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RESEARCH OF UNIT TRAIN LOADING TECHNOLOGIES AT THE SIDINGS OF GRAIN ELEVATORS WITH THEIR SHUNTING LOCOMOTIVES

Summary. *The purpose of the study is to increase the unit train load efficiency at the elevators having their shunting locomotives. The research is based on the analysis of time series, methods of organizing the operational work of railways, and methods of traction calculations. The paper considers the problem of organizing shunting work at elevators when loading grain unit trains. Critical wear and tear of shunting locomotives in railway transport of general use necessitates using their locomotives at the elevators. As a result of the research, the dependence of the duration of shunting and cargo operations on the number of cars in the unit train and on other factors was established. Various types of shunting locomotives were compared. Based on the analysis, it was established that it is advisable to use four-axle shunting diesel locomotives with hydraulic transmission for shunting work at the elevators. The traction force of such locomotives is sufficient to deliver empty cars to the elevator at a speed of 14–15 km/h. Loaded cars can be removed at a speed of 14–15 km/h with a slope of the connecting track up to 2–5 ‰. With greater slopes, the removal of loaded cars should be performed at a speed of 5 km/h. The main factor affecting the duration of shunting operations is the distance of delivery and removal of cars. Technologies for loading the grain unit trains at the elevators, providing for the presence of cars at the loading stations for two and three days, have also been developed. The main factor affecting the duration of unit train loading is the staff of locomotive assembly teams. The originality of the study is in obtaining the dependence between the parameters of the technical support of the elevators and the duration of the presence of cars in the connecting station – elevator's siding system. The practical value of the paper is that its results can be used in the design of the reconstruction of existing and construction of new elevators, as well as in the estimation of costs associated with various loading technologies of the unit trains for the corresponding sidings.*

Key words: *railway transport; grain elevator; grain cargo transportation; unit train; siding; shunting locomotive.*

1. INTRODUCTION

Today, grain is one of the vital export goods of the domestic economy and a crucial cargo transported by railway transport. Its share in the freight transportation structure of Ukrzaliznytsia JSC has reached 21 %. One of the problems to be solved to increase the competitiveness of domestic grain on international markets is the reduction of logistics costs for its transportation to seaports or land border crossings. When transporting by rail, the most effective technology that ensures a decrease in transportation costs is route planning. One of the tasks that has to be solved when implementing routed freight grain transportation is the performance of shunting work at the loading stations. Therefore, the problem of the article, which is aimed at improving the technical support and technology of shunting work at the sidings of elevators, is relevant.

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The requirements for the infrastructure design for loading grain into the cars are given in «Standards for technological design of grain receiving enterprises and elevators» (hereinafter Standards). These Standards are valid, but they were created in the USSR and approved in 1988 for working conditions in a different economic system. It should be noted that the Standards were developed based on the condition of the most effective use of railway cars and shunting locomotives. At the same time, fulfilling the requirements specified in Standards regarding the technical support of elevators when loading unit trains is connected with the creation of significant reserves of the processing capacity of the cargo handling terminals of the elevators. In conditions where about 60 % of grain carriers in Ukraine are private, and the level of wear and tear of shunting diesel locomotives of Ukrzaliznytsia JSC is approaching 100 %, the duration of unit train loading for each enterprise should be established based on a technical and economic comparison of technology options.

The study of the problem of routed grain transportation has a long history. The first scientific articles with suggestions about routed grain cargoes date back to the beginning of the 20th century. At the same time, there were attempts to form grain unit trains, but due to organizational shortcomings, these attempts turned out to be economically ineffective. Scientific methods of organizing the routed grain transportation were formed in the USSR. The works of I. H. Tykhomirov, V. T. Osypov, M. L. Orlov, V. V. Povorozhenko, A. P. Petrov and other authors are devoted to this problem. The specified methods form the basis of the car traffic volumes organization, which is still used on the railways of Ukraine today [1].

It should be noted that in [1], the efficiency of routed freight conveyance is evaluated without analyzing its influence on the operating conditions of shippers and cargo receivers. Standards and [1] formulate such requirements for the organization of transportation, which ensure the minimum transportation costs for the carrier at the expense of increasing the transportation costs for shippers. The disadvantage analysis of this approach is given in [2]. Traffic volumes of grain cargo, in contrast to other bulk cargoes, originate at many small enterprises. Therefore, the processes associated with the concentration of cargo traffic volumes to route batches significantly influence the overall logistics costs of grain transportation and cannot be considered in isolation from grain transportation by rail.

