ЕКОНОМІКА ТА УПРАВЛІННЯ

UDC 656.222

G. YA. MOZOLEVICH[1*]

[1*]Dep. «Stations and Junctions», Dnipropetrovsk National University of Railway Transport named after Academician
V. Lazaryan, Lazaryan St., 2, Dnipropetrovsk, Ukraine, 49010, tel. +38 (056) 373 15 12, e-mail MrMozG81@mail.ru

OPERATIONAL DISTRIBUTION OF THE TRAIN TRAFFIC VOLUME ON THE SECTIONS OF RAILWAY OPERATING DOMAIN

Purpose. The task of the operational distribution of train traffic volume on the sections of operating domain is the optimization one. It is solved in the operational conditions by the dispatch station. The article sets the problem of formalizing and finding the new ways to solve this urgent problem. **Methodology**. A new approach to solving the problem of operational distribution of train traffic volume on the sections of the rail network with a choice of routes for all train traffics was proposed. **Findings**. A study of possible routes for the train traffic handle on the operating domain used for mass freight transportations between Krivyi Rih and Donbas was carried out. The use of the proposed method allowed us to obtain a rational distribution of trains on the rail network sections. **Originality.** The method of train traffic volume distribution in the network under operational conditions was improved. The method, as opposed to the current one allows one to select the route of separate units handle (according to the criteria of the weighted average cost for 1 ton of cargo). **Practical value**. The use of the proposed technology of the operational distribution of train traffic volume will increase the efficiency of the railways in general and ensure the competitiveness of rail transportations. The methodology implementation involves the use of railway dispatch station for the automated workplaces with appropriate informational support.

Keywords: train traffic volume distribution; train traffic volume; profit of railways; route selection; optimization task; operating domain

Introduction

Formation of profitable mechanism in the field of freight transportation in the conditions of transport market functioning involves minimizing of their costs. This requires the development of both new technologies and new approaches to the organization of the train traffic volume, operational management improvement [2, 7]. Selection problem of the rational traffic volume distribution over the network sections is the optimization one. A considerable number of scientific papers is devoted to its solution. [1, 5, 6, 9, 10]. The scientists solved this problem in the conditions of motion in the network of indivisible elements (liquid, gas, etc.) and separate units of the traffic volume (trains, cars). Other papers propose the solution of this problem in the conditions of owner interest of separate network sections.

General distribution of train traffic volume over railway domain can be implemented according to the criterion of total profits of railways and it can be directed to the railway profitability increase. But in the conditions of constant change of train situations in the domain sections the obtained distribution may be ineffective. That is why train dispatchers have to correct it in conditions of operational change of train situation and to determine the rational routes for train handling according to additional selection criteria.

Purpose

The purpose of the article is the search for new approach concerning solution of the urgent problem of operational distribution of train traffic volume over the sections of railway network with a choice of routes for all traffic units.

Methodology

The weighted average cost of 1 ton of cargo in the freight train set is proposed to use as the selection criterion. This criterion can ensure handle of more valuable cargo weight on the fastest routes. This allows the increase of cargo turnover at the sections and speed up the movement of circulating assets of cargo owners.

