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METHOD OF OPERATIONAL REGULATION BY SHUNTING LOCOMOTIVES AT RAILWAY STATIONS

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Annotatsiya: Temir yo‘l stansiyalarida manyovr lokomotivlaridan foydalanish sharoitida yuk ob’ektlari o‘rtasida lokomotivlarni jo‘natish bo‘yicha tezkor qaror qabul qilish zarur. Lokomotivlarni bir yuk ob’yektidan boshqasiga o‘tkazishni tartibga solishda ko‘plab variantlar paydo bo‘ladi, bunda ulardan eng ratsionalini tanlash kerak. Mazkur maqolada manyovr lokomotivlarining rezerv bosib o‘tgan yo‘lini kamaytirish va samarali qaror qabul qilish jarayonini avtomatlashtirish maqsadida temir yo‘l stansiyalarida manyovr lokomotivlarini tezkor taqsimlash usuli ishlab chiqilgan va bu usulga asos qilib simpleks usuli yechim sifatida tanlab olingan. Ushbu usul temir yo‘l stansiyasi tezkor xodimlariga yuk ob’ektlariga xizmat ko‘rsatuvchi manyovr lokomotivlarining ishini tezkor tartibga solish texnologiyasini ishlab chiqish imkonini beradi.

Kalit so‘zlar: tezkor taqsimlash, manyovr lokomotivi, Simpleks usuli, transport masalasi, qaror qabul qilish.

Аннотация: В условиях эксплуатации маневровых локомотивов на железнодорожных станциях необходимо принятие оперативного решения по пересылке локомотивов между грузовыми объектами. При регулировании пересылки локомотивов с одного грузового объекта на другой возникает множество вариантов, из которых необходимо выбирать наиболее рациональный. В данной статье разработан метод оперативного регулирования маневровыми локомотивами на железнодорожных станциях на основе Симплексного метода решения с целью минимизации резервного пробега маневровых локомотивов и автоматизации принятия эффективного решения. Данный метод позволяет оперативному персоналу железнодорожной станции разрабатывать технологию упорядоченного регулирования работы маневровых локомотивов, обслуживающих грузовые объекты.

Ключевые слова: оперативное регулирование, маневровый локомотив, Симплексный метод, транспортная задача, принятие решения.

Annotation: In the conditions of operation of shunting locomotives at railway stations, it is necessary to make an operational decision on the transfer of locomotives between cargo objects. When regulating the transfer of locomotives from one cargo object to another, many options arise, from which it is necessary to choose the most rational one. In this article, a method has been developed for the operational regulation of shunting locomotives at railway stations based on the Simplex solution method in order to minimize the reserve mileage of shunting locomotives and automate an effective decision. This method allows the operating personnel of the railway station to develop a technology for the orderly regulation of the operation of shunting locomotives serving cargo objects.

Key words: operational regulation, shunting locomotive, Simplex method, transport problem, decision making.

Introduction. In modern conditions, new requirements arise to reduce operating costs. Reducing operating costs in recent years has been a strategic challenge. One of the significant items of expenditure is the cost of transport for fuel and other material resources.

The problem of saving energy and fuel resources in railways attracts special attention. One of the tools that contribute to improving the quality and efficiency of planning and control of technological processes at stations, as well as the best use of shunting means and devices, is the operational regulation of shunting locomotives, especially when there are a large number of them at stations.

When shunting, along with saving time, it is necessary to reduce fuel costs. This cost item ranks second after wages, so the development of measures and recommendations for fuel saving is always effective.

In recent years, large-scale measures have been carried out on the CIS railways aimed at the transition to the formation of trains on fixed lines of the schedule [1]. In this transitional stage, the operating costs associated with the processing of wagons at stations, the organization of shunting operations, etc.

Thus, the need to reduce the cost of diesel fuel requires an immediate start of work on the development and implementation of technically sound norms of time and fuel consumption for shunting work and optimization of the regulation of the reserve run of shunting locomotives.

Today, scientists and specialists of railway transport are carrying out a lot of work to improve methods for performing various types of shunting work and to develop such a technology of shunting, which would take into account the potential capabilities of shunting means and devices, as well as the achievements of modern theory and practice of science. However, all these works are mainly aimed at the efficient operation of one shunting locomotive, replacing with shunting locomotives, reducing the time for performing shunting operations due to the development of stations, improving their track development schemes and equipment with modern means of automation and telemechanic [2-4].