The largest grain exporter in the world is the USA. Conveyance by routed freight here began to be used when transporting grain for export in the mid-60s of the 20th century [3]. Changes in grain logistics in the USA started in the 1970s in response to a sharp increase in the demand for grain in the global market [4]. Research performed in [5] shows that with an increase in the number of cars in trains, the costs of grain transportation decrease and the carrying capacity of railways increases. Therefore, the US railways began transporting grain cargo by increasingly long trains to increase competitiveness. The main technology used today for grain transportation by rail in North America is the shuttle train [6, 7]. This technology involves abandoning the use of shunting locomotives. Trains consisting of 75-120 cars move between loading and unloading points according to a schedule agreed in the contract for 6-9 months without reshaping and uncoupling train locomotives at loading stations.

Routed freight conveyance of grain cargoes is shown as the crucial method of increasing the grain transportation efficiency in Ukraine in the works of various researchers [8, 9]. The problems of the domestic grain delivery system for export are related to the low loading capacity of the elevators [10].

Therefore, as shown in the study [11], in Ukraine, similarly as in the USA, it is expedient to create a network of nodal elevators to ensure export transportation of grain cargoes by unit trains. On the one hand, solving this problem requires improving the design of the elevators themselves [10]. On the other hand, the organization of interaction between elevators and the railway carrier also needs improvement. The analysis performed in [12] shows that in the conditions of Ukraine, the possibility of unit trains loading without shunting operation is limited. Therefore, determining the rational level of technical support and effective technology for shunting operation at the elevators is currently relevant for Ukrainian railways and needs to be solved. Ensuring the competitiveness of domestic grain on world markets is an essential task for the economy of Ukraine. At the same time, the reduction of logistics costs in the grain delivery chain from the producer to the transshipment point (seaport, land border crossing) is possible only with the coordinated work of all its elements. The American technology of shuttle trains, when elevators are serviced by grain trains according to the schedule, can be taken as the basis of grain transportation technology in Ukraine. However, considering the peculiarities of Ukrainian grain logistics mentioned above, this study investigates the element of car circulation related to shunting operation at the elevator's sidings and connecting station, which is absent when using a shuttle train technology.

2. PURPOSE

The aim of the study to increase the loading efficiency of unit trains at the elevators, having their shunting locomotives. The research task is to establish the relationship between the technical support parameters of elevator's sidings and the duration of cars' staying in the connecting station-elevator's siding system.

3. METHODOLOGY

Grain transportation by rail has many features compared to other bulk cargoes. First, significant seasonality is characteristic of grain loading. The analysis of time series for grain transportation was performed to assess its level. Fluctuations in the transportation volume were assessed by the unevenness coefficient, which was defined as the ratio of the monthly cargo transportation volume to the average for the year. Fig. 1 presents the coefficients of monthly unevenness of grain transportation by railways of Ukraine compared to iron and manganese ore. While the ore transportation volume deviates from the annual average by 5 %, the volume of grain transportation deviates by 46 %.

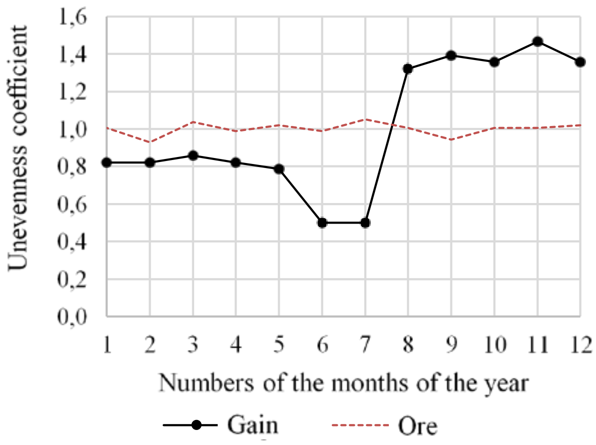

Fig. 1. Unevenness of grain and ore transportation by Ukrainian railway transport

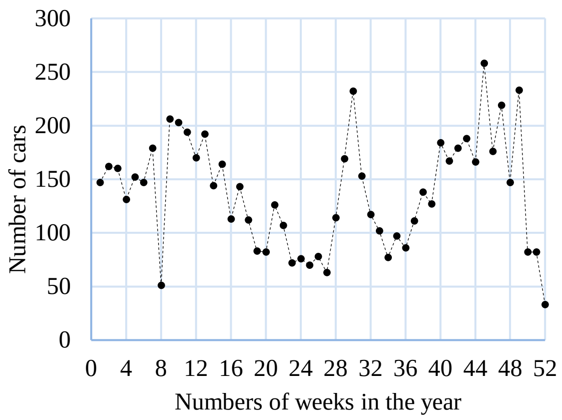

Fig. 2. Unevenness of grain load at the elevator

Secondly, a characteristic feature of railway transportation of grain cargo is the dispersion of grain loading at a significant number of stations. Therefore, individual elevators are characterized by even greater irregularity. For example, Fig. 2 shows the dynamics of grain loading volumes by week of the year at one of the large elevators.

