The Throughput Capacity of Rail Freight Corridors on the Particular Railways Network

Ukupan izravni kapacitet koridora željezničkog prijevoza na posebnim mrežama željeznica

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Summary

Rail transport has an irreplaceable role within the international and national transport market. The effective support of railway transport is necessary for maintain sustainable development in European area and support of railway transport is one aim of European Union. The adoption of Regulation (EU) No. 913/2010 of the European parliament and of the council – concerning a European rail network for competitive freight is one possibility to increase the transport volume in railway transport. The article is focused on the operation characteristic of rail freight corridors in the Slovak Republic and their capacity consumption by the common rail operation – passenger and freight.

KEY WORDS

throughput efficiency
throughput capacity
rail freight corridor
Slovak railways network
transport volume

Sažetak

Željeznički prijevoz ima nenadomjestivu ulogu unutar međunarodnoga i nacionalnoga tržišta. Djelotvorno podržavanje željezničkog prijevoza potrebno je da bi opstao održivi razvoj u europskome prostoru i dala se podrška željezničkome prijevozu, što je jedan od ciljeva Europske unije. Usvajanje Regulacije (EU) Br. 913/2010 Europskoga Parlamenta i Savjeta koja se tiče europske željezničke mreže za konkurentnu vozarinu je jedna mogućnost povećanja volumena transporta u željezničkome transportu. Članak se fokusira na operacione karakteristike koridora željezničkoga prijevoza u Slovačkoj Republici i njihove potrošnje kapaciteta uobičajenim aktivnostima željeznice – putnika i tereta.

KLJUČNE RIJEČI

izravna djelotvornost
izravni kapacitet
željeznički teretni koridor
Slovačka željeznička mreža
volumen transporta

1. INTRODUCTION

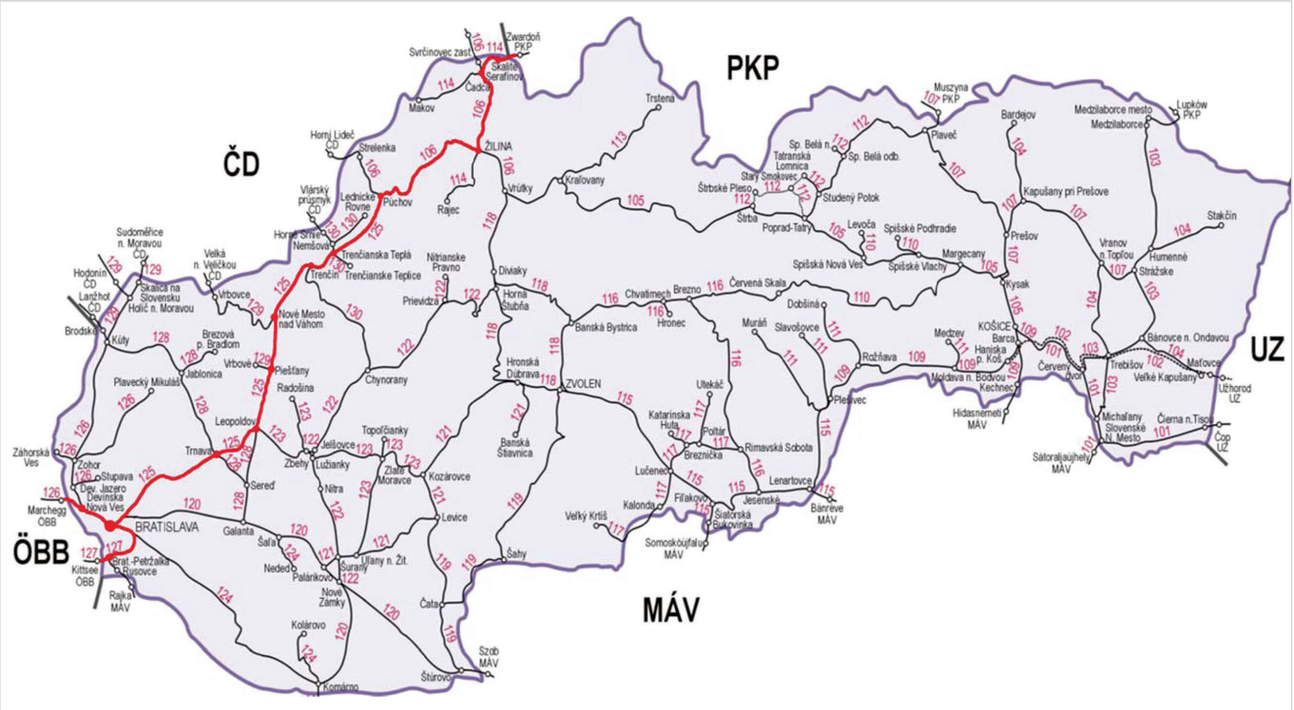
Conception of rail freight corridors is one of the elements for support the aims of the White paper of EU - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system published in 2011. Creation of competitive rail market in the European area may allow strengthen the position of rail transport.

