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IMPROVEMENT OF SUPERVISORY CONTROL OF TRAIN MOVEMENT BY MEANS OF INTRODUCTION OF OPERATIONAL ZONES

Purpose. The work is aimed to investigate the feasibility of transferring automatic control to low-density stations of the sections (according to the principle of supervisory control of trainline) to the operators at principal stations. **Methodology.** The article analyzes the work of heavy traffic sections of the Ukrainian Railways JSC. It was found out that the information workload of dispatchers who control the train movement at the sections of the main course, constantly exceeds the permissible level. The possibility of using the technology of supervisory control of train movement by the introduction of operational zones has been investigated. **Findings.** The authors found out that the capacity of receiving and departure tracks at the stations of the sections is extremely limited. The occupancy of run-around tracks by the out-of-work trains hinders any regulatory measures at the sections. Trains pass one after another without giving priority, that is, they pass through the section in the order in which they entered it. Due to the limited number of tracks at the pre-section intermediate station, freight trains are placed for run-around by the passenger ones at the distant approaches. This leads to a loss of service speed and reduces the level of utilization of the sections` working capacity. The introduction of operational zones will significantly reduce information flows and facilitate the work of the train dispatchers, create the necessary conditions for creative decision-making on the inter-sectional regulation, and will contribute to increase in the service speed of trains. **Originality.** The article developed a new technology to improve the management of train sections by dividing them into operational zones. In each zone, consisting of two or three run-arounds, the duty officer of the principal station, performing in this case the functions of the train dispatcher, can control the train movement. **Practical value.** It has been proposed to put trains from technical stations that idle due to uneven movement, especially the trains from the terminal stations (division points) of the locomotive circulation sections, to reserve routes of the pre-section intermediate stations. Laying the reserve tracks and their maintenance, taking into account the periodicity of use and reduced permissible speed, can be allowed according to less tight standards for the construction of the roadbed, ballast section, sleeper density, taking into account the use of switches and decommissioned tracks.

Key words: train schedule; dispatch control; freight trains; train delay time; principal station

Introduction

In our country railway transport has a significant influence not only on improving the economic and financial results, but also on the results of other sectors of the economy. Improvement of the system of interaction between railways and production is carried out in the direction of increasing the quality of transportation

process with the expansion of the range of services, which contributes to the growth of transportation volumes. Therefore, in the conditions of competition, the total volumes of railway transportations depend primarily on the production volumes. In addition, they are also influenced by the quality of transport services, which in modern conditions is of particular relevance. Thus, improving the quality of transport

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services with increase in the list of services significantly expands the customers` circle, contributes to the growth of railways revenues, strengthens the railway transport`s positions in the market and positively influences the overall result of economic transformations.

According to the experience of improving the organization of railway operation in different countries, in modern realities, they aim to fully satisfy the requirements of customers regarding the terms of goods delivery due to the high reliability train movement schedule, which is the basis of the transportation process technology [2]. Under conditions of the existence of a multi-level management system of transportations, the separation of management at the level of the transport corridors network becomes necessary. This will make it possible to coordinate the technological and infrastructural capabilities of all units of PJSC «Ukrainian Railways» within the defined railway line in order to form a rational system for the promotion of specialized car traffic volumes [10].

Railway transport directs its efforts to strict adherence to the traffic schedule and the order of use of rolling stock in accordance with the plan for trains formation, technical regulation. On the other hand, large financial-industrial groups, which make up the majority of cargo owners, began to minimize their expenses with the aim of maximizing income, primarily transferring the cargo storage costs to the state-owned company PJSC «Ukrainian Railways» (PJSC «UZ») by using public cars as «wheeled warehouse». The financial-industrial groups began to include railway transport in the management of the sales process (and this is nothing more than the management of freight traffic volumes) and influence its technology [9]. So, whereas previously the department of traffic management exclusively dealt with the issues of the train formation plan, in recent years – with the issues of harmonization of the routes and conditions of goods transportation in individual companies. Due to the sharp decline in production and transportations, the need to compete for custom in the new economic conditions, railway transport has increasingly become to take into account the custom`s requirements and adapt to them.

