Modeling violations of the plan for the formation of freight trains for the effective organization of the transportation process

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Abstract. The purpose of the work is to model violations of the plan for the formation of freight trains for the effective organization and management of the transportation process by rail transport. For this, the methods of graphs and plural theory, formal modeling and systematic analysis are used. Factors causing violations of the plan for the formation of freight trains were identified and a hierarchy was developed. As a result of the analysis of the identified factors, violations of the plan for the formation of freight trains on the certain railway routes under JSC "O'TY" were modeled. Based on the analysis of the modeling results, the levels of influence of their railway transport on the main operational performance indicators were determined. As a result, taking into account the inefficient time losses caused by violations of the plan for the formation of freight trains in determining the technical norm of work indicators also made it possible to reasonably normalize these indicators. **Keywords:** plan for the formation of freight trains, violation of the plan for the formation of freight trains, transportation process, technical station, modeling, wagon flows.

1 Introduction

In order to effectively organize and manage the transportation process of railway transport, it is necessary to monitor the implementation of the plan for the formation of freight trains at freight and technical stations (PFFT)and develop comprehensive measures to prevent and timely eliminate its violations [1-4].

When determining the efficiency of the transportation process, the indicators of the work of freight and technical stations (transit and standing time of local wagons, the ability to process and transfer the station, the time of standing of wagons in one freight operation, etc.) are determined.) the execution of plays an important role [10]. Therefore, it is considered necessary to model technological processes that are carried out at these stations in order to prevent and eliminate any violations of the performance of PFFT.

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2 Methods

For modeling PFFT execution disorders, a rail route or section is initially selected. As an example for modeling, Chukhursoy-Sergeli-Angren, Chukhursoy-Nazarbek-Khovos, Chukhursoy-Khovos-Marokand railway routes under JSC "O'TY" were selected (fig.1)

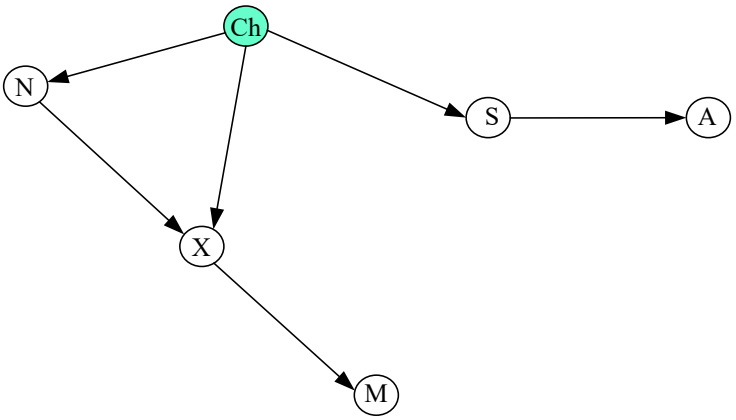

Fig. 1. Railway lines under "O'TY" JSC.

On the basis of Figure 1, the process of transportation, organization and control of wagon flows, PFFT can be described as plural. Therefore, in the mathematical modeling of PFFT execution disorders, plural theory is used. The plural is taken as follows: unification criterion – PFFT; object – wagons and trains.

Hence, the official description of the model will consist of two plurals.

$$\{V; P\}$$

there $V = \{v_i, i \in I\} -$ many wagon flows, i.e. PFFT elements, $i = [1, \dots, I]$;

$i -$ Number of wagon flow groups by PFFT;

$P = \{P_j, j \in J\} -$ many train, i.e. PFFT elements

$$(P_1 \cup P_2 \cup P_2 \dots \cup P_j = \text{PFFT}), j = [1, \dots, J];$$

$j -$ Number of trains on PFFT.

In addition, mathematical designations were introduced to develop the model as follows:

PFFT – plan for the formation of freight trains;

$v -$ freight wagon.

there PFFT can be described in the form of $\text{PFFT} = \{v\}$.

To the composition of many PFFT "v (wagon) – According to PFFT (a wagon that goes at its destination)" includes wagons with the property. The train, which is made according to PFFT, is also composed of (P_j) and wagons with the same characteristic, i.e

$$P_j = \{v,\ v \in \text{PFFT}\}$$

Under this condition, the wagons contained in the train will move at the destination stations specified in PFFT [3].