Based on the analysis of the experience of railways and the works of scientists, it can be concluded that the problem of resource conservation on railways, both in the near and far abroad, is given a lot of attention. However, research on improving the methods of operational regulation of shunting locomotives with a large number of them at railway stations on the basis of transport tasks has been insufficiently performed.

Analysis and results. Traditionally, the work of shunting locomotives is delimited by some territorial areas. There are two reasons for this:

- there is no need for operational distribution of work between them;
- the possibility of decoupling hostile routes incorporated in the projects of the signaling system is used.

With such a distinction between the work of locomotives, the work of the station attendant or shunting dispatcher is simplified. But the possibility of obtaining the effect of centralized control is lost:

- there are situations when some drivers are overloaded, while others are idle and cannot help them;
- the decoupling of hostile routes is achieved by delaying some movements at the expense of others.

When shunting locomotives operate without binding them across territorial areas (especially in conditions of industrial railway transport), the problem arises of developing a method for minimizing the reserve runs of shunting locomotives at railway stations.

The article deals with the operational regulation of shunting locomotives between cargo objects when there are large numbers of them. For various combinations of cargo objects with surplus and deficiencies of locomotives, as well as various combinations of surplus and deficiencies of shunting locomotives, it becomes necessary to periodically optimally “attach” a cargo object with a lack of locomotives to a cargo object with an excess of shunting locomotives. As a criterion for the optimality of “attachment”, it is advisable to take the minimum of total locomotive-kilometers of reserve mileage for the planned period. To optimize the reserve runs of locomotives within the circulation section, an algorithm for solving the “transport problem” was used, for which a program for solving this problem on a computer can be developed.

The solution of the transport problem, as you know, is carried out by several methods, which differ from each other in the way of filling in the transport matrix. At the same time, the transport task is divided into two types:

- open, in which the total number of free shunting locomotives differs from the total number of locomotive needs at cargo objects;
- closed, if the total number of free shunting locomotives is equal to the total number of trains that need to be supplied with shunting locomotives.

For the problem being solved, the appearance of free locomotives and cargo objects that need shunting locomotives is a random process, therefore, the total number of cargo objects that need to be provided with shunting locomotives and the number of locomotives that can be used for operation will be different. In this regard, the transport problem of optimizing the reserve runs of shunting locomotives within the circulation section will be of an open type. However, the solution to an open transport problem does not exist, so it must be reduced to a closed type. To do this, we introduce a fictitious cargo object (the shunting locomotive remains at the end of work, waiting for the command to operate them), which accepts all surplus locomotives if the number of shunting locomotives that can provide cargo objects exceeds the need for cargo objects for locomotives. If there is a shortage of locomotives, i.e. cargo objects that need more shunting locomotives than cargo objects in excess, then we introduce a fictitious cargo object that could send shunting locomotives (the cargo object is serviced by the shunting locomotive as they are released).

Initial data for solving the transport problem:

- the number of cargo objects that need to be provided with shunting locomotives;
- the number of shunting locomotives that can be used to provide these cargo objects;
- the distribution of the considered shunting locomotives by cargo objects;
- distance between stations.

Let's formulate the transport problem. It is required to draw up such a regulation plan for shunting locomotives, in which the total cost of locomotive-kilometers of reserve run would be minimal.

This plan is presented in the form of a table (matrix), the rows of which correspond to the cargo objects of surplus (release) of shunting locomotives, the columns - to the cargo objects in need of shunting locomotives (Table 1).

On the left of the table there are numbers of cargo objects, where shunting locomotives are waiting for work *1, 2,…, i,…, m;* at the top – numbers of cargo objects that need shunting locomotives *1, 2,…, j,…, n;* on the right – the excess number of shunting locomotives at each cargo object $a_1, a_2,..., a_m$, below – the number of missing locomotives for each cargo object $b_1, b_2,..., b_n$.

Each element of the matrix at the intersection of a row and a column means a possible dispatch to a cargo object with a shortage of shunting locomotives. So in cell 12 at the intersection of the first row and the second column, it means a possible dispatch from cargo object 1 (excess of locomotives) to cargo object 2 (lack of locomotives). In general, the number of shunting locomotives sent from cargo object i to cargo object j is denoted as x_{ij}. In the upper left corner of each cell, the distance between cargo objects c_{ij}.

Table 1.