Each cargo owner tends to accelerate the turnover of their funds by the reduction of procurement time, manufacturing of cargo transportation and sales, so the delivery speed of cargo is very important in the period of its life cycle.
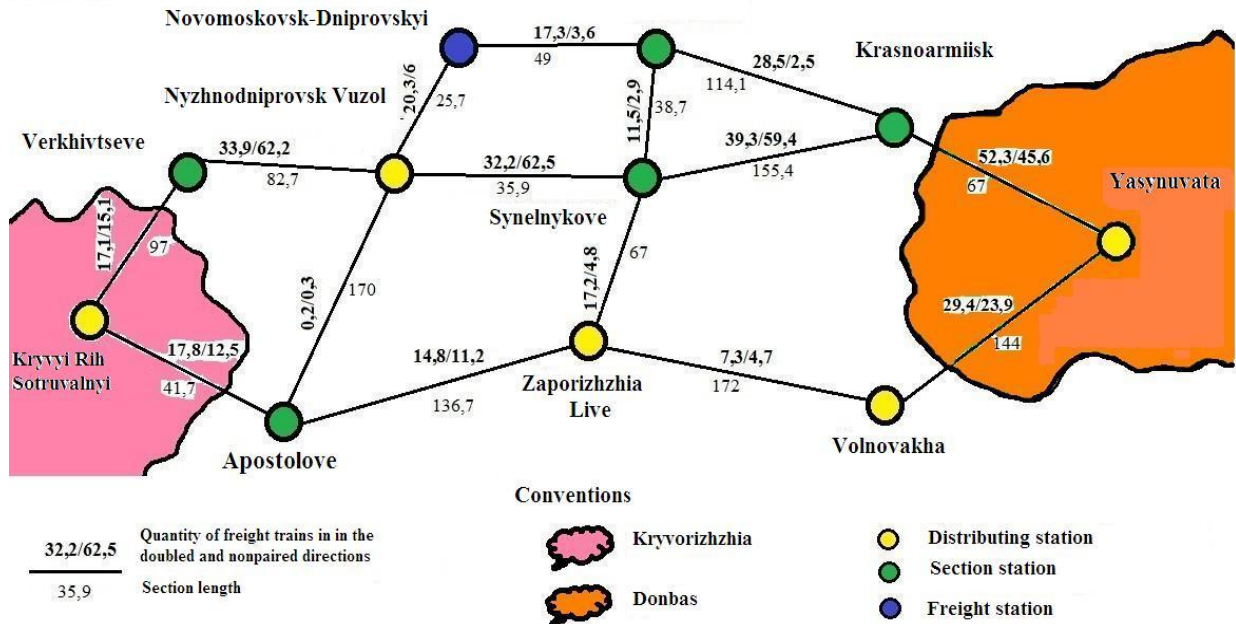
ЕКОНОМІКА ТА УПРАВЛІННЯ

Fig. 1. General structure of operating domain and amount of freight train traffic according to directions
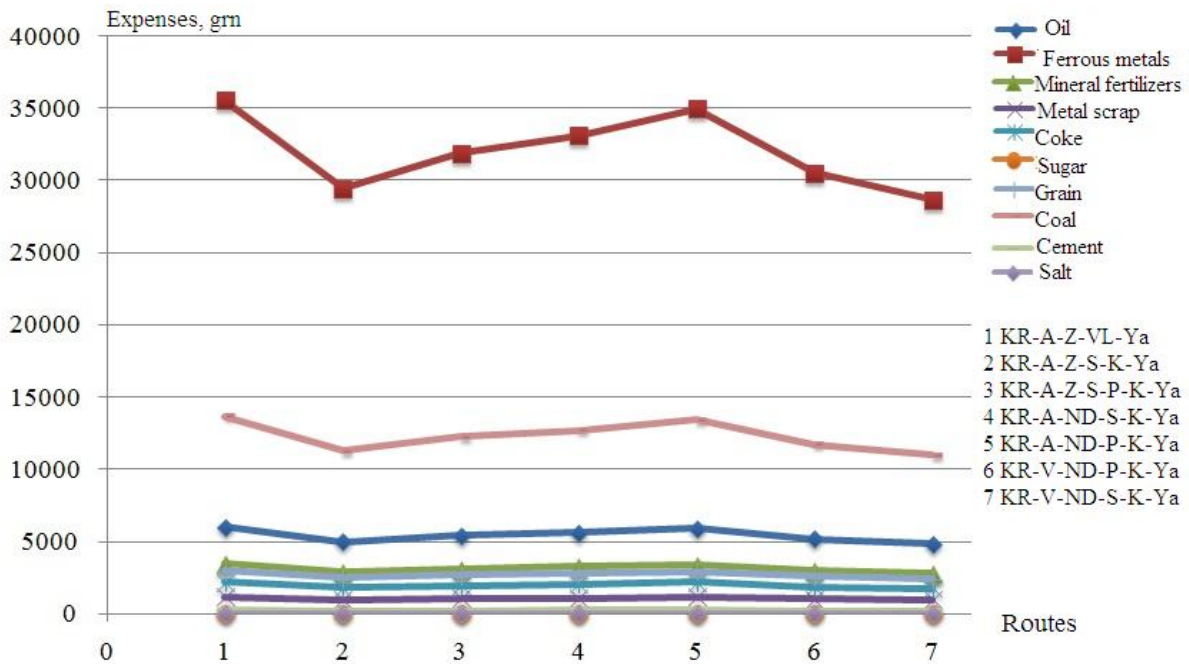

Fig. 2. Cost dependency of the cargo owners on train routes

Customer costs, which are used in cargo motion can be determined by the formula:

$$C_{\text{в}} = Aqc_{\text{т}}d_{\text{ст}}t_{\text{дост}},\qquad(1)$$

where A – is a daily train traffic in one direction of the given cargo type, weight; q – is the average loading of the car on the direction, tn; $c_{\text{т}}$ – is a weighted average cost for the one ton of cargo, grn; $d_{\text{ст}}$ – is a discount rate; $t_{\text{дост}}$ – is the average time of cargo when moving from the dispatch station to the destination one.