In general, grain loading volumes in Ukraine are insufficient for the creation of elevators ensuring daily unit train formation, as this leads to an irrational increase in the grain transportation distance by road transport from farms. The studies performed in [12] show that it is rational to load the unit train once or twice a week. As a result, the load level of technical equipment and the number of employees will significantly fluctuate during specific days and throughout the year. It increases the payback period of investments in the development of the loading capacity of elevators.

This research examines elevators built according to a dead-end scheme, which have their shunting locomotives and are adjacent to intermediate stations. It is assumed that the arrival and departure of trains with cars to the connecting station are carried out according to the schedule at the same time of day. Therefore, the time unit trains stay at the elevator's station and sidings is determined by whole days. In the congestion period, the work with unit trains at the connecting station is performed on two tracks, whose assignment may change between them. A unit train with empty cars arrives at one of the tracks, and a loaded unit train is located on the other. The total duration of occupation of both tracks includes operations for re-coupling a train locomotive and sending a loaded unit train and does not significantly affect the working conditions of the station and its service to other railway customers. One track must be used constantly to work with the unit train; such a track must either be built or selected from the existing track reserves. The simultaneous arrival of more than two unit trains at the connecting station is not considered in this study due to the accepted limitations of track layout.

The carrier (Ukrzaliznytsia JSC) at the elevator's connecting station performs the operations of securing the empty train, uncoupling the locomotive, acceptance-delivery operations with empty and loaded cars, running of train locomotive from the empty train to the loaded one, coupling the locomotive, testing the brakes, removing the brake pads and dispatching. The duration of technological operations at the connecting station and the elevator are random values. It is necessary to additionally provide a time reserve to ensure the fulfillment stability of the traffic schedule under the influence of random factors. It is assumed that the total duration of technological operations performed by the carrier, taking into account the time reserve, is 16 hours: 4 hours upon arrival and 12 hours upon departure.

Hopper cars are mainly used for grain transportation on the railways of Ukraine. They are loaded through the roof hatches. The process of car loading with grain includes cargo, technical and commercial operations. The pace which is necessary for the unit train loading can only be provided when grain is loaded by the hopper method. At the same time, the loading duration is determined by the capacity of the hopper and by the productivity of the bucket hoists filling the hopper with grain and is defined as:

$$T = \min(T_h, T_b), \quad (1)$$

where T_h – duration of car loading based on the hopper capacity, min; T_b – duration of car loading based on the bucket hoists productivity, min.

The duration of the car loading m_dur, based on the hopper capacity, is determined by the formula

$$T_h = m_\mathrm{dur}\left(\frac{600Q_\mathrm{c}}{\mathrm{C_h}} + t_\mathrm{aux}\right) + t_\mathrm{prep} + t_\mathrm{fin}, \quad (2)$$

where Q_c – carrying capacity of the car; $\mathrm{C_h}$ – throughput capacity of the hopper, t/h; t_aux – duration of auxiliary operations, min; t_prep, t_fin – duration of preparatory and final operations, min;

Capacity of the hopper:

$$\mathrm{C_h} = 2655\pi n_\mathrm{op}\rho\lambda(D-a)^{2,5}, \quad (3)$$

where n_op – the number of outlet pipes; ρ – bulk grain mass, t/m^3; λ – grain mass leakage coefficient; D – outlet pipe diameter, m; a – grain size, m.

Auxiliary operations include opening the hatch covers of the car, lowering the loading pipes into the car, starting the grain, raising the loading pipes and adding grain, closing the hatches, and changing cars at the cargo handling terminal. When performing these operations consecutively, their total duration is about t_aux =10.8 min. An increase in the number of people and partially parallel execution of auxiliary operations allows for reducing the time expenditures up to t_aux = 4.5 min.

Preparatory and final operations include negotiations between the assembler and the grain loading supervisor and, if necessary, securing the shunting winch rope before loading and releasing it after the finish. Time expenditures for preparatory and final operations are 2–7 minutes per submission.

The duration of the car loading m_dur based on the bucket hoists productivity is determined by the formula:

$$T_1 = 60\frac{m_\mathrm{dur}Q_\mathrm{u} - Q_\mathrm{h}}{\mathrm{P_h}k_\mathrm{u}k_\mathrm{c}}, \quad (4)$$

where Q_h – hopper capacity, t; P_h – bucket hoists productivity, t/h; k_u – utilization coefficient of the bucket hoists productivity when feeding grain into the hopper; k_c – the coefficient which takes into account the bucket hoists productivity decrease when transporting the grain with a different bulk weight than that of wheat.

The total loading duration of a group of 18 cars is about 360 minutes. According to the requirements of Standards, the technical support of the cargo handling terminal of grain unit trains should be designed subject to the division of the unit train into two or three supplies and loading one supply within 220 minutes. Some operations must be performed in parallel to achieve such a loading rate, which requires both a complication of the elevator's technical equipment and an increase in the number of workers involved. The parallelism of operations can be achieved due to the parallel loading of several cars on one technological line or the construction of parallel loading lines.

