METHODOLOGY OF TRAIN SORTING ON ZAGREB – RIJEKA RAILWAY LINE

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Abstract: *The absolute train sorting method was used to calculate the optimal method of train composition on the Zagreb-Rijeka railway line regarding the characteristic of the section selection. In the Zagreb-Rijeka direction the current and calculated wagon hours of their accumulation in reception yard have been compared, whereas for the Rijeka–Zagreb direction the current wagon hours of accumulation depend on the operation of the Port of Rijeka, arrival and unloading of ships and the types of freight and the selection of the traffic infrastructure for transport.*

For the current number of scheduled trains the required number of locomotives has been determined as well, on two traction sections, for Zagreb–Moravice and Moravice–Rijeka.

Key words: *railway freight transport, absolute method of train sorting, Zagreb – Rijeka railway line, line capacity*

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1. Introduction

The Zagreb – Rijeka railway line is a branch of Corridor V known as Corridor Vb and one of the first railway lines constructed on the Croatian territory. Apart from the Croatian economy it is also important for the economies of other European countries that gravitate towards the ports on the Adriatic Sea.

There are 30 stations arranged along the 228.8km long railway line. Because of the calculation of the number of trains using the method of forming single-group and multi-group trains, the railway line is divided into blocks between four technical stations.

The calculation method of the plan for forming single-group trains is used to select the variant according to which the trains will be formed, with the aim of optimal usage of wagon and locomotive rolling stock. The tendency is also towards maximally rational usage of the capacities of the track infrastructure (lines, station tracks, SS train control and TC telecommunication devices as well as the loading-unloading areas at stations and on industrial tracks). This method is used to compare all the variants of organizing wagon flows, and if it is not possible to select the optimal variant, a satisfactory one can be selected, which is closest to the optimal one. Besides, it is necessary to determine the relevant parameters for organizing wagon flows, both of loaded and of empty wagons. The line capacity and the usage of the line, regarding the difference between the theoretical and actual capacity depends on the quality of the transport service, mean mass of freight trains, i.e. mean number of the seats of the passenger trains, to some extent on the composition and construction of the transport means, and then of goods flows and passengers carried (Čičak, Vesković, 2005). All this depends on the following technical and organisational parameters of the railway line.

The plan and the profile of the tracks, the lengths of station tracks and the structure of the flows determine at a given type of the locomotive the maximally possible mass of trains (Hansen, Pachl, 2008). However, the locomotive power can be used both for the increase of the train mass, and for the increase in the technical speed. The increase in the train mass, at given other conditions reduces the technical speed, thus reducing also the line capacity and vice versa (Čičak, 2003). Maximal transport capacity of the railway line is insured by rational relation between the train mass and speed (Pachl, 2004).

2. Condition of Available Capacities on the Network

2.1 Division of railway line into blocks

Apart from Zagreb RK station as the origin and the Rijeka railway station as the terminal station on this line, the following stations have been selected as the technical stations:

- railway station Ogulin: station of the forking off of the Ogulin-Split line, and

- railway station Moravice: station of the change of the electrical traction system and reduction of trains to gross weight of 1,000t.

The routes for which the wagon hours of accumulation will be calculated include:

- Zagreb – Ogulin; on the average daily 42 wagons (loco Ogulin and wagons for Split),
- Zagreb – Moravice; on the average daily 27 wagons (railway line to Moravice),
- Zagreb – Rijeka; on the average daily 266 wagons (directly gross for Rijeka),
- Ogulin – Moravice; on the average daily 4 wagons,
- Ogulin – Rijeka; on the average daily 1 wagon,
- Moravice – Rijeka; on the average daily 30 wagons.

The dispatch from the interstations is calculated to be divided into routes at an equal ratio.

2.2 Problem of capacity availability

On the proposed railway line sections, and due to the usage of line capacity, there are limiting interstation intervals that determine the capacity of these sections (*Figure 1*).

