ISSN: 2350-0328
International Journal of Advanced Research in Science, Engineering and Technology
Vol. 8, Issue 2 , February 2021

The Improvement Decision Method of Decision on the Choice of Delivery of Wagons to the Defined Station on the Basis of Information Technologies

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ABSTRACT: This article analyzes the average stagnation of transit recycling wagons in JSC "UTY", as a result of studying the mathematical characteristics of the group lengths of wagons in a multi-group train, the length of a group of wagons in a single-track multi-group train subordination was determined. A mathematical model has been developed to determine the feasibility of attaching a group of wagons to trains on the basis of software for feasibility study of possible options for adding a group of wagons to trains on the way. The software for the developed exposure allows you to quickly determine the option with the least amount of costs associated with adding a group of wagons to the trains on the way.

KEYWORDS:local wagon flow, multi-group train, group length of wagons, Erlang law, road train, computer program, mathematical model.

I. INTRODUCTION

Today, one of the important criteria in railway transport is the choice of the direction of delivery of wagons to the destination station using optimal methods. This criterion will reduce the delivery time of goods and accelerate the movement of wagons. Factors that negatively affect the acceleration of wagon traffic occur mainly at technical (sorting, section stations) and intermediate stations located on the railway section, ie overcrowding of wagons at these stations, which, by itself, adversely affects the delivery time of wagons. Therefore, it is expedient to develop targeted measures to accelerate the flow of local wagons at technical and intermediate stations.

The share of multi-group trains plays an important role in the delivery of local wagon flow to their destinations at technical stations. In order to identify problems in this area, JSC "UTY" analyzed the average stability of recycled transit cars over the years in terms of technological processes of the station and real data (Figure 1).

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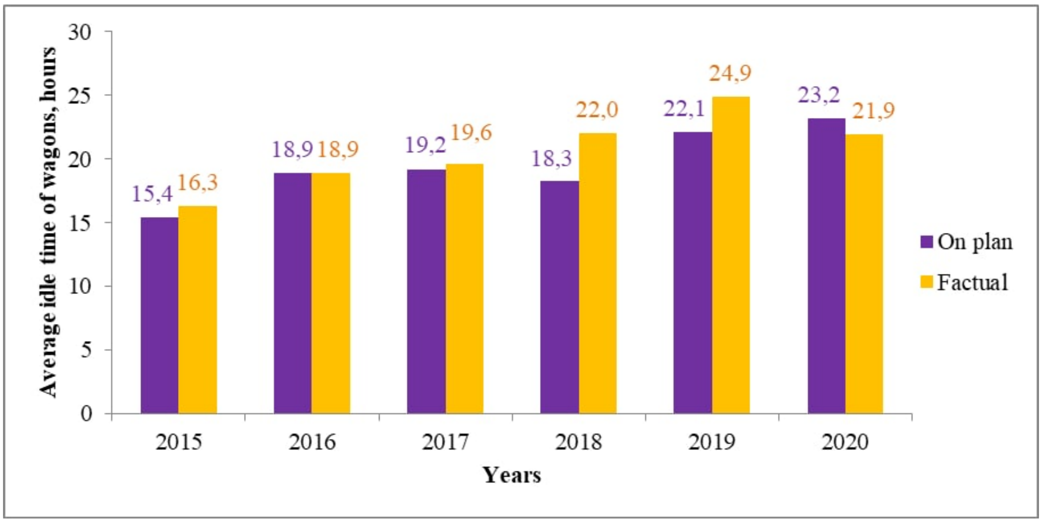

Figure 1. Transit processing wagons at JSC"UTY" average persistence

As can be seen from Figure 1, the downtime of the flow of transit recycled wagons at technical stations is increasing. To determine the reason for this, we will consider the technology of processing transit trains at technical stations.

When analyzing the standard time of transit wagons to be recycled in 2020 at the station "Ch", one of the largest sorting stations of JSC "Uzbekistan Railways", it was found that these wagons are longer than the normal time in all parks of the station. was distributed as follows [1]:

- 9.6% excess waiting to the reception park;
- 34.2% excess waiting for the qualifying park;
- 46.9% of overtime falls on the departure fleet;
- The average time of wagons in one freight operation is 12.0 hours, the average time spent on the processing of transit wagons is 17.0 hours.