Shunting operation at the elevator includes direct shunting movements and initial and final operations. Shunting locomotives and shunting winches can be used as shunting engines. This study examines the possibility of using consumed shunting diesel locomotives with hydraulic transmission at the elevators. One of the main parameters of shunting diesel locomotives is the number of axles. Therefore, they can be divided into groups. Their characteristics are given in Table 1.

Table 1

Characteristics of shunting diesel locomotives

Parameter	TGK2		TGM23		TGM4		TGM6	
Number of axes	2		3		4		4	
Estimated speed, km/h	5	10	5	10	5	15	8,7	14
Long-term traction force, kN	70.6	35.7	125.5	63.7	225.5	88.3	246	138.0
Weight, t	28		44		80		90	

The maximum weight of the car supply that can be moved by a shunting locomotive is determined by the formula:

$$Q_{sup} = \frac{1000 F_t k_{ec} \gamma_t}{(w + 9,81 i_p)} - P, \quad (5)$$

where F_t – locomotive traction power under standard atmospheric conditions, kN; k_{ec} – coefficient which takes into account diesel power decrease due to environmental changes; γ_t – coefficient which takes into account decrease in the locomotive traction power during operation; w – specific movement resistance of the rolling stock, N/t; i_p – track slope, ‰; P – locomotive weight, t.

The dependencies of the number of loaded cars, which can be moved by a shunting locomotive, on the track slope is shown in Fig. 3.

Analysis of the obtained dependencies shows that two- and three-axle diesel locomotives usually do not have enough power to remove the loaded cars from the elevator to the connecting station. The four-axle diesel locomotives, TGM4 and TGM6, have sufficient power to move the loaded car groups from the elevator to the station. In both cases, the empty trains can be transferred from the connecting station to the elevator in train mode at 14–15 km/h. The loaded cars can be transferred in train mode only with favorable longitudinal profile of the connecting track when it is located on a slope or a slight hill (up to 2 ‰ for TGM4 and up to 5 ‰ for THM6). It is possible to remove the loaded cars to the connecting station in shunting mode using TGM4 with the calculated slope of the connecting track up to 9–10 ‰ and TGM6 with the slope up to 10–11 ‰. In this study, it is assumed that the movement speed of the loaded car groups from the elevator to the station is 5 km/h.

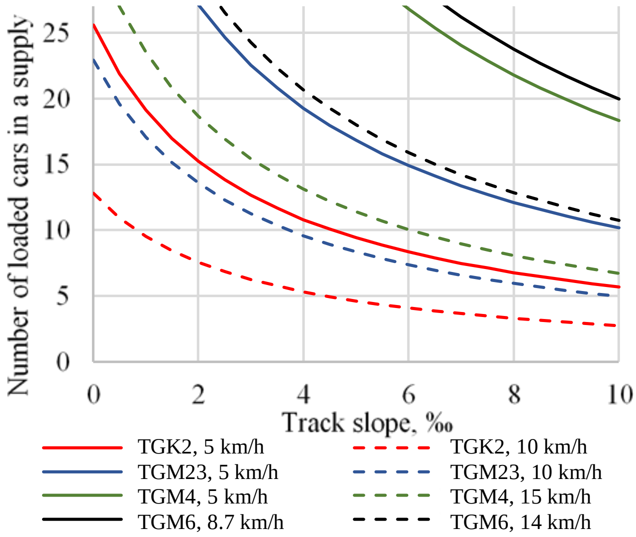

Fig. 3. Dependencies of the number of loaded cars, which can be moved by a shunting locomotive, on the track slope

Taking into account that the cargo handling terminals' tracks must be located on a horizontal site, it is accepted that the shunting locomotive's power is sufficient to rearrange the shunting train consisting of $m_r/3$ loaded and $m_r/3$ empty cars when changing the wagons at the cargo handling terminal (where m_r is the number of cars in grain unit train). When dividing the train for loading into two parts during the change of cars at the cargo handling terminal, it is necessary to rearrange the shunting train with $m_r/2$ loaded and $m_r/2$ empty cars. As a rule, the power of four-axle shunting locomotives is not enough to perform such an operation. Therefore, the case of dividing the train into three parts is considered in the future.

The track layout of the elevator's siding should include a loading track, two set-out tracks and a dead-end track for equipping and servicing the locomotive. The transmission track for the unit train formation should be provided at the station. The length of the set-out tracks of the elevator should be equal to $l_r/3$ (where l_r is the route length, m). If the shunting locomotive moves the supply of cars when loading, the length of the loading track must be at least $l_r/3$. In the case when the car supply is moved by a shunting winch during loading, the length of the loading track should be at least $2l_r/3$.