All freight wagons involved in the transportation process can be described as (v) many wagon streams (V).V

According to the developed regulatory documents, many V should move according to PFFT [00], namely

$$\mathrm{V} = \mathrm{PFFT}$$

However, according to the results of the study on the dissertation work, it was found that the above condition is not met at the expense of PFFT violations in the process of compiling trains at freight and technical stations, namely

$$\mathrm{V} \neq \mathrm{PFFT}$$

there PFFT violations-defined as VPFFT.

Hence, in practice, many PFFT and VPFFT associations form V, namely

$$\mathrm{PFFT} \cup \mathrm{VPFFT} = \mathrm{V}$$

Many VPFFT can be expressed as follows

$$\mathrm{VPFFT} = \{\mathrm{v}',\ \mathrm{v}' \notin \mathrm{PFFT}\}$$

there v' – wagon, according to VPFFT (wagon transferred from its destination to another address)

In this case, a train configured with a VPFFT will form a (v') from destination wagons in accordance with PFFT, which are not compatible with (v) and PFFT, from wagons being transferred from their destination to another destination.

$$\mathrm{Pv}' = \{\mathrm{v}, \mathrm{v}';\ \mathrm{v} \in \mathrm{PFFT},\ \mathrm{v}' \in \mathrm{VPFFT}\}$$

If, in the composition of the train formed at a particular station, $v = 0$, then the entire composition is considered to be composed of VPFFT. Otherwise, that is, in the case of $v' = 0$, the structured content will be according to PFFT.

Based on the implemented mathematical designations and Figure 1, the influence of PFFT on the main performance indicators of railway transport was modeled.

3 Results and Discussion

For the purpose of modeling and analysis of the effect of PFFT disorders on the transportation process, an approximate scheme of the transportation process was drawn (fig.2)

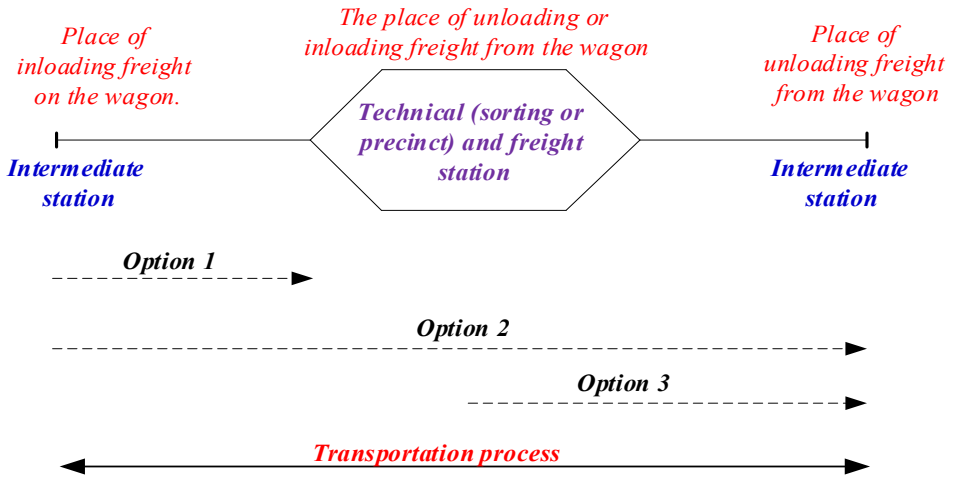

Fig. 2. Estimated scheme of the transportation process.

In Figure 2, violations caused by sending wagons to the wrong destination in processes from initial load on the wagon to loading and unloading [4-5] were divided into 3 groups (Figure 3): general by rail; in station work; in peregon.