When analyzing the natural sheets of trains coming from JSC "Kazakhstan Railways" station "Aris" to JSC "Uzbekistan Railways" station "Ch", 65% of the wagons in these trains are multi-group trains. distribution to the nals [2, 3]. From the above, one of the current challenges is to accelerate the flow of domestic wagons based on the improvement of processing technology of multi-group trains at technical and intermediate stations.

II. MATHEMATICAL DESCRIPTION OF THE LENGTHS OF A GROUP OF WAGONS IN A MULTI-GROUP TRAIN

Excessive time spent on shunting operations with multi-group trains at technical and intermediate stations leads to a slowdown in the flow of domestic wagons. The reason for the excessive time spent on shunting operations with multi-group trains is the irregular placement of a group of wagons in the train. The study found that the bulk of the time spent on shunting operations with multi-group trains was spent on sorting and reassembling groups of wagons. Also, another important feature of the location of wagons in a multi-group train is the distribution of length of the wagon groups in a particular direction. Statistics'

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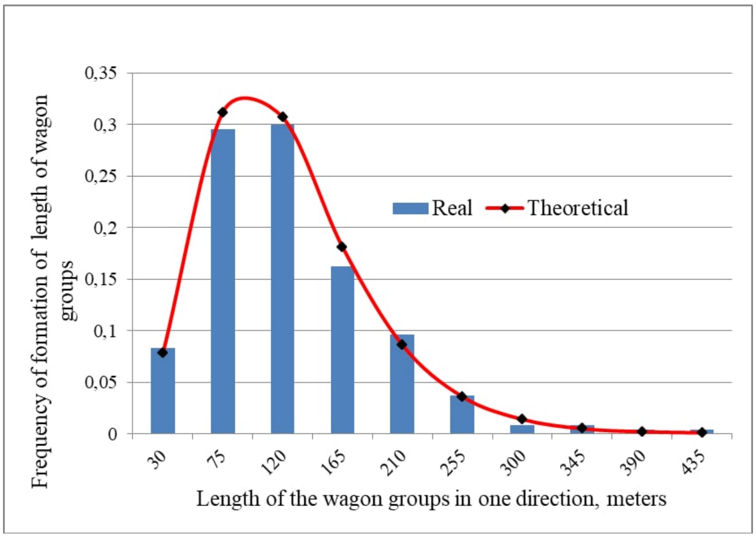

Figure 2. According to Erlang's law, the length of the wagongroups of multi-group trains in one direction depends on the frequency of their formation(when l_{ot} = 112 meters).

The density function of the Erlang distribution law has the following form

$$f_k(L_{\text{rp}}) = \frac{(\lambda \cdot k)^k L_{\text{rp}}^{k-1}}{(k-1)!} e^{-\lambda \cdot k \cdot L_{\text{rp}}} \quad (1)$$

in this L_{gr} – average length of the wagon groups in the formation of multi-group freight trains, m;
l– density of Erlang's distribution law (magnitude inverse to mathematical expectation);
k– a parameter of the Erlang distribution law.

Accurate identification of the basic parameter laws and numerical characteristics in the distribution of wagon flow allows to assess the possibilities of development paths of local sorting systems and to accelerate the process of sorting train trains.

One of the measures to accelerate the flow of local wagons at technical and intermediate stations is to select the optimal methods of transporting groups of wagons at these stations by adding them to other trains moving in the same direction. The introduction of these methods in practice will allow to accelerate the flow of wagons based on the principle of timely delivery of goods and the rational use of rolling stock. When sending groups of wagons at technical and intermediate stations with other trains on the same route, the standards of length and weight of trains installed on this section of the railway must be fully complied with.

II. DETERMINING THE NUMBER OF OPTIONS THAT CAN BE ADDED TO A CERTAIN PORTION OF A GROUP OF WAGONS ON A PASSING TRAIN

In the example of five technical stations, we consider the number of options from which it is possible to add a certain part of a group of wagons to the composition of a train on relatively short routes from long-distance trains (Figure 3) [4].