The article [11] emphasizes that competition at transport is a struggle for cargo owners and passengers, obtaining the most beneficial effect on the basis of the use of modern, more efficient technologies, improving the quality of transportations, their reliability and speed of movement of goods and passengers. The expediency of the use of modern dispatch train movement control systems is confirmed by the results of the study, set forth in the article [3]. Also, this study focuses on the fact that the task of constructing and improving the transport technologies and traffic management systems are relevant.

The article [1] studies the influence of various factors on the implementation of the technology of car traffic volume passage under conditions of rigid route schedules based on the criteria for rationalization of fuel and lubricant costs, timely goods` delivery, etc. in order to identify competitive variants of the organization of train traffic volumes. Establishing priorities for the provision of services at the section and the use of the balance methodology makes it possible to rationalize the work of a given railway station or direction [8]. The authors` thoughts on the network effects that arise during the train operation are quite interesting. The authors emphasize that one section cannot be considered as a completely independent part of the entire railway network.

The work [17] uses integration of software products of micro and macro levels of simulation was used, which allows estimating the influence of the primary delay in train movement on the distribution of general delay at the section and improving the research accuracy. The analysis of primary delays and the use of carrying capacity shows that there is a high degree of dependence between periods with a high frequency of delays and bottlenecks in carrying capacity [16]. In the article [12], the authors argue that the train movement schedule is stable if any delay in the train movement of can be compensated by time reserves without the need to activate the work of train dispatcher.

The paper [6] introduces the term «operational reliability» in order to assess the stability of the train schedule. The team of authors in the paper [14] proposed to assess the adherence stability of the train movement schedule, depending on the

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complexity of operations: the fewer conflicts in the schedule, the higher the stability of the movement schedule. The manual [5] presents the methodology of determining the time reserve for solving conflict situations that occur during the laying of passenger and freight trains` movement on the schedule.

The works [13, 15, 18–19] solve the task of transportations dispatching at the level of management not only to control the train schedule, but also for the purpose of its operational correction. In their research, scientists also attempt to create a standard schedule of train movement on the tactical level of planning.

In the study [4], the authors propose a method for ranking trains and route schedules according to priority. They attempted to develop an automated system «Predicted train schedule» at the Belarusian railway, with the help of which it is possible to predict the schedule for 3 hours. Thus, the authors resolved the task of increasing the operation efficiency of a section by automating the supervisory control of the train work. Research in this direction is quite promising.

In the article [7], the authors developed a method of algorithmic description of the process of making managerial decisions by the train dispatcher in relation to the determining the cross-over stations taking into account the priority of trains. In the future, this algorithm can become the basis for creating a decision support system that will be integrated into the automated work station of the train dispatcher (AWS TD).

In today's realities, train dispatchers (DNCs) operate under heavy load conditions. From time to time, this affects the quality of their decisions during the operational management of train work at the sections. In view of this, it is expedient to develop the measures that will allow transferring the part of the functions of train management to other participants in the transport process; in particular, it may be duty officers at the principal stations.

Purpose

For further development of the technical means of Ukrainian railway transport it is necessary to have several variants of the rational technology of

the main production process – the organization of the train movement.

The purpose of the article is to investigate the expediency of the automatic control transfer of low-density stations of a section (according to the principle of centralized traffic control) top the duty officers at the principal stations.

Methodology

Already, in some areas of the railway network, there is a tension in the work due to a significant reduction of available capacity reserves. The work carried out at the railways in order to maximize the delineation of lines for freight and passenger traffic, will significantly increase the operating voltage on the lines where the concentration of freight and passenger traffic takes place. The growth of transportation volumes in the future will further complicate the transportation on these lines, will worsen the operation of railways, disrupt the rhythm and quality of transport services. Taking into account these circumstances, the development of railway capacity under new conditions should be addressed as an increase in the line power. To do this one should have adequate financial resources, as well as the search for new technologies and reserves at each element of the railway system.

The state of operational activity of railways indicates a violation of the complexity of approach to the capacity development of the lines, stations, use of rolling stock, etc. Today, the construction of train schedules is carried out as follows. At the first stage, according to the established directive documents and taking into account the set priorities and constraints, the passenger and freight lines are laid.