Currently, it is possible to notice a growing trend of using the road transport. Road transport is particularly effective for its flexibility but it lacks the capacity of rail transport. The negative impact on the environment, including increasing frequency congestion, increasing noise and the construction of the road network and land occupation are other important facts. Transport safety is closely related to the damage caused during transport. Road safety with advancing is dramatically decreasing, because there is an increase in traffic accidents.

Development and support of the automobile industry in Slovakia has had a synergic effect of the using and development combined transport. The inclusion three track lines from net of Slovak railways has a important meaning for the making the speed and quality rail connection between European ports (Koper, Rijeka, Hamburg and Bremerhaven) and intermodal terminal in Slovakia (Žilina, Bratislava, Dunajská Streda, Košice). Common rail operation (passenger and freight) on the rail freight corridors can cause several problems: construction of traffic diagram (trains path for passenger trains and freight trains), consumption capacity of the track lines or operation problems [1-6].

2. CHARAKTERISTICS OF RAIL FREIGHT CORRIDORS IN THE SLOVAK REPUBLIC

The opening rail freight market allows entering new rail operators to the rail network. To optimise the use of the network and ensure its reliability, it is useful to introduce additional procedures to strengthen cooperation on allocation of international train paths for freight trains between infrastructure managers [7], [8].



Source: authors

Figure 1 Rail Freight Corridor 5 on the Slovakian railways network

The implementation of international rail freight corridors, forming a European rail network for competitive freight, should be conducted in a manner consistent with the trans-European Transport Network (TEN-T) and/or the European Railway Traffic Management System (ERTMS) corridors. To that end, the coordinated development of the networks is necessary, and in particular as regards the integration of the international corridors for rail freight into the existing TEN-T and the ERTMS corridors [8].

The planned measures to improve the performance of rail freight transport should have little impact for users of rail. Therefore, it is necessary to include all the planned measures to the implementation plan. Also, all planned measures, which should have impact to less capacity of infrastructure, must be regularly published or discussed with the infrastructure managers [8].

The management of freight corridors should also include procedures for the allocation of the infrastructure capacity for international freight trains running on such corridors. Those procedures should recognise the need for capacity of other types of transport, including passenger transport.

Through the territory of the Slovak Republic are routed three rail freight corridors:

- rail freight corridor 5 – RFC 5,
- rail freight corridor – RFC 7,
- rail freight corridor – RFC 9.

2.1. Characteristic of rail freight corridor 5

Rail reight corridor 5 (Baltic – Adriatic corridor) make connection between Nord part of Europe (Baltic Sea) and South part of Europe (port of Khoper in Slovenia). Corridor passes cross countries: Poland, Slovakia, Austria, Italy and Slovenia.

On the network of Slovak railways entry point of corridor, the station Skalité from Poland railway network is considered to be the cross-border station and exit point is cross-border station Devínska Nová Ves (alternative station is Petržalka) to Austrian railway network. In figure 1 and table 1, the RFC 5 in the Slovakia are showed.

Table 1 Rail Freight Corridor 5 on the Slovakian railways network

Corridor	Route	Distance
RFC 5	Skalité št. hr. – Čadca – Žilina – Púchov – Trnava – Bratislava hl. st. – Devínska Nová Ves št. hr.	264 km
RFC 5	Skalité št. hr. – Čadca – Žilina – Púchov – Trnava – Bratislavské spojky – Petržalka št. hr.	252 km

Source: authors

In figure 2, the speed profile of rail freight corridor 5 on the network of Slovakia railways are illustrated. As it can be seen on the dynamic profile, the great limitation of this corridor is track speed from Skalité to Čadca. In these track section, it is slow speed and there are bad track and slope conditions. Maximum length of train in the track section Skalité – Zwardoň (PKP) is 300 m. Then, it is necessary dividing the intermodal trains which are running from Žilina to port of Hamburg (or Bremerhaven or in Kaliningrad`s area) [9]. This fact causes technological problems on the rail freight corridor and then railway undertakings are using another rail routes for their intermodal trains [1], [3], [7].

