EXAMINATION OF SIMULTANEOUS METHODS APPLICATION FOR SECONDARY SORTING IN SLOVAKIA

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ABSTRACT
There are many known algorithms to organize secondary sorting. Simultaneous sorting is an effective approach. The simultaneous sorting was compared to basic sorting algorithms and natural sorting schemes. Important savings were attained on a number of used tracks and on a sorting time as well. The savings attained in tested cases were around 30 percent of a sorting time and more than half of necessary sidings. This paper describes an idea of examination of possibilities of using simultaneous sorting methods in Slovakia.

Key words: simultaneous sorting, marshalling yard, train formation, simulation, Villon

INTRODUCTION

This paper informs about intents and aims of the research oriented on simultaneous sorting methods application for secondary sorting by Slovak railways.

Presented research is based on dissertation work results [4], [5]. According to these results, the simultaneous methods are more effective than the standard step methods as for the time required for trains formation and the number of necessary sorting tracks. This is supported by facts published in [3] as well as by experience of Swiss railways.

In this paper the simultaneous methods principles are explained on local freight trains formation. The paper does not deal with simultaneous methods application within industry sidings and marshalling yards with special functions (e.g. in seaports or transshipping stations between normal and wide gauge). Basic assumptions used by explanation in this paper are that trains arranged by using simultaneous methods are composed like wagon groups and that each wagon has its own assigned group in train formation according to the predetermined rules (e.g. train formation plan of marshalling yard and its aids). The groups sequence in train is generally predetermined, too. Mostly this sequence is determined by a geographical location and an operation technology of stations on line served by local freight train.

BASIC PRINCIPLES OF SIMULTANEOUS METHODS

The formation of local freight trains is performed in marshalling yard in two main phases. The first phase is executed during the particular inbound trains sorting. This phase is called primary sorting too. During the primary sorting the wagons for direct trains without groups and long-distance group trains that are created by joining of wagon groups from two or more different sorting sidings are gathered on a part of sorting sidings. On the rest of sorting sidings the wagons for local trains with wagon groups are gathered. These trains are created after
the end of the secondary sorting. During the secondary sorting, terminating trains are not split, but the wagons accumulated on a part of sorting sidings during the primary sorting are. The secondary sorting is the second phase of local freight trains formation.

There are two important differences between step and simultaneous sorting methods. The step sorting methods always use the same principle for the wagon accumulation during the primary sorting (wagons are sorted according to directions). The simultaneous methods use different schemes for the wagon accumulation already during the primary sorting. By the step methods, the train formation always ends independently for each train (trains are finished gradually). By the simultaneous methods the train formation ends for all trains in the same time (simultaneously), after splitting of wagons from the last sorting siding and the wagons for local freight trains accumulated during the primary sorting.

By sorting according to the simultaneous methods, wagons are accumulated during the primary sorting on sorting sidings according to the groups to which they were assigned, according to the sorting scheme. During the secondary sorting the wagons are accumulated according to their referring to the particular trains.

There are four different simultaneous sorting methods described in literature [3]. The most understandable is a basic simultaneous method [1]. During the primary sorting all wagons are accumulated for local freight trains by the sequence number of their groups. As an example the formation of four trains A, B, C and D is used. Six wagon groups from “1” to “6” compose each train. All wagons from the first group of “A” train are marked as “A1”; all wagons from the second group of “A” train are marked as “A2”, etc. Groups that are in completed trains farthest from the hump obtain number “1”. Groups that are nearest to the hump obtain number “6”. During the first sorting phase wagons are accumulated by the group index (each index – one sorting siding). Sidings that are used for wagon accumulation during the first sorting phase are called group sidings (these sidings are marked by Roman numeral from I to VI). The situation of the group sidings after the first sorting phase end can be shown as follows:

<table>
<thead>
<tr>
<th>Group sidings</th>
<th>Departure sidings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
</tr>
<tr>
<td>C1</td>
<td>C2</td>
</tr>
</tbody>
</table>

Wagons with the same group index are mixed on the siding. The bordering in the table marks this. The number of the group sidings needed for the first sorting phase is equal to the number of the wagon groups in the composed trains. If the number of the wagon groups in the particular trains is different the train with the biggest number of the wagon groups is determining for the number of needed sidings.