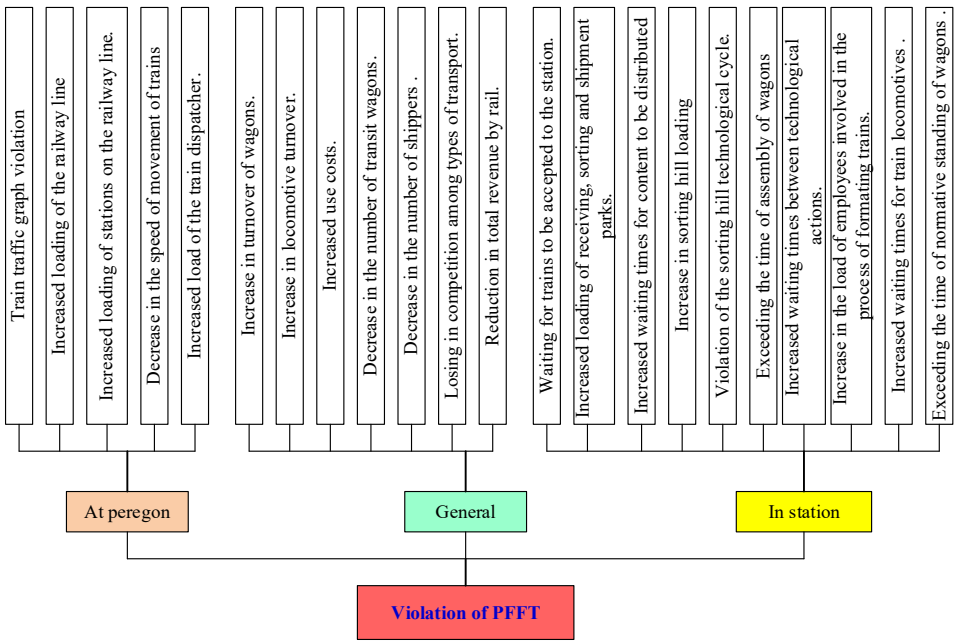

Fig. 3. Hierarchy of violations of PFFT.

As a result of the violation of PFFT, only trains that can originate in peregon can cause such consequences as a decrease in the speed of movement (Figure 3), a negative impact on the main operational indicators of railway transport, a decrease in the carrying capacity of railway sections, a slowdown in wagon flows, a decrease in the confidence of freight shippers in.

Based on pictures 1÷3, the effect of VPFFT on the transportation process was modeled. In this, railway lines (Figure 1) can be expressed as an undirected graph using "Graph theory".

Expressed as 3 plurals of undirected graph elements (ends – stations, edges – peregones, arcs – sections:

$$Gr = \{St, Pr, Sec\}$$

there $St = \{s_1, s_2, \dots, s_k\} -$ many ends of the graph, $k = [1, \dots, K]$;

$Per = \{p_1, p_2, \dots, p_f\} -$ many edges of the graph, $f = [1, \dots, F]$;

$Sec = \{u_1, u_2, \dots, u_l\} -$ many arcs of the graph, $l = [1, \dots, L]$;

$k -$ number of stations on the route;

$f -$ number of peregones;

$l -$ number of sections.

The sections on railway routes (peregons)shown in Figure 1 expressed the times of movement of trains and processing of wagon flows at freight and technical stations along the road in the form of a matrix:

Train running times on peregones and sections:

$$T_{Per} = \begin{pmatrix} t_{Per11} & t_{Per12} & \dots & t_{Per1y} \\ t_{Per21} & t_{Per22} & \dots & t_{Per2y} \\ \dots & \dots & \dots & \dots \\ t_{Per\ f1} & t_{Per\ f2} & \dots & t_{Per\ fy} \end{pmatrix}, T_{sec} = \begin{pmatrix} t_{sec11} & t_{sec12} & \dots & t_{sec1o} \\ t_{sec21} & t_{sec22} & \dots & t_{sec2o} \\ \dots & \dots & \dots & \dots \\ t_{sec\ k1} & t_{sec\ k2} & \dots & t_{sec\ ko} \end{pmatrix}$$

Wagon flow processing times at freight and technical stations along the way:

$$T_{St}^{proc.} = (t_{St1} \quad t_{St2} \quad \dots \quad t_{St\ l})$$

there $t_{Pr12} -$ running time between stations 1 and 2, hours;

$t_{sec12} -$ running time between section 1 and section 2, hours;

$t_{St1\dots l} -$ Time for processing wagon flows at station 1 or l, hours.

Ch-A (Figure 4), presented in Figure 1, was considered on the example of Ch, S and stations located on the railway route.

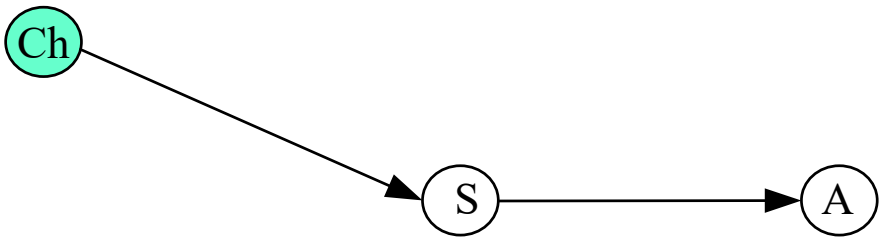

Fig. 4. Ch-A railway route, consisting of 3 stations under JSC" O'TY".

