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COMPARATIVE ANALYSIS OF MARSHALLING YARD SORTING METHODS

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Abstract

Marshalling yards have a decisive impact on accuracy, availability and cost efficiency of rail freight services.In that sense, an efficient and effective operation of marshalling yards is at the heart of the future single wagonload (SWL) freight service in Europe. The SWL supply includes grouping and sorting of wagons in order to assembly full trains with different shipmentsTwo types of methods for formation of multigroup trains are described and analyzed. The first is analysis of methods for consecutive forming of multigroup trains and the second is analysis of methods for simultaneous formation of multigroup trains. Comparative analysis is given for both groups of methods.Finally, conclusions for marshalling yard sorting methods analysis are presented.

***Keywords**: marshalling yards, single wagonload, sorting methods, multigroup trains, heuristic approach.*

1 INTRODUCTION

Marshalling or shunting yards play important role in freight railway transport. The efficient use of shunting yards has a deep impact on the efficiency and reliability of rail freight services due to reduction of transportation cost and increasing reliability and punctuallity. Main processes of marshalling yards focus on the disaggregation and forming composition of trains according the freight wagons destination.

Specifically, inbound trains are disassembled or humped, and the wagons are then reorganized to generate outbound trains via a system of tracks and switches. Using this consolidation and redistribution procedure, wagons can be sent through the network efficiently without providing a large number of end-to-end services. In practice, the processing time of freight wagons in a railroad yard represents a large proportion of the total railroad end-to-end transportation or trip time, so continuously improving the efficiency of railroad yard operations has received significant attention by decision makers and operations researchers in the rail industry.

The basic elements that define the quality of transport are transport time and transport costs. It means that the optimal transport of goods may be provided by minimizing the time and cost of transport. Transport time of freight depends on the wagon retention on commodity operations (loading and unloading), the speed of the trains on main lines and retention in freight yard. The organization of shunting operations directly causes spent time of wagons at the freight yards and thus significantly affect the overall transport time.

Traffic regulations and guidelines indicate that safety must be taken into account first during shunting. Shunting is done in such a way to achieve maximum efficiency in the work and price is a key factor in shunting.

The usual practice on marshalling stations indicates that an important factor is the number of maneuvers and that the goal is with the least possible number of maneuvers to achieve greater result. In addition, the repair of the wagons, servicing trains, cargo and other operations are performed.

Marshalling yard is usually found in the context of large railway nodes, which are close to industrial or commercial transport centres, mining and metallurgical companies, distribution centers or major sea or river ports.

The main tasks of marshalling yard are dismantling trains, coming from local boundary stations, industrial zones, after that sorting wagons and forming a new trains (collection, direct or block trains). Collecting trains are delivered to the neighboring yards, while direct freight trains wagon shipped to neighboring or marshalling yards without intermediate changes in its composition.

Marshalling yards are railway yards placed at some freight train stations where wagons are separated in order to collect them into trains according to their transport destinations. There are three types of marshalling yards: flat, gravity and hump yard.

Flat yards are constructed on flat ground, or on a gentle slope and freight cars are pushed by means of locomotive and reach to their required location.

Hump yard is the largest and the most effective classification yard, with the largest shunting capacity. Main part of this yard is the hump on a small hill over where a locomotive pushes the cars. Single cars or a block of coupled cars roll by gravity onto their destination tracks.

Operating in gravity yard is similar as in hump yard, and whole yard is set up on a continuous falling gradient. Almost all gravity yards have been equipped with humps and are worked as hump yards.

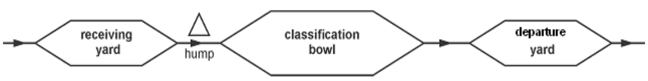

***Fig. 1** Common marshalling yard*

The typical layout of a marshalling yard, shown in Fig.1, consists of a receiving yard where incoming trains arrive, a classification group of tracks where they are sorted, and a departure yard where outgoing trains are formed.A typical classification bowl (classification group of tracks) is shown in Fig.2a, in which the classification tracks are connected to the departure yard at the end opposite the hump. Not all yards have receiving and departure tracks; some have single-ended classification bowls as in Fig.2b, while others have a secondary hump at their opposite end as in Fig.2c. However, almost all yards have the layout of Fig.2b as a substructure.

