A Flexible Scheduling Mode of Gantry Cranes for Railway Container Terminal

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Abstract. This paper discusses problem about improving the utilization ratio of gantry cranes, accelerating the container circulating of railway container terminal, at the same time, reducing the waiting time of trains and trucks in the station. We mainly study at the mode named multi-line flexible range loading and unloading hybrid scheduling. In the case of two train lines and the truck line, the working area of gantry crane is unlimited. This mode is proposed for sequence optimization of gantry crane loading and unloading simultaneously, as well as shortening the accomplishing time of the most difficult task for the all gantry cranes.

1. Introduction
Since the emergence of container transportation, domestic and foreign scholars have never stopped studying on it. The research on resource dispatching optimization of container port can be divided into port and railway topics, according to the different research objects. Daofang Chang [1] researches single-crane scheduling at rail transshipment yards, in which gantry cranes move containers between trains, trucks and a storage area. Dirk Briskorn’s[2] studies the crane scheduling problem of container ports, and his paper minimized the departure time by considering the uncrossed constraint between cranes and allowing containers to move first. He gave the basic complexity proof and an effective heuristic solution. Virgile Galle[3] introduces a new optimization problem, which is caused by the Scheduling Problem of Yard Cranes and the Container Relocation Problem. He is the first person to consider combining the two problems and determining the storage and relocation position through scheduling storage, retrieval and relocation requests. Aiming at the challenges and constraints brought linked to the new architecture, Marie-Anne Beens[4] models the scheduling problem of wharf crane under the special structure, and proposed a solution based on branch price. Aiming at the joint scheduling problem of container terminal cranes and trucks, Lixin Tang [5] took the coordination of two kinds of equipment into consideration to reduce the idle time between two consecutive tasks. In order to solve the problem of one-way flow of single incoming container, he proposed a mixed integer linear programming model, which can minimize the span of incoming container.

Although the optimization of port container resource scheduling is researched excellently by scholar home and abroad. However, railway container resource scheduling is different in many ways from port such as layouts, loading unloading equipment, working process and so on, which leads to the research achievements of port are difficult to apply directly in railway container yards. Resent years have seen
the prosperous development of railway container transportation in China, so the problem of resource dispatching optimization of railway container yards has become urgent to be solved.

2. Functions and Layout of railway container terminals

As a significant center of the railway container transportation network and the container multimodal transport network, the central station is the hub of inland containers as well as a regional logistics center with many business functions.

(1) The loading and unloading work of container trains is well handled in a railway container terminal, and the checking, maintaining, cleaning and parking services are available there.

(2) A port supervision service institution is equipped, and domestic and international container multimodal transport as well as international freight forwarding could be well handled.

(3) It is equipped with well-established logistics system. With the advantages of railway container transportation. A logistics base with modern information processing, warehousing and distribution functions is built. It connects railways, highways and ports to provide high-quality logistics services for customers.

(4) The central station management information system is equipped. Dynamic tracking and management of containers come to reality by the management and transmission of containers, vehicles and goods information. It also has the functions of inquiring, consulting and accepting other container services.

(5) It is also equipped with empty container loading and unloading apparatus and storage area, and temporary storage of containers and empty container allocation are feasible.

In conclusion, the central station has a complete and modern loading and unloading facility, which can make the entire railway block container train arrive and depart. It is also equipped with yard management and dispatch monitoring system, which are necessary for efficient and automatic operation. Warehouses, similar-goods areas and other service facilities to meet the various logistics needs of customers. At the same time, advanced and complete information management system is convenient for customers to handle various businesses to track the states of containers at any time, with the seamlessly connection with other systems such as ports, customs and banks.

According to the functional layout, the central station can be divided into three functional areas: the main operation area, the auxiliary container area and the service area. The Schematic representation of a railway container terminal is shown below.

![Figure 1. Schematic representation of a railway container terminal.](image-url)
(1) The main container yard is the critical core of the central station in production and operation. It is composed of the main yard, loading and unloading lines, gantry crane, and truck passages. Lots of important work of central station is done here, which mainly include container train arriving and departure, container loading and unloading, arrived container storage as well as sending containers and so on.

(2) Other than the main container yard, the auxiliary yard is another area that is used for storing some different containers. The auxiliary storage area is mainly composed of special container yard, a refrigerated container yard, an international container yard and an empty container yard. The loading and unloading equipment of the auxiliary storage area mainly includes reach stackers and forklifts.