Shunting operation includes supplying empty cars from the station to the elevator's siding, moving cars between the loading and set-out tracks and removing loaded cars from the elevator's siding to the station.

The number of cars in the shunting train during their supply and removal to the connecting station depends on the lead track length used for shunting. According to the design standards [13], the length of the lead track should be from 200 m to half the useful length of the receiving-departure tracks at the station. Considering the requirements [13], and the restrictions of the locomotive traction power, this study analyses the case of dividing the train into three parts during the transfer of empty and loaded trains between the station and the elevator's siding.

The calculation scheme for determining the time required to deliver an empty train from the station to the elevator's siding is shown in Fig. 4. The time expenditures for shunting include the time spent for the movement of the shunting locomotive with and without the cars, testing brakes, coupling and uncoupling the locomotive, uncoupling and coupling the car groups, installing and removing brake shoes, transfer of commands and messages between the employees.

The time expenditures for these operations were determined according to the methodology presented in [14]. According to this, the time spent on the empty train's rearrangement from the connecting station to the elevator is equal to:

$$T_{e} = 19.0 + 0.024(L_{sr} + l_{yn}) + 0.7m_{r}, \quad (6)$$

where L_{sr} – the distance of supply-removal of cars to the elevator's siding, m; l_{yn} – length of the yard neck, m.

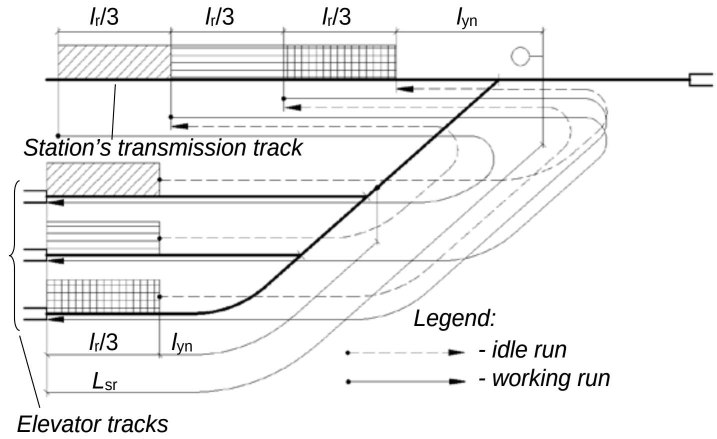

Fig. 4. Calculation scheme for determining the time spent on empty cars' moving from the station to the elevator industrial sidings

According to a similar method, the time required for moving the car groups between the set-out and loading tracks and the train loaded with grain from the elevator's siding to the station was determined. The total time expenditures for rearranging the car groups are:

$$T_{cg1} = 64.0 + 0.072(L_{sr} + l_{yn}) + 0.1l_{en} + 2.5m_{r}, \quad (7)$$

where l_{en} – the neck length of the elevator's siding, m.

The cars during grain loading can be moved using a shunting winch to reduce the loading of the shunting locomotive. Given this, it is forbidden to leave the cars without a locomotive at turnouts; the loading track must correspond to the length of two car supplies. As a result, the duration of shunting movements is increased by moving the length of two trains, coupling and uncoupling the shunting winch, coupling and uncoupling the shunting locomotive, and air-filling the brake system of the last car group. The total time spent on rearranging the car groups in this case is:

$$T_{cg1} = 82.0 + 0.072(L_{sr} + l_{yn}) + 0.1l_{en} + 2.9m_{r}, \quad (8)$$

The analysis of formulas (7) and (8) shows that the main factor affecting the movement duration of shunting locomotive is the distance of supply-removal of cars. Thus, a change in the distance of this supply-removal by 5 km leads to a change in the duration of shunting operations up to 360 minutes. At the same time, changing the train length within ten cars affects the duration of shunting operations by 25–29 minutes.

4. FINDINGS

Graph-analytical modelling [15] of the operation of the elevator's stations and sidings with their different technical equipment was performed to determine the loading capacity of the elevators depending on the parameters of their technical equipment. According to the research results, the following was found.

With the accepted variants of technical equipment, it is impossible to ensure the unit train location in the connecting station-elevator's siding system for more than one day. This is because the accepted duration of technological operations performed by the carrier is 16 hours. It is impossible to process the required cargo and shunting operations in 8 hours. Track capacity should be added at the station or the elevator for car staging to ensure the departure of trains every day during peak periods.

When solving the problem of staying on the unit train in the connecting station-elevator's siding system for two days, the main restricting element is the continuous working time of the shunting team. It can work continuously for no more than 12 hours with a 12-hour break. In this case, the loading of the unit train can be performed according to the following technology variants.

Variant 1: grain loading and shunting operation is performed around the clock, as shown in Fig. 5.