Fig. 1. Limiting Zagreb –Rijeka railway line sections

On the Zagreb – Rijeka relation, according to 2007/08 timetable the following trains were in operation:

- 2 trains on Zagreb RK – Ogulin (Split) relation,
- 3 trains on Zagreb RK – Rijeka relation,
- 1 train on Zagreb ZK – Rijeka relation,
- 2 trains on Kutina – Zagreb RK – Ogulin – Split relation,
- 4 trains on Koprivnica – Zagreb RK – Rijeka relation,
- 2 trains on Zagreb Žitnjak – Zagreb RK – Rijeka relation,
- 1 train on Kutina – Zagreb RK – Rijeka relation,
- 1 train on Vinkovci – Zagreb RK – Rijeka relation.

The total number of trains is:

- 5 trains of own formation of Zagreb RK railway station,
- 1 train of own formation of Zagreb ZK railway station,
- 10 trains that transit through Zagreb without classification.

On the average in the scheduled trains for the Rijeka direction there are in a group 5 wagons, so that for the accumulation of wagons for one train of 25 wagons arrival of 5 trains is necessary ($\gamma=5$):

$$g = \frac{m}{m_g} = \frac{25}{5} = 5 \quad (1)$$

The planned train formation interval for the direction towards Rijeka, for 3 trains, amounts to an average of 7.5 hours, and when the parameter is calculated per wagon arrival and the actual situation, for scheduled trains, it amounts to:

$$c = 12 \cdot \left(1 - \frac{1}{\gamma \cdot g} \right) \quad (2)$$

Thus the accumulation parameter for the direction to Rijeka railway station is:

$$c = 12 \cdot \left(1 - \frac{1}{5 \cdot 5} \right) = 12 \cdot \left(1 - \frac{1}{25} \right) = 11,52 \quad (3)$$

For the direction to Split there are on the average 8 wagons arriving in a group, and for the accumulation of wagons for one train of 24 wagons, 3 trains need to arrive ($\gamma=3$).

For the direction to Split, the accumulation parameter is:

$$c = 12 \cdot \left(1 - \frac{1}{24} \right) = 11,5 \quad (4)$$

According to the statistical data on dispatch and arrival of wagons from 01 January – 01 June 2008, to the railway stations on the Zagreb-Rijeka railway line, to Karlovac railway station there are on the average daily 25 wagons operating, which is satisfied by the route of one train that is planned for the dispatch of wagons for the stations along the line.

To Moravice railway station on the average daily there is need to transport 10 wagons, whereas the need to Rijeka railway station is the transport of 59 wagons daily. Since the train composition from Moravice railway station to Rijeka railway station is with a maximal number of 16 wagons, 4 trains are necessary, whereas the trains from transit with maximum weight of 1,400t are reduced to maximal weight of 1,000t, so that on this section of the railway line out of 5 arrived trains, 7 trains are formed on the average in dispatch, depending on the train composition according to the quantity of loaded and empty wagons in the composition of each train.

In the period from January to June 2008, between the railway station Hrvatski Leskovac and the Rijeka junction, in dispatch and arrival there was a total of 45,842 wagons, as follows:

- in dispatch 22,872 wagons or 896,448 tonnes,
- in arrival 22,970 wagons or 641,129 tonnes.

The number of wagons, that are dispatched to the ports on the Adriatic Sea is increasing from year to year, although the pre-war performance cannot be reached. The usage coefficient of the wagons is very low due to the dependence on the arrival of various types of freight to the ports, and also on their dispatch, so that few wagons terminate with full loaded turnaround. This means that with the increase of gross towards and from ports we have to calculate also with an increase in the number of empty wagons in the turnaround.

3. Selection of the Calculating Method

The characteristics of the position of HŽ network favour a simple selection of the method for calculating the train sorting without any complicated solutions, for which the absolute calculation method of sorting single-group and multi-group trains is ideal.

For technical railway stations, according to the specific characteristics of the railway line, four railway stations were selected that suit us for the calculation, and approximately coincide with interstation distances that stipulate the usage of line capacity

There are not many branches in the railway network, and one may say that these are routes directed to loading-unloading basin of Dalmatia and Rijeka (*Figure 2*).