At the second stage (if it exists), it is attempted to optimize the modes of train movement in certain areas and routes to save energy resources, speed of delivery of passengers and goods. At the same time, these goals, as a rule, conflict with each other.

As a result, the railway receives a plan that is far from ideal, both in terms of costs and in terms of the passenger service and operators of freight commercial transportations.

We propose a solution to these problems, which includes:

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- application of complex approach to the construction of the schedule of passenger and freight trains;
- accounting of resource-saving modes at the stage of construction of schedules of passenger (first of all, as a type of traffic with fixed schedules and less energy-consuming) and freight trains;
- accounting of electricity billing to optimize traction costs.

Findings

Train sections play an important role in the transportation process. Suffice it to say that 25% of the general time of car turnaround accounts for movement at the sections.

Reduction of the lengths of block-sections makes it possible to reduce the spacing of trains. At some runs one can lay third and fourth main tracks.

In connection with the non-synchronization of train movement, the minimum calculation interval cannot be realized both from departure and from the arrival of trains at the section's final station. In this case, the calculated value of the carrying capacity is not achieved and the average speed of the train traffic flow sharply declines.

The information workload of the dispatchers, who control the train movement at the sections of the main course, constantly exceeds the permissible level. Under these conditions dispatcher apparatus often manages only to fix the train situation. As a result, there are miscalculations in the passage of trains at a section, in the choice of the order of their entering to the junction, which ultimately leads to an even greater decrease in the service speed.

The number of trains that can be simultaneously in motion and at the same time move with the speed set for this section is strictly limited. Accumulation of trains at the sections, which exceeds a certain maximum value reduces the speed of their movement. But in practice, nobody sets this maximum permissible value and nobody is guided by it, which sometimes leads to

unacceptable oversaturation of sections by trains over the established limits.

If the excess of trains is insignificant and the technical stations and stations, capable to cope with the increased size of movement are in front, then, certainly, one should force the transfer of the train traffic volume. If there is no such opportunity during this period, it is necessary to restrict the movement of trains at such a section. To shorten the number of trains, which are simultaneously in motion on lines, to the established limit in exceptional cases can be due to the temporary withdrawal of compositions at intermediate stations of the district.

In exceptional cases it is possible to shorten the number of trains, which are simultaneously moving on lines, to the established limit due to the temporary leaving of trains at intermediate stations of the section.

Stable, reliable operation of intermediate stations for the acceptance of trains can be provided in the presence of free main and one receiving-and-departure track (duplicate element). In case of a failure (train stopping at the station for any reason), it is always possible to let the next trains to pass from this reserve track.

The maximum number of trains left at the station should not exceed the total number of available tracks, minus one track for each direction at each intermediate station. In this case, one can use sidings, branches of enterprises with seasonal work.

Fig. 1 shows a fragment of the graph of traffic delay. At the limited number of (only one) run-around tracks at the pre-section and other intermediate stations due to the delay of not accepting the first train going in a pack, the following trains are placed for run-around at the previous intermediate stations. At this, even in the case of favorable acceptance of trains from the section, in the future there is a loss of carrying capacity Δ_{pas}^{r-a} , caused by nonidentity of the runs and the difference in the time of passage of the freight and passenger trains.

