Feasibility Analysis of “Container Truck-Container Train” Mode Application for Railway Container Terminals

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Abstract. The appearance of containers has changed the traditional form of railway freight transportation, and has also boosted the development of railway container terminals greatly. Rail mounted gantry cranes are the core resource of railway container terminals with its loading-unloading mode directly affecting the operational efficiency of railway container terminals. Based on the problem of loading-unloading mode selection of rail mounted gantry cranes, this paper analyses and compares the mode of "container truck-storage yard-container train" and "container truck-container train". The results show that the latter one is more beneficial to improve the operational efficiency of rail mounted gantry cranes and reduce the waiting time of container trucks and container trains.

1. Introduction

Container multimodal transport combines railway and highway organically, and provides the "door-to-door" freight service, which provides great convenience for container freight. As an important node of container transportation network, railway container terminal is the bridge and link between railway and other transportation modes and it is also an important unit to realize logistics system service. That is why the connection of public rail transport in the station is particularly important. As the key facility of the railway container terminals, rail mounted gantry cranes are located in the main operation area of the railway container terminals and spans the loading-unloading line of container trains, the main yard, and the container truck operation lane. It is responsible for all loading-unloading operations of arriving and leaving containers. The effectiveness of the operation scheduling of the rail mounted gantry cranes, which are the only loading-unloading equipment in the main operation area, directly determines the efficiency of production and operation of railway container terminal.

At present, container transportation in ports is relatively mature, and the research on the operation mode of large container loading-unloading equipment is also mostly centered on ports. However, due to some differences between container ports and railway container terminals, the research results of ports are difficult to apply to railways.

With the development of container transportation, more and more studies have been conducted on railway container terminals: Le et al. have considered the constraint that multiple rail mounted gantry cranes cannot cross each other when they work in the same container area, and the mathematic model of rail mounted gantry cranes scheduling is constructed for the purpose of the shortest total time of completion of all operations [1]. Guo et al. proposed a hybrid integer programming model which considers the constraints of rail mounted gantry cranes, and used discrete artificial bee swarm algorithm to solve the model [2]. To solve the problem of unloading efficiency of container trains, Liang et al. set up a two-objective optimization model which considers the effects of running time and
waiting time of container trucks in container area [3]. Guo et al. used the system simulation method to construct the overall operating model based on the work flow of container logistics center. Through simulation experiments, the impact of model parameters such as arrival time interval and the number of container trucks on the operation was studied [4].

Nowadays rail mounted gantry cranes in railway container terminals adopt the "container truck-storage yard-container train" mode, but this paper will analyze the feasibility of the implementation of "container truck-container train" mode and explain the significance of the model to railway container terminals.

2. Layout and Equipment of Railway Container Terminals
According to the functional layout of the railway container terminals, the terminal can be divided into three functional areas: the main operation area, the auxiliary storage area and the service area.

2.1. Main Operation Area
The main operation area consists of the main yard, loading-unloading line, rail mounted gantry cranes, container truck operation lane and some other facilities. In the main operation area, the loading-unloading operations of rail mounted gantry cranes mainly include: unloading operation of containers which are delivered by container trains (unloading to the storage yard or unloading to container trucks), loading operation of containers which will be taken by container trains, unloading operation of containers which are delivered by container trucks (unloading to the storage yard or unloading to container trains) and loading operation of containers which will be taken by container trucks.

2.2. Auxiliary Storage Area
The auxiliary storage area is a container storage area outside the main operation area. It is used to store various containers except ordinary heavy kind. It mainly consists of special container yard, cold container yard, international container yard, and empty container yard. The loading-unloading equipment in the auxiliary storage area mainly includes container front-handling mobile cranes and forklifts.

2.3. Service Area
The service area is mainly responsible for containers-related business handling, railway container terminal dispatching management, cleaning and repairing containers, parking of the loading-unloading vehicles, management of incoming and leaving vehicles and inspection of arriving containers.

3. Operation Procedure of Railway Container Terminals
The object storage and loading-unloading operations of containers in railway container terminals can be divided into: arriving containers, leaving containers and transfer containers. Arriving containers refer to the containers which are transported to railway container terminals through container trains to wait to be taken by container trucks. Leaving containers refer to containers which are transported to railway container terminals through container trucks to wait to be loaded onto container trains. Transfer containers refer to the containers which are transported to railway container terminals through container trains to wait to be loaded onto other container trains.

The current mode of loading-unloading of arriving and leaving containers is mainly "container truck-storage yard-container train" mode, and its operation procedure is shown as the blue arrow in Figure 1. It means that arriving and leaving containers are unloaded by rail mounted gantry cranes to the corresponding container area in main container yard, and then the containers will stay in the yard and wait to be taken before being loaded onto container trucks and container trains respectively.
Figure 1. Operation modes of arriving and leaving containers.