Fig. 2. Port basins of the Rijeka and Split railway line

4. The Absolute Train Forming Method

The routes that determine the train sorting are determined so that the technological process of Zagreb marshalling yard operation is separated concerning the districts:

- R-67/68 (Rijeka, Bakar),
- R-56-59 (Split, Zadar, Šibenik)
- railway line to Moravice.

When sorting trains according to PTU, the train composition that are formed at Zagreb RK marshalling yard, the wagons for the railway line to the Moravice railway station is included in the system of train 61206. The train operates on Zagreb RK – Rijeka relation, which leads to the conclusion that the method of train sorting is used with combining of routes Zagreb – Moravice and Zagreb – Rijeka, as well as routes Ogulin – Moravice and Ogulin – Rijeka (Figure 4).

Fig. 3. Graphical representation of the number of wagons per direction

According to the mentioned actual situation, and comparing and calculating the quantities of wagons at dispatch obtained by absolute method we come to the conclusion that variant 6 is used of merging routes that gives according to calculation 1,691 wagon hours of accumulation (*Table 1*). All the wagon hours of accumulation are cancelled by accumulation large quantities of wagon of district R-68 at Zagreb RK marshalling yard, and the shunting railway station loses its basic shunting function, and becomes a depot station (of garaging) which alleviates the impossibility of receiving so many wagons of the railway line and the railway station toward the Port of Rijeka and the impossibility of HŽ train traction to insure a sufficient number of properly operating locomotives.

6.	1, 2+3	wagon flows	1-3	0			
	4 + 5	that are processed	1-4	0	2 6 6		
	6		2-4	0			
		number of transit wagons in processing		0	2 6 6	2 6 6	
		additional hours of processing		0	1 0 6 4	1 0 6 4	
		$c \times m =$	187,5	k 1 = 2	3 7 5		wagon hours
		$c \times m =$	252	k 2 = 1	2 5 2		of accumulation
				$\Sigma =$	1 6 9 1		

Tab. 1. Wagon hours of acumulation of wagons in reception yard

According to the absolute train forming method the optimal variant of wagons dispatch per directions is variant “1 + 2, 3, 4 + 5, 6”, according to which the number of wagon hours of accumulation is minimal.

Fig. 4. Graphical representation of sorting directions

According to composed wagon flows, according to the table of calculations of wagon hours of accumulation, the total hours amount to 708 wagon hours of accumulation (Table 2).

4.	1+2, 3	wagon flows	1-3	27		
	4+5	that are processed	1-4	0	0	
	6		2-4	0		
		number of transit wagons in processing		27	0	21
		additional hours of processing		81	0	81
		$c \times m =$	187,5	$k_1 = 2$	375	wagon hours
		$c \times m =$	252	$k_2 = 1$	252	of accumulation
				$\Sigma =$	708	

Tab. 2. Calculation wagon hours of accumulation

According to the calculated variant the following is formed:

1. Direct trains on relation:

- Zagreb - Rijeka :

$$N_{AD} = \frac{266}{25} = 10,64 \approx 11 \text{ trains} \quad (5)$$

2. Section trains relation:

- Zagreb – Ogulin relation:

$$N_{AB} = \frac{42}{25} = 1,7 \approx 2 \text{ trains} \quad (6)$$

- Ogulin – Moravice relation:

$$N_{BC} = \frac{32}{21} = 1,52 \approx 2 \text{ trains} \quad (7)$$

- Moravice – Rijeka relation:

$$N_{CD} = \frac{31}{17} = 1,8 \approx 2 \text{ trains} \quad (8)$$

A total of 11 direct and 6 section trains are composed, whereas the number of wagons approximately amounts to:

- in direct trains:

$$N_v = 11 \cdot 25 = 275 \text{ wagons} \quad (9)$$

- in section trains:

$$N_v = (2 \cdot 25) + (2 \cdot 21) + (2 \cdot 17) = 126 \text{ wagons} \quad (10)$$

On the entire relation from Zagreb to Rijeka daily on the average 401 wagons can be dispatched.