(3) The container service area is mainly composed of facilities and equipment outside the main container yard and the auxiliary container yard. It is mainly constructed for container business handling, central station dispatch management, container cleaning and repairing, truck parking and access management, and container security inspection.

As for the port container terminal, it is different from the railway container terminal in function layouts and scheduling. First, the main container yard of the railway central station is mainly for loading and unloading, as well as storage. The function of main contain yard is equivalent to that of the berth and pile area of port. In the limited space, space resources such as train loading and unloading lines, main pile yards, and truck working channels, and equipment resources such as gantry cranes, trucks and trains are available. It is difficult to improve the capacity of the central station by expanding space or adding equipment. So a more complex scheduling strategy is in need in the railway container terminal. Second, the gantry cranes are the only loading and unloading equipment in main container yard, so actually they are scheduled to do the loading and unloading work, as well as the container storage. However, gantry cranes are not permitted to do crossing work, which makes the gantry cranes scheduling of railway station more complex.

3. A Flexible Scheduling Mode of Gantry Cranes
The scheduling of gantry cranes has a crucial impact on the operation efficiency and service quality of the railway container terminals. As the only loading and unloading equipment in main working area of central station, the scheduling of gantry crane is the key capacity of the central station and determines the efficiency of production and operation of central station. An excellent loading and unloading equipment scheduling strategy effectively improves the utilization of cranes, as well as accelerates the working speed of containers, and the waiting time of trains and trucks is reduced.

At present, most of the central stations adopt a fixed-range loading and unloading scheduling mode, which divides the assignment into several plots according to the quantity of gantry crane participating in the process. Every gantry crane works in the corresponding plot. This mode is simple, and is efficient to avoid mutual interference between gantry cranes.

However, in this mode, the idle driving reduces the utilization ratio of the truck greatly and it also makes the operating cost of central station grow. The empty truck driving not only affects the accomplishing time of a segment, but also affects the waiting time of next connected equipment, thereby affecting the operation completing time of entire central station and reducing the operating efficiency of central station.

Now we consider the Multi-line flexible range loading and unloading hybrid scheduling optimization model. It means to balance the assignment of loading and unloading tasks and optimize the simultaneous loading and unloading sequence of each gantry crane, minimize the maximum completion time of each crane loading and unloading tasks, at the same time, balance the resource and improve the efficiency of loading and unloading tasks. Unlike the fixed-range loading and unloading scheduling mode, whose target is the shortest time of all tasks completed, it is aim at shortening the finishing time of the most difficult tasks among all gantry cranes.

Comparing with the fixed-range loading and unloading scheduling mode, the second mode has three distinct merits.

(1) Simultaneous loading and unloading. At present, most terminals adopt the simple loading or unloading scheduling mode, in which the loading and unloading work is separated. It avoids mutual
interference, but increases the empty driving distance. On the contrast, the loading and unloading hybrid scheduling is effective to reduce the empty-truck distance while it is more complex. Schematic representation of two loading and unloading modes is shown as follows.

![Diagram of Loading/Unloading Modes](image)

**Figure 2.** Schematic representation of two loading and unloading modes.

(2) Flexibility. Different from the fixed mode the flexible mode does not define a fixed working area for gantry crane, but a flexible scheduling is used to avoid interference among gantry cranes. This mode increases the utilization ratio of equipment effectively. However, it is more complex, because interference and safe working distance need to be considered.

(3) Quality of operating line. Single line loading and unloading mode is commonly used in central stations now, suitable for separate loading and unloading scheduling mode mentioned before. And multi-line mode is often used in loading and unloading simultaneous scheduling mode.

Schematic representation of two loading and unloading modes shown as follows, as well as the fixed and flexible area.

![Diagram of Multi-line and Single Line Modes](image)

**Figure 3.** Schematic representation of multi-line and single line mode

4. **Conclusion**

From what we discussed above, the multi-line flexible range loading and unloading hybrid scheduling mode is superior to the single-line fixed-range loading/unloading scheduling mode in efficiency theoretically.

However, due to the complexity of the multi-line flexible range loading and unloading hybrid scheduling mode, the computing time is also increased, which makes a certain impact on the working
efficiency of gantry cranes. With the quantity of containers booming, terminal stations may reach a plateau due to the low efficiency of the gantry crane, it could be considered to choose the complex multi-line flexible range loading and unloading hybrid scheduling mode.

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