Assessing the efficiency of application of the technology of handling heavy multiple unit trains

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Abstract. The paper presents the results of studying the efficiency of use at the railway loop of the technology of handling heavy multiple-unit trains made up with several heavy train units, the mass of each of which is higher than the scheduled one. This technology is advisable to apply in conditions where the mass of a heavy multiple unit train consisting of \( m \) heavy train units exceeds the mass of a scheduled train by more than \( n \) times. The paper presents the main advantages and disadvantages of the technology of making-up and handling of heavy multiple-unit trains, as well as the classification of the main cost indicators, which should be taken into account when determining the economic efficiency of the technology. The formulas for calculating the cost, return and investment are presented. Assessing the economic efficiency of applying the technology for making-up and driving heavy multiple-unit freight trains can be done using indicators – operating profit, comparative economic effect and a simple payback period of investments. In addition to the specified set of indicators, economic criteria can be calculated taking into account the influence of the time factor: net present value, profitability index and discounted payback period of the project. Using the presented methodology will allow evaluating economic effect of application of the technology of making-up and handling of heavy-duty multiple-unit trains as that responding the growing freight traffic.

1. Introduction
At the present stage of development, rail transport is facing the goal of reducing and optimizing the expenses of subdivisions when exporting cargo from the areas of mass mining. In cargo-intensive areas, this goal is achieved through the use of the technology of making-up and driving heavy freight trains connected as well as heavy multiple-unit trains. In some cases, such a measure allows reducing the attendant contingent of locomotive crews, fleet of locomotives in operation, also making the most intensive use of the carrying and transporting capacity of stations and spans of a section, as well as speeding up train motion through the section due to non-stop pass, which leads to a shorter delivery time.

The most promising technology is making-up and handling of heavy-weight multi-unit trains consisting of several singular heavy trains. Making-up of such trains will be carried out exclusively from cars with an axial load of at least 25 tons per axle within the effective length of arrival and departure tracks of stations. The greatest technological and economic effect will be achieved due to the making-up of singular heavy trains from loading points, i.e. at bulk loading stations. However, due to the technical peculiarities of the infrastructure, the making-up of singular heavy trains above the scheduled mass might be transferred to technical stations.
At the present stage of rail transport development in European countries there is a question of increasing the capacity of the line due to the increased level of rail traffic [6]. For example, the main traffic flows in Northern Europe are moving along the north-south axis. The economies of the Scandinavian countries depend on about one third of international trade, and Germany is the largest or second largest trading partner of Norway, Sweden and Denmark. Thus, the work of the German-Scandinavian corridor is of great importance.

The European Commission's Transport 2050 strategy, according to which “by 2030, 30% of road transport over a distance of more than 300 km must be transferred to other modes of transport, such as rail or water transport, and more than 50% by 2050” [6]. That leads to an increase in the flow of freight trains, the main focus of solving this problem is to commission cars with a higher axle load, or to build new transport corridors with a decrease in the distance between stations. Thus, an increase in the axle load leads to an increase in train mass, and, consequently, to the handling of heavy trains. Foreign scientists use various methods of traffic capacity analysis based on: principles of optimization of indicators of the transportation process [6]; modeling the work of the railway section [7,8].

In this regard, the research topic is relevant at this stage in the development of railway transport. The object of the study is a double-track railway section, the subject is an assessment of the effectiveness of the use of technology for making up and handling heavy multi-unit trains.

2. Materials and Methods
The main advantages of using the technology of making up and handling heavy multi-unit trains:
1) when only “heavy” loaded wagons are included in a freight train, it becomes possible, under the conditions of using the existing length of arrival and departure tracks of railway stations, to make up and handle heavy trains;
2) in this case, the gross weight of a heavy train increases relative to the graphical norm of train mass, and the power of train locomotives is used more efficiently;
3) for a given wagon traffic, the estimated number of freight trains, and, consequently, the required throughput of sections and polygons of the railway is reduced;
4) there is a possibility, without enhancing the available capacity, to ensure the passage of the estimated sizes of traffic, while the fill factor is reduced;
5) due to a decrease in the estimated size of freight train traffic, the fleet of train freight locomotives in operation and the staffing level of locomotive crews are reduced;
6) no need to invest in the development of the infrastructure of railway stations;
7) time spent by a heavy train in the section between stations due to its non-stop passing is reduced;
8) for some positions of the train makeup planning, the operational costs associated with idle train hours will be reduced;
9) probability of the delivery of goods on time increases;
10) increase in the locomotive runs and locomotive brigades in connection with the requirement of non-stop admission of the heavy multi-unit trains.