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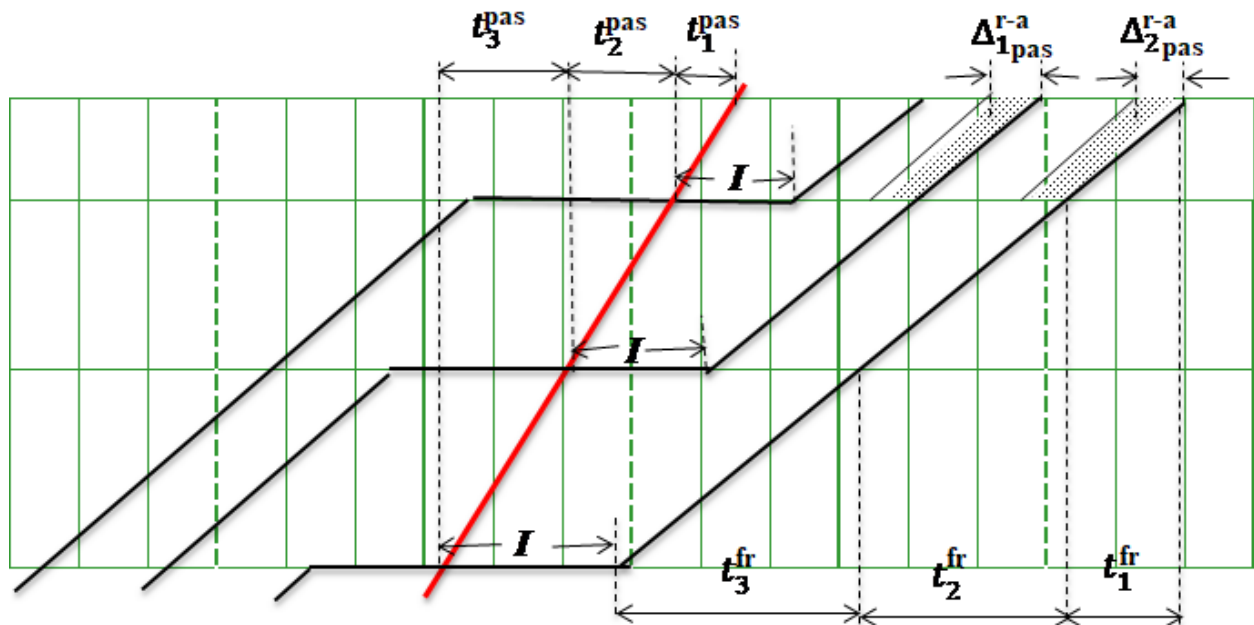


Fig. 1. Delay because of non-acceptance of the first train

Time losses not used for train movement will equal to:

$$\Delta_{1pas}^{r-a} = (I + t_2^{fr} + t_1^{fr}) - (t_2^{pas} + I + t_1^{fr} + I),$$

or

$$\Delta_{1pas}^{r-a} = t_2^{fr} - t_2^{pas} - I, \quad (1)$$

where t_1^{fr} – is the time of freight train movement on the first run (t_2^{fr} – on the second, etc.); t_1^{pas} – is the time of passenger train movement on the first run (t_2^{pas} – on the second, etc.); I – is the succession time.

Accordingly, time losses during the passage of freight train from the third station will equal:

$$\Delta_{2pas}^{r-a} = t_3^{fr} - t_3^{pas} - I. \quad (2)$$

The negative value of the results obtained by formulas (1) and (2) indicates that there will be no time losses and, therefore, carrying capacity.

As a rule, the last runs before the section stations has less time of movement than other runs at the section. It should be pursued further, because most often complications in train movement arise because of their non-acceptance by technical stations.

Fig. 2 shows that if there is a required tracks reserve at the intermediate pre-section station, trains freely pass to it. After passage of passenger train under favorable conditions of its acceptance by station, the run is used without losses of carrying capacity. The general time of train delay is reduced per value of the total value of losses associated with the run-arounds of freight trains by passenger ones.

In practice, a situation shown in Fig. 3 often arises. Due to the non-acceptance by the section station, freight trains are already placed for the run-around by a passenger train, and it is possible to receive a freight train from the section before a passenger one.

