Solutions for transport and technological systems of regular container transportation

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Abstract. The limitations that hinder the effective organization of logistics of cargo transportation by container trains have been identified. The developed technical and technological models of container terminals are presented: a container storage and distribution center (container marshalling yard) and a rack-type container terminal, within the framework of transport and technological systems of regular container traffic. A key distinctive feature of the developed functional models of container terminals is to provide the possibility of end-to-end reception of full-component container trains to the container terminal and performing in-line processing of container trains, eliminating sorting and shunting operations associated with their preliminary reformulation, as well as replacing station sorting work with wagons with container sorting by destination using loading and unloading mechanisms. The technological aspects of their application in transport and technological systems of regular container traffic are considered. The requirements for the provision of container service using the proposed functional models of container terminals as the main elements in the logistics chain are formulated. A SWOT analysis of transport and technological systems of regular container traffic was performed based on the organization of end-to-end in-line processing of container trains in the conditions of terminal technology.

1 Introduction

The transportation of goods by container trains ensures the stability of logistics supply chains, and their effective organization is a factor in the rapid growth of the competitiveness of rail transport [1,2].

The change in the directions and structure of container flows, the emergence of new points of generation and repayment of domestic container flows, due to sanctions pressure and the implementation of import substitution policy, require the development of systemic technical and technological solutions that ensure the improvement of container delivery systems and their timely adaptation to changing conditions [3–5].

According to the strategy of JSC Russian Railways until 2030, the container transportation segment is expected to increase at a rate of up to 5.4% per year, considering the increase in the level of containerization to 9.3% by 2025.

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According to the estimates of the Institute of National Economic Forecasting of the Russian Academy of Sciences (NEF RAS), in the long term, such structural changes in rail transportation are predicted as an increase in the importance of transportation in the eastern direction; an increase in the share of domestic transportation, as well as an increase in container cargo transportation [6–10].

At the same time, there are current restrictions that impede the effective organization of logistics for the transportation of goods by container trains, among which, first, infrastructural ones can be distinguished [11–15]:

1. Lack of transport and logistics infrastructure for processing large-capacity containers. Only 5% of railway stations are capable of handling 20- and 40-foot containers.

2. Lack of throughput and processing capacities of terminal and logistics infrastructure facilities. The reorientation of rail transport in the main directions in the Russian Federation has led to a shortage of capacity of the railways of the Eastern Polygon, as well as railway border crossings (Zabaikalsk, Naushki, Grodekovo, Kamyshovaya). Due to the growth of export-import traffic in connection with the Asia-Pacific region, the loading of terminals in the Far East exceeds 90% [16].

3. The discrepancy between the processing capabilities of the interacting railway stations of the junction and container terminals. The resulting processing capacity of the public infrastructure of the railway stations of the junction, which is influenced by the loading of elements of its track development and technical devices, as well as the technology of working with all freight fronts of general and non-public use, often becomes a limiting factor for realizing the maximum processing capabilities of reconstructed or newly built container terminals. In turn, existing terminal and logistics facilities designed for container processing, as a rule, have a useful length of railway track development of freight fronts that does not correspond to the unified length of container trains adopted on the Russian railway network. This does not allow their processing without performing additional sorting and shunting operations, which leads to an increase in unproductive demurrage of wagons and containers and, as a result, a decrease in the processing capacity of container terminals [17–19].

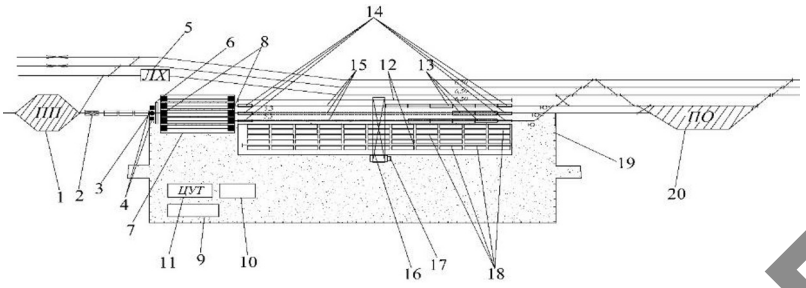
In general, these and other limitations are the reasons for a significant increase in the delivery time of containers to end users, as well as an increase in logistics costs in the final price of finished products.

