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Improvement of the technology for determining the time spent on cleaning gondola cars

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Abstract: The article considers the issues of improving the technology for determining the time spent on cleaning gondola cars. The existing methods for calculating time costs are analyzed, their shortcomings are identified, and ways to optimize this process are proposed. The work takes into account factors that affect the speed and quality of cleaning, such as the degree of contamination, type of cargo, technical equipment, and organizational aspects. An improved method for calculating cleaning time is developed, which allows for increasing the efficiency of rolling stock use and reducing wagon downtime.

Keywords: gondola car cleaning, time costs, optimization, efficiency, rolling stock, cleaning technology, rail transportation

1. Introduction

In the economy of the state, transport plays a very important role, ensuring the continuous movement of objects and means of labor between producers and creating conditions for the continuous functioning of industrial and agricultural production.

According to functional characteristics, transport is divided into main and industrial. Main transport moves products from their places of production to their places of consumption. Industrial transport, unlike main transport, functions as a component of industrial enterprises. It directly participates in the process of producing a new product of labor, performing technological movements within enterprises, and also carries out transport links between enterprises and main transport for the delivery of raw materials and the removal of finished products.

Industrial rail transport (non-mainline) is an integral part of the country's transport system, a full participant in the transportation process and interacts with public rail transport in the initial and final operations of cargo transportation, providing transport services to organizations and enterprises of all sectors of the economy: metallurgy, coal, mechanical engineering, forestry, construction industry and others. On railway sidings, industrial rail transport enterprises (IRTE) carry out a wide range of operations in the interests of customers, from cargo transportation to loading and unloading operations [1].

Today, there are 1,364 railway transport enterprises operating in our country, 86 of which belong to the joint-stock company Uzbekistan Railways, the rest belong to ministries and departments. There are 10,062 kilometers of railways on the balance sheet of railway transport enterprises, of which 2,610 kilometers belong to branch railways.

Mainline and industrial railway transport companies perform a wide range of work in the interests of their clients: from loading and unloading to transportation.

Loading and unloading operations should be performed by mechanized methods using lifting and transport equipment and mechanization means. The mechanized method is mandatory for loads weighing more than 50 kg, as well as for lifting loads to a height of more than 3 m [2].

2. Research methodology

Increased efficiency and increased labor profitability in industrial rail transport should be achieved to a large extent by raising the level of comprehensive mechanization of loading and unloading operations and accelerating the turnover of wagons.

A number of scientific works have been carried out aimed at mechanized cleaning of cargo transported in gondola cars, however, problems associated with non-mechanized closing of gondola car hatches during cargo unloading and non-standardization of the exact duration of its action are one of the urgent tasks in automobile and industrial rail transport.

The time spent cleaning the cars is made up of the following elements:

-total time spent on opening the hatches of gondola cars in one feed, (T_{hatch}^{open});

-total time spent on cleaning the hatches of gondola cars in one feed, (T_{clean});

-total time spent on closing the hatches of gondola cars in one feed, (T_{hatch}^{close});

Thus, the total time spent on cleaning cars on cleaning tracks is determined as follows:

$$T_{clean}^{fr} = T_{hatch}^{open} + T_{clean} + T_{hatch}^{close}, min \qquad (1)$$

The duration of each element represented in the above expression (1) is determined in the following sequence.

total time spent on opening the hatches of gondola cars in one feed (T_{hatch}^{open}) was determined on the basis of the duration of opening of one hatch by one worker during timing observations (t_1).

The speed at which workers can open one hatch is calculated using the following formula for determining labor productivity:

$$x \cdot t_1 \cdot a = 1 \qquad (2)$$

x is the number of workers in the team;

a -the speed of the worker opening the hatch.

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The speed of opening the hatch by the worker is equal to expression (2).

$$a = \frac{1}{t_1 \cdot x} \qquad (3)$$

-the total time spent cleaning the hatches of gondola cars, according to a study [5], is 55 minutes.

Therefore, the hatch closing time (T_{hatch}^{close}) for each access road is different, regardless of whether loading and unloading operations are carried out in a mechanized or non-mechanized manner.

Background information.

On the first track of JSC Uzmetkombinat, which specializes in cleaning gondola cars, 10 cars (ice) were brought. During the day, 50 cars (m/day) are brought to this track for cleaning. To date, it has been established that on the first track of JSC Uzmetkombinat, the work on cleaning cars and closing their hatches will be carried out for a total of 200 minutes (Fig. 1) due to the non-mechanized method of cleaning cars [4].