ЕКОНОМІКА ТА УПРАВЛІННЯ

The weighted average cost of one ton of cargo is determined using the formula [5]:

$$C_{\text{в}} = \sum_{j=1}^{k} \alpha_j c_{\text{вант}j} , \qquad (2)$$

where j – is a cargo type; α_j – is a cargo share of the j type from the total cargo volume in the train; $c_{\text{вант}j}$ – is an average cost of the j cargo.

Findings

The operating domain connecting the industrial regions of Kryvyi Rih and Donbas is the research object. The Fig. 1 shows the network sections that can be used for train handling. Each section is described by the length parameters and the number of trains running in the doubled and nonpaired directions.

For the operating domain the structure of cargo volume was analyzed, the costs for each cargo type and the general traffic volumes with the distribution according to the cargo type was determined [3]. On the basis of the obtained data the weighted average cost for 1 tn of cargo in the particular train was determined. It is equal $C_{\text{в}} = 3\,020$ grn/tn. In addition to solve the problem the daily cargo volume according to the cargo type and the term of train running in the particular route were determined. Results of expense calculations for customers of cargo in motion depending on handle routes are shown in Fig. 2.

Analysis of the calculations shows that the cargo cost has quite a significant impact on costs of cargo owners. Reduce in transportation term by 1-3 hours may cost cargo owners several thousand UAH excluding the expenses for rolling stock. For the railway, in turn, it is more profitable to retain customers, transporting cargo of great cost because the rates for transporting are proportional to the cost. So it is recommended to pass the trains with more expensive cargo by the shortest routes.

Originality and Practical Value

The method of train traffic volume distribution in the network in operational conditions was improved. As opposed to the existing ones it allows choosing a route for handle of separate units of traffic volume according to the criterion of 1 ton of weighted average cost of the cargo in train set.
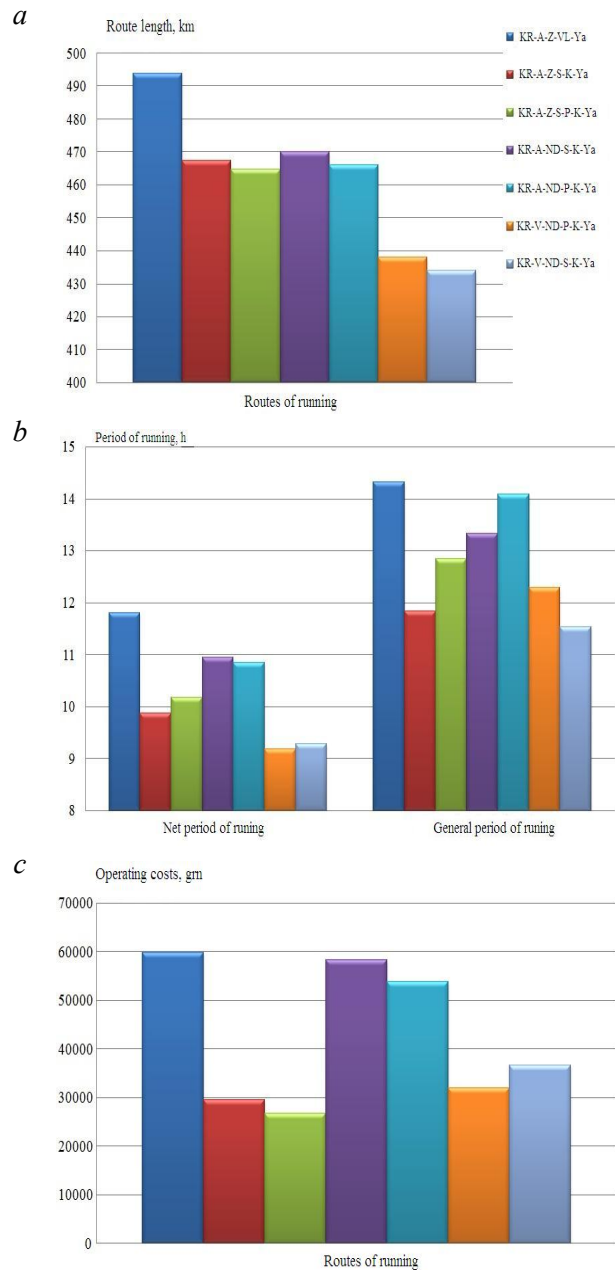
Fig. 3. Comparison of the possible routes for traffic volume handle in the domain:
a – total lengthes of routes in the domain; *b* – time histograms of the freight trains depending on the routes of running; *c* – histogram of operating costs for one train handle depending on the routes of running