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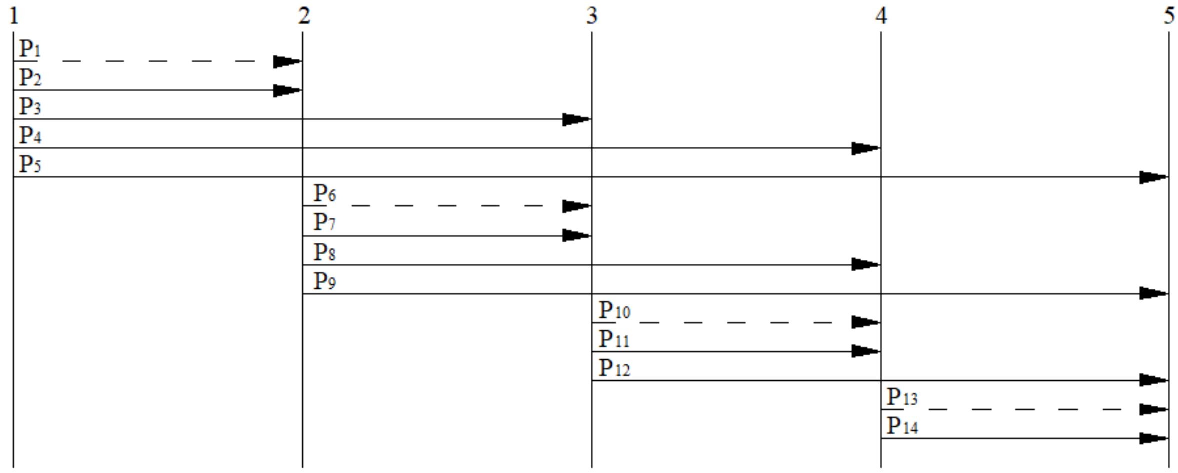

Figure 3. Possible variants of the train construction plan in the conditions of five technical stations

As can be seen from Figure 3, if it is necessary to connect a certain part of a group of wagons to another direction that is relatively close to the direction, there will be only one option for the delivery of wagons (route), i.e. will be taken by national train. If it is necessary to add a certain part of the wagons to a relatively close address other than the direction, then the delivery options of the wagons can be seen in Table 1.$P_2 P_1 P_3$

Table 1

Delivery options by adding a certain part of a group of wagons from one direction to another relatively close addressP_2

Option number	Walking path
1.	$P_1 \rightarrow P_6$
2.	$P_1 \rightarrow P_7$
3.	$P_2 \rightarrow P_6$
4.	$P_2 \rightarrow P_7$

As can be seen from Table 1, a certain part of the group of connected wagons spends a lot of time on the national train, i.e. option. $P_1 \rightarrow P_6$

If it is necessary to add a certain part of the group of wagons to a relatively close address other than the direction, then the options for the delivery of wagons can be seen in Table 2.P_4

Table 2

Delivery options by adding a certain part of a group of wagons from one direction to another relatively close addressP_4

Optionnumber	Walking path	Optionnumber	Walking path
1.	$P_1 \rightarrow P_5 \rightarrow P_8$	7.	$P_2 \rightarrow P_5 \rightarrow P_9$
2.	$P_1 \rightarrow P_5 \rightarrow P_9$	8.	$P_2 \rightarrow P_6 \rightarrow P_8$
3.	$P_1 \rightarrow P_6 \rightarrow P_8$	9.	$P_2 \rightarrow P_6 \rightarrow P_9$
4.	$P_1 \rightarrow P_6 \rightarrow P_9$	10.	$P_2 \rightarrow P_7$
5.	$P_1 \rightarrow P_7$	11.	$P_3 \rightarrow P_8$
6.	$P_2 \rightarrow P_5 \rightarrow P_8$	12.	$P_3 \rightarrow P_9$

If it is necessary to add a certain part of the group of wagons to another relatively close direction, then the options for delivery of wagonsP_5

As can be seen from Table 3.

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Table 3

Delivery options by adding a certain part of a group of wagons from one direction to another relatively close addressP_5