№ п/п	Name of the operation	Executor	Time in minutes															
			0	20	40	60	80	100	120	140	160	180	200	220	240	260	280	300
1	Following the locomotive along the freight front	locomotive crew, compiler	20															
2	Waiting for the locomotive 15-20 meters from the freight front, waiting for the lifting machines to stop working	locomotive crew, compiler		15														
3	Arrival of the locomotive at the freight front, hitching the locomotive to the wagons, testing of car brakes	locomotive crew, compiler		10														
4	Cleaning of brake shoes, cleaning of wagons from the freight front	compiler			10													
5	The route of wagons from the freight front to the st. Zavodskaya	locomotive crew, compiler				15												
6	Approval for departure and follow-up to the cleaning path	station attendant, locomotive crew				10												
7	Uncoupling of the locomotive installation of wagons on the cleaning path laying of brake shoes	locomotive crew, compiler					10											
8	Cleaning of wagons from the remnants of dirt, garbage, and trash about 50% of those who arrived on 10 wagons (20 minutes per wagon)	Loader for cleaning railway wagons										200						
Total length										290								

Fig. 1. Technological schedule for cleaning wagons from freight fronts, rearrangement on the cleaning track and cleaning wagons

Next, we will consider the procedure for reducing the time allocated to wagons for each feed and increasing the number of feeds per day due to the mechanized closing of the hatches of gondola cars on the first track of JSC Uzmetkombinat.

Below is a special device developed for the purpose of mechanized closing of the gondola car hatch (Fig. 2). As a result of the implementation of this special device, which we offer, saving time is achieved for closing the gondola car hatch (T_{hatch}^{close}).

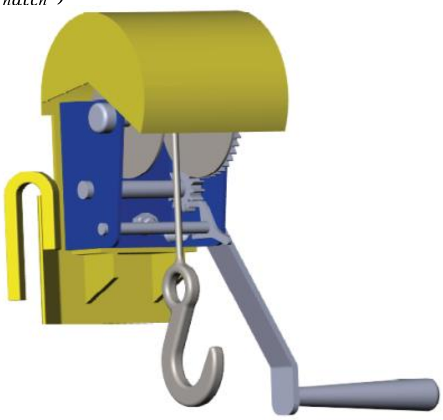

Fig. 2. A special device for closing the hatches of gondola cars

The time between the closing of one hatch and the start of the closing of the second hatch using a special device includes the duration of the action of the following elements:

- with the hatches of the gondola cars open, the cable with the hook of the device is inserted into the space between the body of the gondola car and the sector. The cable with the hook of the device is lowered to the bracket of the hatch. ($t_{loop.}^{separate.}$)
- The responsible worker, having made sure that the cable with the hook and the device are securely fastened, turns the device handle in the opposite direction until the hatch rises to the desired height, after which he installs the hatch bracket with the locking teeth. ($t_{loop.}^{separate.}$)
- At the next stage, a special device is removed from the space between the gondola car body and the sector. After this, the responsible worker secures the cable with a hook using an eccentric sector stopper (according to the results of timing observations, this time $t_{st}^{fastening}$ is 12÷18 seconds).
- the time it takes for the person responsible for closing the hatches to move from locking one hatch to the next hatch to be locked (based on the results of timing observations) t_{move} this time is 10÷16 seconds).

Thus, the expression for determining the duration of time spent on closing one hatch using a special device is as follows:

$$T_{hatch}^{close} = 2 \cdot t_{loop.}^{separate.} + t_{st}^{fastening} + t_{move} \ min. \quad (4)$$

In turn, determining the time required to close one hatch using a special device ($t_{loop.}^{separate.}$) consists of the following sequence.

The procedure for determining the minimum force exerted by a person on a special device for lifting the hatch of a gondola car is described in detail in the scientific paper [10]. Due to the difference in the forces exerted by people on the device, the time it takes to close the hatch also varies (Figure). The results of the experimental test showed that the average time it takes to close one hatch using a special device is 45 seconds ($T_{loop}^{separate} = 45 \ s.$).

3. Results

Thus, it turned out that the average time spent by one responsible person to close one hatch is 2 minutes. The time it took 7 workers to close 140 hatches in 10 cars was 40 minutes. As a result, it was determined that 130 minutes would be spent on mechanized cleaning of cars and closing their hatches on the first track of JSC Uzmetkombinat (Fig. 3).