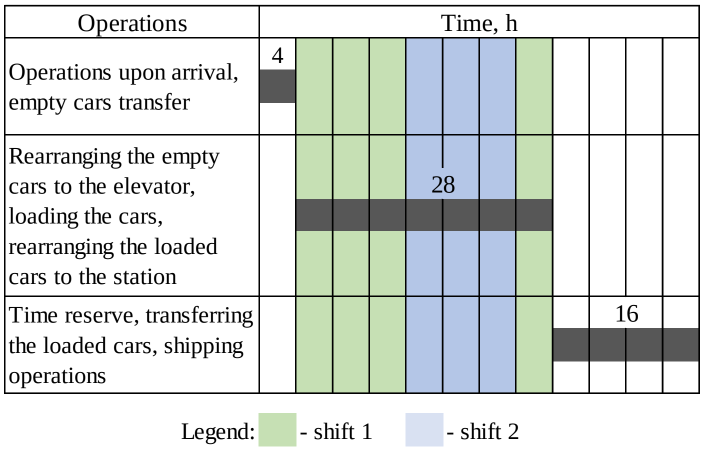

Fig. 5. The schedule of loading the unit train with the participation of two shunting teams and two loader teams during two days

Locating the unit train cars in the connecting station-elevator's siding system for two days can also be implemented using shunting winches to move these cars when loading.

Variant 2 provides for the car loading at the one track, as shown in Fig. 6. In this case, before the start of the second shift, the first and the second car supplies must be loaded, and the third one must be spotted for loading. The cargo handling terminal should provide simultaneous grain loading into two cars to intensify the operations. One car at a time can be loaded in the second shift. Therefore, three loader teams must work at the elevator.

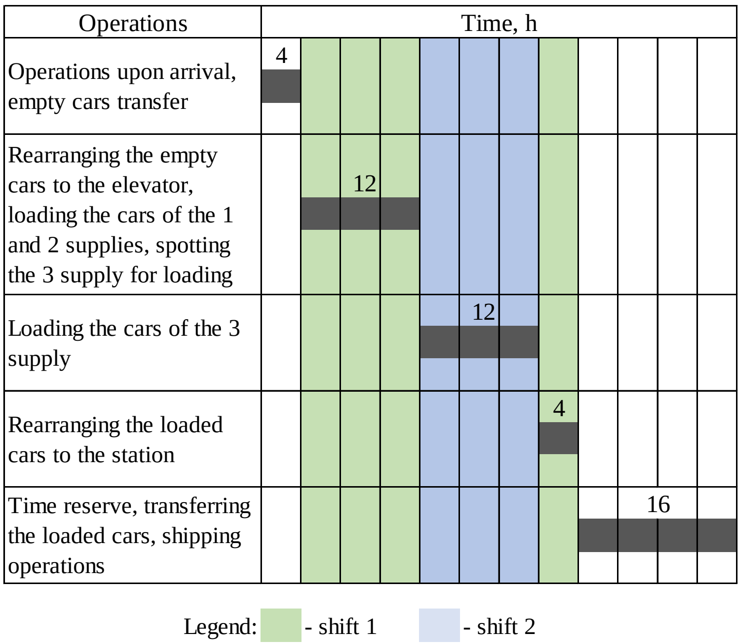

Fig. 6. The schedule of loading the unit train with the participation of one shunting team and three loader teams during two days on one loading siding

Variant 3 also provides for staying for two days the unit train cars in the connecting station-elevator's siding system. It consists of creating two parallel loading lines at the elevator. The organization procedure for variant 3 is shown in Fig. 7. In this case, during the first shift, 1 supply should be loaded, and 2 and 3 supplies should be placed on loading tracks 2 and 2. The groups 2 and 3 are loaded sequentially during the second shift. When using this variant, it is necessary to have two loader teams, one for each shift.

