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EFFECTS OF THE APPLICATION OF CONVENTIONAL METHODS IN THE PROCESS OF FORMING THE PICK-UP TRAINS

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Abstract: This paper examines a problem of forming the pick-up trains by conventional methods (the Futhner method and Special method), aiming at establishing basic characteristics of track facilities and values of shunting operations indicators important for evaluation of the effects of these methods application. The problem under consideration has so far not been examined in the literature to a sufficient extent, although in practice it has been proved to be necessary. For this reason, in this work a simulation study has been undertaken the results of which have to give the values and measures for assessing the quality of station/yard operations, as well as the assessment of new-designed station solutions.

Keywords: Technical freight yards, forming the pick-up, conventional methods, simulation.

1. INTRODUCTION

With an increased volume of global trade, rail transport of goods has been growing daily and is getting a growing importance, especially taking into consideration significantly lower costs and competitiveness in comparison with alternative modes. At the same time in technical freight yards the volume and complexity of operations have increased, related to the processes evolving in forming and splitting the pick-up freight trains. To carry out the operations in the process of forming pick-up trains, technical freight yards use a special group of tracks, or end parts of sorting-departure tracks. In both cases, it is necessary to meet the conditions related to the number and length of tracks for final forming of pick-up trains. Although in practice for forming pick-up freight trains well known and long conceived methods known in literature as: Futhner, Special, Simultaneous and Japanese methods, the effects of their application have not been fully examined so far, especially as far as the indicators of shunting operations are concerned, which is important for defining the elements of the final solution of the station and for the choice of adequate organization and technology of operations in the process of pick-up train forming. The lack of information of this nature makes more difficult a quality planning and investing in new track facilities necessary for carrying out an increased shunting work in freight yards. In view of the complexity and a 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 behaviour, aiming at arriving at the necessary quantity indicators. The simulation models may be an efficient means to assess the necessary station and wagon capacity, as well as to analyse the impact of numerous factors determining the mentioned work processes.

For this reason, the work presents a simulation study used to analyse the complex processes evolving during the forming and splitting of pick-up freight trains in technical stations, aiming at establishing the values of indicators important for the analysis of the real system under consideration and to take relevant decisions [1]. The indicators analysed in the simulation model are: number of tracks, track lengths, numbers of splitting and forming, number of handled wagons (performance) and times required to carry out the mentioned activities.

In determining the numerical values of these indicators, their functional dependences have been analysed in relation to: method applied, number of intermediate stations served by a technical freight yard, number of wagons by intermediate station, number of wagons per train, number of pick-up trains, number of groups per train (intermediate stations) and numbers of groups by intermediate station formed in the process of collection. 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

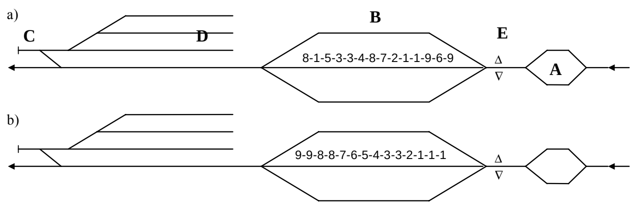
The pick-up trains are one of the three basic categories of freight trains carrying goods by rail. They run on line sections between two technical freight yards, at the same time performing operations in intermediate stations on the principle “leave, pick-up or exchange” wagons. In these intermediate 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, or
- 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 a reduced carrying capacity of the railway and requires a larger fleet to meet the specified traffic volume. In short, such operations diminish the railways 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 groupage 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 trains in technical freight yards, after the completed collection of wagons, on sorting, sorting-departure or on a special group of tracks, which is of a stochastic character. 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 (Figure 1). Owing to these requirements in technical freight yards, the assignments obviously increase, in relation to the volume of shunting operations [4].

To form the pick-up trains, a great number of methods are used in practice, of which the Futhner method and Special method are among the classical ones. Namely, they are the methods of consecutive forming of pick-up trains, which is the subject of consideration in this paper. These methods differ by both applied technology of wagons groupage in stations and possible track capacity used to carry out this process, and hence by effects of performing the whole process [5].



