every terminal is that self-contained and busy that need a flexible mode to shorten its operation time.

Mode II is an advanced scheduling mode. Compared with mode I, the mode II may need a manipulating system to coordinating with the special-designed, complex algorithm. Yet the optimization should not be ignored.

Table 1 is a list of strengths and weaknesses of two modes.
Table 1. The strengths and weaknesses of two scheduling modes

| Mode     | Strength                                      | Weakness                                            |
|----------|-----------------------------------------------|-----------------------------------------------------|
| Mode I   | No complex algorithm is needed.               | Wasting resources and consequent inefficiency.       |
| Mode II  | i. Maximizing the utilization of gantry cranes. | i. Complex.                                         |
|          | ii. Raising the turnover velocity of facilities. | ii. Supporting hardware facilities are needed.       |
|          | iii. Fostering productivity and efficiency     |                                                     |

To conclude, mode I is easy to manipulate and sophisticated, while mode II is beneficial to foster terminals’ productivity.

4. Conclusion
The working procedure, overall layout of railway container terminal is showed in this article. Based on that and studies of other researches on gantry cranes scheduling problem, different handling modes is brought about. And two modes, one most popular used and one better organized, are compared. Their strengths and weaknesses are clearly listed.
Although multi-lane, fixed-range, hybrid-handling mode is much more complex and hard to apply, but if we can design an appropriate algorithm, there must be prospect of step change in efficiency and productivity of railway container terminals.

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