Taking into account the multiple circuit of railways and a large number of variants for handle of the particular train, the train and road dispatchers should cope with the task of determining the optimal route for a separate train and improvement of general operation performance of the domain sections. Most often,

ЕКОНОМІКА ТА УПРАВЛІННЯ

when the problem arises, dispatchers are governed by regulatory documents (Plan for Train Formation, Schedule of train movement, etc.), which can not account all the changes of the train situation on the handle routes. First of all this affects the reduction of operation performance and the level of railway profitability. When the problem of distribution can not be solved by recommendations of regulatory documents, dispatcher takes operational decision on train distribution based on his own experience, but not always it gives maximal results.

As for the rationalization of freight trains handle it is proposed to take into account such criterion as the weighted average cost for 1 ton of cargo in the train and the load capacity of handle route sections. That is, when the problem of the separate train handling arises, the possible routes of the train running between stations of departure and destination are determined. The period of train running for each route is estimated using a model of railway domain or its separate directions [4, 8, 11, 12 13], load capacity of the section and weighted average cost for 1 ton of cargo in the train. This should provide the appropriate software equipment for AWM (automated work place) of dispatcher. According to these criteria, trains with more expensive cargo are departed by the shortest routes considering the load capacity of route sections. Research shows that with the load

capacity of the shortest route section of 85% and up, it is excluded from the priority variants and can be used in accordance with appropriate load capacity of all other routes only.

For the railway domain between the stations Kryvyi Rih Sortuvalnyi – Yasynuvata the main routes of freight trains running and the total period of running for a separate train with standard loading of sections, as well as the total operating costs for one train handle on the routes of running were determined.

Graphical comparison of routes is presented in Fig. 3.

Based on the obtained dependencies, one can conclude that it is reasonable to handle the trains with more expensive cargo on routes 2 and 3. Although they are not the shortest and the fastest the total operating costs are much lower than the faster routes 6 and 7. The train handle on routes 1, 4 and 5, which differ by significant cost and long period of transportation is not reasonable at all. First of all it is caused by the fact that the sections with diesel locomotive traction are included into the route. Therefore, one should handle the trains with relatively low weighted average cost for 1 ton of cargo in the train on these routes. These routes should only be used when the other ones are loaded. The general distribution of train traffic volume on the domain sections is presented on Fig. 4.
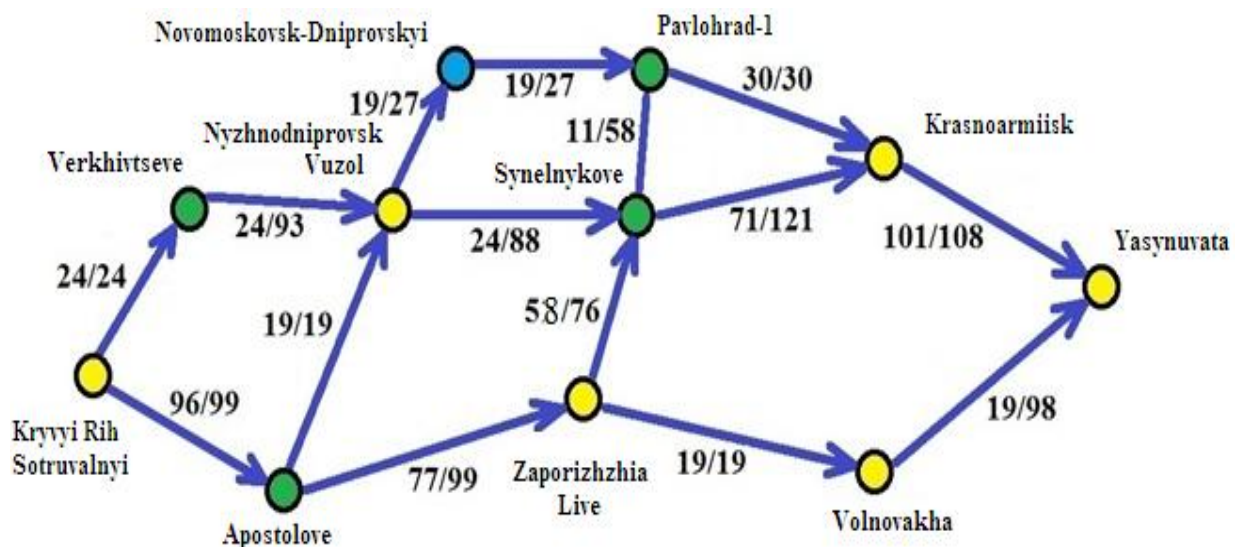