According to figure 4, The times of trains walking on peregons and sections, as well as the processing of wagon flows at stations Ch, S and a, will be as follows:

$St = \{Ch, S, A\} -$stations;$Per = \{ChS, SA\} -$peregons;

$Sec = \{Ch - A\} -$sections;

$T_{Per} = \{t_{ChS},\ t_{SA}\},\ hour;\ T_{Sec} = \{t_{Ch-A}\},\ hour;\ T_{St}^{proc} = \{t_{Ch},\ t_S,\ t_A\},\ hour.$

Based on the above, the effect of violations on the transportation process was modeled on the example of the following violations: $(P \subset PFFT)$

1) sending wagons to a route that does not correspond to PFFT [6].

If, at Ch station in Figure 1, all trains to stations N, X and S are made $(P \subset PFFT)$ on the terms of PFFT

(fig.5)

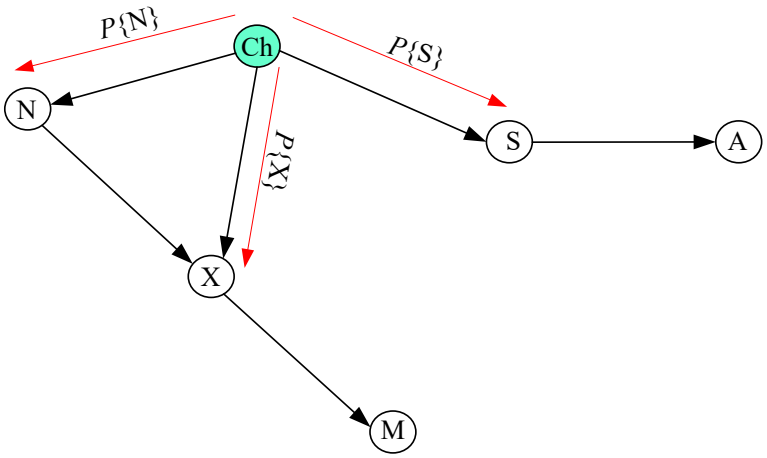

Fig. 5. Organization of wagon flows on railway lines, consisting of 6 stations under PFFT under JSC "O'TY".

there, the Ch station-N, X and S will train to the stations;

N, X and a – stations where trains are distributed;$P\{N\},\ P\{X\}, P\{S\} -$

Many trains composed of $\mathcal{V}$ wagons from Ch station to N, X and S distribution stations respectively P, $P\{N\} \subset PFFT,\ P\{X\} \subset PFFT,\ P\{S\} \subset PFFT$;

$P\{N_1, N_2, \ldots, N_n\}, P\{X_1, X_2, \ldots, X_x\}, P\{S_1, S_2, \ldots, S_s\} -$ a train composed of a group of n, x va s wagons, respectively, configured to N, X and S distribution stations.

If, at Ch station in figure 1, all trains to stations N, X and S are made $(P \subset VPFFT)$ according to VPFFT (fig.6).

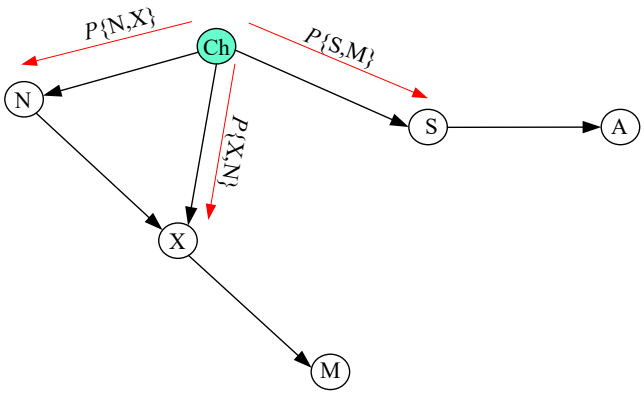

Fig. 6. Organization of wagon flows on railway lines consisting of 6 stations under JSC "O'TY" according to VPFFT.

there $P\{N, X\},\ P\{X, N\}, P\{S, M\} -$ Many trains formed with VPFFT from Ch station to N, X and S distribution stations, respectively, consisting of v and v' wagons from Pv';

X, N va $M -$ wagon (v') or group of wagons, that is, according to PFFT, had to go to stations X, N and M, respectively.