During the second sorting phase wagons are pulled from the siding I to VI and splitted to the departure siding of composed trains (departure sidings are marked by the letters A, B, C, D). The situation on the group and departure track after the splitting of the wagons from group III is following:

<table>
<thead>
<tr>
<th>Group sidings</th>
<th>Departure sidings</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>II</td>
</tr>
<tr>
<td>empty</td>
<td>A4</td>
</tr>
</tbody>
</table>

All four trains are composed on the departure sidings with a proper sequence after the splitting of the wagons from group siding VI. The number of the departure sidings needed for second sorting phase is equal to the number of the composed trains. Group siding “I” may be used like a departure siding, too if the group sidings are beside departure siding and they are connected to the same hump. It is because group siding “I” is empty before the beginning of the second sorting phase. More group sidings may be used like departure sidings if some of the trains have smaller number of wagon groups than six. So six group sidings could be enough for the mentioned train formation in case that train A has all six groups, train B has five groups from B2 until B6, train C has four groups from C3 until C6 and train D has three groups from D4 until D6. The situation after the end of the first sorting phase end is following:
Each wagon passes through hump two times during its stay in a marshalling yard. Once during each sorting phase. In case of an application of other simultaneous methods some wagons have to pass through the hump more than two times. Description and principles of other simultaneous sorting methods are explained in detail in works [3], [4] and [6].

**CONDITIONS FOR SIMULTANEOUS METHODS APPLICATION**

For the application of the effective simultaneous methods it is necessary to fulfill the following conditions:
- a) sufficient number of wagon groups in local freight trains,
- b) sufficient number of composed local freight trains,
- c) sufficient number of reception sidings; they are used as terminating trains buffer,
- d) sufficient number of sorting sidings,
- e) sufficient length of sorting sidings,
- f) possibility to cumulate the finished trains departures to one time interval (e.g. from 5 to 7 a.m.),
- g) sufficient capacity of lines segments that are used for finished trains departures from the marshalling yard.

In case of a) and b) it generally holds that the simultaneous methods application is useful only when the train is composed from at least three wagon groups. Number of composed trains should not be less then three, too.

It is possible to reduce the working time in the marshalling yard after the simultaneous methods application. In this case local freight train formation is executed in night and early morning. Terminating trains arrive mainly in the evening and overnight. This is related with the condition c), because the time between two terminating trains’ arrivals is shorter than the time between two trains splitting from the same reception siding especially in the evening and at night.

In the case of the simultaneous methods application it is necessary to count on that the sorting sidings used for the wagon accumulation during the first sorting phase are occupied all the time. Therefore it is not possible to use them for another purpose. Either it is not possible to use them when the sorting sidings for the direct trains and the long-distance group trains are overflowed. Depending on the number of the composed local freight trains and on the number of the wagon groups about ten sorting sidings could be needed (marshalling yard Lausanne Triage, Switzerland). The sorting sidings are used for the train formation during the second sorting phase and after it, too. After the end of the second sorting phase the trains on the sorting sidings are prepared for their departure (technical inspection, break test, etc.). The more local freight trains are composed, the more free sorting sidings are needed (condition d).

The length of the sorting sidings is very important so that it would be possible to accumulate there as many wagons as possible during the first sorting phase (condition e). The length of the sorting siding may affect the number of the sorting sidings needed during first sorting phase partly.

There are several local freight trains finished after the end of the secondary sorting in the same time. Therefore it is necessary to count on that these trains will need departure from the marshalling yard in 15-20 minutes intervals (conditions f and g). Departure time of the local freight train is not determined only by the station service time on the served line. E.g. in Switzerland all local freight trains have to leave the marshalling yards before the beginning of the busy hours in passenger transport in the morning.

**DETERMINATION OF THE SUITABLE MARSHALLING YARD FOR THE SIMULTANEOUS METHODS APPLICATIONS IN SLOVAKIA**

To meet the conditions mentioned in the previous part and to apply the simultaneous sorting methods in some of Slovak marshalling yard, it is necessary to fulfill the following criteria by the chosen marshalling yard:
1. existence of hump,
2. regional importance at least (central position in region),
3. suitable layout of reception and sorting sidings (serial).