Fig. 4. Rational distribution of train traffic volume on domain.
a/c – distributed number of freight trains / maximum number of freight trains, which can be handled on the section including technical equipment and volumes of passenger trains traffic

Conclusions

The article determines and analyzes additional expenses of cargo owners related to the use of funds to purchase the cargoes that are in the process of transportation. It was determined the connection between increase of the cargo delivery speed and decrease of these costs by the rational distribution of train traffic volume between the routes according to the criterion of the weighted average cost for 1 ton of cargo in the train. First of all, the technology will help the dispatch service of railways and the directions to carry out operational distribution of train traffic volume between the separate stations of the operating domain.

For the Ukrzaliznytsia in general the technology of operational distribution can serve as additional "lever" of competitive growth during cooperation with the cargo owners.

LIST OF REFERENCE LINKS

1. Босов, А. А. Визначення раціональних маршрутів руху поїздів на мережі доріг / А. А. Босов, Ю. В. Чибісов // Вісн. Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. – Д., 2010. – Вип. 34. – С. 180–188.
2. Бутько, Т. В. Методологічний підхід до формування логістичних технологій на залізничному транспорті / Т. В. Бутько, Д. В. Ломотько // Залізн. трансп. України. – 2010. – № 4. – С. 47–49.
3. Державний комітет статистики. [Електронний ресурс]. – Режим доступу: http://www.ukrstat.gov.ua. – Назва з екрану.
4. Козаченко, Д. М. Моделювання роботи залізничного напрямку / Д. М. Козаченко, Г. Я. Мозолевич, О. В. Власюк // Вісн. Дніпропетр. нац. ун-ту залізн. трансп. ім. акад. В. Лазаряна. – Д., 2009. – Вип. 28. – С. 143–148.
5. Мозолевич, Г. Я. Підвищення ефективності вантажних перевезень на залізничній мережі / Г. Я. Мозолевич, Ю. В. Чибісов. – Д. : Вид-во Маковецький Ю. В., 2013. – 172 с.
6. Поттгофф, Г. Теория транспортных потоков / Г. Поттгофф ; под ред. Е. П. Нестерова. – М. : Транспорт, 1975. – 342 с.
7. Практичний посібник з упровадження технолого-економічної моделі перевізного процесу. – К. : Голов. упр. перевезень, 2009. – 270 с.
8. Скалозуб, В. В. О приближенной декомпозиции NP-полных задач управления сложными процессами / В. В. Скалозуб, А. А. Бардась, М. В. Скалозуб // Системні технології. Регіональний міжвузівський зб. наук. пр. – 2011. – № 4 (75). – С. 174−184.
9. Чибісов, Ю. В. Вибір раціональних варіантів пропуску поїздопотоку по паралельних залізничних лініях за економічним критерієм / Ю. В. Чибісов // Вісн. НТУ «ХПИ». – Х., 2012. – Вип. 68. – С. 151–155.
10. Чибісов, Ю. В. Математична модель вибору раціональних варіантів пропуску поїздопотоків по залізничній мережі / Ю. В. Чибісов, Г. Я. Мозолевич // Восточно-европ. журн. передовых технологий. – 2012. – № 3/11 (57). – С. 37–41.
11. Campbell, S. Modeling and Simulation in Scilab/Scicos / S. Campbell. – New York : Springer, 2006. – 313 p.
12. Nesterenko, G. I. Optimal route selection when distributing the freight trainflow in the railway junction with the consideration of the level of the traffic capacity saturation / G. I. Nesterenko, Yu. V. Chibisov // Вісн. Східноукр. нац. ун-ту ім. В. Даля. – 2012. – № 3 (174) – С. 138–143.
13. Newman, M. The structure and function of complex networks / M. Newman // SIAM Rev. – 2003. – № 45. – P. 167–256.