Hence, the trains configured with VPFFT according to (figure 6) are as follows:

$P\{N_1, N_2, \ldots, N_n, X\} \subset$ VPFFT;

$P\{X_1, X_2, \ldots, X_x, N\} \subset$ VPFFT;

$$P\{S_1, S_2, \ldots, S_s, X\} \subset \text{VPFFT};$$

As a result, VPFFT affects the transportation process as follows:

a) increased load ($l_{freight}$) or empty (l_{empty}) flight of a wagon (v') or group of wagons subjected to VPFFT (negative);

b) wagon turnover increase of ($\theta_{wag.turnover.}$) (negative);

c) increase in the imperfection of the working park of wagons (negative);

d) reduced wagon stand time (positive for the station forming the train).

e) the time of the process of assembly of wagons to the route on which the train is being formed with the violation of the PFFT is reduced by ($t_{assem.}$) (for example figure 6 Ch-s railway route for station C in the example of the $P\{S, M\}$ train-positive, for station M – negative, that is, leads to an increase in $t_{assem.}$.

2) violation of the integrity of dispatch routes and passing trains [9].

If, on the terms of PFFT, a transitory train to station M at Station Ch in Figure 1 is drawn up by a (P_o, $\subset$ VPFFT) according to ($P_{pas} \subset$ PFFT) or VPFFT (fig.7).

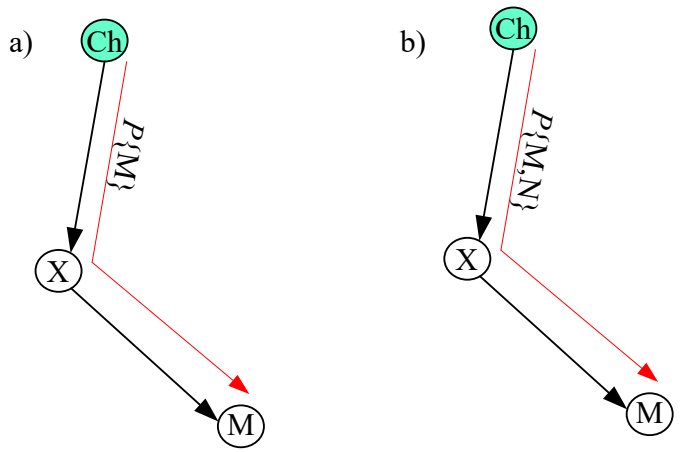

Fig. 7. On the Ch-X-M rail route on PFFT (a) and VPFFT (b organization of wagon flows).

There (Figure 7)

a) many trains formed from $P_{pas}\{M\} -$ Ch station to M station composed of v wagons according to item P_{pas}, $P_{pas}\{M_1, M_2, \ldots, M_m\} \subset$ PFFT;

b) from $P_{pas}\{M, N\} -$ Ch station on clause to M station consisting of v and v' wagons,many trains formed with the VPFFT are operated by $P_{pas}v'$, , $P_{pas}v'\{M_1, M_2, \ldots, M_m, N\} \subset$ VPFFT.

VPFFT affects the transportation process as follows:

a) increased running time on the road (negative-due to the disconnection of the wagons of the N destination station at station X from the composition);

b) wagon turnover increase of ($\theta_{wag.turnover.}$) (negative);

c) reduced speed of movement of trains (negative);

d) for the station – negative, that is, leads to an increase in $t_{assem.}$.

3) failure to comply with the established drawing up plan procedure [10].

If, on the terms of the national train PFFT to the M station on the Ch station in Figure 1, A ($P_t \subset$ VPFFT) on ($P_t \subset$ PFFT) or VPFFT is formed (fig 8).