In terms of criteria weight the first criterion is the most important. The second criterion is less important than the first. The smallest weight has the third criterion.
Six marshalling yards fulfill the first criterion in Slovakia: Čierna nad Tisou, Košice, Zvolen, Žilina, Štúrovo and Bratislava. If we take the second criterion into consideration Čierna nad Tisou and Štúrovo are out of list because the train formation is related with the train formation center in Čierna nad Tisou (this train lines on the Slovak-Ukraine border) and Štúrovo marshalling yard is located on Slovak-Hungarian borders. Therefore the train formation is specialized to an import and an export traffic there. Only two marshalling yards – Bratislava východ and Košice nákladná stanica – remain in the selection after third criterion application. It is because several independent parts used for the train formation (Zvolen – 2 parts, Žilina – 3 parts) compose the marshalling yards in Zvolen and Žilina. None of these parts have the sufficient capacity for executing all train formation only within them. It is necessary to execute transfer trips between these parts. Both mentioned marshalling yards have few reception sidings, too. However, the third criterion has small weight. Therefore it is not possible to exclude the examination of the simultaneous methods application in Zvolen and Žilina. Especially marshalling yard in Žilina could be an object of the examination in the future in the connection with finishing of the new marshalling yard Žilina-Teplička.

**DESIGN OF EXAMINATION PROCESS**

Examination of the possibility to apply the simultaneous sorting methods in the specific marshalling yard can be executed in a different scope. This scope depends on the examination aim. It is possible to examine an effect of the simultaneous methods application by the unchanged number of the composed local freight train. It is possible to examine an effect of the simultaneous methods application by a concentration of the train formation within the defined part of the railway network operated by the examined marshalling yard and related increase in composed local freight trains. In any case, this examination contains analysis of:

- different sources and input data about the marshalling yard,
- pattern of the train formation processes in the marshalling yard,
- relations with other marshalling yards in the railway network.

Firstly, data about the relations created in the marshalling yard should be analyzed. List and scope of relations are available in operating instructions to valid timetable – “Train formation plan” valid for the whole railway network and “Procedure of technological processes of station” that is elaborated and valid for each important marshalling yard in Slovakia separately. In frame of this analysis it is necessary to observe an actual arrangement of the local freight trains, a number of the operated line segments, an operation frequency (once a day, twice a day) and scheduled departure times of trains. Concerning the agreed operation times in operated stations it is possible to predict that the scheduled departure time is really met. Thanks this it is not necessary to regard an unstableness of the freight railway transport that could make the examination more difficult. In frame of this analysis it is very important to compare departure times of all composed local freight trains. It is possible to ponder on the simultaneous train formation of these trains without changes in the marshalling yard operation plan if all composed trains departure from the marshalling yard throughout an interval between half an hour and two hours. After this analysis it should be clear if the simultaneous methods application is effective by the current scope of the local freight trains formation. It is necessary to observe what happens when the departure time is shifted to one time interval if the simultaneous methods can be effectively applied but the trains do not currently departure in same time interval. The change of departure time could affect the train formation process of other trains (e.g. conflicts in need of shunting locomotive, personnel or sorting and feed sidings). The change of the operation times in the operated transport will result from the change of the departure time, too. Therefore it is necessary to consult it by customers.

It is possible to observe the possibility of the train formation relocation from some small marshalling yard to the examined marshalling yard too, in case of designed concentration of train formation within a defined future part of the railway network operated by the examined marshalling yard. Thanks the relocation of the train formations it will be no more necessary to execute shunting in yards without a mechanismisation and an automation. It can bring a better usage of a technical equipment in greater marshalling yards. It is necessary to define which other local freight trains could be composed in examined marshalling yard in this case. Primary criterion for the selection of other trains is time required to reach the last operated station on the line segment. This time include running time and operation time in passed stations.
THE USE OF COMPUTER SIMULATION

Design of a process organization of the future train formation is the result of any analysis described in the previous part of this paper. Especially it is valid for the secondary sorting. It is necessary to observe an impact of changes in the process organization of the train formation on the rest of the operation processes in the marshalling yard. It is necessary to observe if the organization changes in the secondary sorting are possible in regard of hump, siding groups, personnel and shunting locomotives capacity and what scope of modifications for all mentioned areas this change will raise. The only suitable tool for this examination is computer simulation, especially in regards of the unstableness of the railway operation and the system complexity of the marshalling yard.