2 Materials and methods

For the effective development of mass technology of cargo transportation by container trains, new container services based on route diversification, eliminating the shortage of transport and logistics infrastructure, it is proposed to supplement the main elements of the transport and technological system of regular container traffic with such innovative models of container terminals as a container storage and distribution center (container marshalling yard) and a rack-type container terminal.

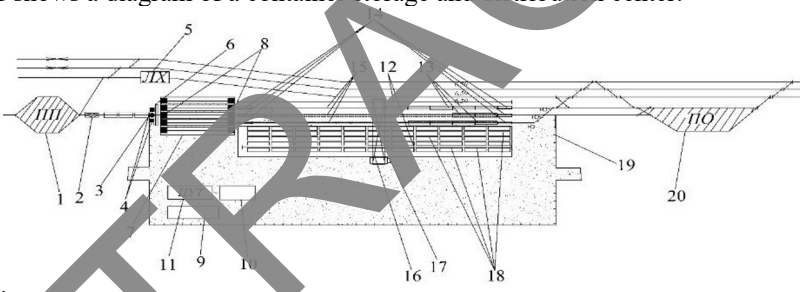
A key distinctive feature of the developed functional models of container terminals is to provide the possibility of end-to-end reception of full-component container trains to the container terminal and performing in-line processing of container trains, eliminating sorting and shunting operations associated with their preliminary reformulation, as well as replacing station sorting work with wagons with container sorting by destination using loading and unloading mechanisms.

shows a diagram of a container storage and distribution center.



Legend:
1 – Reception park
2 – Shunting locomotive
3 – Axis counter
4 – Photocells and photo sensors
5 – Locomotive industry
6 – Floor devices for automatic uncoupling of wagons
7 – A device designed for the transverse movement of wagons (self-moving sorting platform)
8 – Brake stops
9 – Hardware
10 – Utility block/workshop
11 – Terminal control center
12 – Under-crane tracks
13 – Compositions formed from detachments
14 – Accelerators – decelerators
15 – Sorting tracks
16 – Crane
17 – Truck
18 – Containers
19 – Fence
20 – Departure yard.

Fig. 1 shows a diagram of a container storage and distribution center.



Legend:
21 – Reception park
22 – Shunting locomotive
23 – Axis counter
24 – Photocells and photo sensors
25 – Locomotive industry
26 – Floor devices for automatic uncoupling of wagons
27 – A device designed for the transverse movement of wagons (self-moving sorting platform)
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Fig. 1. The scheme of the container storage and distribution center.

The proposed technical and technological model of a container terminal is applicable for the consolidation, sorting and distribution of container flows traveling in container trains along feeder routes, and the formation of full-component container trains along the main routes. Due to the presence of a special sorting device – a self-moving sorting platform (SSP) - groups of wagons can be exchanged: part of the wagons can be cordoned off for further

loading at the current container terminal or in the feeder direction, the other part can be uncoupled for the subsequent formation of full-component container trains along the main routes.

The technological principle of operation of the self-moving sorting platform (Fig. 2) ensures the disbandment of container trains by moving railway rolling stock with containers or empty railway rolling stock from a mobile transborder platform to the railway tracks corresponding in the direction.