The main disadvantages of using the technology of making-up and handling heavy trains:
1) in some cases, it will be necessary to make capital investments in the purchase of a new fleet of train locomotives, if the series of locomotives used do not provide the possibility of driving heavy trains;
2) handling heavy trains may require investment in the power supply system;
3) railway line may also require modernization to provide possibility of passing heavy trains;
4) due to an increase in dynamic load will require large operating costs for maintaining the path;
5) at some technical stations, the use of technology for making-up and passing heavy cargo trains will cause an increase in the neck load factor and / or railways occupancy;
6) the need to replace the fleet of cars on cars with an axial load of at least 25 tons per axle;
7) training teams for driving heavy multi-unit trains.
At the present time, there is no methodology for determining the technical and economic efficiency of making-up and handling of heavy-weight multi-unit trains. As part of the study, a systematic analysis of the influence of various factors on the effectiveness of the technology used was carried out.

3. Results
In the case of the use of technology for making-up and driving of heavy-duty multi-unit trains, Russian Railways has the following additional operating costs associated with:
1) need to replenish a singular freight train to the mass of a heavy-weight one (in the case of making-up a multi-unit train with two freight trains of a scheduled mass and length without changing their composition, this cost element is not taken into account);
2) making-up a multi-unit heavy freight train, which can be made using long paths of technical stations or in their absence with the occupation of the main route of the haul;
3) breaking up the heavy train, which can be made using long paths of technical stations or in their absence with the occupation of the main route of the haul;
4) need to reduce the mass of a heavy-weight cargo train to a scheduled one (in the case of making-up a multi-unit train of two cargo trains of a scheduled mass and length without changing their composition, this cost element is not taken into account);
5) need to breaking up and subsequent making-up of a heavy-weight multi-unit train at the locomotive change station (changes in the type of current or type of traction). They are taken into account only if the stations do not have an appropriate track development for admission a multi-unit heavy train;
6) passing an additional traffic of cargo trains in the section (in excess of the estimated traffic range) due to releasing the train schedule threads;
7) delays in departure of trains of various categories from the station in the case of making-up of a multi-unit heavy train with occupying the track;
8) annual operating costs for maintaining the additional infrastructure of the section (if necessary, modernization and reconstruction of stations of the section).

When describing the revenue section, the following additional effects are taken into account:
1) savings in operating costs associated with the crew work hours of locomotive crews by reducing the traffic range of freight trains and accelerating the movement of multi-unit heavy trains along the loop;
2) savings in operating costs associated with locomotive hours of train locomotives by reducing the traffic range of freight trains and accelerating the movement of heavy-weight multi-unit trains;
3) savings in operating costs associated with a decrease in locomotive-kilometers run by reducing the traffic range of freight trains;
4) income from the additional freight trains above the estimated traffic range.

In the investment part of the project, the following costs can be taken into account:
1) investment in reorganization of the station for making-up the multi-unit heavy trains, associated with the lengthening of station tracks;
2) investment in reorganization of one or more technical stations of the change of locomotive crews, associated with the extension of station tracks to carry out the necessary operations without dividing the multi-unit heavy train;
3) investment in reorganization of one or more technical stations for the change of locomotives, associated with the lengthening of station tracks and laying the exit in the central part of the track to carry out the necessary operations without dividing the multi-unit heavy train;
4) investments in reorganization of the station for breaking up the multi-unit heavy trains, associated with the extension of station tracks;
5) investments in reorganization of stations of the section that allow the passage of multi-unit heavy trains, associated with the extension of station tracks in case of need to overtake such trains by passenger trains;
6) investments in modernization of the power supply system, related to the need ensuring the inter-train interval of not more than 10 minutes;
7) investments in modernization of locomotives for driving multi-unit heavy trains;
8) investments in modernization of the working fleet of cars on cars with an axial load of at least 25 tons per axle;
9) investments in modernization of wagon and locomotive depots for maintenance and ongoing repairs.