A simulation software Villon will be used to simulate the marshalling yard operation. The simulation tool Villon has been developed since 1994. It is the result of the cooperation of University of Žilina, Faculty of Management Science and Informatics and SIMCON s.r.o. Žilina. Up to now the simulation models of many marshalling yards were built with help of Villon. We can mention especially the following marshalling yards: Wien Zvbf, Linz Ost Vbf, Hamburg Alte Süderelbe, Basel SBB RB I and Lausanne Triage. Experts from Austria, Germany [7], Switzerland [2] and China did measure already qualities and properties of Villon.

SIMULATION MODEL OF BRATISLAVA VÝCHOD MARSHALLING YARD

Construction of simulation model of Bratislava východ marshalling yard begins in autumn this year. This is the first step of the research described in this paper.

Bratislava východ marshalling yard is located in Bratislava railway junction, close to Hungarian and Austrian borders. This marshalling yard meets all criteria mentioned in the previous parts of paper:
- serial layout of reception and sorting sidings groups,
- number of reception sidings - 12,
- number of sorting sidings - 37,
- number of composed local freight trains - 6,
- free capacity to compose more local freight trains.

For a development of the simulation model, different basic documents will be used. The list of the basic documents follows:
- layout of Bratislava východ marshalling yard in 1:1000 scale,
- list of work professions, including job description,
- list of shunting locomotives, including job description,
- output files from the information system of the freight transport – files contain the list of arrival trains in a period of one week, including wagon lists of these trains,
- list of departing freight trains from Bratislava východ marshalling yard according to the train formation diagram,
- list of industry sidings and schedule of their attendance,
- list of Slovak railways stations with an authority to register wagon-load consignment,
- list of relations and assigned destination stations valid for Bratislava východ marshalling yard according to the train formation diagram,
- basic rules for group train formation,
- freight wagon catalog.

It is possible to import the documents provided in an electronic form in modules of the Villon simulation tool.

Work on the model development can be divided to several phases:
1. defining of entering data,
2. development of a basic simulation model,
3. verification of results of the basic model,
4. preparation of a simulation model with the applied simultaneous sorting methods,
5. processing of results.

In the basic simulation model one week of traffic will be simulated.

Basic model will simulate the current traffic including secondary sorting that use the classical methods. Second model will simulate an application of the simultaneous sorting methods and other traffic that will be affected by the simultaneous sorting application. Thanks statistics and results modules of Villon it will be possible to compare both models using different economic and operational criteria, especially:
- sorting sidings usage,
time of a wagon stay in the marshalling yard,

♦ shunting locomotives usage,
♦ personnel utilization.

The construction of both simulation models will take one year. During this time several visits of the marshalling yards will be necessary. These meetings will help to clarify technological processes and to discuss designed changes in the train formation process.

During the construction of the second model new scheme for the primary and secondary sorting will be developed. At the same time a possibility of modification of the terminating trains arrival times and departing trains departure times will be examined. The aim of the modification of the arrival and the departure time is a reduction of the working time of marshalling yard. However, this will not be the main aim of the whole research.

CONCLUSION

High costs of shunting and too long wagon circulation in the railway network are clear disadvantages of the wagonload transport. Concerning these disadvantages volume of the wagonload transport decreases every year. Nevertheless, customers are still interested in using this kind of the freight railway transport. It is necessary to make the train formation more efficient because it has an impact on a possibility to perform the wagonload transport in the future. One of the possible ways is an application of the simultaneous sorting methods for the local freight trains formation.

Although the simulation methods are not news, they still have their power that is necessary try to use. The result of the described research can be a recommendation for a new organization of the train formation in Slovakia or a finding that the application of the simultaneous methods in Slovak marshalling yard is not possible.

REFERENCES:

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