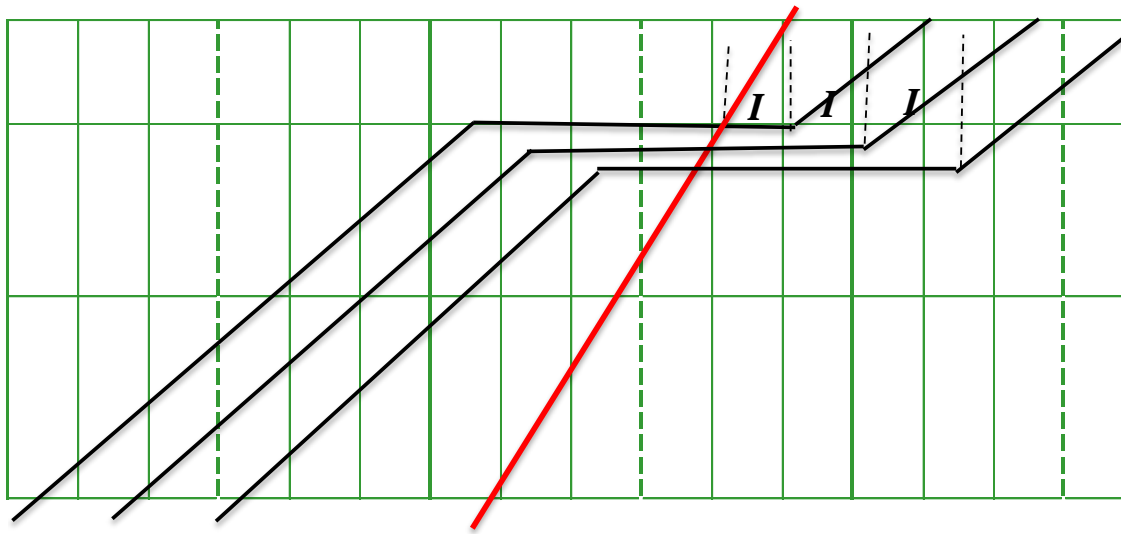


Fig. 2. Availability of the required reserve of tracks

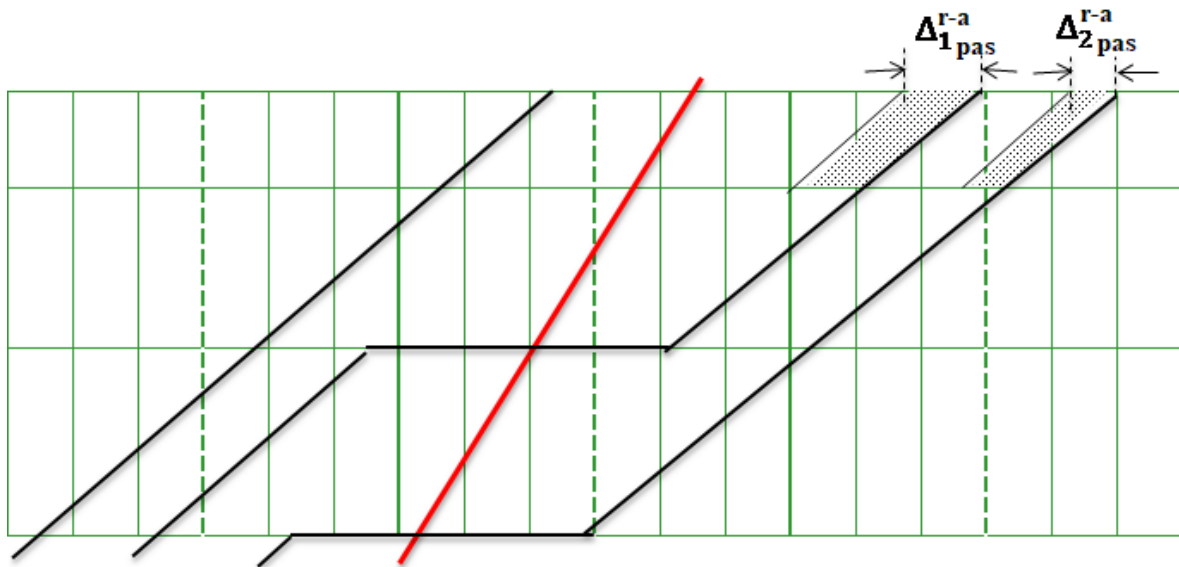


Fig. 3. Possibility of acceptance of a freight train before a passenger one

In this case, as shown in Fig. 3, after passage of a passenger train at the pre-junction station, there are no available trains and, even in case of favorable acceptance, its carrying capacity is not used. The availability of reserve receiving-and-departure tracks at pre-section intermediate stations will create the necessary «support» for trains.

An analysis of the work of freight-loaded sections also indicates the expediency to equip the run-arounds before the technical stations by either-direction automatic block system. In practice, there

is often a need to pass a passenger or other urgent train, but the right run-around track is occupied. Passing along the wrong track takes a lot of time for execution of train documentation. Often, there are no access tracks required for implementation of this regulatory measure at both intermediate and section stations. In this connection, one should foresee double dispatching access tracks on both sides of the pre-section intermediate stations, as well as the floating specialization of the receiving-and-departure tracks. Such rearrangement of the necks of pre-section intermediate stations should

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be carried out now, without waiting for a comprehensive solution of the issues of improving the train sections reliability.

