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A Study of Wagon Turnaround in the Current Context

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ABSTRACT Wagon turnaround remains the key performance indicator of railway transport operations characterizing the efficiency both of a wagon fleet owner and of "Russian Railways" Company (RZD). Freight logistics efficiency in the railway sector can also be assessed using this indicator. For determining the wagon turnaround time, the duration of operations at technical stations, freight handling time and the time in motion are taken into account. "Russian Railways" company and operator companies control the three components of the wagon turnaround time. The synergies of railways, intermodal types of transport, and private railways belonging to major freight owners are of particular interest. Their interaction efficiency can be calculated using the wagon turnaround formula that considers the freight idle time and the local operations factor. The local operations at the station for serving private tracks and port sidings are regulated by a number of documents that determine the procedure for supply and departure of wagons, the number of wagons in supply, the regularity of these operations, the number and series of shunting locomotives, etc. The optimal number of wagons in supply will be determined by the minimum cost of wagon movement and wagon idle time on the station tracks. The calculation of the cost function sensitivity will make it possible to determine the limits in the optimal wagon movement changes.

KEYWORDS: logistics; freight flow logistics; wagon turnaround; local operations; optimal wagon supply; private tracks; port sidings; inventory management theory; cost function; function sensitivity; wagon fleet

Исследование оборота вагона в современных условиях

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АННОТАЦИЯ Оборот вагона остается ключевым эксплуатационным показателем работы железнодорожного транспорта, характеризующим эффективность деятельности владельца вагонного парка и ОАО «РЖД» Логистический процесс продвижения грузопотока с участием железнодорожного транспорта также может быть оценен с использованием этого показателя. При определении оборота вагона учитывается продолжительность операций на технических станциях и под грузовыми операциями, время в движении. Все три составляющих времени оборота вагона находятся в области управления и ОАО «РЖД», и операторской компании. Интерес вызывает стык взаимодействия железнодорожного и смежных видов транспорта и путей необщего пользования крупных грузовладельцев. Эффективность такого взаимодействия можно оценить составляющей произведения грузового простоя и коэффициента местной работы в формуле оборота вагона. Проведено исследование оптимального количества вагонов в подаче на пути необщего пользования или портовые пути. Оптимальность количества вагонов в подаче будет определяться минимумом затрат на передвижение вагонов и простой на станционных путях с использованием теории управления запасами. Оценка чувствительности функции затрат позволит установить пределы изменения оптимального количества вагонов в подаче, которое даст возможность минимизировать грузовую составляющую в обороте вагона.

INTRODUCTION

"Russian Railways" Company (RZD) is the largest carrier and infrastructure owner that interacts with the operators of railway rolling stock at all stages of transport management [1]. Rail transport performance is evaluated by quantitative and qualitative operational indicators [2]. Operational indicators include such an important parameter as wagon turnaround, which is defined as the time interval between two successive loadings [3]. The interaction between "Russian Railway" Company (RZD), the railway transport operator, large freight owners, and other types of mainline transport traditionally have always been of particular interest for research [4–6]. Such interaction efficiency is reflected in the wagon turnaround indicator, because its main components are wagon time in motion along the section, time of wagon handling at sorting stations and loading/unloading operations. With the transfer of wagon fleet management to the operator companies, wagon empty runs have significantly increased. The operating companies have been adjusting the transportation operations but additional studies are necessary to amend the fundamental works of a number of scientists in the current situation context [7]. However, efficient freight train routing will improve the wagon turnaround indicator and allow assessing the participants' interaction efficiency and increasing the attractiveness of domestic rail transport in the context of international transport corridors [8–10]. In this study, the wagon turnaround is investigated in terms of freight idle time on private tracks and port sidings. The efficient technical, technological and organizational interaction between a railway station, the starting point and the destination of freight flows are the concepts of logistics to be observed. It will improve operational performance and bring additional profits [11–13]. It is difficult to overestimate the importance of transport terminal service [14–16]. Largely, it has an impact on the entire process of freight flow movement on national railways. The loading of wagons at freight flow starting points can also be attributed to terminal services. Yard time of freights is a component of wagon turnaround and it describes the efficiency of wagon handling on private tracks, which requires further research [7, 12, 17].