Additional operating costs associated with the need to replenish a single freight train to a heavy weight are determined by the formula:

\[ O_{p,c} = (N_{t,c} \cdot \tau) \cdot \tau_{p,c} \cdot (C_{b-h} + C_{loc-h}), \]  

where \( N_{m,c} \) - number of multi-unit heavy trains passing through the loop, trains per day;
\( m \) - number of heavy freight trains combined into one multi-unit train, units;
\( \tau_{p,c} \) - duration of shunting operations to replenish a singular freight train to the weight of heavy one, h. It is determined on the basis of calculations by formula (2.5.2) [4] with the correction of the obtained value for duration of additional work, associated, for example, with testing the brakes.
\( C_{b-h} \) - unit expenditure rate of 1 crew-hour of locomotive crews, RUB / h;
\( C_{loc-h} \) - unit expenditure rate of 1 locomotive-hour for locomotives of the Russian Railways fleet, RUB / h.

Additional operating costs associated with making-up of multi-unit heavy freight train are determined by the formula:

\[ O_{for} = N_{t,c} \cdot \tau \cdot \tau_{for} \cdot (C_{b-h} + C_{loc-h}), \]  

where \( \tau_{for} \) - duration of operations on making-up of a multi-unit heavy train, h. It is determined on the basis of the developed technological schedules for making-up the heavy-weight multi-unit trains, taking into account the provisions of [4].

Additional operating costs associated with breaking up a multi-unit heavy cargo train, are determined by the formula:

\[ O_{exp} = N_{t,c} \cdot \tau \cdot \tau_{exp} \cdot (C_{b-h} + C_{loc-h}), \]  

where \( \tau_{exp} \) - the duration of operations for breaking up a multi-unit heavy train, h. Determined on the basis of calculations by the formula (2.5.2) [4] with correction of the obtained value for duration of additional work, for example, testing the brakes.

Additional operating costs associated with need to reduce the weight of a heavy freight train to the scheduled one are determined by the formula:

\[ O_{r,c} = N_{t,c} \cdot \tau \cdot \tau_{r,c} \cdot (C_{b-h} + C_{loc-h}), \]  

where \( \tau_{r,c} \) - duration of shunting operations to change the weight of a heavy freight train to the scheduled, h.

It is determined on the basis of the developed technological schedules for making-up of heavy-duty multi-unit trains, taking into account the provisions of [Time Standards].

Additional operating costs associated with the additional time spent by a heavy-duty multi-unit train at the locomotive changing station \( O_{c,l} \) to be calculated by the formulas similar to (3) and (4).

Additional operating costs associated with handling additional traffic of freight trains on the section \( O_{add.fr} \) (over the estimated traffic range) due to release of train schedule threads can be determined by the method of expenditure rates [3]. This takes into account expenses dependent and independent of traffic volumes.

Dependent operating costs in the freight traffic per day are determined by multiplying the expenditure rate by the corresponding value of the work meter:

1. Car-kilometers are determined by the formula:
\[ \sum nS = N_p \cdot n_w \cdot L, \]  
\hspace{2cm} (5) \]

- \( N_p \) - additional traffic range of freight trains, passing through the considered loop, trains per day. The calculation of this indicator is recommended for [1];
- \( n_w \) - the number of cars in the freight train, wag.;
- \( L \) - route length, km;

2. Locomotive-kilometers are calculated as:
\[ MS = NL(1 + \beta_{act.pas}), \]  
\hspace{2cm} (6) \]

where \( NL \) - run of freight trains, train-km;
- \( \beta_{act.pas} \) - ratio of auxiliary run of locomotives to run in the head of trains;

3. Locomotive hours are determined by the formula:
\[ Mt = 24 \cdot \frac{MS_{lin}}{S_t}, \]  
\hspace{2cm} (7) \]

where \( MS_{lin} \) - locomotive linear mileage, locomotive-km;
- \( S_t \) - locomotive average daily mileage, km;

\[ MS_{lin} = NL(1 + \beta_{lin}), \]  
\hspace{2cm} (8) \]

where \( \beta_{lin} \) - ratio of auxiliary linear run of locomotives to run in the head of trains;

4. Crew work hours calculated as:
\[ \sum Mt_{crw} = \frac{MS_{lin} \cdot k_l}{v_{sec}}, \]  
\hspace{2cm} (9) \]

where \( k_l \) - coefficient that recognizes extra-work time of locomotive crews;
- \( v_{sec} \) - sectional speed of freight trains, km / h;

5. Gross tonne-km of cars and locomotives are determined by the formula:
\[ \sum Pl_{crw} = \sum nS \cdot p_w + MS_{lin} \cdot p_{loc}, \]  
\hspace{2cm} (10) \]