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

Figure 1: Sequence of wagons in the composition: a) after the completed wagon collection; b) after the completed groupage of wagons

Which and what type of track facilities are necessary to apply the mentioned method and what effects are expected in the considered process of forming the pick-up trains, are the most important questions to which the simulation model has to offer answers.

3. DESCRIPTION OF THE REAL SYSTEM

3.1. A brief presentation of the Futhner method

The Futhner method is the oldest method of forming the pick-up trains, It is named by the author Harry Futhner who was first to apply it in practice in 1880 in the Liverpool station, which had a small number of tracks and where the shunting operations were carried with great difficulties.

According to Futhner method, by the means of two splittings and two repeated connecting of wagons or groups of wagons collected at random on tracks for collection of pick-up trains, one can quickly arrange wagons in groups for a number of stations (intermediate stations) making a square of the number of tracks available for a shunting operation in question [6,] or [9]. Between the number of groups, and the number of intermediate stations and number of shunting tracks respectively, for arranging the groups by intermediate stations, there is an inter-dependence of forms:

$$n_{gr} = n_{is} = n_t^2 , \quad \text{or} \quad n_t = \begin{cases} \sqrt{n_{is}} ; \sqrt{n_{is}} \in N \\ \left\lceil \sqrt{n_{is}} \right\rceil + 1; \sqrt{n_{is}} \notin N \end{cases}$$

Where:
n_{is} – number of intermediate stations for which a pick-up train is formed;
n_t – number of tracks for shunting operations.

In order to note more easily the characteristics of this method, a general example of forming the pick-up train is given, which has in its composition the groups of wagons for "n_{is}" intermediate stations, and the forming itself is made on "n_t" tracks (case $n_t = \sqrt{n_{is}}$).

The procedure is as follows:

The wagons collected for the pick-up train from the sorting or sorting-departure track are first moved to the shunting track and then the process of sorting by destination station is carried out. In the first sorting of wagons for intermediate stations *1; n_t+1; 2n_t+1;…;* up to n_{is}-n_t+1 are left on the first track, wagons for intermediate stations *2; n_t+2; 2n_t+2;…;* up to n_{is}-n_t+2 to the second track and so on up to the wagons for intermediate stations *n_t; 2n_t; 3n_t;…;* up to n_{is} which are left on the n_t*-th* track (if $n_t = \sqrt{n_{is}}$). In this way the first process of splitting up wagons by track is completed. This is followed by the first process of connecting wagons from individual tracks and their forwarding the shunting track in order to get prepared for the second process of sorting. For this process it is important to know the location of the locomotive and what should be the sequence of wagons in the train in relation to the locomotive. This means that one should know if the wagons starting from the locomotive toward the end of the train are arranged from the departure to the destination stations (from 1 to n_{is}) or from the destination to the departure station (from m to 1). This is because in the former case making up will be from the 1st to the n_t*-th* tracks and in the latter the other way round, from the n_t*-th* to the first track. After the forming is completed, another process of sorting starts, where all wagons in the group for one intermediate station are left on one track, for the second, not-neighbouring intermediate station on the second track and so on, until one arrives to the wagon with the serial number of the intermediate station which is a neighbouring station to one the wagons of which are already sorted. In that case such a wagon is added – sorted to that track. (Example: the wagons for intermediate stations *1; 2;…;* up to n_t*-th* are left on the first track, wagons for intermediate stations *n_t+1; n_t+2;…;* up to 2n_t on the second track and so on up to wagons for intermediate stations *n_{is}-n_t+1; n_{is}-n_t+2;…; n_{is}*, which are left on the n_t*-th* track.). In this way all sorted wagons from the pick-up train are arranged by the sequence of intermediate stations, but on different tracks. Therefore another process of connecting by track remains to be carried out, so that the wagons in train are fully arranged by the sequence of intermediate stations. In this making-up process it is important to know that it is done by the same sequence as the previous one. Hence, if in the first process of making-up the sequence was from the 1st to the n_t-th tracks and from the n_t-th to the 1st tracks respectively, then in the next making-up process the same sequence is maintained.

