SIMULATION MODEL FOR ESTIMATING EFFECTS OF FORMING PICK-UP TRAINS BY SIMULTANEOUS METHOD

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Abstract

This paper examines the problem of forming the pick-up trains using the stimulation method in order to establish the basic characteristics of track facilities and values of the shunting operation indicators that are important for evaluation of the effects of the application of these methods. Observed problem hasn't been explored to a sufficient extent in the literature, although practice shows the need for it. Therefore, this paper serves the development of simulation studies, whose results should give the values and the measures for assessing the quality of yard operations, as well as the assessment of solutions of newly designed stations.

Key words: Technical freight yards, pick-up goods trains, simultaneous method, number and length of tracks, simulation.

Presenting Author's biography

Sanjin Milinković received his Dipl. Ing. degree in traffic and transportation engineering in 2001. and his MSc degree in 2007., from University of Belgrade, Faculty of Transport and Traffic Engineering. He is currently working on a PhD thesis and his research interests include analysis of railway systems by modeling, simulation and operations research methods. Hi is currently working as a teaching associate with University of Belgrade, Department for railway exploitation.

1. Introduction

With an increased volume of global trade, the transport of goods by rail has been growing daily and is getting more and more important, especially taking environmental, security, economic and other criteria into consideration and comparing it with alternative modes. At the same time, volume and complexity of operations in technical freight yards, related to the processes that take place during the accumulation and the formation of pick-up freight trains have increased. Technical freight yards can use a special group of tracks or the end parts of sorting-departure tracks to carry out the operations in the process of forming pick-up goods trains. In both cases, it is necessary to meet the conditions related to the number and length of tracks for the final forming of pick-up goods trains. Although well known and long conceived methods known in literature as Conventional method (Futhner, Special and Japanese methods) and Simultaneous method are in practice used for forming pick-up goods trains, the effects of their application have not been fully examined so far, especially as far as track capacity and the indicators of shunting operations are concerned, which is important for defining the elements of the final solution for stations and the choice of adequate organization and operation technology in the process of pick-up goods train forming. The lack of information of this nature makes planning of high quality and investing in new track facilities necessary for carrying out an increased shunting work in freight stations more difficult. Regarding complexity and stochastic nature of the processes under consideration, the simulation represents one of the most efficient techniques that may be applied in the analysis of such systems behavior in order to get the necessary quantity indicators. The simulation models may be efficient means to assess the necessary station and wagon capacity, as well as to analyze the impact of numerous factors determining the mentioned work processes.

In order to establish the values of indicators important for the analysis of the observed real system and to make relevant decisions, the work presents a simulation study used for the analysis of complex processes that take place during the wagon accumulation and forming of pick-up goods trains in technical stations [1]. The indicators analyzed in the simulation model are: number and length of tracks required to carry out the mentioned activities.

In determining the numerical values of these indicators, their functional dependences have been analyzed in relation to: number of intermediate stations served by pick-up goods trains formed in technical freight yards, number of wagons by intermediate station and number of wagons per train formed in the process of accumulation. The applied simulation study gives results that may be of help to designers and shunting dispatchers in their daily work.

2. Problem definition and objective of the paper

The pick-up goods trains are one of the three basic categories of freight trains carrying goods by rail. They run on line sections between two technical freight yards, at the same time performing operations in intermediate stations on the principle “leave, pick-up or exchange” wagons. In these intermediate stations the locomotives can perform operations with wagons in one of the following ways:

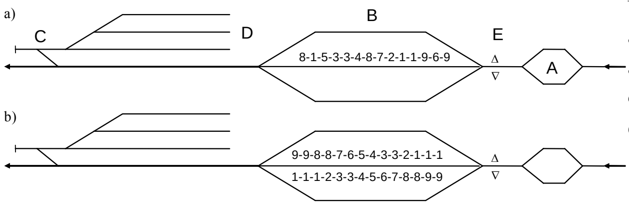
- Pick-up wagons from the initial train composition formed in technical freight yards and leave them in loading-unloading and handling points in the yard;
- Pick-up wagons from loading-unloading and handling points in the yard and connect them to the train;
- Perform both afore-mentioned activities, one after the other.