6. Electricity consumption for train traction is calculated as:
\[ E = \sum Pl_{crw} \cdot \frac{a_E}{10^3}, \]  
\hspace{2cm} (11) \]

where \( a_E \) - consumption rate of electricity for traction trains, kWh per 10,000 ton-km gross;

7. Locomotive hours of shunting locomotives are determined by the formula:
\[ \sum Mt_{sh} = \frac{a_{sh} \sum nS}{10^3}, \]  
\hspace{2cm} (12) \]

where \( a_{sh} \) - consumption rate of shunting locomotive hours per 1000 car-km, Lok-h;

8. The number of dispatches is calculated as:
\[ \sum K_d = \frac{\sum N_p \cdot n_{fr}}{m_d}, \]  
\hspace{2cm} (13) \]

where \( \sum N_p \) - total additional traffic range of freight trains passing through the loop under consideration, taking into account both directions, trains;
- \( m_d \) - average number of cars in one dispatch, wag.

Additional operating costs associated with delays in departure of trains of various categories from the station in the case of making-up a multi-unit heavy train occupying the track route are determined by the formula:
\[ O_{det} = \frac{N_{sh} \cdot C_{t-h}}{t_p}, \]  
\hspace{2cm} (14) \]

where \( C_{t-h} \) - aggregated expenditure rate of 1 train-hour, rub. / h.
Additional annual recurring costs associated with the maintenance of additional infrastructure of
the section, are determined by the formula:

\[ O_{\text{infr.}} = (L_{\text{track1}} - L_{\text{track2}}) \cdot O_{\text{km}}, \]  

(15)

where \( L_{\text{track1}} \) - length of laid railway track, km;
\( L_{\text{track2}} \) - length of dismantled railway track, km;
\( O_{\text{km}} \) - cost of maintaining one kilometer, rubles / year.

Savings in operating costs associated with reduction of crew-hours is determined by the formula:

\[ O_{\text{cr-h}} = M_{\text{cr,ec}} \cdot C_{b-h}, \]  

(16)

where \( M_{\text{cr,ec}} \) - crew-working-hours saving due to use of technology of making-up and driving multi-
unit heavy trains, h. Hour savings should be determined by:
- reduction of the number of locomotive crews due to making-up of a smaller number of freight trains
in conditions of using the technology of driving heavy multi-unit ones. At the same time, an important
criterion is the mass ratio of a heavy multi-unit train and a scheduled train.– \( \beta_{\text{mass}} \) [Ошибка!
Источник ссылки не найден.] determined by the formula:

\[ \beta_{\text{mass}} = \frac{O_{\text{km}}}{Q_{fr}}, \]  

(17)

Where \( Q_{hm} \) – gross weight of a heavy-weight multi-unit train, t. gross;
\( Q_{fr} \) - gross weight of a freight train of a graphic mass and length, t. gross., accelerated motion of multi-
unit heavy trains on the loop by reducing their running time compared with trains of scheduled mass
and length, as well as through the possible elimination of stops at crew changing stations.

\[ M_{\text{gr,ec}} = \Delta M_{\text{gr}} \cdot \theta_{\text{gr}} + N_{hm} \cdot m \cdot T_{\text{gr,ec}}, \]  

(18)

Where \( \Delta M_{\text{gr}} \) – reduction in the number of crews due to making-up of a smaller number of freight
trains;
\( \theta_{\text{gr}} \) – turnover of locomotive crew when driving trains of a scheduled mass and length, hours.
Determined by the known formulas depending on the operating conditions of locomotive crews;
\( T_{\text{gr,ec}} \) – saving time spent by locomotive crews of a heavy-weight multi-unit train at the considered
loop as compared to one freight train of scheduled mass and length, h. Reduction in the number of
crews due to making-up of a smaller number of freight trains is determined by the formula:

\[ \Delta M_{\text{gr}} = N_{mh} \cdot (\beta_{\text{mass}} - m), \]  

(19)

Saving the time spent by locomotive crews of a heavy-duty multi-unit train at the considered loop:

\[ T_{\text{ec, gr}} = (T_{fr} - T_{hm} + t_{pf,1} + t_{pf,2}), \]  

(20)

where \( T_{fr} \) - total running time of a freight train of scheduled mass and length of the sections, h;
\( T_{hm} \) - same for the heavy-duty multi-unit train, h;
\( t_{pf,1} \) – total duration of preparatory and final operations performed by the locomotive crew at the crew
changing station for the first crew work section, h;
\( t_{pf,2} \) – same, for the second crew work section, h.