The example of the process of forming the pick-train by stage, in the case where there are three tracks on which collection is made for 9 intermediate stations, is presented in Figure 2.

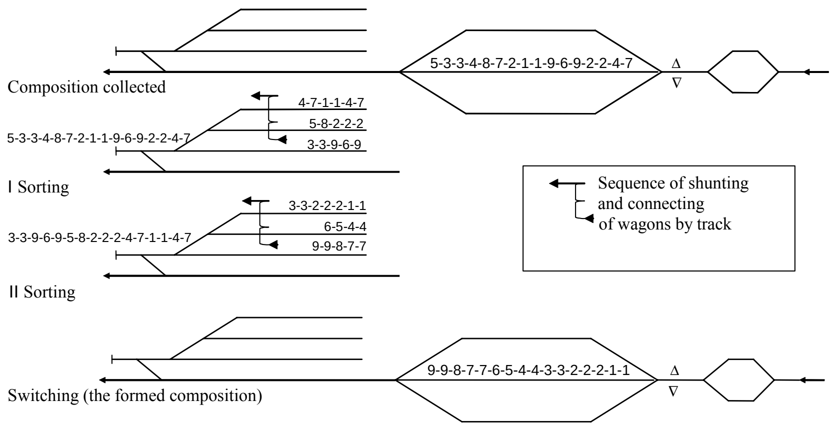


Figure 2: The forming of pick-up train by the Futhner method

3.2. A brief presentation of the Special method

The Special method of pick-up trains forming is also applied in stations equipped with small number of tracks, as in the case of Futhner method. In applying this method, there is no inter-relation between the track numbers and numbers of intermediate stations in which wagons have to be grouped up in trains. It can be applied on an arbitrary number of tracks, as opposed to the Futhner method, where it is not the case. Its application is reflected on the values of shunting operation indicators and the length of tracks on which this process takes place, which has not been investigated so far.

To enable a better identification of this method characteristics, a general example of forming the pick-up train consisting of groups of wagons for "n_{is}" intermediate stations, and the forming itself is made on "n_t" tracks (case n_{is}>n_t).

The procedure is as follows:

The wagons collected for a pick-up train from the sorting or sorting-departure track are first brought to the shunting track, and thereafter a process of sorting by destination station takes place. In the first sorting, the wagons for intermediate stations from *1* up to n_t *-1*, are left on corresponding tracks, and all other wagons are forwarded to the *n-th* track. This is followed by the first process of connecting the wagons from different tracks, starting from the n_t-*th* track, through n_t-1^{st}, up to the 2nd and their moving to the shunting track to get prepared for the next process of sorting. In this sorting process all wagons in groups for intermediate stations from the 2^{nd} up to n_t-1^{st} are grouped up and sorted by their respective sequence, and they are therefore all left on the

1st track, where the wagons for the first intermediate station are already placed. To these groups of wagons on the 1st track the wagons for the n_t-*th* intermediate station are added, and on other tracks the wagons are sorted by the following sequence: on the 2nd track, wagons for n_t+1 intermediate station, on the 3rd track wagons for n_t+2 and so on up to n_t-*1st* track where wagons for $2(n_t-1)$ intermediate station arrive, and on n_t-*th* track, the wagons for $2n_t$-*1st* station and so forth up to the m-th intermediate station. Then the wagons are grouped up again by track, starting from the n_t-*th* track up to the 2nd one, and they are brought to the shunting track to be prepared for the third process of sorting, similar to the previous one. The process is continued until the wagons for the last intermediate station are sorted.

In the case $n_{is} \leq n_t$, during the first sorting a complete splitting-up of wagons by intermediate station is carried out, so that only a grouping-up – connecting of wagons by track is to be done.

For a better insight into the process of forming a pick-up train by stage by means of this method, in case there are 3 tracks on which the wagons are collected for 9 intermediate stations, a presentation thereof is given in Figure 3.