Such operations of composition changing require additional shunting operations in the intermediate stations under consideration and significantly affect the speed of freight transport. At the same time, such work means reduced carrying capacity of the railway and requires larger fleet to meet the specified traffic volume. In short, such operations diminish the railway's capacity and affect its quality of service. To what extent the indicators of its operation will be disturbed will greatly depend on the methods used for carrying out the railway operations and on the capacity employed for realization of the method used.

In order to achieve the best possible effects, i.e. to speed up the process of carrying out the additional shunting operations in intermediate stations, the technical freight yards have an assignment to make necessary preparation of compositions for this purpose. This preparation involves the grouping and coupling of wagons to the train according to the sequence of intermediate stations along the line, and in order to meet this requirement, it is necessary to carry out additional forming of pick-up goods trains in technical freight yards, after the completed accumulation of wagons, which is of a stochastic character, on sorting, sorting-departure or on a special group of tracks. This process requires corresponding track and locomotive facilities, in combination with the scheduled organization and technology of operations, i.e. the methods for performing it (Fig. 1). Owing to these requirements in technical freight yards, the assignments obviously increase in relation to the volume of shunting operations [5].

To form the pick-up goods trains, a great number of methods are used in practice. The Futhner method and Special method are among the classical ones that are known by consecutive forming of pick-up trains. On the other hand there is the Simultaneous method that tries to synchronize forming of pick-up trains. These methods differ by both applied technology of wagon accumulation in stations and track capacity used to carry out this process [6]. However, as the aim of all modern railway enterprise is forming and dispatching of trains in the shortest possible period and with as little as possible usage of tracks, the Simultaneous method is chosen to be presented in this paper.

What type of tracks are needed for the application of this method and what effects are expected in the reporting process of forming pick-up goods trains are the most important issues to which the simulation model should provide answers.



A – ***Reception tracks;*** **B** – ***Sorting-departure tracks;***
C – ***Shunting neck;***
D – ***Sorting tracks;*** **E** – ***Hump***

Fig. 1 Sequence of wagons in the composition:
a) After the completed wagon accumulation;
b) After the completed grouping of wagons

3. Description of the real system

Simultaneous method of collecting pick-up goods trains represents, at the same time the method of forming a number of pick-up goods trains in order to allow timely dispatch of trains from marshalling yard,. This method first was applied to the French railways during the First World War in 1917, when it was necessary to form more trains to transport food to supply troops at the front.

This method differs from traditional ones as well in the fact that the trains are formed on the reception tracks or sorting-departure tracks, and not on the station group of tracks used in conventional methods. The pick-up goods trains that are formed in the station may belong to different lines or different sections of certain lines.

Efficient use of simultaneous method requires appropriate adjustment of the timetable and more qualified shunting staff. Work on the preparation of pick-up goods trains using the simultaneous method can be performed over the hump or on the shunting neck. According to the current research, the number of tracks for grouping of wagons depends on the number of intermediate stations. Applying this method, the wagons for pick-up goods trains are being grouped so that during the process of splitting up of trains, the wagons are singled out according to the order of the intermediate stations for all trains simultaneously at the same track. This means that the wagons, for all intermediate stations that are first in line, second and so on, are sorted out according to the order defined by this method, regardless of the fact that they belong to the different trains, tracks and sections of the tracks.

The process of the final forming of pick-up goods trains begins simultaneously at the moment when the sufficient number of wagons is gathered for all the trains that depart from the marshalling yard. In the application of simultaneous method the required number of tracks for the accumulation of wagons depends on the number of intermediate stations [8, 9]. The relationship between the number of intermediate stations (m) which are served by pick-up goods trains and required number of sorting tracks (k) which are used for wagons accumulation for these trains, assuming that, by so far performed researches, no additional sorting is expected, except the dismantling of accumulated wagons, is given by the following expression in Eq. (1) and (2):

$$m_{\max} = 2^k - 1 \tag{1}$$

$$k = \begin{cases} \dfrac{\log(m_{\max}^{stv} - 1)}{\log 2}; & \dfrac{\log(m_{\max}^{stv} - 1)}{\log 2} \in N \\ \left\lceil \dfrac{\log(m_{\max}^{stv} - 1)}{\log 2} \right\rceil + 1; & \dfrac{\log(m_{\max}^{stv} - 1)}{\log 2} \notin N \end{cases} \tag{2}$$

where:

m_{max} – maximum number of intermediate stations that can be served by a pick-up train,

m_{max}^{stv} – maximum real number of intermediate stations served by one of pick-up trains formed in the station, and

k – number of sorting tracks for accumulation of wagons.