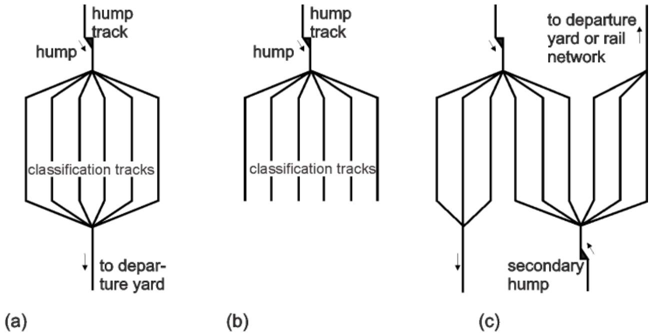

Fig. 2 *Some common classification bowl layouts. (a) double-ended yard, (b) single-ended yard, (c) advanced layout*

Monitoring of each wagon on every marshalling yard is crucial for operators to provide reliable freight transportation and to be more competitive to road transport. To provide more reliable and flexible freight transportation system according New Single Wagon Load system is one of the key elements of TD5.2 Access and Operations in [1].

Single Wagon Load (SWL) represents the transport of freight in individual railway wagons or groups of wagons where the shipment is less than a whole trainload. The SWL supply includes grouping and sorting of wagons in order to assembly full trains with different shipments, in order to take advantage of the full train size and, thus, increasing the productivity. It means that sorting and grouping wagons are crucial activities for SWL.

Recent EC study [2] estimated that SWL accounts for 27% of rail freight. It is obvious that market share of SWL v. full trainload is decreasing. On the other hand, SWL is also a key feeder for rail freight:

- Only 20-30% of full trains are shuttles
- 70-80% of full trains use SWL to distribute wagons between marshalling yards

The second important issue is the fact that there are different levels of SWL traffic across the different European countries. It varies from less than 10% to more than 40%. That fact makes SWL concept and future directions of its improvement more complex from perspective of integration and standardization of rail freight services and their general market share. Regarding optimization, it becomes more complicated for collecting relevant data because of different conditions and different ambitions on national level for SWL in European countries. Also, it is necessary to take into account EU countries and non EU countries where statistical data are not available for SWL share and traffic.

As a conclusion of this chapter it can be said that efficient and effective operation of marshalling yards is at the heart of the future SWLfreight service in Europe. In that sense, optimization of marshalling processes becomes more important for further improvements of rail freight services. As an inevitable part of optimal marshalling processes in marshalling yards different sorting methods are presented and analyzed. Sorting methods are analyzed from perspecive of forming multigroup trains as a key element of SWL concept.

2 METHODS FOR FORMATION OF MULTIGROUP TRAINS

As it stated above, multigroup trains play a significant role in the rail freight transportation. The formation of multigroup trains is considered a highly complex problem of railway. Multigroup trains are composed of a number of groups of wagons that have to be classified according to the order of intermediate stations.

Formation of multigroup trains shortens the time needed for collection, and enables concentration of maneuvering operations to a smaller number of marshalling yards. This concentration of maneuvering operations leads to greater use of track capacities, maneuvering facilities and personnel, while also enables rationalization of capacities and operating technology at intermediate and final stations where maneuvering is reduced on separation of vehicle groups that have already been formed.

Methods for formation of multigroup trains are generally divided into methods for consecutive formation of trains, and methods for simultaneous formation of trains. According to consecutive formation methods, which are more frequently used in railways, the next train can not be formed before formation of the previous train is completed. On the other hand, concept of simultaneous methods primarily lies in the fact that wagons are collected according to the order of appropriate intermediate stations i.e. according to vehicle groups belonging to intermediate stations of the same number for different trains, rather than according to trains.