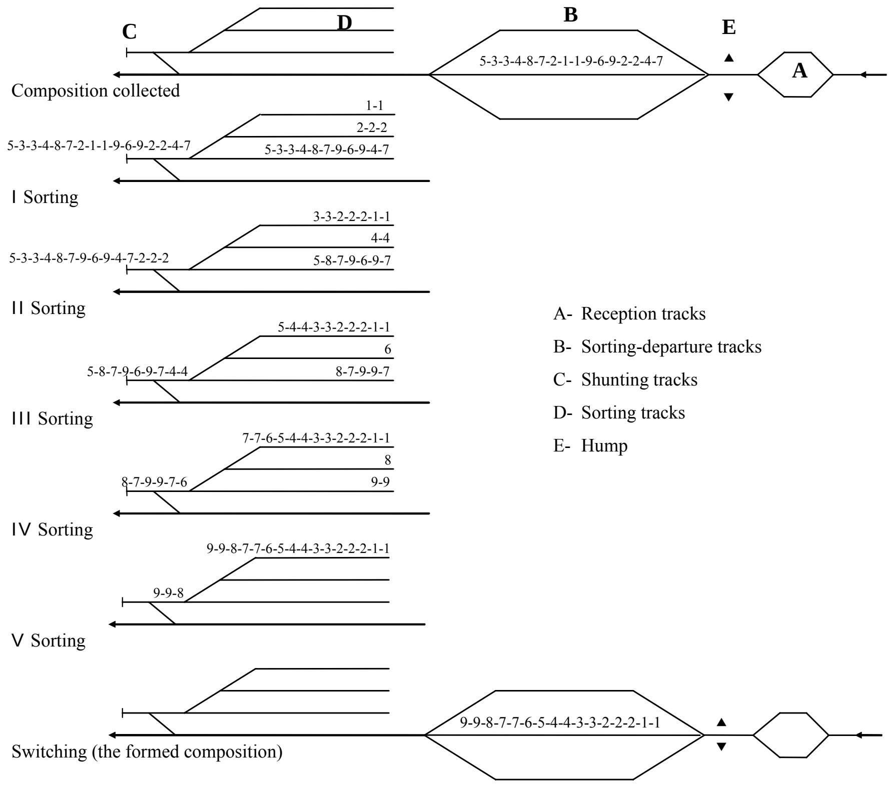


Figure 3: The forming of pick-up train by the Special method

(Note: For this method, as well, it is important to know a location of the locomotive and what sequence of wagons in trains is required in relation to the locomotive. Thus, one should know whether the wagons, starting from the locomotive towards the train end are arranged from the departure to the destination station (from *1* up to n_{is}), or from the destination to the departure station (from n_{is} up to *1*). This is because in the first case the splitting up will be made by order from 1^{st} up to n_t-*th* intermediate stations, and otherwise the other way round, from the n_t-*th* up to 1^{st} intermediate stations)

4. CONSTRUCTION OF THE SIMULATION MODEL

The internal structure and design of the simulation model of forming the pick-up trains by the Futhner and Special methods 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 [8]:

1. Track lengths required for carrying out the scheduled processes (indicators important for design);
2. Values of performance indicators of the process of final forming of pick-up trains (indicators important for evaluating the functioning of the system under consideration).

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. The simulation approach to this problem assumes quite different methodology including:

1. Set up the starting number of tracks in the station group of tracks on a real value.
2. Set up the composition of pick-up 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. Reiterate of the experiment, changing the train composition and number of intermediate stations.
4. Follow-up 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:

- *3* and *4 tracks* in the station group of tracks;
- *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 the Belgrade and Lapovo marshalling yards on the Railways of Serbia network (for the application of the Futhner method in the case with 5-9 intermediate stations three tracks are necessary, and in case with 10-16 intermediate stations four tracks are necessary);
- from *0.4* up to *0.7 min*. – average time required for collection – sorting per wagon by track.

5. OUTPUT RESULTS

Instead of complete output results which are numerous and have a standard GPSS/H form [2, 3, 9, 11], the work presents a recapitulation of selected results of individual indicators important to:

- determine the size of track capacity on which the final forming of pick-up trains is made;
- evaluation of new-designed solutions of technical freight yards for the purpose of taking adequate measures before the yard and facilities are built and placed in operation and
- assess the quality of station/yard operation and functioning of the system, respectively, by the application of the method under consideration.