Optionnumber	Walking path	Optionnumber	Walking path	Optionnumber	Walking path
1.	$P_1 \rightarrow P_5 \rightarrow P_8$	12.	$P_1 \rightarrow P_8 \rightarrow P_{14}$	23.	$P_2 \rightarrow P_7 \rightarrow P_{12}$
2.	$P_1 \rightarrow P_5 \rightarrow P_9$	13.	$P_1 \rightarrow P_9$	24.	$P_2 \rightarrow P_8 \rightarrow P_{13}$
3.	$P_1 \rightarrow P_6$	14.	$P_2 \rightarrow P_6 \rightarrow P_{10} \rightarrow P_{13}$	25.	$P_2 \rightarrow P_8 \rightarrow P_{14}$
4.	$P_1 \rightarrow P_6 \rightarrow P_9$	15.	$P_2 \rightarrow P_6 \rightarrow P_{10} \rightarrow P_{14}$	26.	$P_2 \rightarrow P_9$
5.	$P_1 \rightarrow P_7$	16.	$P_2 \rightarrow P_6 \rightarrow P_{11} \rightarrow P_{13}$	27.	$P_3 \rightarrow P_{10} \rightarrow P_{13}$
6.	$P_2 \rightarrow P_5 \rightarrow P_8$	17.	$P_2 \rightarrow P_6 \rightarrow P_{11} \rightarrow P_{14}$	28.	$P_3 \rightarrow P_{10} \rightarrow P_{14}$
7.	$P_1 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{14}$	18.	$P_2 \rightarrow P_6 \rightarrow P_{12}$	29.	$P_3 \rightarrow P_{11} \rightarrow P_{13}$
8.	$P_1 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{13}$	19.	$P_2 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{13}$	30.	$P_3 \rightarrow P_{11} \rightarrow P_{14}$
9.	$P_1 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{14}$	20.	$P_2 \rightarrow P_7 \rightarrow P_{10} \rightarrow P_{14}$	31.	$P_3 \rightarrow P_{12}$
10.	$P_1 \rightarrow P_7 \rightarrow P_{12}$	21.	$P_2 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{13}$	32.	$P_4 \rightarrow P_{13}$
11.	$P_1 \rightarrow P_8 \rightarrow P_{13}$	22.	$P_2 \rightarrow P_7 \rightarrow P_{11} \rightarrow P_{14}$	33.	$P_4 \rightarrow P_{14}$

Thus, the number of path options of a particular part of a group of wagons to be added to a given station can be determined by solving a system of linear algebraic equations using the Gaussian method.

The system can be expressed in the form of an extended matrix as follows[5]:

$$\begin{pmatrix} 2^n & 2^{n-1} & 2^{n-2}.... & 2^0 \\ 3^n & 3^{n-1} & 3^{n-2}.... & 3^0 \\ 4^n & 4^{n-1} & 4^{n-2}.... & 4^0 \\ 5^n & 5^{n-1} & 5^{n-2}.... & 5^0 \\ \multicolumn{4}{c}{..................................} \end{pmatrix} \begin{pmatrix} 1 \\ 4 \\ 12 \\ 33 \\ .... \end{pmatrix} \quad (2)$$

We write the system in the form of a matrix with n = 3

$$\begin{pmatrix} 8 & 4 & 2 & 1 \\ 27 & 9 & 3 & 1 \\ 64 & 16 & 4 & 1 \\ 125 & 25 & 5 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 4 \\ 12 \\ 33 \end{pmatrix}$$

Multiply the first row by (27). Multiply the second row by (-8). We add the second line to the first line:

$$\begin{pmatrix} 0 & 36 & 30 & 19 \\ 27 & 9 & 3 & 1 \\ 64 & 16 & 4 & 1 \\ 125 & 25 & 5 & 1 \end{pmatrix} \begin{pmatrix} -5 \\ 4 \\ 12 \\ 33 \end{pmatrix}$$

Multiply the second row by (64). Multiply the third row by (-27). We add the third line to the second line:

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$$\begin{pmatrix} 0 & 36 & 30 & 19 \\ 0 & 144 & 84 & 37 \\ 64 & 16 & 4 & 1 \\ 125 & 25 & 5 & 1 \end{pmatrix}\begin{pmatrix} -5 \\ -68 \\ 12 \\ 33 \end{pmatrix}$$

Multiply the third row by (125). Multiply the fourth row by (-64). We add the fourth line to the third line:

$$\begin{pmatrix} 0 & 36 & 30 & 19 \\ 0 & 144 & 84 & 37 \\ 0 & 400 & 180 & 61 \\ 125 & 25 & 5 & 1 \end{pmatrix}\begin{pmatrix} -5 \\ -68 \\ -612 \\ 33 \end{pmatrix}$$

Multiply the first row by (4). Multiply the second line by (-1). We add the second line to the first line:

$$\begin{pmatrix} 0 & 0 & 36 & 39 \\ 0 & 144 & 84 & 37 \\ 0 & 400 & 180 & 61 \\ 125 & 25 & 5 & 1 \end{pmatrix}\begin{pmatrix} 48 \\ -68 \\ -612 \\ 33 \end{pmatrix}$$