MATERIALS AND METHODS

The study of wagon turnaround is conducted in the context of local operations at the station and the interaction of the station with private tracks or port sidings. Inventory management theory, where wagons at the station are represented as inventory is used for calculating the optimal wagon handling. The optimal number of wagons for loading is investigated taking into consideration the cost function minimization. The function sensitivity is determined using a differential. The necessity to transfer the wagon fleet under the management of operator companies was caused by objective reasons such as shortage of rolling stock, high depreciation of the wagon fleet, insufficient funds for providing the required traffic volume. Today, "Russian Railways" Company (RZD) is the main carrier and owner of the infrastructure, but the transfer of the wagon fleet management to the operator companies had a negative effect on the railway industry as a whole. In spite of the positive aspects such as investing more money in the industry and creating a system of corporate transport service in order to improve customer orientation and competitiveness, it is necessary to highlight a number of drawbacks. The main and most sensitive one is the loss of wagon versatility, i.e., the ability to be loaded at any time at any place. It leads to the accumulation of wagons and their unproductive idle time resulting in an increase of empty wagon runs and turnaround time. Thus, financial losses of the operator companies, which inevitably affects the operation of "Russian Railway" Company (RZD) as a whole. That is why it is necessary to adjust the theory of intermodal transportation and interaction in current conditions [7]. It is important for railway transport partners to reduce the costs of wagon fleet operation and maintenance. The interaction of "Russian Railways" Company (RZD) with major freight owners, rolling stock operators, and other mainline modes of transport includes four major issues: freight traffic transfer issue; information transfer issue; station facilities layout and private tracks or port sidings; spatial facilities layout (*Fig. 1*). Therefore, the interaction process is a complex concept, which includes a number of parameters such as organizational, technological, technical, legal and informational.
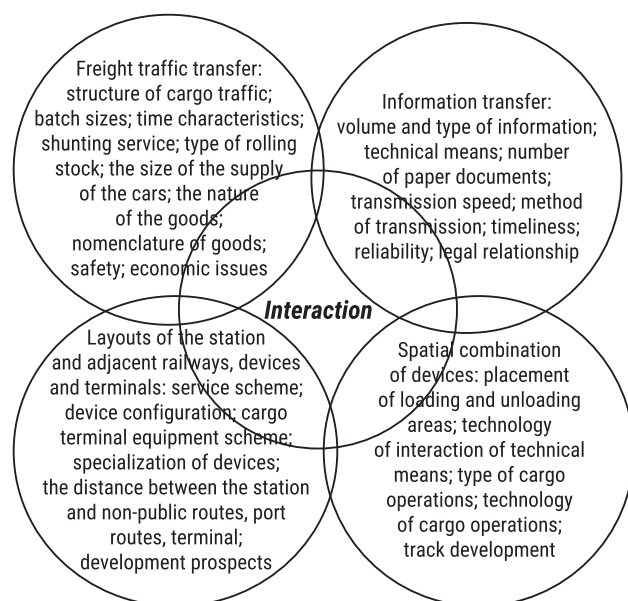
Fig. 1. Interaction diagram

Let us analyse freight logistics issues. The freight chain delivery consists of terminal services and freight movement by different modes of transport (T). Freight loading can be performed either directly, from vehicle to vehicle (which is potentially disadvantageous for one of them), or at a terminal. The terminal can be used for loading/unloading of wagons from origin to destination points. An important link in the logistics chain freight delivery is the interaction of railway stations with freight owners' private tracks and port sidings. The transfer of the wagon fleet management to the operator companies has intensified the need for the competent transportation management to ensure rhythmic operation of rail transport. The freight traffic operation should be comprehensive, i.e. it should ensure uninterrupted operation of the railway network at the planning, operative regulation and performance assessment stages. Under Soviet-era state management, this was achieved by planned economy methods [7]. At present, these methods of regulating the interaction between different modes of transport is not possible. World practices show that the Total Quality Management system used by many companies including railway transport companies have been very successful. This system is based on international ISO quality standards. The TQM approach assumes that the result of a process is a product or, in this case, a transport service. Every product or service is the result of a process, so improving the process is an effective way of improving quality. If we consider rail freight transportation as a process, it is appropriate to apply the Deming-Schuchart "Plan – Do – Check – Act" or PDCA. The application of the Deming-

Schuchart cycle in transport operation is deemed an effective tool that will ultimately improve the quality of transportation services (*Fig. 2*).