The indicators of the system functioning comprises:

- number and length of tracks;
- time required for forming the pick-up train (sorting and groupage);
- wagon handling performance (number of wagons handled) and
- number of movements in connecting and splitting-up of wagons.

These results are shown in tables T-1 – T-2 in figures 4 – 7, and the symbols used have the following meaning:

- *max* n_{wi} - maximum number of wagons appearing on the *i-th* track when forming the pick-up train;
- *Tm* - time needed to make up (connect - groupage) of wagons by track on the station group of tracks;
- *Ts* - time needed to split (sorting, splitting-up) of wagons on the station group of tracks by intermediate station;
- *VSO* – wagon performance (volume of shunting operations, i.e. the number of wagons moved from the collection track up to the return to the departure track);
- *NM* – number of movements in forming of pick-up train, i.e. the number of splittings and connections.

Table 1: Output results of simulation for 5, 10 and 16 intermediate stations (Futhner method)

Input parameters / Functioning indicators	Values of the indicators of the existing system functioning								
	Number of intermediate stations								
	5			10			16		
	Number of wagons per composition			***Number of wagons per composition***			***Number of wagons per composition***		
	30	40	50	30	40	50	30	40	50
T_s	13,4	28,6	26,5	21,3	30,3	40,2	38,5	54,7	60,9
T_m	10,8	9,9	10,2	14,3	15,4	13,6	14,0	16,6	15,6
max n_{w1}	16	23	24	17	8	13	13	15	11
max n_{w2}	16	22	32	9	29	29	27	11	28
max n_{w3}	8	12	7	5	15	18	23	17	9
max n_{w4}	-	-	-	13	13	4	3	14	9
VSO	98	143	165	132	188	215	218	207	231
NM	23	44	43	35	47	65	65	58	71

Table 2: Output results of simulation for 5, 10 and 16 intermediate stations (Special method)

Input parameters / Functioning indicators	Values of the indicators of the existing system functioning								
	Number of intermediate stations								
	5			10			16		
	Number of wagons per composition			***Number of wagons per composition***			***Number of wagons per composition***		
	30	40	50	30	40	50	30	40	50
T_s	12,6	23,1	21,2	22,1	26,6	34,7	25,9	34,0	40,5
T_m	7,6	8,1	8,7	15,5	17,1	19,2	22,4	27,2	25,5
$max\ n_{w1}$	30	40	50	30	40	50	30	40	50
$max\ n_{w2}$	15	9	23	4	13	4	5	4	5
$max\ n_{w3}$	24	28	39	2	4	13	2	10	16
$max\ n_{w4}$	-	-	-	24	32	40	24	35	45
VSO	100	134	179	153	253	300	262	404	376
NM	22	41	38	39	48	63	45	61	72