Multiply the second row by (400). Multiply the third row by (-144). We add the third line to the second line:

$$\begin{pmatrix} 0 & 0 & 36 & 39 \\ 0 & 0 & 7680 & 6016 \\ 0 & 400 & 180 & 61 \\ 125 & 25 & 5 & 1 \end{pmatrix}\begin{pmatrix} 48 \\ 60928 \\ -612 \\ 33 \end{pmatrix}$$

Multiply the first row by (7680). Multiply the second row by (-36). We add the second line to the first line:

$$\begin{pmatrix} 0 & 0 & 0 & 82944 \\ 0 & 0 & 7680 & 6016 \\ 0 & 400 & 180 & 61 \\ 125 & 25 & 5 & 1 \end{pmatrix}\begin{pmatrix} -1824768 \\ 60928 \\ -612 \\ 33 \end{pmatrix}$$

Now the last system can be written as follows:

x4 = -1824768/82944
x3 = [60928 - (6016x4)] / 7680
x2 = [-612 - (180x3 + 61x4)] / 400
x1 = [33 - (25x2 + 5x3 + x4)] / 125

From the first line we express x_4:

$$x_4 = \frac{-1824768}{82944} = -22$$

From the second row we express x_3:

$$x_3 = \frac{60928 - 6016\cdot(-22)}{7680} = \frac{193280}{7680} = 25{,}167$$

From the third row we express x_2:

$$x_2 = \frac{-612 - 180\cdot 25{,}17 - 61\cdot(-22)}{400} = \frac{-3800}{400} = -9{,}5$$

From the fourth row we express x1:

$$x_1 = \frac{33 - 25\cdot(-9{,}5) - 5\cdot 25{,}17 - 1\cdot(-22)}{125} = \frac{166{,}667}{125} = 1{,}333$$

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Thus, by formula (3) it is possible to add a certain part of the group of wagons to the station to reach the desired number of stations.

The number of options can be determined:

$$\sum P = \frac{4}{3} \cdot K^{n} - \frac{19}{2} \cdot K^{n-1} + \frac{151}{6} \cdot K^{n-2} - 22 \tag{3}$$

In Table 4, taking into account that there are no more than 10 technical stations on the railway section of the wagons on a particular route in the train construction plan, a certain part of the group of wagons to the station of arrival the number of options that can be added is given.

Table 4

If there are up to 10 technical stations on the railway section of the carriageway on a particular route in the train construction plan, the number of options that can add a certain part of the group of wagons to the arrival station

Number of stations (K)	The number of walkway options specified to the arrival station ($\sum P$)
2	1
3	4
4	12
5	33
6	75
7	146
8	254
9	407
10	613

As can be seen from Table 4, the greater the number of technical stations on the walkway, the greater the number of walkway options for a particular portion of the group of wagons to be added to the designated station. Determining the most efficient option for the route of a certain part of the group of wagons to be added to the designated station is determined by technical and economic calculations, regardless of which train the connected wagons run on.

In the absence of section train routes, the flow of wagons to the neighboring technical station can be carried out as part of a national train. In this option, the organization of the flow of wagons to be added, incurs additional costs associated with the transfer and distribution of national trains on the site, assembly, assembly of the group of wagons to be added to the designated station. The area of efficiency of the options of the path of the lumbar part is determined on the basis of complex feasibility studies.

Sending a group of wagons to the trains on the way does not justify itself in all cases. To do this, first of all, it is necessary to determine the expediency of attaching a group of wagons, based on mathematical approaches to it.

IV. MATHEMATICAL MODEL FOR DETERMINING THE EXPEDIENCY OF ATTACHING A GROUP OF WAGONS TO TRAINS

It is necessary to make full use of self-justifying methods of work, which contribute to the acceleration of the movement of local freight, taking into account the various features of use in the organization of domestic train traffic. The most common such methods along the railways of JSC "Uzbekistan Railways" include:

- sending pre-selected groups of local wagons to transit trains in order to increase the actual weight of the train from the generalized weight norm to the section norm during the stay of local wagons at the stations;
- removal of local groups of wagons with the next spare locomotive on the section due to the lack of traffic measurements;
- use of locomotives returning after pushing with the permission of the train dispatcher, as well as driving locomotives idle due to disproportionate movement to deliver local groups of wagons to their destinations.