The elements \( t_{pf,1} \) and \( t_{pf,2} \) are taken into account in the event of the possible elimination of a
change of crews en route for heavy-duty multi-unit trains. The decision to changing a crew en route is
made based on compared work time of the crews in laden direction and standard norm of continuous
crew work duration accepted for the considered railway loop.

Savings in operating costs associated with the reduction of locomotive-hours are determined by the formula:

\[ O_{\text{loc-h}} = M_{\text{sl}} \cdot C_{\text{loc-h}}, \]  

(21)
where $M_{t_{sl}}$ - saving locomotive-hours, loc-h.

Savings of locomotive hours to be determined taking into account:
- reduction of the locomotive fleet in operation due to making up of a smaller number of freight trains with using of heavy-duty multi-unit driving technology;
- accelerated movement of multi-unit heavy trains on the loop by reducing their running time compared with trains of scheduled mass and length, as well as through the possible stop elimination at the crew changing stations.

\[
M_{t_{sl}} = \Delta M_l \cdot 24 + N_{hm} \cdot m \cdot T_{sl},
\]

where $\Delta M_l$ - reduction of the operated train locomotive fleet due to making up of a smaller number of freight trains;
$T_{sl}$ - saving time spent by locomotives of one heavy-duty multi-unit train at the considered loop compared with one freight train of scheduled mass and length, h.

Reducing of the locomotive fleet in operation due to making up of a smaller number of freight trains is determined by the formula:

\[
\Delta M_{loc} = N_{hm} \cdot (\beta_{mass} - m),
\]

Saving time spent by locomotives of heavy-duty multi-unit train at the considered loop is determined by the formula:

\[
T_{st} = (T_{fr} - T_{hm} + t_{ch}),
\]

where $t_{ch}$ – duration of the cargo train at the locomotive crew changing station for which there is a possibility of liquidation, h.

Savings in operating costs associated with the reduction of locomotive-km run is determined by the formula:

\[
O_{loc-km} = M_{ls} \cdot C_{loc-km},
\]

where $M_{ls}$ - saving of locomotive-kilometers run by reducing the fleet of train locomotives, loc-km.

\[
M_{ls} = 2 \cdot L \cdot M_{t_{sl}} / 24,
\]

Revenues from the transporting of additional freight trains above the estimated traffic range are calculated by the formula:

\[
R_{add} = N_p \cdot n_w \cdot (p_1 \cdot d_{rev}^{emp} + L \cdot p_{emp} \cdot d_{rev}^{emp})
\]

Where $P_{emp}$, $P_1$ - average mass of empty and loaded cars, respectively, t;
$d_{rev}^{emp}$ - average value of income per one car-km of an empty car, rubles/car-km;
$d_{rev}^{emp}$ - average value of income from the transportation of goods per 1 ton, rubles/ton.

Investments in the infrastructure of the loop for heavy-duty multi-unit trains $I_{inf}$ can be determined according to aggregate cost norms in accordance with the scope of work or according to estimates developed.

Economic efficiency evaluation of the use of technology for making-up and driving of heavy-duty cargo trains can be made using the following set of indicators:

1) Operating profit:

\[
P = \Sigma CIF - \Sigma COF;
\]

where $\Sigma CIF$ – total cash inflow from operating activities;
$\Sigma COF$ – total cash outflow from operating activities.

\[
\Sigma CIF = CIF_{gr-h} + CIF_{loc-h} + CIF_{loc-hm} + CIF_{add}.
\]
\[ \sum COF = COF_{p.c} + COF_{for} + COF_{exp} + COF_{r.c} + COF_{add} + COF_{del} + COF_{inf}. \] (30)

The value of operating profit must be greater than zero. Otherwise, the railway will incur losses in the implementation of the technology of forming and passing heavy connected trains.

2) Comparative reduced economic effect:

\[ EEff = P - \frac{I_{inf}}{T_{sl}}, \] (31)

where \( T_{sl} \) – service life time (or useful use) of infrastructure facilities, years.

The value of the comparative reduced economic effect must be greater than zero. Otherwise, the technology of making-up and handling of heavy-duty multi-unit trains is not recommended to apply.