In future, the automatic control of the low-density stations of the section can be transferred to the principal stations (according to the principle of dispatching centralization). This will make it possible to quickly cover the costs of modernization due to the payroll budget economy, as well as to stimulate the work of the train dispatchers, duty officers at the principal stations of the operational zone.

The organization of the operational zone for controlling the train movement on the ground significantly reduces the information flows and facilitates the work of the section's train dispatchers, will create the necessary conditions for creative decision-making for inter-sectional regulation, will contribute to increasing service speed of train movement.

The principle diagram of the transmission of the source information may look in the following

way. In addition to the section stations, two pre-section intermediate stations located at the ends of the section and one or two principal stations of the operational zone carry out the direct negotiations with the train dispatcher of the section. The allocation of the operational zone at the sections does not require any capital investments, since the existing communication lines can be used for data transmission.

The reduction of the number of information sources upon the availability of modern communication of the principal stations with the train dispatcher of the section also creates better conditions for automation of the process of movement graph plotting. With the allocation of the operational area on the section, there is no need to reflect the trains passing through the stations located inside them, except the cases where these stations carry out run-arounds and other regulating measures. It will be sufficient to note only the time when trains enter the operational zone and leave it, as shown in Fig. 4.

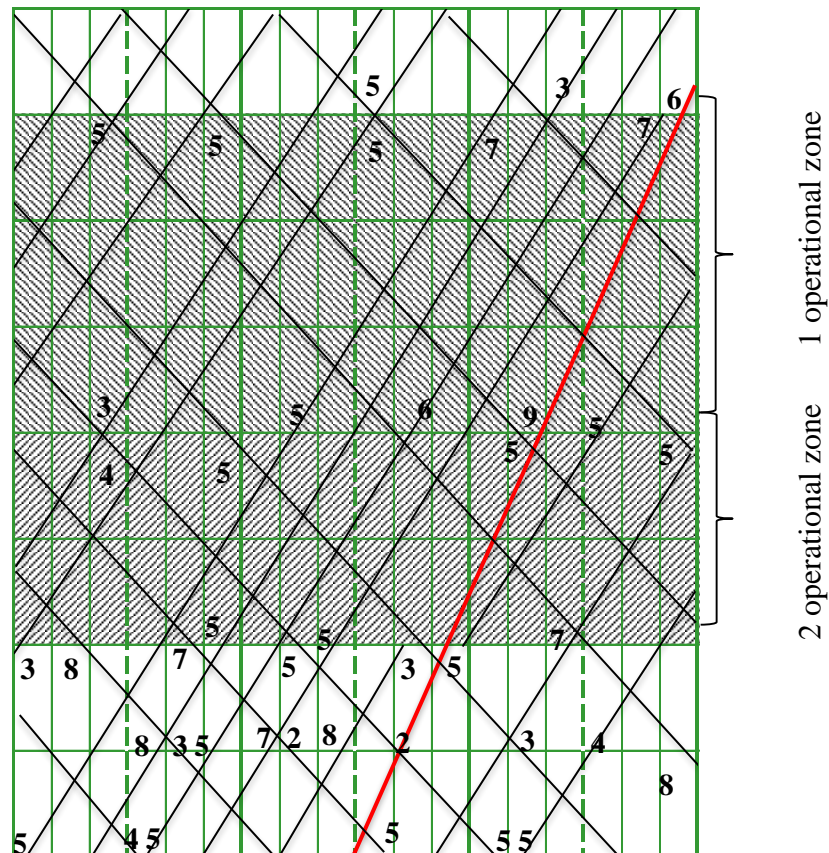


Fig. 4. Train passage through the operational zones

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Maintenance of the graph (displaying the lines of train passage through the section) can be entrusted to operators. This will considerably extend the range of people who are in urgent need of current information about the course of train work at the sections (ДІП, chiefs and senior dispatchers of the traffic departments, etc.).

The measures to improve the reliability of train sections operation considered in the article will accelerate the passage of car traffic volumes, improve the conditions and increase the efficiency of the work of train dispatchers.