It yields to the difference in the track capacities usage and in the realization of the overall forming process. Simultaneous methods can greatly improve station operating parameters, as they enable simultaneous formation of several trains, which in turn enables their timely dispatching from marshalling yards and deliveringto required destinations. Application of simultaneous methods, in practice and everyday tasks requires appropriate adaptation of the timetable and professionally trained maneuver staff. Sensitivity to possible disturbances can be indicated as the major shortcoming and faults as well as their direct negative impact on dispatching of trains.

2.1 Methods for consecutive forming of multigroup trains

Different methods can be used for forming of multigroup trains according to the required number of shunting tracks and shunting mode. It also depends on the technical characteristics of marshalling stations and the number of intermediate stations. Thus, if the number of intermediate stations 4 or less than some conventional shunting method is applied where wagon allocates to each individual intermediate stations at every track.

However, in the case, which is more common, some of the methods for succession forming a multigroup trains are used. These methods are considered the train marshalling problem, which consists of disassembling the incoming accumulated composition wagons on a separate marshalling track (track for sorting) and reassembly (merging) group of wagons according to the plan for formatting multigroup train. Shunting is conducted in such a way that the wagons with the same destinations (intermediate stations) are placing in succession, forming individual groups of wagons, and finally forming multigroup train.

2.1.1 Single stage sorting method

Single stage sorting method, in addition to the initial disassembling operation (roll-in operation), allows only one more operation - the car accumulation according to the plan of formation the group of trains. Both processes are performed by maneuvering locomotive.
In a single stage sorting, required number of tracks for one train sorting is equal to the number of groups of cars i.e. the number of intermediate stations [3].
However, analysis in [4] has shown that the number of tracks for sorting does not depend on the number of intermediate stations, and there are two important parameters:
- Number of accumulated composition cars of the train
-The minimum number of cars from one of intermediate stations.

2.1.2 Futhner's method

Futhner's method is based on marshalling system where on one track (marshalling track) performs classification of the cars - wagon for several different intermediate stations. The root of the number intermediate stations determines the required number of shunting track for two-step sorting procedure [5]:

$$n_t = \sqrt{n_{is}} \tag{1}$$

where is: n_t - the required number of shunting tracks, rounded to a whole number, n_{is} - number of intermediate stations.
- In the first sorting phase
On the first track segregate cars for intermediate stations
$1, \sqrt{n_{is}}+1, 2\sqrt{n_{is}}+1, \ldots n_{is}-\sqrt{n_{is}}+1$
On the second track segregate cars for intermediate stations:
$2, \sqrt{n_{is}}+2, 2\sqrt{n_{is}}+1, \ldots n_{is}-\sqrt{n_{is}}+2$
On n_t*-th* track segregate cars for intermediate stations:
$\sqrt{n_{is}}+1, 2\sqrt{n_{is}}, \ldots n_{is}$

Now the first phase of sorting is completed in which, on each track, segregate the group of cars for the same intermediate stations but not yet in an order that would correspond intermediate stations. With that, go to the second sorting phase.

- In the second sorting phase, after the unification of multigroup train (in order of increasing tracks number) sorting performs on the marshalling tracks in the order of intermediate stations [5].
On the first track segregate cars for intermediate stations: *1,2,3, ... ,* $\sqrt{n_{is}}$
On the second track segregate cars for intermediate stations:
$\sqrt{n_{is}}+1, \sqrt{n_{is}}+2, \sqrt{n_{is}}+3 \ldots 2\sqrt{n_{is}}$
On the third track segregate cars for intermediate stations:
$2\sqrt{n_{is}}+1, 2\sqrt{n_{is}}+2, 2\sqrt{n_{is}}+3 \ldots 3\sqrt{n_{is}}$
On n_t*-th* track segregate cars for intermediate stations:
$\sqrt{n_{is}}-1, \sqrt{n_{is}}+1, \ldots n_{is}$
So, two important parameters for application of Futhner's method are:
- The number of intermediate stations on the basis of which is determined
- The number of shunting tracks
After the first sorting, follow the second phase of sorting, according to accumulated composition from the first stage (first pulling groups from the first track, then the second and the third at the end of the track). Next, composition of the train is formed in order of intermediate stations.

