# ORGANIZATION OF CAR FLOWS IN MARKET CONDITIONS

***Levin, Dmitry Yu.,*** *Russian University of Transport (MIIT), Moscow, Russia.*

## ABSTRACT

In market conditions one of the former main criteria of the system of organizing car flows, which was reduction in the turnover time of cars, has lost its relevance. Now it is necessary to abandon the evaluation of the variants of the train formation plan using costs calculated in reduced car-hours. Therefore, as a replacement, it is offered to fulfill the delivery deadlines. At the same time, in conditions of the privatized car fleet, a combination of criteria for meeting the deadline for the delivery of goods and minimizing the processing of car flows at technical stations was required. In the process of calculating the plan for the formation of one-group trains, all streams of car flows, from the furthest ones, are consistently considered. If the accepted conditions are not met, the procedure of combining distant ones with shorter streams with their processing at one, two, three, etc. stations is performed – until the proper level of organization is achieved.

*Keywords: railway, train formation plan, design norms, combinatorics, terms of cargo delivery, organization of car flows.*

**Background.** *At the beginning of 20th century the theory of organization of car flows arose. And it soon became clear that science deals with a complex and diverse section of exploitation of railways, in improvement of which there is no limit. The tasks formulated in the guidelines for organization of car flows, issued by industry departments in 1967, 1984 and 2007 [1–3], will still serve as beacons for many generations of researchers. And how many new tasks arise?*

*Many problems have not yet been solved for the inventory of cars, and completely new problems have arisen when using own cars. First of all, these are fundamentally different criteria that require other design norms and completely new methods for calculating the plan for formation of trains [4]. In particular, the previous criterion for estimating costs in «reduced car-hours» has lost relevance, and even the use of car-hours in monetary terms does not change the situation.*

**Objective.** *The objective of the author is to consider different issues related to organization of car flows in market conditions.*

**Methods.** *The author uses general scientific and engineering methods, modeling, graph construction, mathematical methods, comparative analysis.*

**Results.**

***I.***

*It is interesting to recall that the goal of not only the organization of flows, but also of the whole operational science was the saving of car-hours. And acceleration of car turnover was regularly established every three to four years by the order of the Minister of Railways under the same number (No. 1C). Acceleration of turnover should be achieved at any cost, including by delaying locomotives, excessive expansion of loading and unloading fronts from the clientele to handle entire routes, etc. This was explained by the inadequate number of cars, and their inefficient use. The solution was one – to squeeze the most out of the existing fleet of cars. This is reflected, including in the theory of the formation plan. The use of car-hours as a criterion at that time was considered an indisputable truth, and if at times they were disputed, they did not offer anything else. Indeed, the car turnover in the USSR has reached six days, while on the US railways – 20 days [5]. In the conditions of continuous growth of freight intensity and acceleration of turnover of cars, alternative solutions were simply not required.*

*With the switch to a for-profit model in the 1980s the roads had to use better not only cars, but also locomotives, economically spend labor resources. With the strategy of optimal operation of railways (labor saving with a maximum of transport products and limited costs), the theory of the formation plan was faced with the need for a comprehensive solution of all problems, i.e. to take into account the costs of traction, to more fully reflect the specifics of the work of railway lines, including delays in trains at stations and sections, the shortage of station tracks, the capacity of lines, etc. For the voyage, an average of 11 technical stations were passed, of which four were marshalling yards. The average daily processing of cars at stations reached unjustifiably large sizes (on average 130 km at technical stations, 400 km – on marshalling yards). But then the theory of the plan of formation did not change.*

*At present, the organization of car flows affects the costs of rail transport because of the failure to meet the deadline for delivery of cargoes and the processing of cars at technical stations. Therefore, it is suggested that these factors should be used as criteria for assessing the organization of car flows.*

*Fulfillment of delivery deadlines is one of the main tasks of JSC Russian Railways. The fulfillment of regulatory deadlines for delivery of cargoes is one of the most important indicators of the quality of rail transport products, and it is it which characterizes the organization of the transportation process.*

*In accordance with the Charter of the Russian Railways, JSC Russian Railways bears material responsibility to the consignees for failure to meet the delivery deadlines and loses a significant part of the revenue due to loss of loading resources. The current procedure for calculating the delivery time is approved by the Russian Ministry of Railways Order No. 27 dated June 18, 2003 and registered with the Ministry of Justice of Russia on June 23, 2003 under No. 4816 [6].*