4.1 Application of the Method on Rijeka-Zagreb Railway Line

The following railway stations have been selected as technical railway stations:

- Moravice railway station: shunting railway station and railway station of electrical traction system change,
- Ogulin railway station: merging with Ogulin – Split railway line.

The relations for which the wagon hours of accumulation are to be calculated are (Hrvatske željeznice, 2007):

1. Rijeka – Lokve: on the average daily 9 wagons of dispatch,
2. Rijeka – Ogulin: on the average daily 26 wagons of dispatch,
3. Rijeka – Zagreb: on the average daily 120 wagons of dispatch,
4. Moravice – Ogulin: on the average daily 15 wagons of dispatch,
5. Moravice – Zagreb: on the average daily 21 wagon of dispatch,
6. Ogulin – Zagreb: on the average daily 87 wagons of dispatch.

According to the current situation all the trains formed on the relation from Rijeka to Zagreb depend on the longitudinal railway line profile from the Rijeka basin to the Lokve railway station on the initial railway line section to the Moravice railway station, with maximal load of 900t, and from the Lokve railway station the maximal load of the trains amounts according to PTU to 1,700t.

On the entire section the trains are combined so that the routes Rijeka – Moravice, Rijeka – Ogulin (alternatively Karlovac) and Rijeka – Zagreb are dispatched together, whereas other routes are dispatched separately, so that wagon hours of accumulation amount to 1,775 wagon hours (*Table 3*).

7.	1+2+3	wagon flows	1-3	26			
	4, 5	that are processed	1-4	120	120		
	6		2-4		0		
		number of transit wagons in processing		146	120	266	
		additional hours of processing		584	360	944	
		c×m=	231	k1 = 1		231	wagon hours
		c×m=	300	k2 = 2		600	of accumulation
					Σ =	1775	

Tab. 3. Current wagon hours of accumulation

According to the absolute method the optimal variant of dispatch of wagons per directions is variant “1 + 2, 3, 4 + 5, 6”, according to which the number of wagon hours of accumulation is minimal.

Fig. 5. Graphical representation of variant of optimal wagon hours of accumulation

According to the combined wagon flows, according to Table 4 of the calculation of wagon hours of accumulation, the total wagon hours amount to 929 wagon hours:

4	1+2,	wagon flows	1-3	26			
	4+5	that are processed	1-4	0	0		
	6	2-4			21		
		number of transit wagons in processing		26	21	47	
		additional hours of processing		104	63	167	
		$c \times m =$	231	$k_1 = 2$		462	wagon hours
		$c \times m =$	300	$k_2 = 1$		300	of accumulation
					$\Sigma =$	929	

Tab. 4. Calculation of wagon hours of accumulation

In this method the following are formed:

1. Direct trains on relation:

- Rijeka – Zagreb:

$$N_{AD} = \frac{120}{21} = 5,71 \approx 6 \text{ trains} \quad (11)$$

2. Section trains:

- on Rijeka – Moravice relation:

$$N_{AB} = \frac{35}{21} = 1,7 \approx 2 \text{ trains} \quad (12)$$

- on Moravice – Ogulin relation:

$$N_{BC} = \frac{62}{25} = 2,5 \approx 3 \text{ trains} \quad (13)$$

- on Ogulin – Zagreb relation:

$$N_{CD} = \frac{108}{25} = 4,32 \approx 5 \text{ trains} \quad (14)$$

A total of 7 direct and 8 section trains are composed, whereas the number of wagons they consist of amounts to:

- in direct trains:

$$N_v = 6 \cdot 21 = 126 \text{ wagons} \quad (15)$$

- in section trains:

$$N_v = 10 \cdot 25 = 250 \text{ wagons} \quad (16)$$

On the entire relation from Rijeka to Zagreb 376 wagons would be dispatched daily on the average.

5. Possibility of Applying the Results obtained by the Method

This method of transport organisation requires certain organisational changes in the method of train formation and the rearrangement of technological processes according to the selection of technical railway stations.