2.1.3 General method

Contrary to theFuthner's method, the general method can form the train whose number of intermediate stations is the highest:

$$n_{is} = \frac{n_t\left(n_t+1\right)}{2} \tag{2}$$

After determining the required number of shunting tracks, the procedure of disassembling accumulated composition of cars is done on the basis of equality between the ordinal number of tracks in the group for forming and the number of groups that are segregated on track at the moment ofbeginning the process of sorting cars [4].
In the first phase of the sorting:
On the first track segregate cars for intermediate stations: *1,-*
On the second track segregate cars for intermediate stations:*2,* n_t+1*, -,*
On the third track segregate cars for intermediate stations: *3,* n_t+2*,*$(2n_t-1)+1$*, -...*
On n_t*-th* track segregate cars for intermediate stations: n_t, $2n_t-1$, $3n_t-(1+2)$, $4n_t-(1+2+3)\ldots\frac{n_t\left(n_t+1\right)}{2}$
Next steps of sorting do not have to implement by unified pulling and sorting of all cars from all tracks, but they can be achieved with a series of extraction and sorting wagons from individual tracks.
This characteristic can come to the fore with limited resources (insufficient length of pull out or insufficient power of maneuvering locomotives) [4].
Thus, in the second phase of the sorting:
On the first track segregate cars for intermediate stations: *1, 2, 3...* n_t
On the second track segregate cars for intermediate stations: $n_t+1 \ldots 2n_t-1$
On the third track segregate cars for intermediate stations: $(2n_t-1)+1, \ldots, 4n_t-(1+2+3)\ldots$
On n_t*-th* track segregate cars for intermediate stations:
$\frac{n_t\left(n_t+1\right)}{2}$
However, the negative characteristic of the general method is that at certain the number of tracks, a smaller number of groups can be sorted in accordance with the Futhner's method.

2.1.4 The special method

Special method is based on an arbitrary number of tracks, i.e. on the number of tracks available for shunting.

Contraryto the previous methods, there is no correlation between number of intermediate stations and the number of shunting tracks [6]. Forming of multigroup train after classification according the intermediate stations is carried out by the following procedure, explained below.

In the first stage of sorting, wagons for intermediate stations n_{is} to n_{is}-n_t+2 leave on separate tracks, and all the other cars together at first track. Then, the first assembly of cars on the tracks should be followed and unification from the first to the n_t-1 track, in order to prepare for the second stage of sorting.

At this stage all cars for intermediate stations from n_{is}-1 to n_{is}- n_t+2 are grouped according to the order of intermediate stations and are left on track n_t where there are already cars for intermediate station n_{is}.

Groups of wagons on track n_t add wagons for intermediate station n_{is}- n_t+1, and on the other tracks is carried out sorting in the following order: on track n_t-1 wagons for intermediate station n_{is}-n_t , on track n_t-2 wagons for intermediate station n_{is}-n_t-1 and so on, until the second track where wagons for intermediate station n_{is}-2n_t+3are coming.

Any remaining wagons, for intermediate station 1 to n_{is}-2n_t+2, are left to the first track. After this disassembling, unification of wagons per tracks from the first to the n_t-1 tracks is carried out and wagons are pulled in order to be prepared for the third stage of sorting with very similar procedure to the previously described procedures.

This process continues until wagons for the first intermediate station are not sorted [4] [7]. So, the important parameter for using special methodis the number of intermediate stations.

Modification of special methods is achieved by eliminating the need for merging and unifying segregate groups of wagons, after the completion of each step of sorting. This switching operation of each next step is because of the smaller number of cars that is needed to move. Unifying composition cars segregate per tracks is done only after the last step of sorting thereby forming a composition for multigroup train, in the order of intermediate station.

2.1.5 Method of unified groups

The parameters that characterize the method of unified groups are a large number of groups to sort and insufficient number of tracks. This method is based on the implementation process of sorting a group of some of the previous method which is suitable for forming the train which has a half less intermediate station $n_{is}/2$. Unifying the group is carried out by pairing the cars for: intermediate stations: 1 i $n_{is}/2+1$, 2 i $n_{is}/2+2$, 3 i $n_{is}/2+3$ etc.