*For the year, more than 20 000 claims are filed against JSC Russian Railways related to non-fulfillment of delivery deadlines, a penalty for delay in delivery of hundreds of millions of rubles is paid [4].*

*At the same time, in terms of operational performance and regulatory documents, there is no assessment of the delivery of cargoes.*

*Among the main criteria for assessing the current system of organizing car flows, the delivery of cargo is also not fulfilled. In case of delay in the delivery of cargoes, losses are related to inadequate transportation needs and the possibilities of railways, interoperational idle times of cars at technical stations due to ineffective distribution of sorting work between stations, oversaturation of sections by trains and lack of effective levers for operative change of an unfavorable situation.*

Table 1

**The minimum power of assignments of trains being formed (the minimum number of trains per day)**

| $\Sigma t_{exp} + \Sigma t_{tech}$, h | $n_{min}$, trains/day, for $L_{dest}$, km | | | | |
|---|---|---|---|---|---|
| | 100 | 200 | 320–1000 | 1700–3000 | 3900–7000 |
| Marshalling yard | | | | | |
| 2 | 2,34 | 1,81 | 1,06 | 0,64 | 0,52 |
| 4 | 2,74 | 2,06 | 1,13 | 0,66 | 0,53 |
| 6 | 4,40 | 2,40 | 1,22 | 0,68 | 0,54 |
| 8 | 4,74 | 2,94 | 1,34 | 0,70 | 0,55 |
| 10 | 10,21 | 4,00 | 1,48 | 0,73 | 0,56 |
| 12 | – | 7,49 | 1,69 | 0,76 | 0,58 |
| Section station | | | | | |
| 4 | 2,72 | 2,05 | 1,13 | 0,65 | 0,53 |
| 6 | 3,28 | 2,36 | 1,22 | 0,68 | 0,54 |
| 8 | 4,29 | 2,82 | 1,32 | 0,70 | 0,55 |
| 10 | 7,01 | 3,62 | 1,46 | 0,73 | 0,56 |
| 12 | – | 5,60 | 1,64 | 0,76 | 0,58 |
| 14 | – | – | 1,90 | 0,79 | 0,59 |
| Border railway station | | | | | |
| 6 | 3,24 | 2,34 | 1,21 | 0,68 | 0,54 |
| 8 | 4,06 | 2,74 | 1,31 | 0,70 | 0,55 |
| 10 | 5,83 | 3,40 | 1,44 | 0,72 | 0,56 |
| 12 | 16,11 | 4,74 | 1,60 | 0,75 | 0,57 |
| 14 | – | 10,21 | 1,83 | 0,80 | 0,59 |
| 16 | – | – | 2.17 | 0,83 | 0,61 |

## II.

*In the course of reforming the railway transport at the turn of 20th and 21st centuries, the inventory fleet of cars began to decline and in 2011 it disappeared, the cars became private. At the same time, one of the main criteria of the system of organizing car flows – reduction in the turnover time of cars – has lost its relevance. Accordingly, the costs for the organization of car flows, expressed in the reduced car-hours, cannot be a criterion for evaluating the train formation plan.*

*The time norm for transportation of cargoes from the departure station to the destination station is calculated in days. The delivery time consists of the time norms for the operations related to departure and arrival of cargo, its movement through the sections, and the time norms for additional operations (transfer and reception of cargo during transportation through the waterways of the traffic transported in a direct mixed traffic, reloading the cargoes into cars with wheel sets of a different track width, carrying out various types of state control, etc.).*

*Norms of daily run for calculating the time of delivery of cargoes transported within the Russian Federation depend on the range of cargo transportation, the mode of transportation speed and the category of shipment. The standards for determining the delivery time, the procedure for calculating the delivery time are approved by JSC Russian Railways.*

*In order to assess the delivery of goods, in February and September, in the integrated processing of road lists, primary data on the duration of the cargo are processed and analyzed by mechanical sampling of about 10 % of shipments. The data are grouped according to the speed regime (freight, large), the types of traffic (local, direct), the categories of shipments (route, car, small without containers, cargo in containers), the type of cargo and the distance of transportation. The average duration and speed of delivery are calculated per shipment and one ton of cargo, taking into account and without regard to the time of its location at the destination station. At the same time, the average speed of delivery is determined only by the actual, and the average duration of the delivery of the goods, in addition, and regulatory.*