General rule for the accumulation of wagons for pick-up goods trains based on the simultaneous method should look like presented in Tab. 1.

Description of the execution process of accumulation and the formation of pick-up goods trains using the simultaneous method is most easily seen in the following example [3, 7, 12]:

Assuming that:

- Five pick-up goods trains are being formed (A, B, C, D and E);
- Each train in its structure has a wagon for up to nine intermediate stations according to its order, which may be expressed with numbers 1, 2, ..., 9, by applying the simultaneous method;
- Four sorting tracks that can be labeled with K_1, K_2, K_3 and K_4, are for wagons accumulation;
- Wagons in train that should be split-up are distributed by intermediate stations, as shown in Fig. 2.

Tab. 1 General rule for the formation of pick-up trains by simulation method

Track number in-line (k_i)	Intermediate station numbers in-line for all the sections for which pick-up trains are formed (m_{is})	General rule for wagon accumulation by intermediate stations	
1 2 3 4 5	1 3 5 7 9 11 13 15 17... 2 6 10 14 18 ... 4 12 ... 8 ... 16 ...	$m_{1,s} = 2^0 + 2*(j-1)$ $m_{2,s} = 2^1 + 4*(j-1)$ $m_{3,s} = 2^2 + 8*(j-1)$ $m_{4,s} = 2^3 + 16*(j-1)$ $m_{5,s} = 2^4 + 32*(j-1)$	$i = 1, ..., k$ $j = 1, ..., N$ $s = 1, ..., m^{stv}_{\max}$
k_i	2^{k_i-1} ...	$m_{i,s} = 2^{i-1}(1+ 2*(j-1))$	$m_{i,s} \leq m^{stv}_{\max}$

The direction of dismantling the composition ➔

8	9	6	3	5	9	4	7	3	9	2	5	1	3	7	2	1	6	4	8	5	4	1	2	3

Fig. 2 The order of wagons that should be split-up in intermediate stations

In the splitting-up process on the first track, wagons are being accumulated for all the first, third, fifth, seventh and ninth intermediate stations of all 5 trains together. On the second track, wagons are being accumulated for all the second and sixth, while on the third track wagons are being accumulated for all the forth intermediate stations of all trains and are being accumulated for all the wagons of the eighth intermediate sections, on the fourth track (Fig. 3).

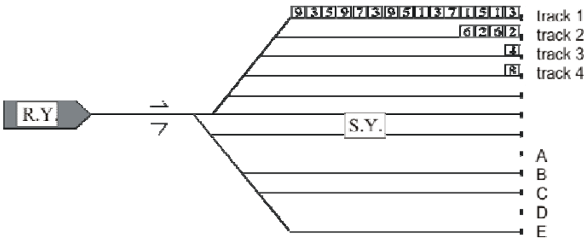


Fig. 3 The order of wagon accumulation in sorting tracks according to the intermediate sections after splitting-up the train in the Figure 2

- The First Phase of forming pick-up goods trains by using simultaneous method –

When the sufficient number of wagons for all the pick-up trains is accumulated, one begins with their formation. First, the accumulated wagons are drawn from the first track and sorted out so the wagons for the first intermediate stations of certain trains are separated into different tracks (from A to E), and for each train separately. Wagons for the third and seventh intermediate stations are being allocated to the second track, those for the fifth to the third track, while the wagons for all the ninth intermediate stations are joined with the wagons on the fourth track (Fig. 4).