For the technical changes through the increase in the number of tracks or technological ones through increase in the number of staff at technical railway stations at times of saving and reduction of the number of employees is not acceptable, but with the rearrangement of the technological processes the optimal variant can be organised.

For the trains that are sorted at Zagreb RK marshalling yard, the composition of trains of combined directions would be:

- up to locomotive the wagons for interstations on the railway line (for the railway stations from Karlovac to Moravice);
- at the end of the train the wagons for R:56-59 (gross for the “Dalmatian basin”).

Upon arrival of the train to the railway station Oštarije the wagons for R:56-59 would be uncoupled, and the rest of the wagons would continue with the same locomotive to the railway station Ogulin. The wagons at the railway station Oštarije would be coupled to the Diesel locomotive and via railway junction Krpelj it would take trains to the “Dalmatian Basin”. For the trains from the direction of the “Dalmatian Basin”, the solution would be the delivery of trains with Diesel locomotives to the railway station Ogulin and adding to the end of the train that runs the wagons of the interstation from Moravice to Karlovac towards Zagreb.

The saving in wagon hours of accumulation for this method of the technological process of sorting trains is also obvious from the calculation and for Zagreb – Rijeka relation it amounts to:

$$t_{nak} = 1691 - 708 = 983 \text{ wagon hours} \quad (17)$$

For Rijeka – Zagreb relation the difference in wagon hours of accumulation amounts to:

$$t_{nak} = 1775 - 929 = 846 \text{ wagon hours} \quad (18)$$

6. Conclusion

On Zagreb – Rijeka railway line there are from time to time traffic congestions which, regarding the number of wagons that increase every year towards the Port of Rijeka represents a big problem in the competitiveness of railway as high-quality, punctual and reliable carrier. For the average of wagons running the half-yearly parameters of loading and unloading at the railway stations of the studied routes have been taken.

Regarding regular maintenance and railway line overhaul, from the beginning to the first half of the year, out of a total of 4,380 hours, the railway line was closed for 1,402 hours, which amounts to 32% of time.

The works that are underway are related to the exchange of the electrification system, so that the entire railway line be electrified by 25 kV system. Big investments

in the system replacement will throw out from the use the electrical locomotives of series 1061, and the shortage of locomotives that is present anyway, will only be more emphasised.

The cost-efficiency of this project of infrastructure modernisation is questionable, since the plans and projects of the construction of the lowland line and the second track from Koprivnica to Karlovac have been developed by the EU countries which find interest in more efficient usage of Corridor Vb, and for the investment the locomotive rolling stock could be renewed to a greater extent by purchasing multi-system locomotives that would use the existing infrastructure, and at the same time they would fit into the optimal method of train sorting, as if referring to railway lines with the same electrical traction system.

The saving of wagon hours of wagon accumulation and shortening of transport times as well as faster turnaround of wagons on the route towards the Port of Rijeka, allows greater competitiveness of the port itself which would lead to increase in the coefficient of the loaded wagons, i.e. reduction of empty wagon running. The wagon hours of accumulation would also be reduced by better transiting of the trains via Zagreb RK without partial or complete processing, which would reduce the costs for HŽ as carrier, and all this for the sake of better and higher quality organisation of technical and technological and organisational infrastructure capacities.

7. References

- Čičak, M. (2003). *Modeliranje u železničkom saobraćaju, Modeling in Railway Transport, Saobraćajni fakultet*, ISBN 86-7395-154-2, Beograd
- Čičak, M.; Vesković, S. (2005). *Organizacija železničkog saobraćaja 2, Organization of Railway Transport 2*, Saobraćajni fakultet u Beogradu, ISBN 86-7395-195-X, Beograd
- Hansen, I. A.; Pachl, J. (2008). *Railway Timetable & Traffic*, Eurailpress, ISBN 978-3-7771-0371-6, Hamburg
- Pachl, J. (2004). *Railway Operation and Control*, VTD Rail Publishing, ISBN 0-9719915-1-0, Mountlake Terrace
- Hrvatske željeznice (2007). *Vozni red 2007/08, Railway Timetable 2007/2008*, Zagreb