The railways face a complex task of tying up the forecast of electricity consumption with the forecast of transportation volumes. Since the transportation process is influenced by many factors, the Ukrainian railways may have additional economic costs due to the overestimation or understatement of the declared norms of electricity consumption.

The use of two-zone or three-zone tariffs gives an effect not only with the steady and uniform filling of the daily traffic schedule, but also at the intensity of movement above the level determined by the specific conditions. In this context, it is the various optimization measures for regulating the train movement schedule that are relevant.

The capacities of the receiving-departure tracks at the section stations are extremely limited. The occupancy of the run-around tracks by out-of-work trains prevents carrying out any regulating measures inside the section. Trains pass one after another without giving priority, that is, they pass through the section in the order in which they entered it. Frequently, due to the limited number of tracks at the pre-section intermediate station, freight trains are placed for run-around by the passenger ones at the distant approaches. This leads to a loss of service speed and reduces the level of utilization of the sections' working capacity.

Originality and practical value

To improve the management of train stations, it is expedient to divide them into operational zones. In each zone, consisting of two or three run-arounds, the duty officer of the principal station, performing in this case the functions of the train dispatcher, can control the train movement. He

determines the order of train passage within the zone, maintains a schedule of performed traffic, informs the train dispatcher of the section about the passage of trains through the operational zone according to the established procedure, and receives from him instructions on intra-zone regulation of train traffic.

For the development of pre-section intermediate stations, it is necessary to provide construction of one or two tracks for receiving multiple trains. Uncoupling them at the stations' runs always leads to lower carrying capacity. The presence of stations capable of performing separation operations at the ends of the sections will facilitate the application of already well-known at the railways method of inter-sectional regulation of train movement. Thus, the construction of reserve tracks at pre-section stations increases the possibility of inter-sectional regulation of trains, provides a significant economy of train-hours and increases the service speed.

One can also place the trains from technical stations that are idle due to uneven traffic, especially from the terminal stations (division points) of locomotive circulation sections on the reserve tracks of pre-section intermediate stations. The laying of such tracks and their maintenance, taking into account the periodicity of use and reduced permissible movement speed, for example, 10-15 km/h, can be allowed according to less tight standards for the construction of the roadbed, ballast section, sleeper density, taking into account the use of switches and decommissioned tracks, etc. If necessary, the parks of reserve tracks designed for hold of the out-of-work trains that are placed for run-around, can be located outside the station area, using a favorable terrain.

Conclusions

Increasing the capacity of all railways transport enterprises of Ukraine in modern conditions and in the future means, first of all, increasing the carrying and transportation capacity of the most freight-loaded railway lines. Taking into account the projected volumes of transportation at railways, considerable work should be done on the modernization and replacement of outdated equipment, to continue the electrification of

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freight-loaded lines, to introduce modern ATC equipment, to extend the station tracks at the courses of heavy, long and multiple trains, to constantly improve the technology of cargo and passenger transportation, etc. The phased implementation of such a complex and wide-

ranging program will enable PJSC «Ukrainian Railway» to master the growing cargo turnover in the direction of transport corridors and seaports and provide high-quality transport services to cargo owners and population.

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УДОСКОНАЛЕННЯ ДИСПЕТЧЕРСЬКОГО РЕГУЛЮВАННЯ РУХУ ПОЇЗДІВ ЗА ДОПОМОГОЮ ВВЕДЕННЯ ОПЕРАТИВНИХ ЗОН