Г. Я. МОЗОЛЕВИЧ[1*]

[1*]Каф. «Станции и узлы», Днепропетровский национальный университет железнодорожного транспорта имени академика В. Лазаряна, ул. Лазаряна, 2, Днепропетровск, Украина, 49010, тел. +38 (056) 373 15 12, эл. почта MrMozG81@mail.ru

ОПЕРАТИВНОЕ РАСПРЕДЕЛЕНИЕ ПОЕЗДОПОТОКОВ ПО УЧАСТКАМ ЖЕЛЕЗНОДОРОЖНОГО ПОЛИГОНА

Цель. Задача оперативного распределения поездопотоков по участкам разветвленного железнодорожного полигона является оптимизационной, решаемой в оперативных условиях диспетчерским аппаратом. Цель статьи – формализация и поиск новых путей решения этой актуальной задачи. **Методика**. Предложен новый подход к решению задачи оперативного распределения поездопотоков по звеньям железнодорожной сети

ЕКОНОМІКА ТА УПРАВЛІННЯ

с выбором маршрутов для всех единиц поездопотоков. **Результаты**. Проведено исследование возможных маршрутов пропуска поездопотоков по железнодорожному полигону, используемому для массовых перевозок грузов между Криворожьем и Донбассом. Применение предложенной методики позволило получить рациональное распределение поездов по участкам сети. **Научная новизна.** Усовершенствован метод распределения потоков поездов на сети в оперативных условиях, который в отличие от существующих позволяет выбрать маршрут пропуска отдельных единиц потока по критерию средневзвешенной стоимости 1 т груза в составе. **Практическая значимость**. Использование предлагаемой технологии оперативного распределения поездопотоков повысит эффективность функционирования железных дорог в целом, обеспечит конкурентоспособность железнодорожных перевозок. Реализация методики предполагает использование диспетчерским аппаратом железных дорог автоматизированных рабочих мест с соответствующим информационным обеспечением.

Ключевые слова: распределение потоков; поездопоток; прибыль железных дорог; выбор маршрутов; задача оптимизации; железнодорожный полигон

Г. Я. МОЗОЛЕВИЧ[1*]

[1*]Каф. «Станції та вузли», Дніпропетровський національний університет залізничного транспорту імені академіка
В. Лазаряна, вул. Лазаряна, 2, Дніпропетровськ, Україна, 49010, тел. +38 (056) 373 15 12, ел. пошта MrMozG81@mail.ru

ОПЕРАТИВНИЙ РОЗПОДІЛ ПОЇЗДОПОТОКІВ ПО ЛАНКАХ ЗАЛІЗНИЧНОГО ПОЛІГОНУ

Мета. Задача оперативного розподілу поїздопотоків по ланках розгалуженого залізничного полігону є оптимізаційною, що вирішується в оперативних умовах диспетчерським апаратом. Метою статті є формалізація та пошук нових шляхів розв'язання цієї актуальної задачі. **Методика.** Запропоновано новий підхід щодо розв'язання задачі оперативного розподілу поїздопотоків по ланках залізничної мережі з вибором маршрутів для всіх одиниць поїздопотоку. **Результати.** Виконано дослідження можливих маршрутів пропуску поїздопотоків по залізничному полігону, який використовується для масових перевезень вантажів між Криворіжжям та Донбасом. Застосування запропонованої методики дозволило отримати раціональний розподіл поїздів по ланках мережі. **Наукова новизна.** Удосконалено метод розподілу потоків поїздів на мережі в оперативних умовах, що на відміну від існуючих дозволяє обрати маршрут пропуску окремих одиниць потоку за критерієм середньозваженої вартості 1 т вантажу в составі. **Практична значимість.** Використання запропонованої технології оперативного розподілу поїздопотоків підвищить ефективність функціонування залізниць в цілому, забезпечить конкурентоспроможність залізничних перевезень. Реалізація методики передбачає використання диспетчерським апаратом залізниць автоматизованих робочих місць з відповідним інформаційним забезпеченням.