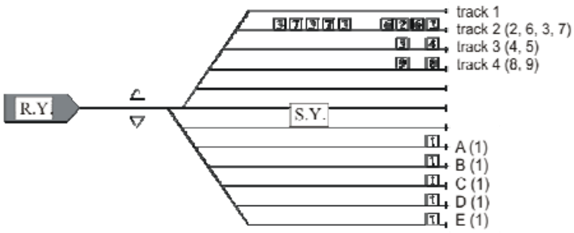


Fig. 4 The order of wagon accumulation in sorting tracks according to the intermediate sections after wagon splitting-up from the first track

-The Second Phase of forming pick-up goods trains using simultaneous method -

Having completed the first round of sorting, the sorting of the wagons on the second track begins (Fig. 5). The wagons from the second track are being sorted in the way that the second and third intermediate stations are being allocated to specific tracks (from A to E) according to certain trains and the trains for the sixth and seventh stations of all trains are being all together allocated along the third track. Wagons from the fourth track, during this time, are not moving.

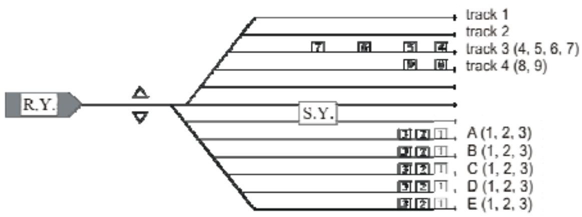


Fig. 5 The order of wagon accumulation in sorting tracks according to the intermediate sections after wagon splitting-up from the second track

-The Third Phase of forming pick-up goods trains using simultaneous method-

The process continues logically, the wagons from the third track are sorting according to the certain trains on the tracks from A to E (Forth Phase), and only then from forth track (Fifth Phase). However, there is also a possibility of drawing and sorting wagons from the forth track and joining them together with those from the third track (Forth Phase), so they can be sorted together according to the specific trains, on the tracks from A to E (Fifth Phase). In this way, it is possible to get all pick-up goods trains according to the specific sections and order of intermediate stations on tracks form A to E (Fig. 6).

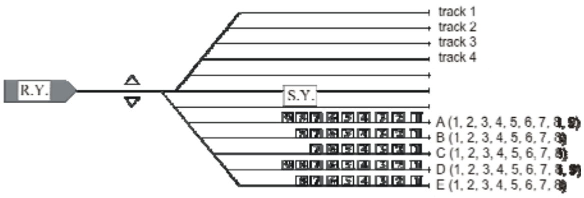


Fig. 6 The final forming of pick-up goods trains

- Forth or Fifth Phase -

(Note: These options have no effect on the length of the track and therefore will not be analyzed in detail.)

For the previous example it is obvious that we needed four tracks in order to shunt the wagons for pick-up goods trains during the process of splitting-up the composition, or the accumulation of wagons on the sorting tracks or sorting-departure tracks, because there are nine groups of wagons that pick-up goods trains use, and a maximum of nine groups that can be found in those trains. As the number of intermediate stations rarely exceeds ten, twelve, and only exceptionally reaches fifteen to twenty, it means that the presumed number of sorting tracks on which wagons for pick-up goods trains should be accumulated during the process of splitting-up and the formation of the composition is not great and ranges from three to four, maximum five.

4. Construction of the simulation model

The internal structure and design of the simulation model of forming the pick-up goods trains by Simultaneous method are directly related to specified objectives. The basic objectives in this work can be brought down to the following assignment: for pre-determined parameters, establish by the simulation method [10]:

1. Number of tracks necessary for wagon accumulation process for pick–up goods trains that are formed in the station;
2. Number of tracks necessary for pick-up goods trains formation;
3. Track lengths required for carrying out the scheduled processes.

In practice so far, such problems have been resolved mainly on the basis of experience and intuition, without any system analyses for the purpose of taking necessary measures. Such approach resulted in adverse effects, which became obvious only after the realization, i.e. construction of stations and the beginning of its exploitation. The simulation approach to this problem assumes quite different methodology including:

1. Set up the starting number of sorting tracks for wagon accumulation process for pick–up goods trains in the station on a real value;
2. Set up the composition of pick-up goods trains which are to be formed within a wider framework, in relation to the number of wagons in the train, number of intermediate stations and distribution of wagons by intermediate station;
3. Reiteration of the experiment, changing the train composition and number of intermediate stations;
4. Follow-up of the impact of the changed train composition and numbers of intermediate stations on the system functioning indicators.