Matrix of the transport problem for the development of a method for minimizing reserve runs of shunting locomotives at railway stations

	1	*2*	...	*j*	....	*n*	
1	C_{11} X_{11}	C_{12} X_{12}	...	C_{1j} X_{1j}	...	C_{1n} X_{1n}	a_1
2	C_{21} X_{21}	C_{22} X_{22}	...	C_{2j} X_{2j}	...	C_{2n} X_{2n}	a_2
...	...	...	...	...	...	...	...
i	C_{i1} X_{i1}	C_{i2} X_{i2}	...	C_{ij} X_{ij}	...	C_{in} X_{in}	a_i
...	...	...	...	...	...	...	...
m	C_{m1} X_{m1}	C_{m2} X_{m2}	...	C_{mj} X_{mj}	...	C_{mn} X_{mn}	a_m
	b_1	b_2	...	b_j	...	b_n	

The cost of locomotive-kilometers for the movement of a shunting locomotive from a cargo object in excess to a cargo object with a deficiency are expressed by products $c_{ij}x_{ij}$, the cost of locomotive-kilometers for all movements:

$$C = \sum_{i=1}^{m}\sum_{j=1}^{n} c_{ij}x_{ij}. \tag{1}$$

The x_{ij} arguments of this linear function are related as follows. The sum of all movements located in the first row of the matrix (table 1) should be equal to the size of the departure from the first station

$$x_{11} + x_{12} + ... + x_{1j} + ... + x_{1n} = a_1. \tag{2}$$

Equality is the same for all other strings. They make up a system of linear equations:

$$\sum_{j=1}^{n} x_{ij} = a_1, \ (i = 1, \ 2, \ ..., \ m). \tag{3}$$

The sum of movements, reflected in the first column, should be equal to the demand of the first station for locomotives:

$$x_{11} + x_{21} + ... + x_{i1} + ... + x_{m1} = b_1. \tag{4}$$

For all columns, this is a system of linear equations:

$$\sum_{i=1}^{m} x_{ij} = b_j, \ (j = 1, \ 2, \ ..., \ n). \tag{5}$$

The solution to the problem makes sense only for positive values:

$$x_{ij} \geq 0, \ (i = 1, \ 2, \ ..., \ m; \ \ j = 1, \ 2, \ ..., \ n). \tag{6}$$

Thus, in general, the transport problem of linear programming based on the Simplex solution method is formulated as follows: it is necessary to minimize the linear function:

$$C = \sum_{i=1}^{m} \sum_{j=1}^{n} c_{ij} x_{ij} = \min \qquad (7)$$

with nonnegative arguments related to the system of linear constraints (8), which include equalities (3) and (5).

$$\left. \begin{aligned} \sum_{j=1}^{n} x_{ij} = a_i, \ (i = 1,\ 2,\ ...,\ m); \\ \sum_{i=1}^{m} x_{ij} = b_j, \ (j = 1,\ 2,\ ...,\ n). \end{aligned} \right\}. \qquad (8)$$

Results and discussion

Microsoft Excel is used to solve the problem. We set the initial data.

1. We write down the distances between cargo objects, as shown in Table 2, and deliberately large values (11111) are written on the diagonal to exclude zero distances from the calculation (for example, loading-unloading front 1 - loading-unloading front 1).

2. In table 3, we describe shunting locomotives for cargo objects, which can be used to ensure shunting work. For example, at stations 5-LUF, 6-LUF and 10-LUF (LUF – loading-unloading front) there is one redundant locomotive each, and at cargo sites 3-LUF, 4-LUF, one locomotive is missing. Since the excess number of shunting locomotives (3) and their insufficient number (2) are not equal to each other, then to bring the task to a closed form, we set a fictitious cargo object (the shunting locomotive remains at the end of work, waiting for a command to operate them).

Table 2.

Distances between cargo objects

Cargo objects with surplus locomotives	Cargo objects that need locomotives									
	1-LUF	2-LUF	3-LUF	4-LUF	5-LUF	6-LUF	7-LUF	8-LUF	9-LUF	10-LUF
1-LUF	11111	500	200	1000	900	1200	1500	480	240	900
2-LUF	1200	11111	800	400	250	700	490	600	780	520
3-LUF	280	900	11111	640	570	480	950	1300	400	500
4-LUF	500	700	600	11111	470	600	750	420	370	460
5-LUF	800	700	420	760	11111	570	680	740	450	640
6-LUF	500	800	800	470	900	11111	290	780	650	210
7-LUF	900	250	700	650	600	600	11111	650	450	560
8-LUF	400	640	450	720	450	650	640	11111	250	920
9-LUF	380	280	580	340	740	540	570	390	11111	1010
10-LUF	470	370	640	450	260	220	600	420	720	11111

Table 3.