*A. F. Borodin [7], considering the reliability of the technology of the transportation process, suggested using the methodology for controlling and managing the time of delivery of goods, existing in the DISPARC system [8]: legal, technological, control and operational.*

*Legal delivery time is calculated in accordance with the «Rules for Carriage of Goods by Rail» [6] or is established by the contract for transportation in the system of corporate transport services.*

*Technological delivery time is calculated in accordance with the current regulatory organization of freight traffic (the order of the direction of car flows, the plan for the formation and the schedule of train traffic).*

*Control delivery time is set to track the implementation of the delivery term in automated systems.*

*Operational delivery time is a dynamic characteristic of time (in contrast to the «static», indicated above).*

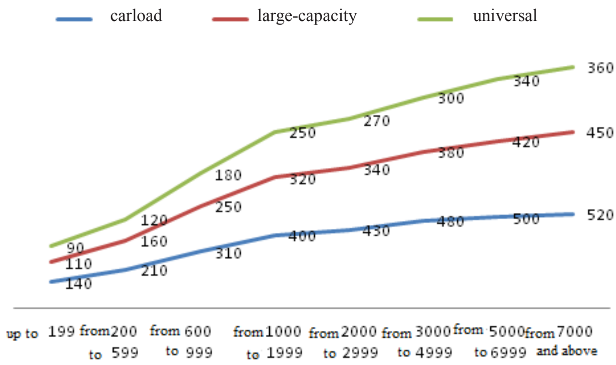
*This division emphasizes the existing contradictions of the possible calculation of the delivery time, but since the railway is responsible for compliance with the standard delivery time, it is reasonable to use it in the calculations of the train formation plan.*

*In the work of A. F. Borodin, A. P. Baturin, V. V. Panin [9] a minimum permissible power standard for train assignments is introduced, based on the standard terms of cargo delivery. Depending on the distance of the destination $L_{dest}$, total duration of idle time of cars with processing (excluding idle time while being accumulated) $\Sigma t_{exp} + \Sigma t_{tech}$ and station type (sorting, section, border) they proposed to determine the minimum power of the assignments for the trains to be formed $n_{min}$ (Table 1).*

**Table 2**

## Norm of daily run of a car

| Transportation distance, km | Norms of daily run by types of shipments, km | | |
|---|---|---|---|
| | Car | Large-capacity refrigerated containers | Universal containers and small dispatches |
| Up to 199 | 140 | 110 | 90 |
| From 200 to 599 | 210 | 160 | 120 |
| From 600 to 999 | 310 | 250 | 180 |
| From 1000 to 1999 | 400 | 320 | 250 |
| From 2000 to 2999 | 430 | 340 | 270 |
| From 3000 to 4999 | 480 | 380 | 300 |
| From 5000 to 6999 | 500 | 420 | 340 |
| From 7000 and above | 520 | 450 | 360 |




***Pic. 1. Norms of daily run of cargo shipments.***

*Table 1 shows the possibility of accounting for the delivery of cargoes during the organization of car flows, but this is still done for the inventory fleet of cars, i. e. taking into account the costs and saving of car-hours.*

*For a private fleet of cars, it is advisable to use the rules for the carriage of cargoes [6], where the norm of the daily run is determined by the freight speed depending on the distance of transportation and the types of shipment (Table 2, Pic. 1).*

*The absolute majority of shipments processed at marshalling yards are carload. Therefore, in the calculations it is expedient to focus on them. The rules for the carriage of goods still show the delivery time at high speed, but such shipments, as a rule, are not processed at marshalling yards and do not participate in calculations of the train formation plan. The terms of delivery of cargo by route shipments are considered separately.*

*It is necessary to take into account the increase in terms of delivery of cargoes provided for by the rules of transportation [6]:*

- *for a day – for operations related to transfer and receipt of goods, in case of carriage of goods with the crossing of waterways (sea, river, strait, lake) on ships and ferries;*
- *for a day – when transferring to another mode of transport, receiving from another mode of transport of goods carried in a direct mixed traffic;*
- *for two days – when cargo is loaded into cars with wheel sets of different track widths;*
- *for a day – when the cars are displaced to wheel sets of a different track width;*
- *for a day – when sending cargoes from the railway stations of the Moscow and St. Petersburg hubs, or the arrival of cars to the railway stations of these hubs, or in case of movement of goods in transit through them;*
- *for a day – in the case of border, customs, sanitary epidemiological, veterinary, phytosanitary and other types of state control exercised at border checkpoints of the Russian Federation.*