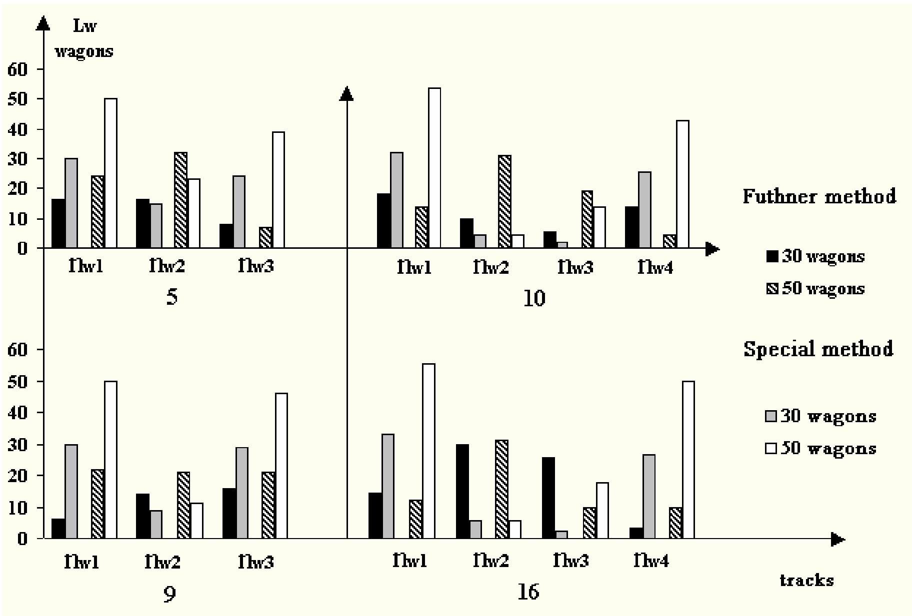


Figure 4: Track lengths necessary for forming of pick-up trains

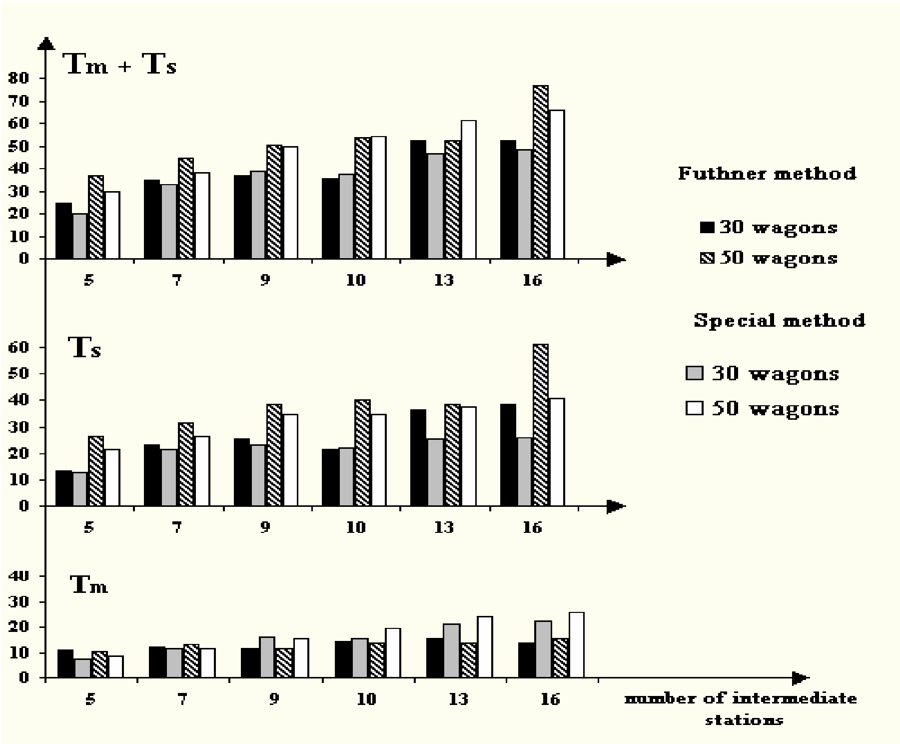


Figure 5: Pick-up train forming time

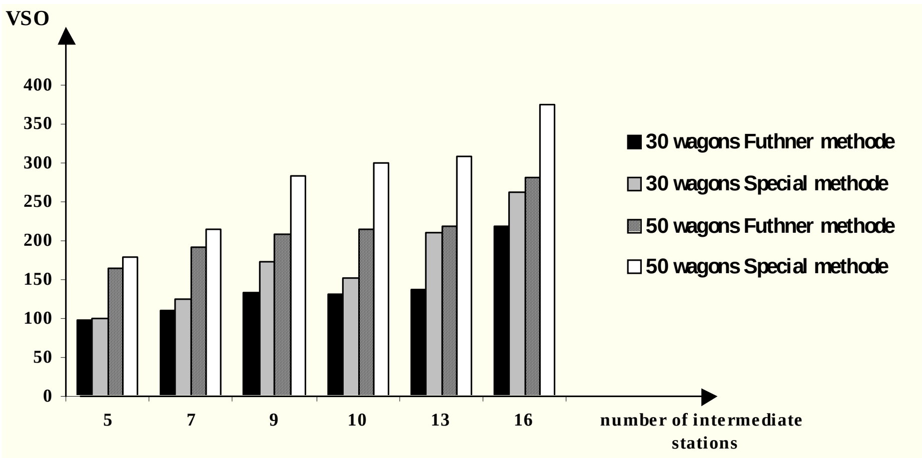


Figure 6: Volume of shunting operations in the process of pick-up train forming

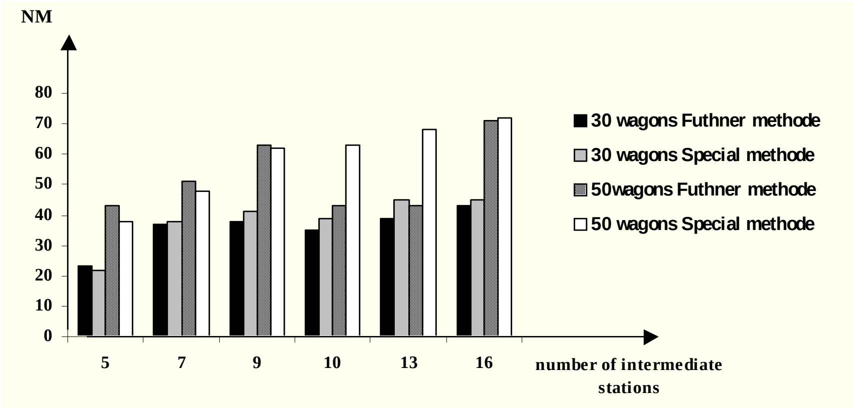


Figure 7: Number of movements in the process of pick-up train forming

The output results show that:

- Tracks on the process of final forming by the Futhner method are of approximately equal lengths, i.e. their mutual differences are not large, whereas with the Special method it is not the case. With this method the track lengths are notably unequal, where the first and the last tracks have equal – but notably greater lengths than the middle – inner ones, which also are of equal lengths. These data have not been known so far and not much attention has been paid to them in choosing the final solutions, although this might play a very important role in that part.
- The total time needed for forming a pick-up train comprises the time needed for distribution of wagons by track (*Tm*) and time needed for groupage (*Ts*). This time changes within the limits from 0.7 – 2.1 (min/wagon), irrespective of the method applied. The wagons groupage time is 2 – 4 times shorter than the time of their distribution and is 0.2 – 0.5 min/wagon. This indicates a high level of stability, equalized duration of the process, irrespective of the method used. As regards the wagon distribution time by track and intermediate station, its value is considerably less stable, and this instability is more notable in relation to the change in the number of wagons than the number of intermediate stations. The total time needed to complete the whole process is longer with the Futhner method, than with the Special method by about 10%.