The use of these methods will reduce the assembly time of national train wagons, speed up the delivery and assembly of local wagons along the road sections.

In production, their stand-alone time is important before connecting local wagons to trains. Exceeding the

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standby time will slow down the wagon turnover and prolong the delivery time. Figure 4 shows a diagram for determining the stopping time of local wagons before they are connected to transit trains.

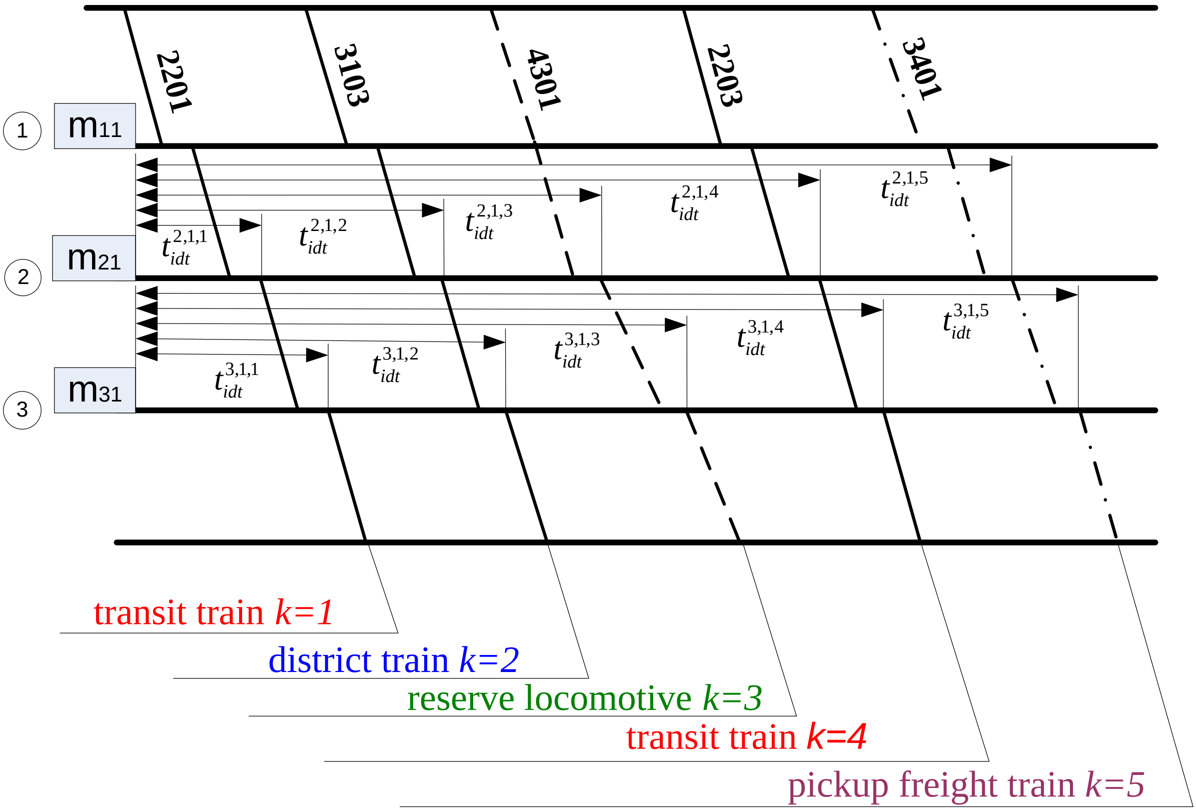

Figure 4.Determining the downtime of local wagons before connecting them to transit trains

The above measures have been identified in the scientific and technical literature [6, 7] as an important factor in improving the reliability of railway routes. However, at present, there are no clear methods for a comprehensive assessment of the effectiveness of their practical application in JSC "UTY".

In practice, these measures can be used as rapid planning, but the application of these measures in long-term planning is not always justified.

Adding rigorous mathematical solutions to the problem will allow for more efficient use of traction types, reduce wagon downtime at intermediate stations, and speed up the delivery of local wagons.

