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Improvement of Interoperability and Joint Utilization of Freight Wagon Fleets in Countries of the "1520 Gauge" for the National Transport System of Ukraine and Other Countries: Analysis of the Structure and Parameters of the Additional Wagon Fleet

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Abstract

Efficient utilization and interoperability of railway equipment and technologies among the 1520 mm rail gauge countries have become essential for modern transportation advancements. This study focuses on enhancing the interoperability and collaborative utilization of freight wagon fleets. The countries currently included in the 1520 mm rail gauge system are Azerbaijan, Armenia, Belarus, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Uzbekistan, and Ukraine. Associated members of this community include Georgia, Estonia, Lithuania, Latvia, and Finland. Within the wide range of shared activities, the collaborative utilization of freight wagon fleets holds significant importance. This research analyzes the structure, parameters, and interoperability aspects of an additional wagon fleet, aiming to improve transportation efficiency, reduce logistics costs, and facilitate seamless operations between the national transport systems of participating countries. The findings of this analysis will contribute to the development of enhanced interoperability standards and practices in the context of the 1520 mm rail gauge system.

KEY WORDS: *railway transport, 1520 mm gauge, interoperability, freight wagon, Unified Management System for Freight Wagons*

1. Introduction

The joint utilization of freight wagon fleets is currently regulated by the Rules of Operation, Numbering, and Settlement for the use of wagons owned by other countries, as well as other documents governing the shared use of inventory of freight wagons by railway administrations operating within the framework of the Community of Nations' Railway Transport Council. Ensuring interoperability and seamless integration of railway systems across countries using the 1520 mm gauge is a critical aspect of modernizing transportation technologies. However, many countries, including those within the 1520 mm gauge system, face challenges in achieving effective interoperability [1-3]. The increasing volume of freight places a significant strain on railway administrations, which already suffer from a shortage of rolling stock. Additionally, the existing rolling stock often exhibits high levels of wear and tear, reaching 60-70 percent. Given the limited financial resources in the industry, it is imperative to explore new approaches to address these challenges and enhance interoperability within the rail networks [4-7].

2. Research

Researching the structure and parameters of the additional wagon fleet that the national transport system of Ukraine and other countries could potentially acquire through the improvement of joint utilization of freight wagon parks within the 1520 mm gauge system, as well as the losses of the wagon fleet due to its utilization by the transportation systems of other countries.

One of the potential measures to enhance the efficiency of joint utilization of freight wagon parks within the 1520 mm gauge system is the improvement of the existing supra-national organization responsible for the operation, numbering, accounting, and settlement of wagon usage belonging to other countries. However, such improvement is constrained by various non-transport-related factors. Researchers, focusing on scientific transport efficiency, have undertaken studies to explore the structure and parameters of the additional wagon fleet that the national transport system of Ukraine and other countries could potentially acquire through enhanced joint utilization of freight wagon parks within the 1520 mm gauge system. These studies also examine the losses incurred by the wagon fleet due to its utilization by the transportation systems of other countries.

The current situation with the wagon fleet can be categorized into several groups within the territory of each railway administration: inventory park wagons of the railway administration, privately owned wagons, and "foreign"

wagons (inventory park wagons and privately owned wagons of other railway administrations), see Fig. 1.

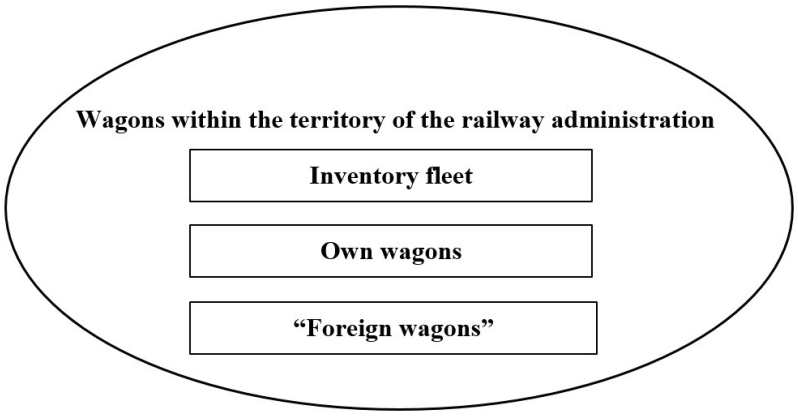

Fig. 1 Diagram of the existing rolling stock fleet within the railway administration territory

Based on the conducted research, it has been established that the dimensions of the additional wagon fleet, which the administrations can potentially acquire to ensure their own loading, depend on several factors. These factors include: the proportion of owned wagons in joint utilization, coincidence of the return direction of empty "foreign" wagons and the availability of cargo in that direction, as well as the specialization match between wagons returning as empty "foreign" wagons and the cargo specialization in that direction [7].

Let us perform a mathematical formalization to estimate the dimensions of the additional wagon fleet. We will derive a formula that enables us to determine the dimensions of the additional wagon fleet that the railway administration can potentially obtain.

$$N_{add}^{wag} = N_{NP}^{wag} + N_{"foreign"}^{wag} + \frac{N_{NP}^{wag} + N_{"foreign"}^{wag}}{4} - N_{"abroad"}^{wag}, \quad (1)$$

where N_{NP}^{wag} – the quantity of wagons in the national proprietary fleet (for calculation purposes, we assume that all wagons in the national proprietary fleet will participate in collaborative utilization, although this matter may warrant further investigation), wagons; $N_{"foreign"}^{wag}$ – the quantity of “foreign” wagons present within the territory of the country, wagons; $N_{"abroad"}^{wag}$ – the quantity of wagons from the inventory and proprietary fleets of other countries present within the territory of the given country, wagons; $\frac{N_{NP}^{wag} + N_{"foreign"}^{wag}}{4}$ – the supplementary wagon fleet obtained through the reduction of empty wagon mileage, wagons.