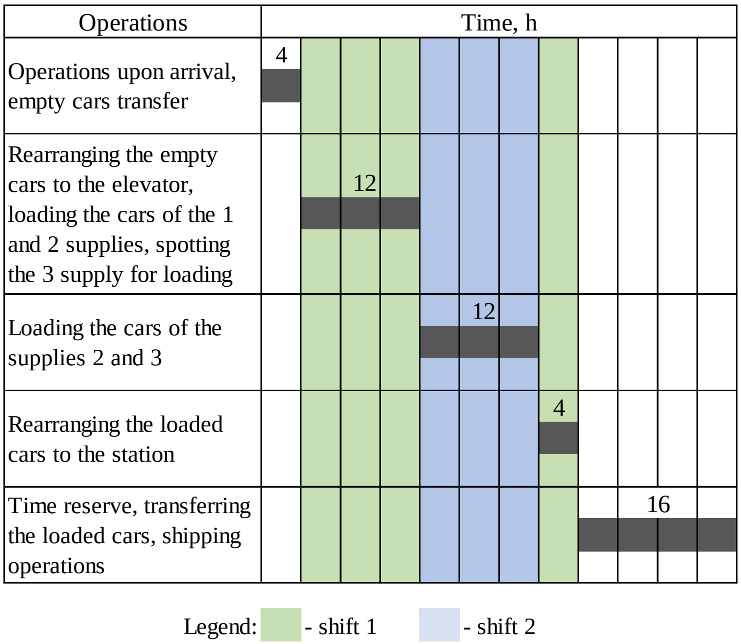

Fig. 7. The schedule of loading the unit train with the participation of one shunting team and two loader teams during two days on two loading sidings

Variant 4 is in the fact that one shunting team and one loader teamwork at the elevator. In such conditions, the cars are loaded only during the day shift, and at night, the technical equipment of the elevator and the cars in the unit train are idle, as shown in Fig. 8. It takes three days to load the unit train.

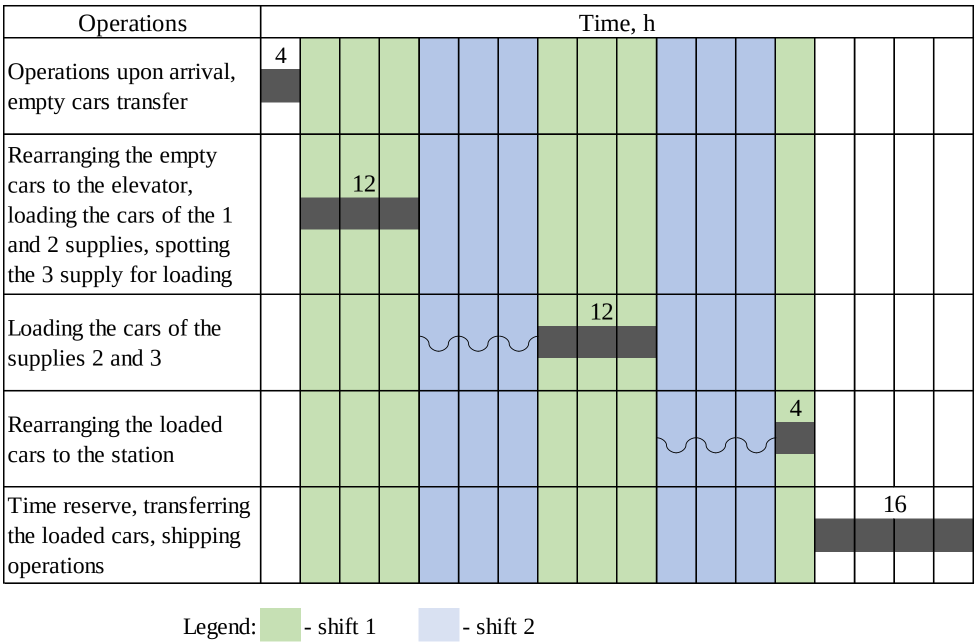

Fig. 8. The schedule of loading the unit train with the participation of one shunting team and one loader team during three days on one loading siding

Preliminary analysis has shown that the most competitive are 1 and 3 variants.

The advantage of the work organization, according to variant 1, is the smallest size of the land plot for the elevator, the minimum capital investments in loading equipment and track layout of the siding, and the possibility of minimizing operating costs under conditions of drop in the transportation volume. The disadvantage of this variant is the need to maintain two shunting teams for seasonal work.

One of the teams should have the right to go to the connecting station. The other can only work within the siding. Provided sufficient territory, the elevator's loading track can be extended and equipped with a winch. In this case, the work of the shunting team in the second shift will consist only of rearranging the groups of cars between the set-out track and the loading track. Other elevator employees can perform these functions in the conditions of positions overlap.

Variant 3 with two loading lines is considered the basic for unit train loading, as in Standards. The advantage of this variant is the possibility of increasing the loading rate compared to variant 1, but it is characterized by the need to create and maintain significant reserves of the processing capacity of cargo handling terminals.

Steady seasonal fluctuations in the grain loading volume (see Fig. 1 and Fig. 2) lead to similar fluctuations in the need for grain cars. It is advisable to use the cars as wheeled warehouses with the transition of the elevators to one-shift work according to variant 4 to reduce the grain transportation cost during the periods of reduced loading volumes. The disadvantage of all variants for the operation of the elevator with its shunting locomotives is the seasonality of work and the low average occupancy of the shunting teams. The problem can be partially solved by the positions overlap. However, in this case, the elevators' operational stability may be at risk due to illnesses, vacations, and other factors related to individual workers. Also, due to the operation of only one locomotive at the elevator, it is economically impractical to create a locomotive reserve in case of failure. In this regard, in grain-growing areas, it is advisable to create specialized enterprises that provide either transport services with shunting locomotives or only the shunting team services. At the same time, it will be possible to perform shunting operations at the elevators under the conditions of outsourcing. Efficiency evaluation of the creation and functioning of such enterprises requires additional research.