Мета. У роботі необхідно дослідити доцільність передачі автоматичного керування малодіяльними станціями дільниці (за принципом диспетчерської централізації) черговим по опорних станціях. **Методика.** У статті проаналізована робота вантажонапружених дільниць ПАТ «Українська залізниця». Виявлено, що інформаційна завантаженість диспетчерів, що керують рухом поїздів на дільницях головного ходу, повсякчас перевищує допустимий рівень. Досліджено можливість використання технології диспетчерського регулювання руху поїздів за допомогою введення оперативних зон. **Результати.** Виявлено, що ємності приймально-відправних колій на станціях дільниці вкрай обмежені. Займання обгінних колій «залишеними» поїздами заважає проведенню будь-яких регулювальних заходів усередині дільниці. Поїзди слідує один за одним без надання пріоритету, тобто слідує по дільниці в тому порядку, в якому вони надійшли на неї. Через обмежену кількість колій на переддільничній проміжній станції вантажні поїзди розставляють під обгін пасажирськими на далеких підходах. Це призводить до втрат дільничної швидкості й знижує рівень використання пропускну здатності дільниць. Уведення оперативних зон значно скоротить інформаційні потоки й полегшить працю поїзних диспетчерів дільниці, створить необхідні умови для творчого прийняття рішень із внутрішньодільничного регулювання, сприятиме підвищенню дільничної швидкості руху поїздів. **Наукова новизна.** У статті розроблена нова технологія вдосконалення управління поїзними дільницями шляхом розділення їх на оперативні зони. У кожній зоні, що складається з двох-трьох перегонів, рухом поїздів може керувати черговий опорної станції, що виконує в цьому випадку функції поїзного диспетчера. **Практична значимість.** Запропоновано на резервні колії переддільничних проміжних станцій виставляти состави з технічних станцій, які простояють у зв'язку з нерівномірністю руху, особливо з кінцевих станцій (стикових пунктів) дільниць обігу локомотивів. Укладання резервних колій і їх утримання, урахуваючи періодичність використання й зменшену допустиму швидкість руху, можна дозволити за менш жорсткими нормами влаштування земляного полотна, баластної призми, епюри шпал, з урахуванням використання стрілочних переводів та колій, знятих з експлуатації.

Ключові слова: графік руху поїздів; диспетчерське керування; вантажні поїзди; час затримки поїздів; опорна станція

ЕКСПЛУАТАЦІЯ ТА РЕМОНТ ЗАСОБІВ ТРАНСПОРТУ

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УСОВЕРШЕНСТВОВАНИЕ ДИСПЕТЧЕРСКОГО РЕГУЛИРОВАНИЯ ДВИЖЕНИЯ ПОЕЗДОВ С ПОМОЩЬЮ ВВЕДЕНИЯ ОПЕРАТИВНЫХ ЗОН

Цель. В работе необходимо исследовать целесообразность передачи автоматического управления малоделятельными станциями участка (по принципу диспетчерской централизации) дежурным по опорным станциям. **Методика.** В статье проанализирована работа грузонапряженных участков АО «Украинская железная дорога». Выявлено, что информационная загруженность диспетчеров, управляющих движением поездов на участках главного хода, постоянно превышает допустимый уровень. Исследована возможность использования технологии диспетчерского регулирования движения поездов посредством введения оперативных зон. **Результаты.** Выявлено, что емкости приемо-отправочных путей на станциях участка крайне ограничены. Занятие обгонных путей «оставленными» поездами мешает проведению любых регулирующих мер внутри участка. Поезда следуют друг за другом без предоставления приоритета, то есть следуют по участку в том порядке, в котором они поступили на нее. По причине ограниченного количества путей на передучастковой промежуточной станции грузовые поезда расставляют под обгон пассажирскими на дальних подходах. Это приводит к потерям участковой скорости и снижает уровень использования пропускной способности участков. Введение оперативных зон значительно сократит информационные потоки и облегчит труд поездных диспетчеров участка, создаст необходимые условия для творческого принятия решений по внутренне-участковому регулированию, будет способствовать повышению участковой скорости движения поездов. **Научная новизна.** В статье разработана новая технология совершенствования управления поездными участками путем разделения их на оперативные зоны. В каждой зоне, состоящий из двух-трех гонок, движением поездов может управлять дежурный опорной станции, выполняющий в этом случае функции поездного диспетчера. **Практическая значимость.** Предложено на резервные пути передучастковых промежуточных станций выставлять составы с технических станций, которые простаивают в связи с неравномерностью движения, особенно с конечных станций (стыковых пунктов) участков обращения локомотивов. Укладку резервных путей и их содержание, учитывая периодичность использования и уменьшенную допустимую скорость движения, можно позволить за менее жесткими нормами устройства земляного полотна, балластной призмы, эпюры шпал, с учетом использования стрелочных переводов и путей, снятых с эксплуатации.

Ключевые слова: график движения поездов; диспетчерское управление; грузовые поезда; время задержки поездов; опорная станция

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