The inclusion of the last component is justified by the fact that the empty wagon mileage increases the turnover time of a freight wagon by approximately 24%. Since measures aimed at incorporating freight wagons into collaborative utilization lead to a reduction in empty wagon mileage, it follows that wagon turnover will be reduced. Therefore, the decrease in wagon turnover leads to the availability of additional capacity of the wagon fleet for freight transportation.

According to the opinions of Professor Zapara V.M. and Associate Professor Kuleshov V.V. from the Ukrainian State University of Railway Transport (Kharkiv, Ukraine), expanding collaborative wagon utilization will enable a reduction in empty wagon mileage by approximately 10%. Thus, the derived formula takes the following form

$$N_{add}^{wag} = N_{NP}^{wag} + N_{"foreign"}^{wag} + \left(\frac{N_{NP}^{wag} + N_{"foreign"}^{wag}}{4} \right) \cdot 0{,}1 - N_{"abroad"}^{wag}. \quad (2)$$

Based on the data obtained from the Ukrainian railway administration, we have the opportunity to determine the sizes of the additional rolling stock fleet that the administration can potentially acquire to ensure its own cargo transportation.

For the railway administration of Ukraine as of 2022, we have the following distribution indicators of the wagon fleet: $N_{NP}^{wag} = 105464$ wagons; $N_{"foreign"}^{wag} = 29150$ wagons; $N_{"abroad"}^{wag} = 2436$ wagons.

The sizes of the additional rolling stock fleet that the Ukrainian administration can potentially acquire to ensure its own cargo transportation are as follows.

$$N_{add}^{wag} = 105464 + 29150 + \left(\frac{105464 + 29150}{4}\right) \cdot 0{,}1 - 2436 = 135543 \text{wagons.}$$

To determine the extent of loss of the wagon fleet due to its utilization by other railway administrations, an extended analysis of the interaction between the participating countries of the "1520 gauge" should be conducted. However, as of 24 February 2022, Ukrainian Railways has closed its border crossings with Russia and Belarus. Currently, there are 14 border railway crossings connecting Ukraine with five countries: Poland, Slovakia, Hungary, Romania, and Moldova. As of June 2023, each day, 3422 freight wagons pass through these border crossings, which constitute an average of 55% of the potential capacity. However, a complex situation has arisen with the accumulation of wagons within the network. There is a backlog of 29,150 loaded wagons waiting to cross the border for more than 15 days. This accumulation of wagons leads to a decrease in network capacity, inefficient utilization of rolling stock, and an increase in operational costs for Ukrainian Railways. In some cases, temporary restrictions on loading are imposed when the number of loaded wagons reaches a critical threshold [8].

Taking into account all the aforementioned circumstances, it can be concluded that additional parameters are necessary for the effective and accurate determination of the extent of loss of the wagon fleet through its utilization by other railway administrations. One of these parameters is the interoperability coefficient of Unified Management System for Freight Wagons (UMSFW). In the context of border crossings and the utilization of wagons by different railway administrations within the “1520 gauge” system, the interoperability coefficient reflects the degree of compatibility and interaction between systems and procedures used for the movement of wagons across border points [5].

To identify the factors that can influence the interoperability coefficient, let's consider that each Railway Administration (RA) participating in the UWMS can be in one of several states:

1. The number of freight wagons in a specific RA (including inventory wagons and own wagons) exceeds the required number for domestic transportation plans.
2. The number of freight wagons in a specific RA is insufficient to meet the domestic transportation plans.
3. The number of freight wagons in a specific RA is approximately sufficient to meet the domestic transportation plans (ideal situation).

In the third scenario, each RA participates equally in the UMSFW. In the second scenario, the RA will consciously be a “consumer” of wagon fleets from other countries. In the first scenario, the RA acts as a “donor” of wagon fleets for other RAs. Thus, we need to choose a criterion to determine the level of participation of RAs in the UMSFW. The criteria can include the country's rail network length, domestic loading levels, territory size, and other objectively existing characteristics. It should be noted that in the organization of the UMSFW without various “artificial” restrictions and conditions, the extent of loss of the wagon fleet due to its utilization by other administrations will be relative to the size of the additional wagon fleet that RAs potentially receive to meet their own loading demands. Therefore, among the main results of creating the UMSFW, the following will be reflected: reduction of empty mileage of freight wagons, increase in the interoperability coefficient and capacity of wagon flows in the “1520 gauge” system.

3. Conclusions

The study of the additional wagon fleet structure and parameters revealed several key findings regarding the Unified Management System for Freight Wagons (UMSFW). As of 2022, each Railway Administration (RA) has three groups of wagons: inventory wagons, own wagons, and "foreign" wagons. The size of the potential additional wagon fleet depends on factors such as the share of own wagons in the UMSFW, alignment of the return direction of empty “foreign” wagons with available cargoes, and alignment of wagon and cargo specialization. To ensure effective UMSFW participation, criteria like rail network length, domestic loading levels, and territory size should be considered. The UMSFW aims to reduce empty mileage, improve interoperability coefficients, and enhance wagon flow capacity in the “1520 gauge” system. Implementing the UMSFW without artificial restrictions will determine the extent of wagon fleet loss relative to the additional fleet RAs potentially receive, ensuring efficient resource allocation.

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