Distribution of locomotives by cargo objects

Cargo objects with surplus locomotives	Lack of the shunting locomotives										Total	Total locomotives awaiting work
	1-LUF	2-LUF	3-LUF	4-LUF	5-LUF	6-LUF	7-LUF	8-LUF	9-LUF	10-LUF		
1-LUF	0	0	0	0	0	0	0	0	0	0	0	0

2-LUF	0	0	0	0	0	0	0	0	0	0	0	0
3-LUF	0	0	0	0	0	0	0	0	0	0	0	0
4-LUF	0	0	0	0	0	0	0	0	0	0	0	0
5-LUF	0	0	0	0	0	0	0	0	0	0	0	1
6-LUF	0	0	0	0	0	0	0	0	0	0	0	1
7-LUF	0	0	0	0	0	0	0	0	0	0	0	0
8-LUF	0	0	0	0	0	0	0	0	0	0	0	0
9-LUF	0	0	0	0	0	0	0	0	0	0	0	0
10-LUF	0	0	0	0	0	0	0	0	0	0	0	1
Total	0	0	0	0	0	0	0	0	0	0	$C=\sum_{i=1}^{m}\sum_{j=1}^{n}c_{ij}x_{ij}=\min$	
Total cargo objects in need of a shunting locomotive	0	0	1	1	0	0	0	1	0	0		

At cargo facilities with an equal number of trains and locomotives (a closed-type problem), 0 locomotives are set to exclude them from the calculation. For example, at stations 5-LUF, 6-LUF and 10-LUF (CO-cargo object) there is one redundant locomotive each, and at cargo sites 3-LUF, 4-LUF and 8-LUF, one locomotive is missing. Then we continue according to the second option.