As a result of the use by workers on Track 1 of a special device specializing in cleaning gondola cars, the percentage indicatorincrease in daily labor productivity is determined as follows:

$$\eta_{e.f.} = \frac{\sum T_m - \sum T_{\text{offer}}}{\sum T_m} \cdot 100 \ \% \qquad (5)$$

$\sum T_m$ − total time spent on cleaning cars on 1 track in this case, min.

$\sum T_{\text{offer}}$ −the total time spent on cleaning cars on 1 track using the proposed special device,min.

$$\eta_{e.f.} = \frac{200 - 130}{200} \cdot 100 \ \% = 35\%$$

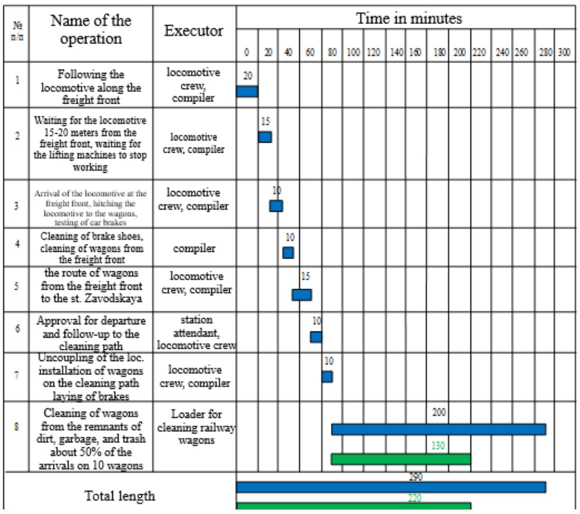

Fig. 3. Technological schedule for cleaning wagons from freight fronts, rearranging the cleaning tracks and cleaning wagons using the proposed device

Thus, as a result of using a special device by workers of the 1st track of JSC Uzmetkombinat, which specializes in cleaning gondola cars, their labor productivity can be increased by 35%.

The increase in worker productivity by 64% was achieved by reducing the time it takes to close the hatches of gondola cars. This allowed for an increase in the number of cars supplied to the cleaning tracks.

The maximum number of wagon feeds to the cleaning path per day is represented by the following inequality, Fig. 4.

$$1440 - T_{break} - T_{\text{get out}} \cdot N_{\text{transmission}} - T^{fr}_{cleab} \cdot N_{\text{transmission}} \geq 0 \quad (6)$$

T_{break} - lunchtime and shift change of responsible employees during the day, min.

$T_{\text{get out}}$ - time of delivery of wagons from freight fronts to cleaning tracks, min.

Based on formula (6), we will specify the existing supply of wagons to the cleaning path in the following sequence.

$$1440 - 120 - 90 \cdot N_{\text{transmission}} - 200 \cdot N_{\text{transmission}} \geq 0$$

$$1320 \geq 290 \cdot N_{\text{transmission}}$$

$$N_{\text{transmission}} \leq 4{,}6$$

Thus, according to the current regulations, in the technological process of the station operation according to formula (6), the number of wagons supplied for cleaning the tracks per day was 5.

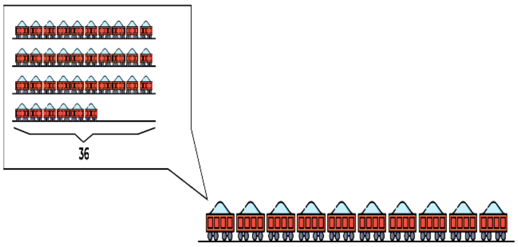

Fig. 4. Number of active wagon feeds on the cleaning route

After using a special device, a reduction was achieved T^{fr}_{clear}, and the number of transfers has been increased accordingly to 2, which in turn allows cars to be transferred to the cleaning tracks 7 times per day.

As a result, the number of wagons supplied to the 1st track of JSC Uzmetkombinat, which specializes in cleaning gondola cars, increased by 56%.