2.1.6 The Japanese method

Technology deployment of the final assembly of trains using the Japanese method does not depend on the number of tracks. It depends on track technical solutions, respectively, applied of track links, single successive track links or double successive track links [7].

These systems consist of three shunting tracks connected by a larger number of track links, usually simple or double track links. Furthermore, all these tracks must have a downward grade of 2.5‰ and must be equipped with track brakes, radars, and axle counters. The central delivery track is usually by 50 to 80 mm higher then the end tracks, so that wagons can easier move to end tracks, depending on their use. In marshalling or classification yards, such track solutions can be:

- With only one track structure where the final sorting is operated for all trains,
- With several track structures, where the number of such structures corresponds to the number of feeder trains to be formed at a particular yard,
- With several truck structures that is defined depending on the needs and expected effects.

It is important that the central track assumes to have the role of delivery track in each track group, while two end tracks are used for wagon collection by intermediate stations. This is why both end tracks must have the number of parts that corresponds to the maximum number of intermediate stations at a distribution section for which feeder trains are formed The method of wagon forming or wagon collection at sections, and by intermediate stations, depends on usage of crossovers:

- If simple crossovers are used, then the use of parts at end tracks must correspond to the order of intermediate stations;
- If double crossovers are used, then the use of parts at end tracks can be arbitrary.

This solution enables wagon sorting and grouping according to appropriate intermediate stations in a single classification effort, so that this phase is followed solely by grouping according to the order of intermediate stations. At the end, we could state that this solution is generally characterized by increasing of investments due to use of additional crossovers and track brakes, while on the other hand significant savings are made by shorter downtime of wagons.

2.1.7 Comparative analysis of methods for consecutive forming of multigroup trains

As it mentioned above, methods for consecutive forming of multigroup trains are used more often than simultaneous one. In Table 1 and Table 2 advantages and disadvantages of consecutive methods are described.

Table 1 Advantages of methods for consecutive forming of multigroup trains

Method name	Advantages
Single stage sorting method	Number of necessary tracks can be reduced if the relative positions of cars in accumulated composition are taken into account
Futhner's method	Sorting a large number of groups and forming multigroup trains through the two-step sorting
General method	Application of the method in resource-limited yards (insufficient length of pull out or insufficient maneuvering locomotive power) because the sorting steps can make a series of extraction and sorting cars from individual tracks
Special method	There is no rigid correlation between the number of intermediate stations and the number of shunting tracks

Modified special method	There is no rigid correlation between the number of intermediate stations and the number of shunting tracks; Eliminating the need for merging and uniting sorted groups of cars at the end of each step
Method unified group	Application when there is insufficient number of tracks; sorting a large number of groups of wagons
Japanese methods	With quickly stopping wagons significant savings are achieved

Table 2 Disadvantages of methods for consecutive forming of multigroup trains

Method name	Disadvantages
Single stage sorting method	With the increase the number of wagons or a number of groups within the wagons, increasing complexity of the problem, and the possibility of reducing the number of required tracks is decreasing
Futhner's method	Steps of sorting are implemented through unified pulling and sorting of all wagons on all tracks
General method	Sorting a small number of groups
Special method	Typical applications in stations with a small number of tracks; the need for merging and uniting sorted group of wagons at the end of each step of the sorting
Modified special method	Typical applications in stations with a small number of tracks
Method unified group	Method is based on the implementation process of sorting a group of some of the previous methods
Japanese methods	Increase in investments due to the use additional links of track and of track brakes

It can be concluded that there is no ideal solution for sorting wagons in marshalling yards using consecutive methods. That fact makes potential marshalling process more complex for automation and design of decision support system as efficient tool for increase reliabilty of rail freight service, in general.

2.2 Methods for simultaneous formation of multigroup trains

Simultaneous formation of multigroup train starts process of disassembling. Wagons of multigroup trains accumulate on the tracks by a particular rule that is a function of the number of groups in trains. This is an important difference compared to conventional methods where the number of tracks for the accumulation is in function of the number of trains. Three different methods for simultaneous formation of multigroup trains are described in this subchapter.