*The streams of car flows, allocated for independent assignments of trains, can be equated to route dispatch by delivery time. In accordance with the rules for carriage of goods, the delivery time for route shipments is calculated from the calculation of the standard period – 550 km per day. Then the expenses for accumulation of trains, which are considered for separation into independent assignments, will be permissible under the observance of the standard terms for the delivery of goods, if the condition is met*

$$st \leqslant 24 \cdot L \cdot N\left(\frac{1}{V_{cl}} - \frac{1}{V_{route}}\right); \quad (1)$$

$$T_{acc} \leqslant 24 \cdot L\left(\frac{1}{V_{cl}} - \frac{1}{V_{route}}\right), \quad (2)$$

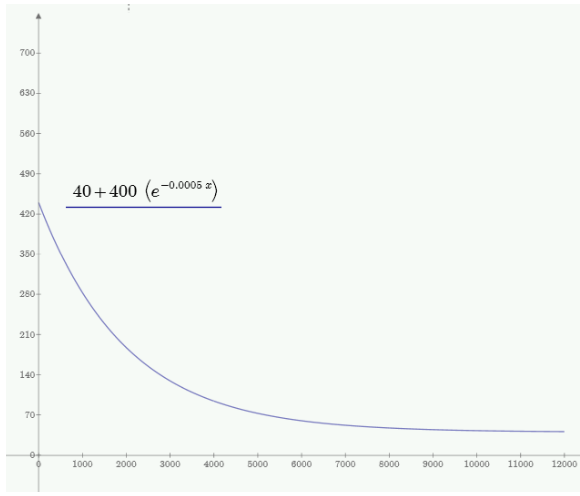
*where L – distance of (additional) movement of the allocated destination of trains, km; $V_{cl}$, $V_{route}$ – norms of daily run of cars, respectively, without allocation (carload) and with allocation of car flows (route shipment) to independent assignment of trains km / day.*

*In the formulas (1) and (2), the expression in parentheses characterizes the possible acceleration of the car flow following the assignment to an independent destination with the dimension of day/km. Graphical change of the right-hand side of inequalities (1) and (2) is presented in a convenient form for calculations and is shown in Pic. 2. Then the formulas will accordingly have the form:*

$$st \leq 40 + 400(e^{-0,0005L}); \quad (3)$$

$$T_{acc} \leq 40 + 400(e^{-0,0005L}). \quad (4)$$

*In addition to justifying the expediency of allocating streams of car flows to independent destinations, the formula (2) can also be used to establish technical assignments for the duty dispatching apparatus, to study the influence of various factors on speed of cargo*




***Pic. 2. Change in the difference in daily run of route and non-route shipments depending on the distance of transportation.***

*delivery, and to find ways to accelerate the transport process.*

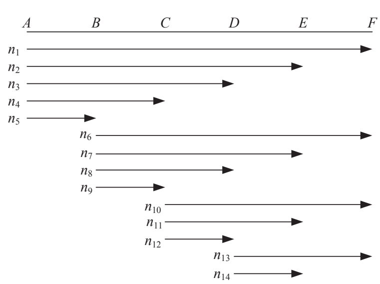
***III.***

*When calculating the plan for formation of one-group trains, attempts have been made several times to use linear programming to construct optimization models. There are serious reasons for this, since this method is the most economically effective, raises the quality of integrated planning, increases analytical capabilities and is convenient for mathematical formalization of the task and the use of computer programs.*

*Unfortunately, the use of linear programming was limited to formalization and mathematical formulation of the problem, and to solve it, approximate methods were offered (successive improvement of the plan [10], stepwise distribution of car flows [9], etc.), which are also related to manual correction of the results obtained.*

*Let's consider the calculation of the plan for formation of one-group trains on the railway network as a combination of streams of car flows and car flows patterns, i.e. distribution of formation and breaking up of trains at selected stations. For the first time, it becomes possible, in the process of calculating the formation plan, to control the transit of car flows and the loading of technical stations. This is achieved by solving a combinatorial problem by combining streams of car flows with the chosen optimal parameters.*