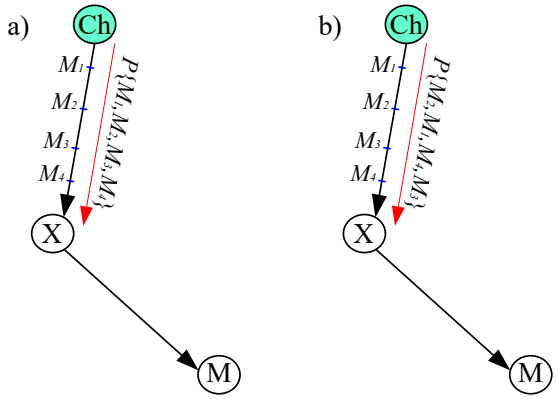

Fig. 8. On the Ch-X railway section according to PFFT (a) and VPFFT (b) organization of wagon flows.

There Figure 8 a) in a fixed sequence from $P\{M_1, M_2, M_3, M_4\}$ – Ch station to M station on the band (M_1, M_2, M_3, M_4) structured national train P_tv, $P_tv\{M_1, M_2, M_3, M_4\} \subset$ PFFT;

b) from $P\{M_2, M_1, M_4, M_3\}$ – Ch station to M Station on bandy, the specified sequence is broken with the (M_2, M_1, M_4, M_3) structured national train Pv_t', , $P_tv'\{M_2, M_1, M_4, M_3\} \subset$ VPFFT..

VPFFT affects the transportation process as follows:

a) an increase in the time of technological operations (due to an increase in the number of operations for disconnecting and connecting the desired wagon or group of wagons from the composition) performed by the national train at the M_i station on the road (negative);

b) a decrease in the speed of movement of trains (due to the fact that at the M_i station along the road the train stops more than the established norm) (negative).

4) distribution of the train at the station without address [00].

If, on the Ch station in Figure 1, a transitory train to station M is formed (P_o, $\subset$ PFFT) on the terms of PFFT, but distributed on station X, which does not have an address on the roadway (fig.9).

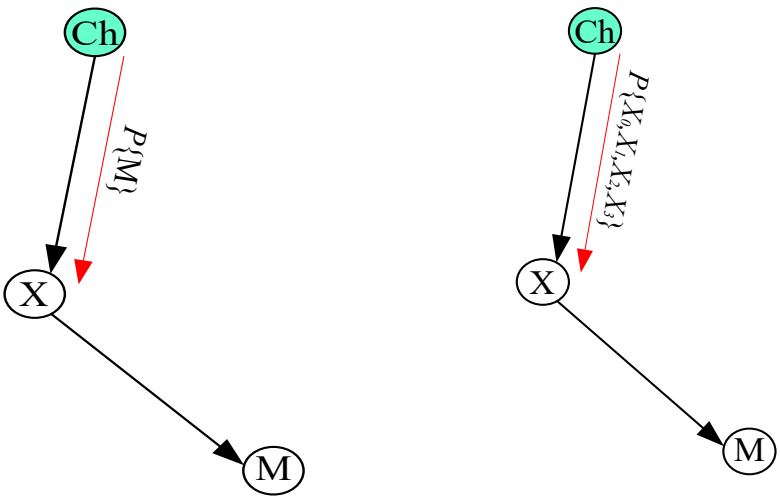

Fig. 9. Organization of wagon flows on the CH-X railway section according to PFFT.

Fig. 10. Organization of wagon flows on the CH-X railway section according to VPFFT.

VPFFT affects the transportation process as follows:

a) increased wagon standing time (negative);

b) decrease in the speed of delivery of goods (negative);

c) the time of the assembly process of wagons for station M at station X is a decrease in (t_{assem}) (if, provided for by PFFT) (positive);

d) an increase in the level of employment of station roads X (negative).

As a result of the modeling, it can be concluded that if VPFFT occurs, the train developer at the station (Ch in a given example) with a breakdown, The times of processing wagon flows for the station to which the train is being transferred will be reduced by ($T_{St}^{proc.}$), but instead the $T_{St}^{proc.}$ will increase for the station to which the PFFT wagon. It can be concluded that rail transport in general causes inefficient time losses in the transportation process.

In addition, the transport process is the main exploitation of the work indicators to some elements of the mathematical expressions Δ value is added.

Hence, it is advisable to analyze the results of modeling and assess the degree of their influence on the transportation process.

4 Conclusions

Analysis of the results of modeling railway transport in addition to the main parameters that make up mathematical expressions when establishing the normative values of the main operational performance indicators, taking into account the inefficient time losses caused by VPFFT also makes it possible to reasonably normalize these indicators. In addition, it also creates opportunities for an objective approach to analyzing, evaluating the actual performance of indicators and determining the level of economic losses caused by them.

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