2.2.1 Elementary method

The elementary simultaneous method consists of two phases. In the first phase, wagons are collected according to intermediate stations. Wagons collection is performed in such a way that wagons for all first, subsequent and all other intermediate stations are brought to tracks previously determined for each intermediate station, despite the fact that wagons belong to different trains. The theoretical minimum number of tracks for collection (n_k) is equal to the maximum number of intermediate stations (g_{max}) in some of train for forming (3). The rule for collection of groups of wagons g_j (j=1,..., g_{max}) by track is given in the expression (4), according [8], where g_k is the number of intermediate stations for trains from which wagons are gathered at the track k:

$$n_k = g_{max} \tag{3}$$

$$g_k = g_j, k = 1 \dots g_{max} \tag{4}$$

After completion of collection phase, the second phase (formation phase) starts where wagons are moved from collection tracksand grouped according to the corresponding trains.
This method enables formation of a great number of multigroup trains with a minimum scope of maneuvering work (number of moves is equal for all groups and amounts to precisely one move per vehicle h=1) and the number of wagons moved, i.e.of wagons which were used in the multigroup train forming process, corresponds to the total number of wagons in all trains.

2.2.2 Triangular method

This method also consists of two phases. Wagons are gathered together in the first phase, and are sorted in the second phase. First, they are sortedat wagon collection tracks according to intermediate stations, and second they are sorted at train forming tracks according to trains they belong to, and according to the order of intermediate stations.
The connection between the maximum number of intermediate stations in a train (g_{max}) and the required number of wagon collection tracks (n_k) is shown in the expression (5) [9]:

$$n_k \begin{cases} \sqrt{2g_{max}} - \frac{1}{2}, & \sqrt{2g_{max}} - \frac{1}{2} \in N \\ \left[\sqrt{2g_{max}} - \frac{1}{2}\right], & \sqrt{2g_{max}} - \frac{1}{2} \notin N \end{cases} \tag{5}$$

The rule for collecting wagon groups g_j (j = 1, ..., g_{max}) at intermediate stations and tracks *k* is given in the expression (6), where wagons for intermediate stations are collected at track *k* at point *i* [10]:

$$g_{k,i} = \frac{k(k-1)}{2} + ik + 1 + \frac{(i-1)(i-2)}{2}, k = 1,..n_k, i = 1,2,.. \tag{6}$$

Unlike the elementary method, in case of triangular forming, wagons for more than one intermediate station are collected at a single track. This calls for a more complex classification plan, and hence a greater scope of maneuvering operations, such as the number of pullout operations per wagon or the number of wagons moved. The number of pullout operations is two for all wagons belonging to the same intermediate station, except for wagons (7) which represent the so called "frontal groups" at tracks *k* and are pulled out once (h=1) [9]. In practice, this means that these wagons pass through the forming process in the same way as in the elementary simultaneous method. As to the number of wagonsmovements, with which the multigroup train forming process is accomplished, it is greater than the total number of wagons in all trains, as up to two pullout operations are made with some trains [4].

$$g_{k,1} = \frac{k(k-1)}{2} + 1 \quad (7)$$

2.2.3 Geometrical method

The geometrical classification constitutes a further advance in the development of simultaneous methods. In fact, an additional reduction in the number of tracks needed for train forming operations has been achieved by using this method.

The connection between the maximum number of intermediate stations in a train (g_{max})and the required number of shunting tracks (n_k) where wagons are collected and sorted according to groups belonging to the same intermediate station, is given in the relation (8), while the general principle for collecting wagons at tracks is given in the relation (9).

$$n_k = \begin{cases} \log_2(g_{max}+1), & \log_2(g_{max}+1), \in N \\ \lceil \log_2(g_{max}+1) \rceil, & \log_2(g_{max}+1), \notin N \end{cases} \quad (8)$$

$$g_{k,i} = 2^{k-1} + 2^k(i-1), \; k = 1 \dots n_k, i = 1,2,3, \dots \quad (9)$$

The reduction in the number of tracks according to this method leads however to an increase in the scope of maneuvering operations, with respect to both the pullout operations and the number of wagons moved. The number of wagon pullout operations is dependent on the number assigned to the intermediate station the wagons belong to, and may amount to no more than h = [$\log_2$g]. Like in triangular method, the "frontal groups" have the lowest number of pullout operations, as wagons are pulled out only once (h=1). Unlike the triangular method, the number of pullout operations for other groups is not limited to a particular value, but rather varies with the change of intermediate stations for a train. In case of geometrical classification, frontal track group *k* is the group $g_{k,1} = 2^{k-1}$.