3. Start the procedure for finding a solution, as shown in Figure 1.

4. In the window **Search for a solution**, select the **Run** command.

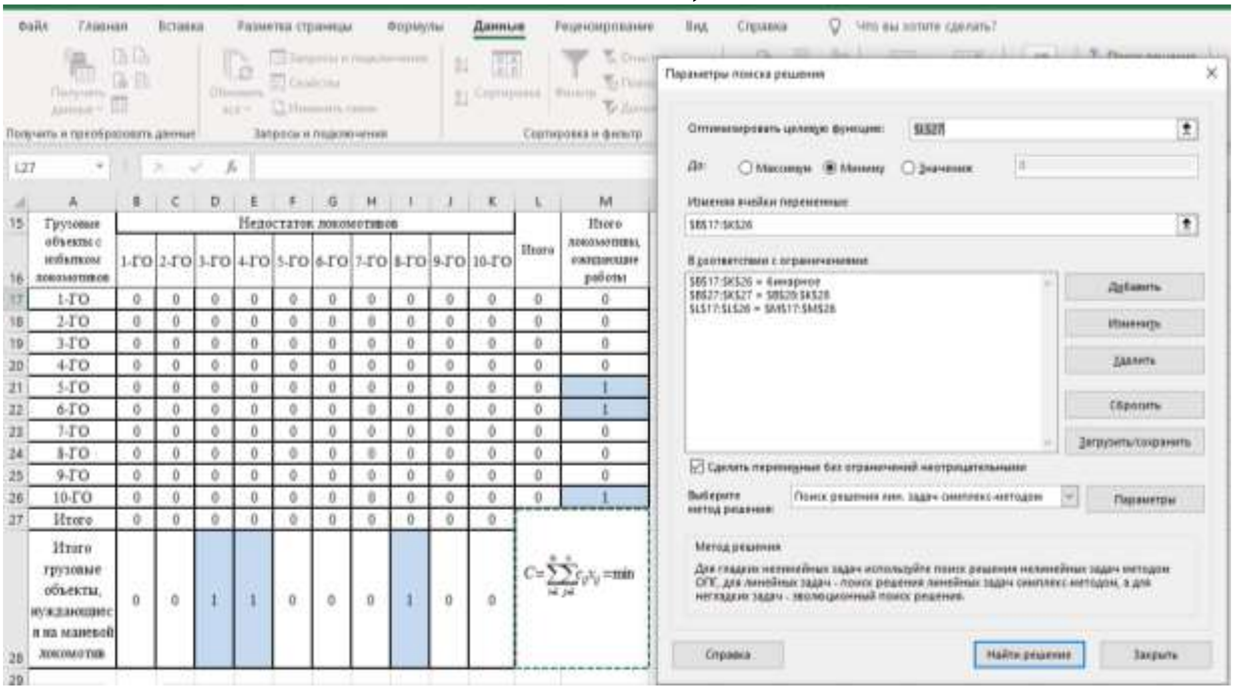

Figure 1. Procedure for finding a solution

5. Instead of the values recorded in Table 3, the values of the rational plan for the regulation of shunting locomotives appear, presented in Table 4. It can be seen from Table 4 that the shunting locomotive waiting for work in the 5-LUF is sent to the 3rd, in the 6th to the 4th CO and 10-LUF to 8-LUF. The total mileage of shunting locomotives is 1310 locomotive-kilometers.

Changing the distances between cargo objects from 5-LUF to 3-LUF, 6-LUF to 4-LUF, 10-LUF to 8-LUF from 420, 470, 420 to 900, 200, 1100, respectively, you can get another rational regulation plan shunting locomotives (table 5). From table 5 it can be seen that a shunting locomotive waiting for work in the 5th CO is sent to the 8th CO, to the 6th CO to the 4th CO (remains) and the 10th CO to the 3rd CO. The total mileage of shunting locomotives is 1580 locomotive-kilometers.

Table 4.

Rational plan for the regulation of shunting locomotives

Cargo objects with surplus locomotives	Lack of the shunting locomotives										Total	Total locomotives awaiting work
	1-LUF	2-LUF	3-LUF	4-LUF	5-LUF	6-LUF	7-LUF	8-LUF	9-LUF	10-LUF		
1-LUF	0	0	0	0	0	0	0	0	0	0	0	0
2-LUF	0	0	0	0	0	0	0	0	0	0	0	0
3-LUF	0	0	0	0	0	0	0	0	0	0	0	0
4-LUF	0	0	0	0	0	0	0	0	0	0	0	0
5-LUF	0	0	1	0	0	0	0	0	0	0	1	1
6-LUF	0	0	0	1	0	0	0	0	0	0	1	1
7-LUF	0	0	0	0	0	0	0	0	0	0	0	0
8-LUF	0	0	0	0	0	0	0	0	0	0	0	0
9-LUF	0	0	0	0	0	0	0	0	0	0	0	0
10-LUF	0	0	0	0	0	0	0	1	0	0	1	1
Total	0	0	1	1	0	0	0	1	0	0	1310	
Total cargo objects in need of a shunting locomotive	0	0	1	1	0	0	0	1	0	0		

Table 5.

Rational plan for the regulation of shunting locomotives after changing the distances between cargo objects

Cargo objects with surplus locomotives	Lack of the shunting locomotives										Total	Total locomotives awaiting work
	1-LUF	2-LUF	3-LUF	4-LUF	5-LUF	6-LUF	7-LUF	8-LUF	9-LUF	10-LUF		
1-LUF	0	0	0	0	0	0	0	0	0	0	0	0
2-LUF	0	0	0	0	0	0	0	0	0	0	0	0
3-LUF	0	0	0	0	0	0	0	0	0	0	0	0
4-LUF	0	0	0	0	0	0	0	0	0	0	0	0
5-LUF	0	0	0	0	0	0	0	1	0	0	1	1
6-LUF	0	0	0	1	0	0	0	0	0	0	1	1
7-LUF	0	0	0	0	0	0	0	0	0	0	0	0
8-LUF	0	0	0	0	0	0	0	0	0	0	0	0
9-LUF	0	0	0	0	0	0	0	0	0	0	0	0
10-LUF	0	0	1	0	0	0	0	0	0	0	1	1
Total	0	0	1	1	0	0	0	1	0	0	1580	
Total cargo objects in need of a	0	0	1	1	0	0	0	1	0	0		

shunting locomotive											

Conclusion

1. A method has been developed for the operational regulation of shunting locomotives at railway stations based on the Simplex solution method in order to minimize the reserve mileage of shunting locomotives and automate the effective decision-making.

2. In the developed method, the minimum reserve mileage of shunting locomotives is taken as a criterion of rationality and it shows the possibility of effective application of the Simplex method in solving problems typical for transport processes in organizing shunting operations at main line and industrial railway stations.

3. On the basis of this method, the operating personnel of the railway station will be able to develop a technology for orderly regulation of the operation of shunting locomotives serving cargo facilities for each planning period.

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