The analysis of the introduced improvements should include several parameters. Traditional performance indicators could be taken into consideration. Accordingly, planning and performance improvement belong to the "Plan" and "Do" parts of the Deming-Schuchart cycle. The introduction of transportation standards and process replanning belong to the "Act" part. Operational parameters that can also act as key performance indicators should be taken into consideration [3, 16]. For example, the transport route speed; average distance of freight delivery; freight loading idle time; empty wagon run ratio; number of empty grouped departures and outbound routes; out-of-service-wagon average time; number of outbound freight shipping based on permanent contracts with consignor and those at single requests; number of double-run operations when arranging the wagon fleet management layouts.

The key parameter of rail transport operation efficiency is wagon turnaround. It is the time required for performing a full freight handling cycle from loading/unloading operations at one point to those at the next point, duration of loading operations at sorting stations, and wagon movement time on sections. Obviously, the wagon turnover reflects the rolling stock operators' efficiency. Thus, "Russian Railways" Company (RZD) efficiency as the main carrier and infrastructure owner can also be assessed in terms of wagon turnaround evaluating at least two parameters such as transit time and load handling time at sorting stations. "Russian Railways" Company (RZD) is also responsible for wagon supply in freight operations.

Studies on the rail transportation market show that the main factors having a negative effect on wagon turnaround growth are the abundance of wagon fleet; inefficient operation of wagon fleet; lack of cooperation between the participants of rail transportation; lack of cooperation between railways and intermodal kinds of
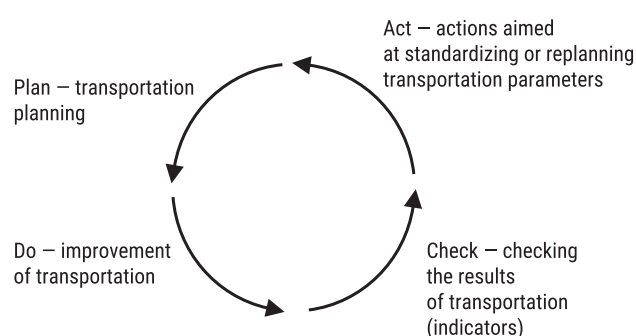

Fig. 2. The PDCA cycle in rail transport operation

transport including sea transport. The three-part formula for wagon turnaround is defined as

$$\vartheta = \frac{1}{24}\left(\frac{l}{v_{uch}} + \frac{l}{L}t_{tec} + k_m t_{gr}\right), \qquad (1)$$

where l is the wagon run; v_{uch} is the speed on the section; L is the wagon haul; t_{tec} is the transit car idle time at sorting stations; k_m is the local operations coefficient; t_{gr} is a single freight operation idle time.

Let us analyse a single freight operation idle time and local operations coefficient. Freight idle time is the time per cargo operation, which is calculated as quotient of dividing the total number of local wagon idle hours by the number of loaded/unloaded wagons.

$$t_{gr} = \frac{\Sigma U t_m}{U_p + U_v}, \qquad (2)$$

where $\Sigma U t_m$ is the total local wagon idle time; U_p and U_v are the volumes of wagon loading and unloading respectively.

Local wagon idle time is the time from the moment of wagon arrival at the station till the moment of its departure. In this regard, it is interesting to study the process of interaction between the railway station and private tracks or port sidings.