2.2.4 The analysis of methods and parameters for simultaneous formation of multigroup train

The characteristic of these methods is the simultaneous formation of more trains. The first phase of wagon collection according to intermediate stations, and the first part of the second phase of wagon classification according to intermediate stations, take place at tracks of the marshalling or marshalling departure park, while the second part of the second phase i.e. wagon sorting phase according to trains and intermediate stations can be operated for all methods on tracks of the marshalling or marshalling-departure park, and for elementary method even on tracks of the departure park.

During the common collection of multigroup trains number of tracks depends on the maximum number of intermediate stations of one train and made a superb sorting plan of wagons. There are two options, i.e. the formation of multigroup trains with a simple sorting plan that requires the engagement of a large number of tracks or complex sorting plan by engaging a smaller number of tracks. The possibility of application simultaneous method should be assessed according to their basic characteristics i.e. each method has its own characteristics in terms of the necessary number of tracks and the quality of the work station. Elementary method allows the formation of trains separating wagons for intermediate stations on separate tracks, after which it is enough to sort wagons belonging to the trains. Geometrical methods engage the smallest number of tracks by applying the most complex sorting plan. Unlike the previous two methods, triangular method applies a different sort plan complexity and limits the maneuver work on two movements per wagon during sorting.

In order to implement the method for the formation of multigroup train in practice it is necessary to analyze the technical and technological conditions maneuver work in the station. The process of forming trains requires engagement of appropriate station facility and maneuvering capacity, in conjunction with the appropriate organization and technology of work. Practical application of methods for multigroup train formation depends on the choice of station facility, maneuvering capacity and technology work.

For the realization of the above methods is necessary to define the technical conditions i.e. necessary tracks group for and type of the processing facilities, the required number and length of tracks, applied connection within the group of track, links between the tracks groups and of the processing facility and the required technical and operational characteristics of shunting locomotives to operate on processing. Besides the technical equipment it is necessary to analyze and technological conditions relating to the interdependence of the activities and operations during the accumulation wagons and the formation of trains, order of execution and norming the time of their realization.

The shape and capacity of track facilities for the accumulation and sorting wagons differ depending on the applied method. While the accumulation of wagons for the multigroup trains can be done on tracks of the marshalling or marshalling departure park for dismantling incoming trains in order to accumulate wagons are used hump, very rare pullout track, while for sorting wagons during the formation can be used hump, or pullout track or modified hump.

Simultaneous methods require two groups of shunting tracks:

- group for collecting and sorting vehicles according to intermediate stations and
- group for sorting vehicles according to trains and intermediate stations.

Technical and operational characteristics of shunting locomotives affect on possibility and effects of the application a particular method for the formation of multigroup train. When using the method for simultaneous formation of multigroup trains, shunting locomotive must allow extraction maneuvering composition from track with the accumulated wagons and pushing them on the hump. The total mass of accumulated wagons on one track must not exceed the maximum permitted mass of the composition according to the criteria of movement also and to the criteria by starting from the beginning of maneuvering composition.

In applying the methods for succession formation of multigroup trains primarily used pullout track. Technology work on pullout track in the formation of multigroup train depends on the applied method for forming of multigroup trains, the number of intermediate stations, the size of composition and technical requirements for successive formation of multigroup trains.
It can be concluded, by comparing methods for simultaneously forming, that sorting time of wagons using the geometric and the triangular method lower in terms of small scale work and a large number of intermediate stations. The elementary method features a smaller train forming time under conditions characterized by a greater number of wagons. If we compare triangular method with geometrical method, we can see that the triangular method is more advantageous in that it is less dependent on the number of intermediate stations.