3) Simple payback period for investments:

\[ PPT = \frac{I_{inf}}{P}. \] (32)

4. Discussion

In addition to the above set of indicators, economic criteria can be calculated taking into account the influence of the time factor: net discounted income, profitability index and discounted payback period of the project [3].

The greatest efficiency of this technology can be achieved when exporting bulk cargo from the mining areas of the Russian Federation. In this regard, a conditional railway section was adopted as an object of testing, on which a promising technology for making-up and handling of freight multi-unit heavy trains consisting of two heavy trains weighing 7100 tons is considered. The formation of such trains will be carried out exclusively from cars with an axial load of at least 25 tons per axle. However, due to the technical features of the infrastructure of the conditional section, the formation of heavy trains weighing 7100 tons from loading points with a plot weight of 6300 tons is currently not feasible.

That is due to the following features:

1) insufficient track development of the junction of non-public places (MNLBs) for loading bulk cargoes, as well as MNLBs themselves, which do not allow accumulating and forming heavy trains from loading points;

2) the presence of areas of application of pushing for trains of mass and length.

In connection with this, the formation of heavy-weight connected trains should be provided for at large sorting stations. The analysis of the station's track development and the most probable technologies for making up of heavy-duty multi-unit trains showed that the best option is to use one long station track after the conversion of track development. In this case, the making up of heavy-duty multi-unit trains can be carried out without occupying the main track, excluding possible delays of trains of various categories on departure from the marshalling yard.

Further, the handling of heavy-duty multi-unit trains in the loop to the locomotive crew changing station can be carried out without interruption, provided that no more than 13 trains are driven per day. This number of trains is determined on the basis of the development of a timetable taking into account fixed trains (passenger trains). If it is necessary to handle a larger number of heavy-duty trains, it is necessary to determine the places where they are overtaken by passenger trains by building a train schedule. The length of one arrival and departure route at these stations should be extended to the length of a heavy, multi-unit train. At the same time, for heavy multi-unit trains, the parking for changing locomotive crews can be eliminated due to less running time and the lack of overtaking by passenger trains in the area. The change of crews will then be envisaged at the station where the change of locomotives is carried out in connection with the change in the type of current. However, such a system of work of the crew is possible only in the preparation of nominal schedules of work of locomotive crews and the departure of multi-unit heavy trains on a solid schedule. In this case, for locomotive crews, it is necessary to establish a critical work time on the way to the crew changing station, after which it is necessary to change it. In this regard, at the crew changing station, it is
recommended to provide for the presence of one long path for receiving a heavy-duty multi-unit train under the locomotive crew change without occupying the station neck.

At the locomotive changing station, to receive a heavy-duty train without taking a track and excluding delays of other trains, there is a necessary track development, excluding the exit in the central part of the track.

The calculations of the throughput capacity of the heavy-duty multi-unit train to the loop showed that if the technology of making up and handling of heavy trains is used, the capacity ratio will decrease by 4%, respectively, it will be possible to skip the additional flow of freight trains of scheduled mass and length - 4 trains per day.

5. Conclusions
The results of the cost indicators allow us to draw the following conclusions.

1) The total additional operating costs associated with the use of the technology of making up and handling of heavy cargo trains will amount to 84.16 thousand rubles per day. The total savings in operating costs associated with the reduction in the traffic range of freight trains and the acceleration of the movement of multi-unit heavy trains over the loop assumed the value of 165.19 thousand rubles per day. Profit from the direct handling of heavy multi-unit trains to the loop amounted to 81.03 thousand rubles per day.

2) Additional operating costs associated with the handling of 4 additional freight trains in each direction are equal to 2,222.50 thousand rubles per day. Additional income from the handling of these trains - 10,815.29 thousand rubles per day. Profit from the handling of additional freight trains on the loop amounted to 8592.79 thousand rubles per day or 2.58 billion rubles in a year.

3) The total profit, taking into account the additional current costs of maintaining the infrastructure, is 7065.6 thousand rubles per day.

4) Investments in the reconstruction of technical stations and on the modernization of barrier sections in the power supply system to ensuring the inter-train interval of no more than 10 minutes amount to 5.2 billion rubles. with a construction period of 3 years.

5) The simple payback period of the project is 2 years, while the duration of construction is not taken into account - 3 years. Comparative reduced economic effect obtained at the level of 2.37 billion rubles. in a year.

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