And there is another less common mode of operation which is called "container truck-container train" mode in the main operation area, and the mode is shown in the red arrow in Figure 1. It means that arriving containers are directly unloaded from container trains onto container trucks by rail mounted gantry cranes, and leaving containers are directly unloaded from container trucks onto container trains by rail mounted gantry cranes. Then the containers will be transported away from railway container terminals. The latter mode mostly exists when there are already some trucks waiting for loading containers.

4. Advantages of "Container Truck-Container Train" Mode
The large-scale use of the "container truck-container train" mode can greatly improve the efficiency of railway container terminals. The specific advantages can be summarized as follows:

4.1. Improving the Efficiency of Rail Mounted Gantry Cranes
It can remove the extra operation of loading and unloading container, and it can also reduce the number of lifting and landing operations and distance of moving., so that rail mounted gantry cranes can complete the operation task in a shorter time.

4.2. Green and Environmental
It can reduce the number of piles, save the space resources, economize the operating costs of railway container terminals, and comply with the prevailing trend of energy conservation and emission reduction.

4.3. Saving the Time Cost of Container Trucks
Sometimes container trucks densely arrive and the operational efficiency of rail mounted gantry cranes cannot fit the demand, and then the number of container trucks in railway container terminals will be controlled, causing the jam of the waiting trucks outside. In order to avoid congestion and other unfavorable conditions in railway container terminals, the "container truck-container train" mode can be used to render rail mounted gantry cranes complete more container operations within unit time, thereby reducing the waiting time of container trucks.
5. Feasibility of "Container Truck-Container Train" Mode

Although the operational efficiency of "container truck-container train" mode significantly outreaches that of "container truck-storage yard-container train" mode, the current operation mode of railway container terminals is still dominated by the latter. The main reasons for this phenomenon can be concluded as follows.

5.1. Uncertainty of Arriving Time

Since there is no fixed timetable for the operation of the container trucks, the arriving time of the trucks is uncertain, and it is difficult to match loading-unloading operations after the arrival of container trains to carry out direct loading and unloading operations.

Figure 2 shows the operation sequence of rail mounted gantry cranes. The gray square represents normal operation sequence of rail mounted gantry cranes, and the green square represents direct loading and unloading operation after the arrival of the container. As upper sequence shows, the arriving time of container trucks is uncertain, it is very likely that container trucks will not arrive in time when the work sequence is executed into the green square, which will destroy the original sequence, reduce the operating efficiency, and even cause confusion in the operation. Therefore, the operation sequence below is taken. After the arriving time of container trucks is known, the direct loading and unloading operation sequence of containers is inserted into the rest sequence, and the subsequent operation sequence is rearranged to maximize the operation efficiency of rail mounted gantry cranes.

![Figure 2. Two kinds of operation sequence of rail mounted gantry cranes.](image)

5.2. Arriving Interval of Container Trucks

A large number of container trucks which enter and leave railway container terminals every day impose lots of pressure on facilities. It requires trucks to reach their respective delivery locations for service, thus creating a high risk of congestion and waiting.

5.3. Restriction of Operational Range

Rail mounted gantry cranes have their fixed operational range. The crossing operation between cranes is forbidden and it is impossible to be carried out. Therefore, the "container truck-container train"
mode may lead to such a situation that the idle cranes cannot complete the tasks of other cranes to reduce the operating pressure.

With the rapid development of science and technology, the increasingly mature Internet technology has begun to help railway workers solve these technical problems, making it more likely that the "container truck-container train" mode will be applied to railway container terminals. The existing Internet of Vehicle (IOV) can collect information such as speed, location and cargo information of container trucks through wireless industrial communication devices, and obtain a more accurate arriving time of container trucks through the calculation and analysis of resources such as simulation software. And then, the time interval between the arrival of container trucks can be controlled to keep the number of trucks at a steady level in the unit time. It can also adjust the work plan in real time to obtain the most suitable loading-unloading plan. (The operation sequence below in Figure 2 can be implemented.) Therefore, "container truck-container train" mode can be used to the maximum extent.

IOV has a strategic role in the development of multimodal transport, and government has offered great attention and great help. In the future, China will continue to actively promote the integration of the Internet, Internet of Things (IOT) and IOV, so that IOV will play an important role in such areas as smart transportation and smart logistics. This will greatly help improve the efficiency of the work and service of railway container terminals.

6. Conclusion
This paper discusses and analyzes the current operation mode of rail mounted gantry cranes in railway container terminals, and puts forward "container truck-container train" loading-unloading mode based on IOV. This mode reduces the number of lifting and landing operations of rail mounted gantry cranes and the waiting time of container trucks. It also improves the ratio of direct loading and unloading operations of containers and greatly improves the operational efficiency of rail mounted gantry cranes. It has important reference value and practical significance for the development of railway container terminals.

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