According to elementary method, trains are formed in such a way that all wagons are moved only once in the course of the sorting process. In geometrical method, the number of movements per vehicle generally increases with an increase in the number of intermediate stations which exceed two movements (applicable to more than 15 groups) [4]. On the other hand, triangular method does not exceed two movements per wagon in the sorting process.
The elementary simultaneous method has the best total effects regarding to formation of trains composed of smaller number of groups with a great quantity of wagons. Triangular and geometrical forming requires a similar number of tracks, but the total track lengths are greater when geometrical method is applied. These methods have differed considerably with regard to quality of service rendered, especially under conditions characterized by a great number of wagons at the forming stage. At the end of this section comparative analysis of above mentioned methods for simultaneous formation of multigroup train is given in Table 3 and Table 4.

Table 3 Advantages of methods for simultanous forming of multigroup trains

Method	Advantages
Elementary	The formation of a large number of multigroup trains with the minimum amount of maneuvering work. The simplest plan sorting wagon.
Triangular	Engagement a smallest number of tracks.
Geometrical	Reducing the required number of tracks for the process of formation trains. Increasing the volume of maneuvering work.

Table 4 Disadvantages of methods for simultanous forming of multigroup trains

Method	Disadvantage
Elementary	Engagement of large number of tracks.
Triangular	The more complex sorting plan (increase in the volume of maneuvering work).
Geometrical	The mathematical complexity of the method.

The main disadvantage is that most of the real problems of simultaneous formation of multigroup train can not be solved optimally in terms of limited time and requested memory and it is necessary to examine the possibility of applying heuristic method for finding optimal solutions.Itraises with challenging demands to provide marshalling yard management in real time. Heuristic approach seems to be more convinient for achieving challenging task regarding real time demand. In general, we have to find optimal or near optimal solution and to give a good answer on deviations and disruptions in marshalling process.

3 CONCLUSION

Multigroup trains combine the profitability of rail transport in greater distances and flexibility transport of individual wagons consignments. From the aspect of the organization and management of transport of individual consignments, the biggest problem is the optimization of wagon flows and method of forming of multigroup train. The formation of multigroup train reduces the retention wagons due to accumulation, and therefore the total spent time of wagons in technical freight stations.
The formation of multigroup train can be done using conventional or the simultaneous methods. Classical methods in current practice frequently used and characterized by individual formation of trains. By these methods, the process of accumulation wagons fully separated from their sorting. The first wagons accumulate especially towards marshalling tasks multigroup train of forming plan, and then for each individual task shunting wagons are sorted according intermediate stations.
The required number of tracks to accumulation of wagons for all classic methods is the same and depends on the number of shunting tasks, while the number of tracks on which wagons are subsequently sorted, vary in relation to the applied method of forming and depending on the number of intermediate stations per trains. The main disadvantage of these methods can be seen in direct dependence of the total time of forming the number multigroup train, which restricts and precludes their effective use in case of a large number of trains.

Simultaneous method of forming multigroup train characterized by simultaneously formation of more multigroup trains, and can be realized by simple plan sorting wagons by hiring a larger number of tracks or a complex plan sort by hiring a small number of tracks. It is possible to form multigroup trains by methods of varying complexity sorting plan. Each simultaneous method has its own characteristics in terms of needed track capacity, and the possibility of applying the method should be assessed according to their basic characteristics.

The research conducted showed that limitations from the point of exploitation and the design of shunting installations greatly affect and change the final effects of the methods applied in relation to the theoretical formulations. Based on the results obtained through research can be given a unique response which method is most appropriate.

Number of group wagons on the formation and size of the wagons flow affects the process of sorting the wagons, which is particularly evident in terms of the large number of wagons on the formation.

The fact that real time optimization and robustness to deviations in marshalling process are too big challenge for traditional sorting methods lead us to coclusion for using heuristic approch in combination with above mentioned methods. That can be a key element for decision support system for marshalling yard as one of specific ongoing objectives in marshalling yard management problem.

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