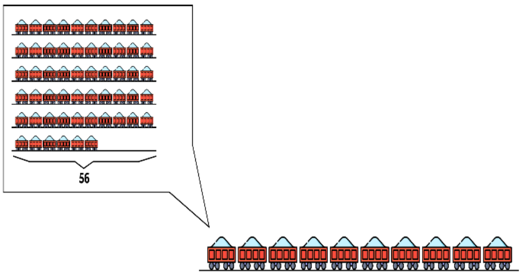

Fig. 5. Number of wagon feeds on the cleaning track using a special device

Annual costs saved by workers of the 1st track of JSC “Uzmetkombinat”, specializing in cleaning gondola cars, using a special device from the idle time of cars at each feed, are calculated using the formula [4]:

$$E^{\text{plain}}_{\text{car clock}} = n \cdot \Delta t_{ec} \cdot e_{\text{car clock}} \cdot 365, \text{ sum} \quad (7)$$

Δt_{ec} - saving time from waiting for cars on cleaning tracks, car-hour;

$e_{\text{car clock}}$ – standard cost for wagon downtime, sum.

n –number of feeds per day, i.e.

As a result of the practical implementation of a specialized device for closing the hatches of gondola cars on the 1st track of JSC Uzmetkombinat, specializing in cleaning, a reduction in the duration of technological operations performed with cars of one transfer was achieved by 70 minutes. Five feeds are made to this track per day. The daily time savings are 350 minutes.

The annual economic efficiency due to the reduction of wagon downtime is determined as follows:

$$E^{plain.}_{\text{car clock}} = \frac{50 \cdot 70 \cdot 16500 \cdot 365}{60} =$$

$$= 351.312.500 \text{ so'm} \approx 351{,}3 \text{ mln.so'm}.$$

As a resultannual economic effect fromusing a special device designed to reduceidle time of wagonsamounted to 351.3 million soums.

Definition of capital investments.

Capital investments in special devices for closing the hatches of gondola cars, necessary to provide the team of workers of the 1st track of JSC Uzmetkombinat, are determined based on the cost of one such device as follows:

$$K_{offer} = n_{\text{device}} \cdot A_{\text{device}}, \text{ sum} \quad (8)$$

n_{device} – number of devices required to the workers of the carriage cleaning team, pcs;

A_{device} – price of one device, sum;

Table 1

Cost of production of one special device

Cost structure	**Sum**
Raw materials and consumables	378 699
Fuel and electricity for technical purposes	
Total cost of material	378 699
Cost of labor	200 000
Social tax	
Total direct costs	578 699
Depreciation charges	
Other costs associated with production	
Cost of production	578 699
Period Costs	2 050 000
Profitability, 20%	115 740
VAT - negotiated price	**2 744 439**

The results of calculating the payback period from the implementation of a special device for closing hatches used by a team of workers on the 1st track for cleaning gondola cars of JSC Uzmetkombinat are presented in Table 2.

Table 2

Net Present Value Calculation Table

Period, t	Capital investments, C_t million sum	Total annual economic profit, R_t million sum	$\frac{1}{(1+E)^t}$	Annual income million sum	Net present value (NPV), million sum
1	31	351.3	0.862	271 845	271 845
2	-	351.3	0.743	261 073	532 918

From the results presented in Table 2, obtained on the basis of calculations when determining the net present value, it is clear that in the first year of the project, the income from its implementation amounted to million sum.

The exact value of the payback period of capital investments is calculated using the following formula [3].

$$T_{\text{payback period}} = 0 + \frac{|NPV_{t_1}| \cdot (t_2 - t_1)}{INPV_{t_2} + |NPV_{t_1}|} \cdot 12 \text{ months} \quad (9)$$

$t_1 -$ the last year in which the NPV balance was negative (NPV);

$t_2 -$ the year in which the NPV balance value is positive (INPV).

$$T_{\text{payback period}} = 0 + \frac{31 \cdot (1-0)}{31 + |271{,}845|} \cdot 12 = 1{,}23 \approx 2$$

4. Conclusion

Research and development work has been completed to adopt a technically and economically sound solution to determine the number of daily deliveries of cars delivered to the 1st track of JSC Uzmetkombinat for cleaning gondola cars, as well as to implement a special device specializing in closing gondola car hatches depending on the expected flow of cars, which in the long term will increase the productivity of work teams engaged in closing gondola car hatches.

By implementing research results into practiceIt was possible to increase the number of daily feeds to 2, the productivity of workers to 35%, and it became possible to clean 56% more wagons on this route than at present. The payback period from the introduction of a special device specializing in closing the hatches of semi-trailers is 2 months, and the total annual economic effect is 351.3 million soums per year.

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