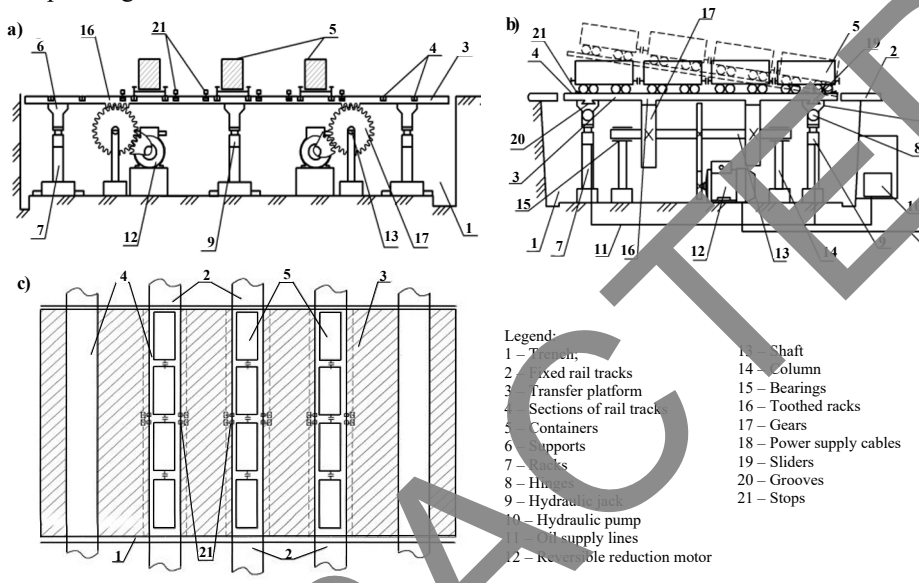


Fig. 2. Device for transversal movement of wagons (self-propelled sorting platform): a) - front view; b) - top view; c) - side view.

After the formation of new container trains along the routes of the sorting and distribution fleet, containers are sorted according to their intended purpose using a gantry crane: unloading containers from railway rolling stock into a crane temporary storage area and/or loading containers from a crane temporary storage area onto railway rolling stock; and/or reloading containers from one container train to another.

In addition, depending on the technology of transport services, the model of a container storage and distribution center can be implemented without using a special sorting device. For example, as the creation of specialized container sorting and distribution parks at the initial and final queuing stations of container trains. At the same time, compliance with the basic structural and planning solutions and technological principles is ensured:

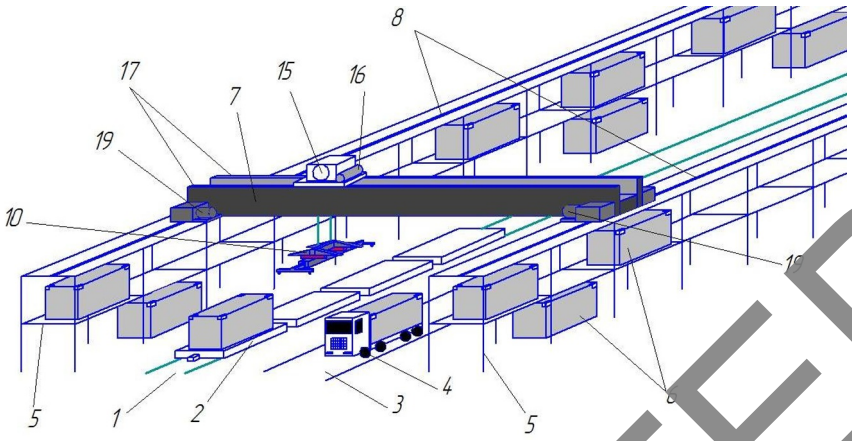
- sequential or parallel arrangement of the container sorting and distribution fleet to the main terminal development (parks) of the station, with the possibility of through reception and departure of container trains;

- the availability of a track development of a container sorting and distribution fleet with a useful length corresponding to the unified length of container trains, with the possibility of processing them without additional re-forming into groups;

- carrying out terminal maintenance operations for container trains in the fleet, including sorting containers by destination using gantry cranes and performing loading and unloading operations;

- the presence of buffer (reserve) paths that allow you to defend or accumulate empty and loaded trains.

Fig. 3 shows a diagram of a rack-type container terminal.



Legend: 1 – Railway track; 2 – Container train; 3 – Roadway; 4 – Automobile transport; 5 – Multilevel racks; 6 – Container;
7 – Double-beam bridge; 8 – Rails for the movement of the double-beam bridge; 10 – H-shaped frame; 15 – Crane trolley;
16 – Electric motor driving the crane trolley; 17 – Rails for the movement of the crane trolley; 19 – Electric motors driving the double-beam bridge.