The following parameters have been adopted for construction of thus conceived simulation model:

- *5* tracks in sorting yard or sorting-departure yard for wagon accumulation process for pick–up trains;
- *5* tracks in departure yard or sorting-departure yard for forming 5 pick–up trains;
- *30; 35; 40;* and *45* wagons per train;
- *5; 7; 9; 10; 13* and *16* intermediate stations with a real wagon distribution by intermediate station, derived from the analysis of operations of Belgrade marshalling yards on the Railways of Serbia network.

5. Output results

Instead of full output which is numerous and have a standard GPSS/H form [2, 4, 11, 13], the paper presents selected results recap of some indicators that are important for:

- Sizing of track capacity on which the final formation of pick-up trains is performed and
- Evaluation of new technical solutions for the technical freight yards and taking in count the appropriate measures before building the stations and plants, or putting them to work.

The number of the track and the track length are the analyzed system performance indicators necessary for the application of the observed method. These results that are shown in Tab. 2, Tab. 3 and Fig. 7.

Tags used in these tables are adjusted to the indicators of system functioning and have the following meaning: *max* n_{wi} – maximum number of wagons on *i* track during the formation of pick-up train.

Tab. 2 Output results for 5, 7 and 9 intermediate stations

	Number of intermediate stations														
	5					7					9				
	Number of wagons in composition					Number of wagons in composition					Number of wagons in composition				
	30	35	40	45	50	30	35	40	45	50	30	35	40	45	50
max n_{w1}	42	121	128	147	112	63	101	132	113	181	73	102	104	128	153
max n_{w2}	67	48	90	104	91	88	93	145	131	138	72	106	62	88	152
max n_{w3}	74	111	82	88	140	88	114	121	129	144	76	71	62	93	163
max n_{w4}											38	33	90	54	30

Tab. 3 Output results for 10, 13 and 16 intermediate stations

	Number of intermediate stations														
	10					13					16				
	Number of wagons in composition					Number of wagons in composition					Number of wagons in composition				
	30	35	40	45	50	30	35	40	45	50	30	35	40	45	50
max n_{w1}	49	73	98	91	126	61	81	114	135	152	75	75	106	125	107
max n_{w2}	57	109	80	109	176	59	66	76	96	190	89	93	86	113	119
max n_{w3}	77	94	72	152	134	84	61	35	124	116	59	98	73	112	162
max n_{w4}	37	39	78	46	55	64	104	113	88	62	78	77	100	114	111
max n_{w5}											11	11	33	14	15

The output shows that:

- The application of the simultaneous method requires two groups of tracks, of which the first is for the accumulation of the wagons, and another group for final formation of pick-up trains.
- The number of tracks on which the final forming process of pick-up trains is performed corresponding to the number of trains that are formed and that their length are uniformed and in the function of the number of wagons on train.
- The length of tracks, where the accumulation of wagons for pick-up trains is performed, are not the same and that primarily depend on the number of wagons on train, and much less on the number of trains serving the intermediate station on railroad or section of the railroad. In addition, these lengths are unacceptable, both from the point of exploitation and the construction, therefore to complete some tasks it is necessary to provide two or more tracks, instead of just one.
- The total number of tracks for the accumulation and formation of pick-up trains can be reduced by applying proper organization of work in the process of final formation of trains, which includes the use of free tracks on which the accumulation of wagons was performed.
- Previous principle, or the rule for the application of simultaneous method by which the number of tracks for the accumulation of the wagons for pick-up trains depends on the number of intermediate stations, is neither substantial nor acceptable primarily from the point of view of the exploitation.