Preliminary data for solving the indicators of operational planning of train and freight operations:

- the remains of wagon groups not removed from the stations located on the railway section at the beginning of the planning period;
- times (moments) of formation of groups of wagons loaded at intermediate and freight stations of the section;
- the schedule of arrival of trains to stations on a site;
- condition of trains on the section;

The problem of optimizing the removal of local wagons from intermediate and freight stations of the section to transit trains will be solved on the basis of minimization of functional capabilities

$$\sum_i \sum_j \sum_k x_{ijk} \cdot t_{idt}^{ijk} \cdot m_{ij} \cdot e_{w-h} + \sum_i \sum_k y_{ik} \cdot \delta_{ik} \cdot \left(t_{idt}^{ik} \cdot \text{С}_{\text{бтс}} + \text{С}_{\text{пт}}\right) \rightarrow \min \qquad (4)$$

where i– serial number of the station to which the wagons are added;

j – the number of the group of wagons ready to connect to the i-station;

k– i- "schedule time" number of the transit train for the station (national train, locomotives and reserve locomotives moving in the same direction) in the train schedule;

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x_{ijk}- a logical variable that represents the possibility of adding a group of j-wagons formed at i-station to the k-train "schedule time";
t_{idt}^{ijk} – stop time of the j-group of local wagons at the i-station before connecting to the k-train, hours;
m_{ij} – number of local wagons j-group at i-station, vag .;
e_{w-h} – one wagon-hour cost rate, UZS;
δ_{ik} – a logical variable representing the possibility of stopping a k-train (driver, spare locomotive) to combine a group of wagons at an i-station;

$$\delta_{ik} = \begin{cases} 0, & \text{if } k \text{ train } i \text{ is technically at the station;} \\ 1, & \text{and so on} \end{cases} \quad (5)$$

y_{ik} – a logical variable representing the possibility of stopping a wagon (a group of wagons, if there are several of them) formed at the *i*-station to be added to the *k*-train;

$$y_{ik} = \begin{cases} 0, \sum_i x_{ijk} = 0; \\ 1, \sum_j x_{ijk} > 0. \end{cases} \forall (i,k) \quad (6)$$

This restriction can be written as follows

$$\sum_i^n x_{ijk} \le n \cdot y_{ik}, \text{ j} = 1, 2, ..., \text{n} \quad (7)$$

$t_{dt.idt}^{ik}$ – duration of standby of the k-train during the process of adding local wagons at the i-station, hours;
$C_{бтс}$ – expenses related to the one-hour stop of trains on the section, soums;
$C_{пт}$ – costs associated with the train stop at the intermediate station, soums;

The condition of delivery of groups of wagons from intermediate and freight stations of a site to the technical station delimiting a site has the following appearance:

$$\sum_k x_{ijk} = 1, \forall (i,j) \quad (8)$$

k-provided that the reserve length of the groups of wagons attached to the train corresponds to the total length:

$$\sum_i \sum_j x_{ijk} m_{ij} \le \Delta m_k, \forall k, \quad (9)$$

herein Δm_k – *k*- reserve length of the train, m;

During the study, the software for feasibility study of possible options for attaching a group of wagons to trains on the basis of the development of a mathematical model for attaching a group of wagons to trains and determining its feasibility. there is a need to create.

V. DEVELOPMENT OF SOFTWARE FOR FEASIBILITY STUDY OF POSSIBLE OPTIONS FOR ADDING A GROUP OF WAGONS TO TRAINS ON THE WAY

Given the disproportionate flow of wagons, the practical results of adding a group of wagons to trains on the way can be introduced, but special attention should be paid to the technical and economic performance of their addition. Taking into account the above, to determine the cost-effectiveness of the organization of the flow of wagons, a program was developed entitled "Selection of an effective option for the organization of wagon flows in a changing schedule." The working window of this program is shown in Figure 5.