Fig. 3. Scheme of a rack-type container terminal.

This technical and technological model of a container terminal can be implemented at reference transit railway stations for terminal maintenance of multi-group container trains of permanent formation, regardless of transportation requests.

The technology of organizing the running of multi-group container trains involves the exchange and/or addition of groups of containers to a container train at passing railway stations. During the parking of the container train, containers are unloaded by destination at this station and containers are loaded by destination at the stations of the route. The technological requirement of such a container service is the arrival/ departure of multi-group container trains of permanent formation at the loading/unloading fronts of the reference transit railway stations according to the "rigid thread" of the schedule, which implies a strictly regulated time for terminal maintenance operations, including loading and unloading operations.

A significant limiting factor in the transport service of the described transport and technological system is the absence, as a rule, of through-type container terminals or loading and unloading platforms with a lateral location to the main terminal development of the station at the main transit railway stations.

Therefore, in order to ensure high speed of the processing process of a multi-group container train, as well as the schedule of its arrival and departure, it is proposed to create side container platforms at supporting transit railway stations, for example, rack type. To do this, multi-tiered racks are installed along the railway track on which the container train arrives and the highways for trucks on both sides, which serve as the basis for a double-girder bridge. The racks are designed for temporary storage of containers. Rails are laid on the upper parts of both racks to move the double-girder bridge, which is driven by electric motors and equipped with a crane trolley. After the arrival of the container train on the railway track, the double-girder bridge, moving along the rails, is positioned using sensors above the rolling stock, after which containers are loaded from temporary storage racks, or containers are loaded according to the direct option - from vehicles to railway rolling stock; unloading of containers with placement on temporary storage racks, or unloading of containers according to the direct option – from railway rolling stock to vehicles.

The structural and planning (first of all, the size of the land plot) and technical requirements of the proposed model make it possible to put into operation this terminal infrastructure facility on the territory of the station in a short time and with minimal investment costs.

3 Results

In Table 1, a SWOT analysis of the transport-technological systems of regular container transportation is presented, based on the implementation of continuous streamlined processing of container trains within terminal technology conditions.

Table 1. SWOT- analysis.

Strengths	**Weaknesses**
- Modular construction of terminals; - Minimum necessary number of container handling operations; - Reduction in shunting work by eliminating operations such as breaking up trains, positioning, and clearing wagons for cargo operations; - Potential for high levels of automation; - Unity and continuity within the transport-technological process; - Acceleration of container turnover and specialized rolling stock; - Reduction in associated operational expenses for containerized cargo transport; - Ensuring decreased delivery times for goods via railway transport	- Need to ensure maximum vertical working space in container loading/unloading zones at intermediate railway stations. - Requirement for developing technical solutions for catenary diversion. - Development and operation of rolling stock capable of autonomous movement on the last mile. - Need for the establishment of station infrastructure on primary routes for container transport to implement technical solutions for continuous streamlined container processing.
Возможности	**Угрозы**
- Ensuring sustainable growth of container transportation. - Increasing the long-term competitiveness of the Russian Railways (OAO "RZD") in the freight transport market and improving the quality of transportation services for cargo owners. - Accelerating container shipments in both international and domestic transportation networks. - Establishing terminal-logistical infrastructure swiftly on major routes for container transport.	- Low investment attractiveness of infrastructure facilities. - Inability to expand the linear parameters of station territories and existing container terminals. - Existing constraints on the throughput capacity of railway tracks.

4 Conclusion

The implementation of the developed techno-technological models of container terminals, serving as fundamental elements of regular container transportation systems, will ensure sustainable advancement in the market of transport and logistics services. This advancement will be based on the principles of seamless reception, dispatch, and terminal servicing of continuously formed container trains, adhering strictly to scheduled timetables. The utilization of such transportation products within supply logistics chains will establish a solid

foundation for reducing overall process durations, shortening delivery times of containerized goods to end consumers, and optimizing supply chains.

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