- The volume of shunting operations (actual wagons handled and the number of moved wagons, respectively) considerably exceeds the number of wagons in the train. This increase ranges from 3 – 10 times in relation to the method applied. Thus e.g. with the Futhner method this increase is up to seven times, and with the Special method up to 10 times. This indicates that the operating costs when using the Special method would be higher than with the Futhner method.
- The number of movements (splitting and connecting) ranges within the limits from 0.7 – 2.0 (movements/wagon), irrespective of the method under consideration. Although the results obtained point to a high level of stability of this indicator, more detailed investigations point to its higher sensitivity to the change in the number of groups and number of wagons in the train than to the total number of intermediate stations for which trains are formed.

6. CONCLUSIONS

Based on the research and the analysis of obtained results, the following conclusions may be drawn:

- The process of forming the pick-up trains by conventional methods (Futhner method and Special method) is relatively easy to model and simulate by means of the simulation language GPSS/H;
- The output results of such model show the actual situation on the application of the analysed methods and point to a series of failures in the process of design and operation so far in technical freight yards. These results, therefore, may be used as an additional argument in making important technological and investment decisions in the process of design and operation of new technical fright yards, or reconstruction of the existing ones, as well as for evaluation of the quality of operation of such yards;
- By extension of the input elements and by additional analyses it is possible to arrive at new important indicators in the application of these method, for which it is necessary to carry out a special study.
- By construction of this model more favorable conditions are established and an incentive is given to involve a wider public and the authors themselves in the further elaboration thereof, addressing this and other similar problems.

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