Ключові слова: розподіл потоків; поїздопотік; прибуток залізниць; вибір маршрутів; завдання оптимізації; залізничний полігон

REFERENCES

1. Bosov A.A., Chybisov Yu.V. Vyznachennia ratsionalnykh marshrutiv rukhu poizdiv na merezhi dorih. [Definition of rational train routs on the roads network]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan], 2010, issue 34, pp. 180-188.
2. Butko T.V., Lomotko D.V. Metodolohichnyi pidkhid do formuvannia lohistychnykh tekhnolohii na zaliznychnomu transporti [Methodological approach to logistics technologies formation for railway transport]. *Zaliznychnyi transport Ukrainy − Railway Transport in Ukraine*, 2010, no. 4, pp. 47-49.
3. *Derzhavnyi komitet statystyky* [State Statistics Committee]. Available at: http://www.ukrstat.gov.ua (Accessed 14 October 2013).
4. Kozachenko D.M., Mozolevych H.Ya., Vlasiuk O.V. Modeliuvannia roboty zaliznychnoho napriamku [Simulation of railway direction operation]. *Visnyk Dnipropetrovskoho natsionalnoho universytetu zaliznychnoho transportu imeni akademika V. Lazariana* [Bulletin of Dnipropetrovsk National University of Railway Transport named after Academician V. Lazaryan], 2009, issue. 28, pp. 143-148.

ISSN 2307–3489 (Print), ISSN 2307–6666 (Online)

Наука та прогрес транспорту. Вісник Дніпропетровського
національного університету залізничного транспорту, 2013, вип. 5 (47)

ЕКОНОМІКА ТА УПРАВЛІННЯ

5. Mozolevych H.Ya., Chybisov Yu.V. *Pidvyshchennia efektyvnosti vantazhnykh perevezen na zaliznychnii merezhi* [Improving the efficiency of freight traffic on the railway network]. Dnipropetrovsk,Vyd-vo Makovetskyi Publ., 2013. 172 p.

6. Pottgoff G., Nesterov Ye.P. *Teoriya transportnykh potokov* [The theory of traffic flow]. Moscow, Transport Publ., 1975. 342 p.

7. *Praktychnyi posibnyk z uprovadzhennia tekhnoloho-ekonomichnoi modeli pereviznoho protsesu* [A practical guide on adoption of technological and economic model in transportation process]. Kyiv, Holovne upravlinnia perevezen Publ., 2009. 270 p.

8. Skalozub V.V., Bardas A.A., Skalozub M.V. O priblizhennoy dekompozitsii NP-polnykh zadach upravleniya slozhnymi protsessami [About approximate decomposition of NP-complete problems of management by complex processes]. *Systemni tekhnolohii − System technologies*, 2011, no. 4 (75), pp.174-184.

9. Chybisov Yu.V. Vybir ratsionalnykh variantiv propusku poizdopotoku po paralelnykh zaliznychnykh liniiakh za ekonomichnym kryteriiem [Rational options choice of trail traffic handling on parallel railway lines by economic criterion]. *Visnyk NTU «KhPI»* [Bulletin of National Technical University «Kharkiv Polytechnic Institute»], 2012, issue 68, pp. 151-155.

10. Chybisov Yu.V., Mozolevych H.Ya. Matematychna model vyboru ratsionalnykh variantiv propusku poizdopotokiv po zaliznychnii merezhi [Mathematical model of rational options choice in train traffic handling on railway networks]. *Vostochno-yevropeiskyi zhurnal peredovykh tekhnolohyi − East-European Journal of Advanced Technologies,* 2012, no. 3/11 (57), pp. 37-41.

11. Campbell S. Modeling and Simulation in Scilab/Scicos. New York, Springer Publ., 2006. 313 p.

12. Nesterenko G.I., Chibisov Yu.V. Optimal route selection when distributing the freight trainflow in the railway junction with the consideration of the level of the traffic capacity saturation. *Visnyk Skhidnoukrainskoho natsionalnoho universytetu imeni V. Dalia* [Bulletin of East Ukrainian National University named after Volodymyr Dahl], 2012, no. 3 (174), pp. 138-143.

13. Newman M. The structure and function of complex networks. *SIAM Review*, 2003, no. 45, pp. 167-256.