*A direct search of all possible variants of combining streams of car flows at technical stations of the railway network leads to an astronomical number of them. This led to the emergence of methods for calculating the plan for the formation of one-group trains in operating domains with a limited number of stations. Using the criterion of minimum processing of cars allows to streamline the search for options, significantly reduce them and perform the task on a computer without limiting participation in station calculations.*




***Pic. 3. Scheme of directions and streams of car flows.***

*For all streams of car flows ($n_1$, $n_2$, $n_3$, $n_4$, $n_6$, $n_7$, $n_8$, $n_{10}$, $n_{11}$, $n_{13}$), including between the initial and final stations ($n_1$), except the section ones ($n_5$, $n_9$, $n_{12}$, $n_{14}$, $n_{15}$) (Pic. 3), we verify that the sufficient condition (1) is satisfied.*

*When it is executed, the stream of the car flow allocated to an independent assignment and is included in the optimal variant of the formation plan.*

*If the stream of the car flow ($n_1$) does not fulfill the sufficient condition (1), the variants of its combination with all shorter streams of car flows starting at the initial station or ending at the final one, i.e., all variants of combining a long stream of car flow ($n_1$) with processing at only one passing station are considered. This combination refers to shorter streams that originate at the initial station and follow up to one of the passing stations ($n_2$, $n_3$, $n_4$, $n_5$) or start at the corresponding passing station and follow the final one ($n_6$, $n_{10}$, $n_{13}$, $n_{15}$).*

*In the section of mathematics – combinatorics, such a combination of streams of car flows in a certain order is called a rearrangement of n elements.*

*Finding the optimal variant of combining the long stream of the car flow ($n_1$) with processing at one of the passing stations is considered in the following order:*

$\{(n_1+n_2)+(n_1+n_{15})\};$
$\{(n_1+n_3)+(n_1+n_{13})\};$
$\{(n_1+n_4)+(n_1+n_{10})\};$
$\{(n_1+n_5)+(n_1+n_6)\}.$

*If the stream of the car flow ($n_1$) after combination and processing at one of the passing stations did not fulfill the sufficient condition (1), the options for its integration and processing at two passing stations are considered in the following order:*

$\{(n_1+n_5)+(n_1+n_9)+(n_1+n_{10})\};$
$\{(n_1+n_5)+(n_1+n_7)+(n_1+n_{15})\};$
$\{(n_1+n_4)+(n_1+n_9)+(n_1+n_{10})\};$
$\{(n_1+n_4)+(n_1+n_{11})+(n_1+n_{15})\};$
$\{(n_1+n_5)+(n_1+n_8)+(n_1+n_{13})\}.$

*If the stream of the car flow ($n_1$) after combination and processing at two passing station did not fulfill the sufficient condition (1), the options for its integration and processing at three passing stations are considered in the following order:*

**Table 3**

**Combinatorial method for calculating the plan for the formation of one-group trains**

| Priority | Number of processing of streams of car flow | Number of sections of movement of the stream of the car flow without processing | Options of processing of the stream of the car flow | Variants of combination of the stream of the car flow ($n_1$) |
|---|---|---|---|---|
| 1 | 1 | 5 | 1 | $n_1$ |
| 2 | 2 | 4+1 | 12 | $n_2 + n_{15}$ |
| 3 | 2 | 1+4 | 21 | $n_2 + n_6$ |
| 4 | 2 | 3+2 | 12 | $n_2 + n_{13}$ |
| 5 | 2 | 2+3 | 21 | $n_2 + n_{10}$ |
| 6 | 3 | 1+1+3 | 123 | $n_5 + n_9 + n_{10}$ |
| 7 | 3 | 1+3+1 | 132 | $n_5 + n_7 + n_{15}$ |
| 8 | 3 | 3+1+1 | 312 | $n_3 + n_{14} + n_{15}$ |
| 9 | 3 | 2+2+1 | 123 | $n_4 + n_{11} + n_{15}$ |
| 10 | 3 | 2+1+2 | 132 | $n_4 + n_{12} + n_{13}$ |
| 11 | 3 | 1+2+2 | 312 | $n_5 + n_8 + n_{13}$ |
| 12 | 4 | 1+1+1+2 | 1234 | $n_5 + n_9 + n_{10} + n_{15}$ |
| 13 | 4 | 1+1+2+1 | 1243 | $n_5 + n_6 + n_{11} + n_{15}$ |
| 14 | 4 | 1+2+1+1 | 1423 | $n_5 + n_8 + n_{14} + n_{15}$ |
| 15 | 4 | 2+1+1+1 | 4123 | $n_4 + n_{12} + n_{14} + n_{15}$ |
| 16 | 5 | 1+1+1+1+1 | 12345 | $n_5 + n_9 + n_{12} + n_{14} + n_{15}$ |