In accordance with Article 2 of the Rail Services Charter, the legal entity or individual entrepreneur who owns or has other rights to the railway track of non-public use, as well as buildings, structures and facilities, and other objects related to transport operations and provision of railway transport services. Freight owners interact with the carrier under the contract for the wagons supply and departure. Private tracks are serviced on the contract basis depending on the ownership of the private track and the locomotive serving that track. The process of wagon loading/unloading on a private track is usually included in process charts specifying the conditions and facilities. Largely, it is convenient to present this process as an algorithm a fragment of which is shown in *Fig. 3*.

It is recommended to determine the number of wagons in supply by the formula

$$m = \frac{U}{n_{pod}}, \qquad (3)$$

where U is the daily volume of the freight flow inbound to the private tracks or port sidings, n_{pod} is a number of shipments per day.

In this case, the number of wagon supplies is recommended to calculate according to the availability and readiness of wagons for delivery at the station, the chosen order of private tracks service and so on. However, the number of wagons in supply on a private track for freight operations is important in determi-
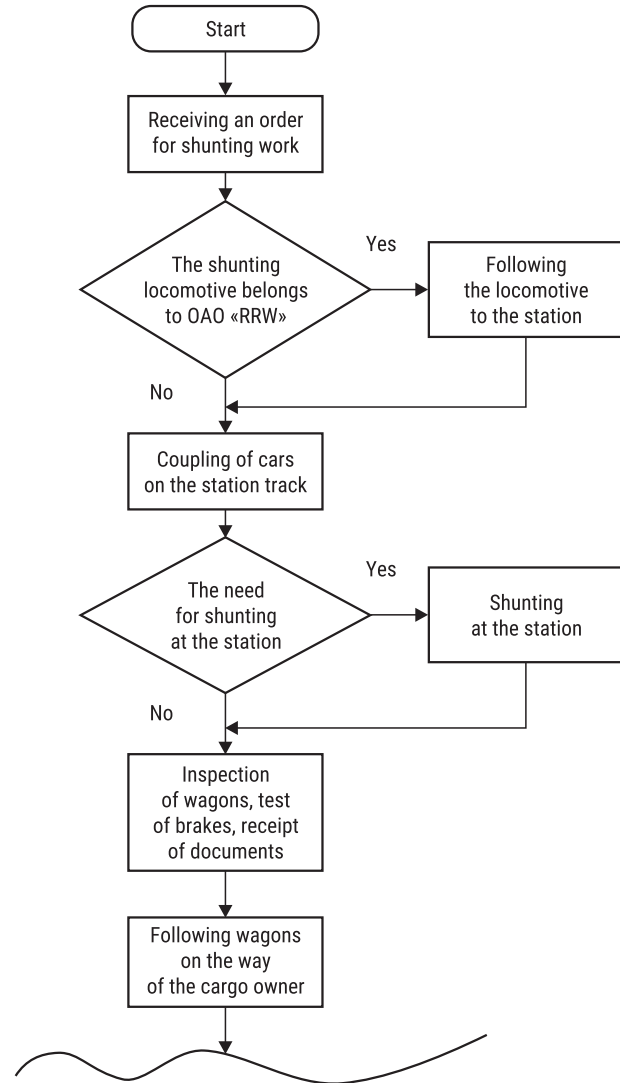

Fig. 3. Interaction of the railway station and the freight owner's tracks

ning the freight idle time parameter of freight idle time and wagon turnaround. It is necessary to determine the optimal number of wagons in supply to minimize idle wagon-hours and, as a result, time and money costs. Various methods can be used to determine the optimal number of wagons in supply. This study suggests using inventory management theory. Wagons are represented as inventory so that to make the above-mentioned theory applicable to them.

Let us assume that in the wagon supply process on private tracks, there are two types of costs, constant (not conditionally dependent on the wagons number in supply) costs of load/unload operations c_l and costs of unproductive wagon idle time on the station tracks in supply c_s. We assume that the wagon stock at the station for the time interval Θ is equal to U (the daily volume of the freight flow inbound on private tracks or port sidings). We will calculate the wagon number

in supply m so as to minimize the private track service cost. The following constraints $m \neq 0$ will be accepted; otherwise, the wagon supply will not make sense. The upper limit will be determined by the capacity of the enterprise (port) tracks and the shunting locomotive capacity depending on what services have been included in the station operations and the service contract. Let us assume that

$$1 \leq m \leq 60. \qquad (4)$$

The average wagon stock during the time period T is equal to $m/2$ according to the inventory management theory.