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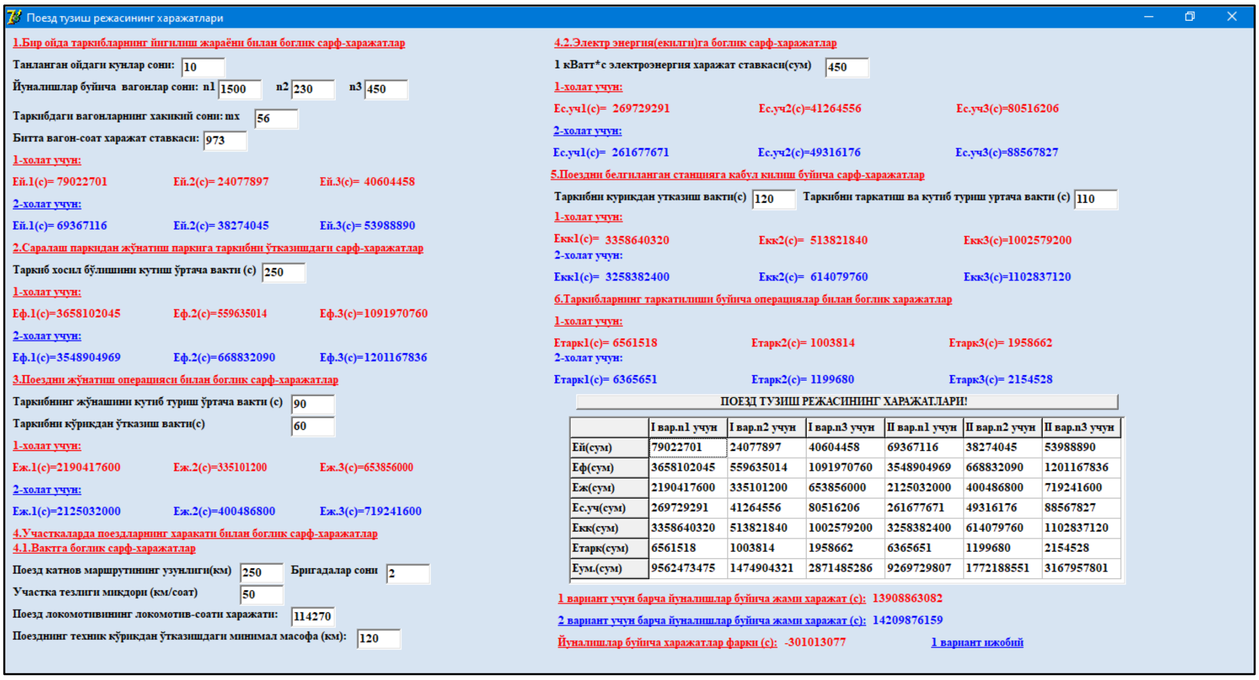

Figure 5. The working window of the program for exposure

The software "Selection of the most efficient option for the organization of wagon flows in a changing schedule" is designed to select the most efficient option of wagon flow when sending trains, taking into account the following costs associated with the movement of trains:

- expenses related to the process of assembling the contents, UZS;
- expenses related to the transfer of content from the sorting park to the sending park and operations on the formation, UZS;
- expenses related to the departure of the train (inspection, waiting for departure), UZS;
- costs associated with the movement of trains on the sections, UZS;
- expenses related to the reception of the train at the designated station, UZS;
- expenses related to the distribution of content, UZS.

VI. CONCLUSION

The train construction plan is standardized on average daily wagon flows and is developed for a one-year period according to constant calculation standards. However, in practice, the situation in real use is radically different from the normative conditions. At the same time, the volume of wagon flows changes, the volume of processing at stations changes, trains are not provided with locomotives in a timely manner, there are slowdowns and breaks in the movement of trains on the section. In modern conditions, it is necessary to ensure the timely elimination of inefficient routes in the work of the railways, and the rapid identification and implementation of effective ones. Information technology allows you to organize the rapid management of wagon flows. For this purpose, a mathematical model was developed to determine the feasibility of attaching a group of wagons to trains on the basis of software for feasibility study of possible options for adding a group of wagons to trains on the way. The software "Selection of the most effective option for the organization of wagon flows in a changing schedule" allows you to guide a group of wagons in universities, research institutes, laboratories, design institutes and technical stations of the railway industry. 'lakay can be used to quickly determine the option with the least amount of cost to add to trains. a mathematical model was developed to determine the expediency of attaching a group of wagons to trains on a minute basis. The software "Selection of the most effective option for the organization of wagon flows in a changing schedule" allows you to guide a group of wagons in universities, research institutes, laboratories, design institutes and technical stations of the railway industry. 'lakay can be used to quickly determine the option with the least amount of cost to add to trains. a mathematical model was developed to determine the expediency of attaching a group of wagons to trains on a minute

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basis. The software "Selection of the most effective option for the organization of wagon flows in a changing schedule" allows you to guide a group of wagons in universities, research institutes, laboratories, design institutes and technical stations of the railway industry. 'lakay can be used to quickly determine the option with the least amount of cost to add to trains.

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