**Table 4**

**Combinatorial method for calculating the plan for the formation of one-group trains for 25 stations**

| Priority | Number of processing of streams of car flow | Number of sections of movement of the stream of the car flow without processing | Options of processing of the stream of the car flow | Variants of combination of the stream of the car flow ($n_1$) |
|---|---|---|---|---|
| 1 | 1 | 5 | 1 | $n_1$ |
| 2 | 2 | 24+1 | 12 | ... |
| 3 | 2 | 1+24 | 21 | ... |
| 4 | 2 | 23+2 | 12 | ... |
| 5 | 2 | 2+23 | 21 | ... |
| ... | ... | ... | ... | ... |
| ... | 3 | 22+1+1 | 123 | ... |
| ... | 3 | 1+22+1 | 213 | ... |
| ... | 3 | 1+1+22 | 231 | ... |
| ... | ... | 2+1+2 | ... | ... |
| ... | 4 | 21+1+1+1 | ... | ... |
| ... | 4 | 1+21+1+1 | ... | ... |
| ... | ... | ... | ... | ... |

$\{(n_1+n_5)+(n_1+n_9)+(n_1+n_{12})+(n_1+n_{13})\}$;
$\{(n_1+n_5)+(n_1+n_6)+(n_1+n_{11})+(n_1+n_{15})\}$;
$\{(n_1+n_5)+(n_1+n_8)+(n_1+n_{14})+(n_1+n_{15})\}$;
$\{(n_1+n_4)+(n_1+n_{12})+(n_1+n_{14})+(n_1+n_{15})\}$.

*If the stream of the car flow($n_1$) after combination and processing at three passing stations did not fulfill the sufficient condition (1) the options for its integration and processing at four passing stations are considered:*

$\{(n_1+n_5)+(n_1+n_9)+(n_1+n_{12})+(n_1+n_{14})+(n_1+n_{15})\}$.

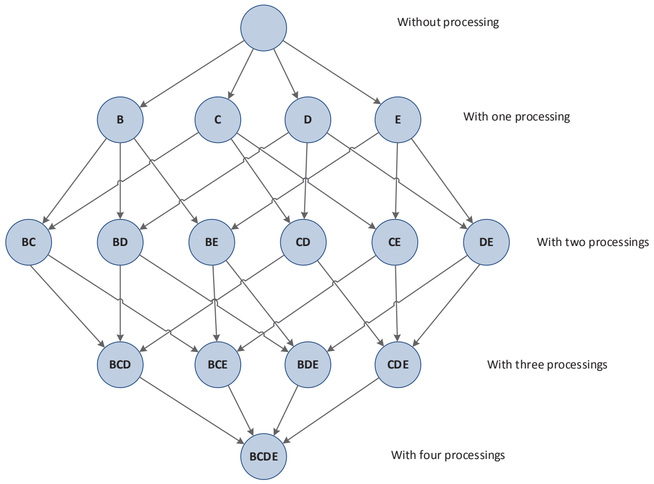
*A graphic representation of the described procedure is shown in Pic. 4.*

*Thus, in the process of calculating the plan for formation of one-group trains, all streams of car flows, starting from the most distant ones, are consistently considered. If the condition is not met, the procedure of combining them with shorter streams of car-flows with processing at one, two, three, ... stations is performed, until a sufficient condition is met or when the combination leads to a section assignment.*

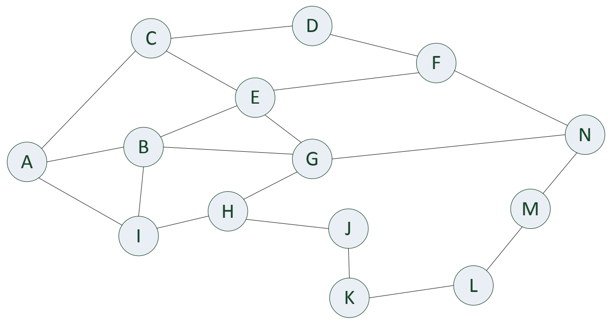
*The order of consideration of combinations of the longest stream of the car flow ($n_1$) according to the number of processing along the route is presented in Table 3. For example, if 25 stations participate in the calculation of the plan for forming one-group trains, Table 3 is converted to Table 4.*