The total costs for the whole period of time Θ will be

$$C(n) = \frac{U C_l}{m} + \frac{\Theta C_s}{2} m. \qquad (5)$$

Therefore, the cost function is a function of the variable m for the specified time interval, number of wagons at the station as well as variable and fixed costs. The first summand of formula (5) is the total cost of wagon supply on private tracks or port sidings C_l, and the second summand is the total cost of wagon idle time on the tracks of "Russian Railways" Company (RZD) C_s. With a certain number of wagons in supply, the value of the cost function will be minimum. This number of wagons in supply will be the optimal one.

The minimum of two variables, namely, the costs of wagon supply and wagon storage on the station tracks with their constant product is achieved if these two types of costs are equal. Then the optimal number of wagons in supply m_0 will be

$$m_0 = \sqrt{2 \frac{U}{\Theta} \frac{C_l}{C_s}}. \qquad (6)$$

The cost function sensitivity is expressed by the differential

$$dC = Cdm = \frac{1}{2} \Theta C_s - \frac{U C_l}{m^2}. \qquad (7)$$

If the optimal number of wagons in supply varies from ($n_0 - 10\%$) to ($n_0 + 10\%$), then

$$\partial C = \frac{1}{2} \left[C(0.9m) + C(1.1m_0) - 2C(m_0) \right] \qquad (8)$$

we obtain

$$\frac{\partial C}{C_0} = \frac{1}{2} \left(\frac{C(0.9m_0) + C(1.1m_0)}{C_0} \right). \qquad (9)$$

The total cost of wagon supply on private tracks or port sidings given the function sensitivity is therefore reflected in *Fig. 4*.
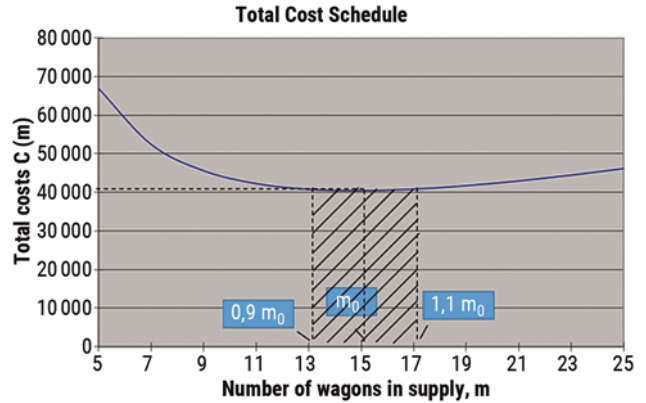

Fig. 4. The chart total cost changes depending on the number of wagons in supply

RESEARCH RESULTS

This study analyses the aspects and technology of the interaction between the railway station and private tracks (port sidings). Freight idle time due to the interaction between railway infrastructure facilities and the freight flow origin/ delivery points is an integral part of the wagon turnaround. Freight idle time reduction can be achieved by determining the optimal number of wagons in supply. The inventory management theory can help to find the function minimum of total expenses for private track services, to determine the function sensitivity, and to calculate the optimal number of wagons in supply as well as its variation limits.

CONCLUSIONS

The study has classified the issues of freight movement interaction into four groups. A study of freight movement interaction between "Russian Railways" Company (RZD), rolling stock operators, tracks of major freight owners, port sidings and terminal complexes has been of particular interest. Improving the freight transportation process using the TQM tools will help to improve the quality of transport services. Analysis of the transportation cycle involves assessing a number of operational indicators. The main operational indicator of wagon turnaround includes the efficiency of interaction between the railway station and private tracks in terms of freight idle time. It is possible to minimize the costs reducing freight idle time by finding the best option for servicing private tracks or port sidings. The presented methodology of finding the optimal number of wagons in supply allows minimizing the total costs of local operations. All participants of railway freight traffic can use the mentioned above methodology.

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