5. ORIGINALITY AND PRACTICAL VALUE

The originality of the study is that the dependencies between the parameters of the technical support of the elevator's siding and the duration of cars' staying in the connecting station-elevator's siding system were obtained.

The practical significance of the work is that its results can be used in the design of reconstruction of existing and construction of new elevators, as well as in the estimation of costs associated with various technologies for loading grain unit trains.

6. CONCLUSIONS

The conducted research allows us to draw the following conclusions:

1. Under the conditions of critical wear and tear of the shunting locomotives of Ukrzaliznytsia JSC, the task of developing technical and technological solutions to ensure grain loading of the unit trains using the elevators' shunting locomotives is urgent.
2. It is advisable to use four-axle locomotives with hydraulic transmission to perform shunting operations related to the supply-removal of cars of the unit trains and their rearrangement between the elevators' tracks. The traction force of such locomotives is sufficient to feed empty cars to the elevator in train mode at a speed of 14–15 km/h. Removal of loaded cars can be performed in train mode when the slope of the connecting track is up to 2–5‰. With larger slopes, the removal of loaded cars should be performed in shunting mode at a speed of 5 km/h. The main factor affecting the duration of shunting operations is the distance of supply and removal of cars.
3. The variant of loading grain with the participation of two shunting teams on one loading track or with one shunting team on two loading tracks is the competitive technology ensuring the location of the unit train's cars in the connecting station-elevator's siding system for two days.

During the period of a seasonal drop in the grain loading volume, it is advisable to switch to grain loading with the participation of one shunting team on one track for three days.

4. The stability of the elevators with their shunting locomotives will depend significantly on the locomotive shunting teams and the technical condition of the diesel locomotives. In this regard, in grain-growing areas, it is advisable to create specialized enterprises that provide either transport services with shunting locomotives or only the shunting team services. At the same time, it will be possible to perform shunting operations at the elevators under the conditions of outsourcing.

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ДОСЛІДЖЕННЯ ТЕХНОЛОГІЙ НАВАНТАЖЕННЯ ВІДПРАВНИЦЬКИХ МАРШРУТІВ НА ПІД'ЇЗНИХ КОЛІЯХ ЗЕРНОВИХ ЕЛЕВАТОРІВ З ВЛАСНИМИ МАНЕВРОВИМИ ЛОКОМОТИВАМИ

Анотація. *Метою роботи є підвищення ефективності навантаження відправницьких маршрутів на елеваторах, що мають власні маневрові локомотиви. Дослідження виконано на основі аналізу часових рядів, методів організації експлуатаційної роботи залізниць та методів тягових розрахунків. У роботі розглянуто проблему організації маневрової роботи на елеваторах із завантаження зернових маршрутів. Через критичне зношення маневрових локомотивів залізничного транспорту загального користування на елеваторах доводиться використовувати власні локомотиви. Під час дослідження встановлено залежності тривалості маневрових та вантажних операцій від кількості вагонів у маршруті та від інших факторів. Виконано порівняння різних типів маневрових локомотивів. На підставі аналізу встановлено, що для виконання маневрової роботи на елеваторах доцільно використовувати чотиривісні маневрові тепловози з гідравлічною передачею. Сила тяги таких локомотивів достатня для подавання на елеватор порожніх вагонів зі швидкістю 14–15 км/год. Забирати завантажені вагони можна зі швидкістю 14–15 км/год за ухилу з'єднувальної колії до 2–5 ‰. За більших ухилів забирання завантажених вагонів повинно здійснюватися зі швидкістю 5 км/год. Основним фактором, що впливає на тривалість маневрових операцій, є відстань подавання та забирання вагонів. Розроблено технології навантаження зернових маршрутів на елеваторах, що передбачають перебування вагонів на станціях навантаження протягом двох та трьох діб. Встановлено, що основним фактором, який впливає на тривалість навантаження маршрутів, є штат працівників локомотиво-складальних бригад. Наукова новизна полягає у визначенні залежності між параметрами технічного забезпечення елеваторів та тривалістю перебування вагонів у системі "станція примикання – під'їзна колія елеватора". Практичне значення роботи полягає в тому, що її результати можна використовувати під час проєктування реконструкції наявних та будівництва нових елеваторів, а також для оцінювання витрат, пов'язаних із різними технологіями навантаження маршрутів на відповідних під'їзних коліях.*

Ключові слова: *залізничний транспорт; зерновий елеватор; перевезення зернових вантажів; відправницький маршрут; під'їзна колія; маневровий локомотив.*