*The proposed method allows to calculate the plan for formation of one-group trains for an unlimited number of stations on a branched operating domain. For this purpose the operating domain of railways is represented in the form of a graph (Pic. 5). The vertices denote the stations involved in calculating the plan. With the help of the album of the shortest distances between stations, we determine the routes of travel (passing stations) and distances. On the routes of streams of car flows we find the most distant stations, from which we begin the process according to the previously described linear algorithm.*

*As the streams of car flows are allocated into separate assignments for each station, the volume of*




***Pic. 4. Scheme of the sequence of consideration of variants of combining car flows with account of processing at passing stations when calculating the plan for the formation of one-group trains on the direction with six stations, shown in Pic. 3.***




***Pic. 5. Graph of the operating domain of railways.***

*processing of cars is summed up, and if several options satisfy the condition (3), preference is given to the variant with processing of the car flow at the least loaded stations.*

**Conclusions.**

*1. Instead of the criterion of turnover time of rail cars it is a suggested to fulfill the delivery deadlines and minimize the processing of car flows at technical stations.*

*2. To develop a plan for formation of one-group trains in a privatized car fleet, a combinatorial method is proposed based on the criteria for meeting the delivery deadline and minimizing the processing of car flows at technical stations. In the process of calculating the plan for formation of one-group trains, all streams of car flows, from the most distant ones, are consistently considered. If the sufficient condition is not satisfied, the procedure of combining them with shorter streams of car flows with processing on one, two, three, etc. stations is performed, until the corresponding organization of the process is achieved.*

## REFERENCES

1. Instructions on organization of car flows on the railways of the USSR [*Instruktivnye ukazanija po organizacii vagonopotokov na zheleznyh dorogah SSSR*] / MPS. Moscow, Transport publ., 1967, 190 p.

2. Instructions on organization of car flows on the railways of the USSR [*Instruktivnye ukazanija po organizacii vagonopotokov na zheleznyh dorogah SSSR*]. Moscow, Transport publ., 1984, 256 p.

3. Instructions on organization of car flows on the railways of JSC Russian Railways [*Instruktivnye ukazanija po organizacii vagonopotokov na zheleznyh dorogah OAO «RZhD»*]. Moscow, Tehinform publ., 2007, 527 p.

4. Levin, D. Yu. Organization of car flows on railways [*Organizacija vagonopotokov na zheleznyh dorogah*]. Moscow, TMC for education on railway. transport, 2017, 443 p.

5. Belov, I. V., Persianov, V. A. Economic theory of transport in the USSR [*Ekonomicheskaja teorija transporta v SSSR*]. Moscow, Transport publ., 1993, 415 p.

6. Rules for the transportation of cargoes by rail: Collection. Book. 1 [*Pravila perevozok gruzov zheleznodorozhnym transportom: Sbornik.– Kn. 1*]. Moscow, Jurtrans publ., 2003, 712 p.

7. Borodin, A. F. Operational work of railway directions [*Ekspluatacionnaja rabota zheleznodorozhnyh napravlenij*]. *Trudy VNIIAS*, 2008, Iss. 6, 317 p.

8. Tishkin, E. M. Automation of fleet management [*Avtomatizacija upravlenija vagonnym parkom*]. Moscow, Intekst publ., 2000, 224 p.

9. Borodin, A. F., Baturin, A. P., Panin, V. V. Organization of car flows: educational guide [*Organizacija vagonopotokov: Ucheb. posobie*]. Moscow, MIIT publ., 2008, 192 p.

10. Duvalyan, S. V. Methods and algorithms for solving planning and accounting problems in railway transport [*Metody i algoritmy reshenija zadach planirovanija i ucheta na zheleznodorozhnom transporte*]. Trudy CNII MPS, 1969, Iss. 401, 256 p. ●

Information about the author:
**Levin, Dmitry Yu.** – D.Sc. (Eng), professor at the department of Management of operational work and safety on transport of Russian University of Transport (MIIT), Moscow, Russia, levindu@yandex.ru.

Article received 16.07.2017, accepted 14.08.2017.