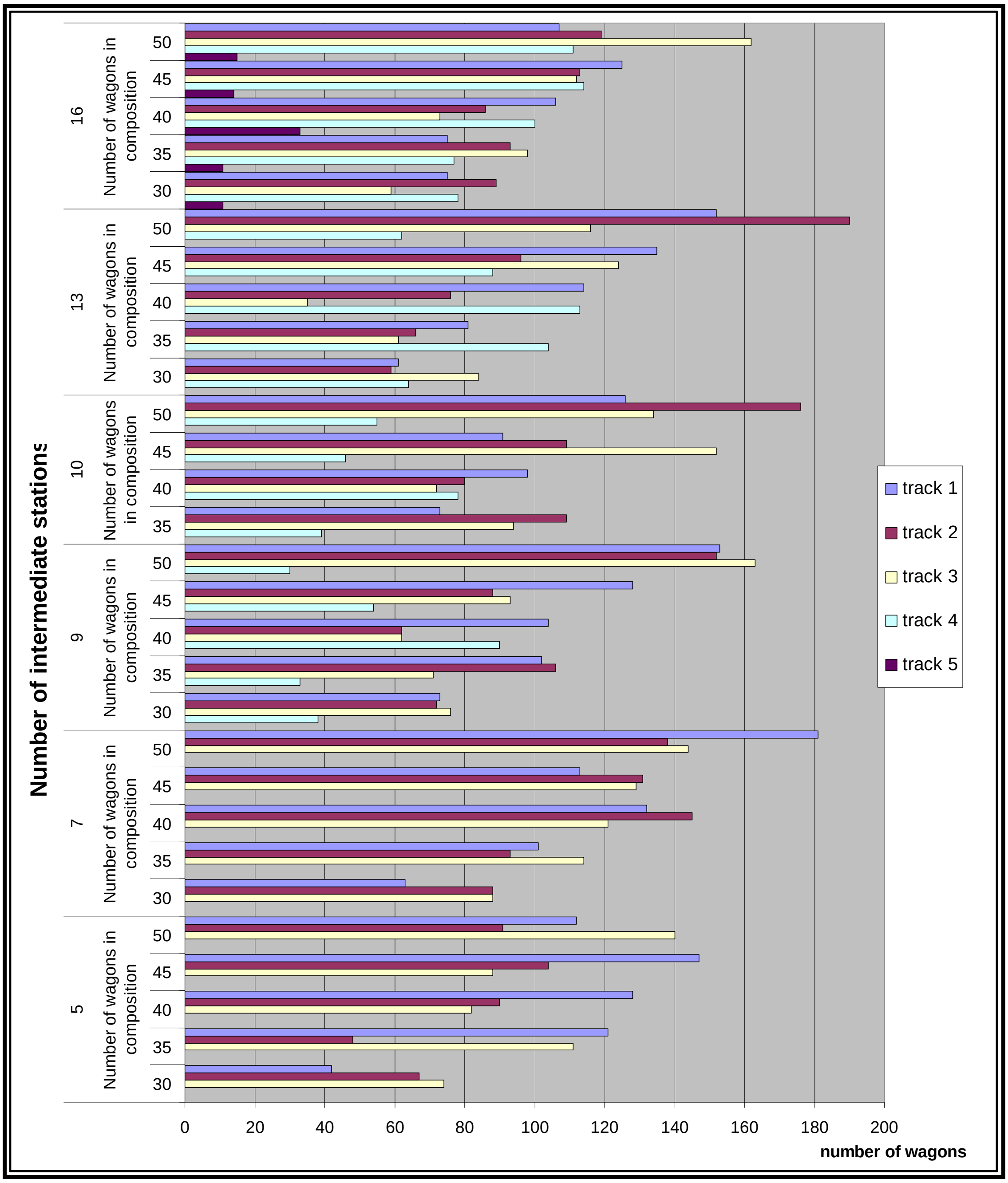


Fig. 7 Necessary length of track for shunting depending on the number intermediate stations

6. Conclusions

On the basis of the conducted research and the analysis of the results, one can draw the following conclusions:

- Process of forming pick-up trains by the simultaneous method may be relatively easy to model and simulate using the simulation language GPSS/H.
- Output results of this model shows the actual situation while applying the analyzed method and points to a number of gaps in the current process of designing and exploitation of technical freight yard. Therefore, these results can be used as an additional argument for the adoption of important technological and investment decisions in the process of designing and exploitation of new technical freight station.
- By extending the inputs and with the additional analysis it is possible to come up with new significant indicators of this method, for which it is necessary to make a special surveys (studies).
- By constructing this model, there have been created favorable conditions and given impetus to include the wider public and the authors themselves in its further development, within the scope of this and other similar problems.

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