In figures 3 and 4, the analyses of number of trains on the rail freight corridor 5 in the Slovakia are performed. RFC 5 in Slovakia is double line, without short line section Čadca –Skalité (single line). Operation on RFC 5 is mixed and consists from passenger and freight transport. It is no ideal situation based on the conditions of directive EU 913/2010. Common operation (passenger and freight) on the corridors could causes great consumption of railway infrastructure capacity.

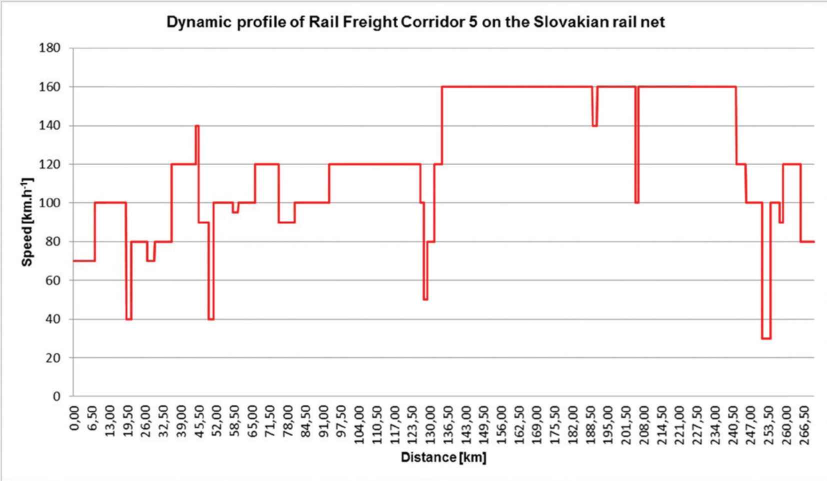


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Figure 2 Dynamic profile of Rail Freight Corridor 5 on the Slovakian railways network

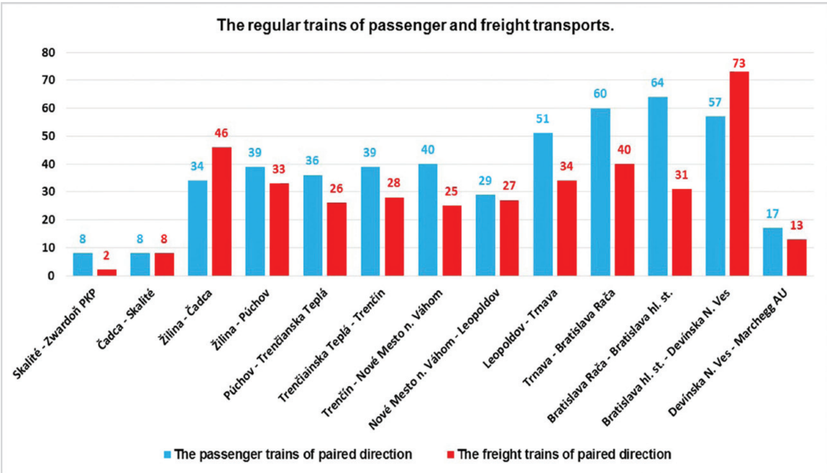

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Figure 3 The regular trains of passenger and freight transports

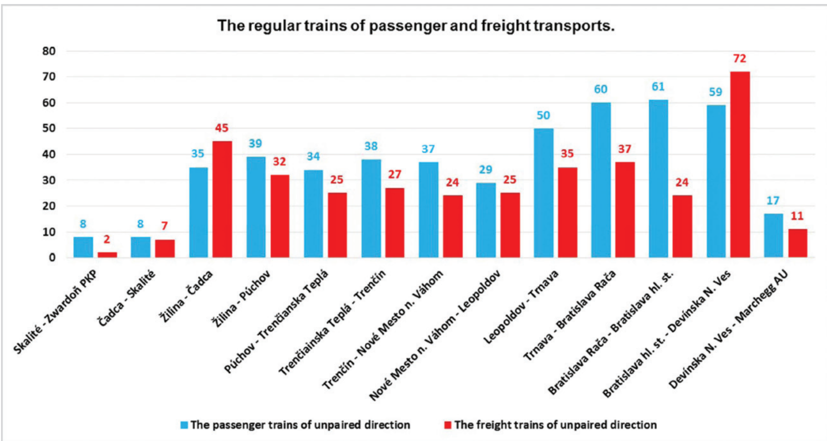

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Figure 4 The regular trains of passenger and freight transports

2.2. Characteristic of rail freight corridor 7

Rail freight corridor 7 connects middle Europe (city of Prague) and east part of Europe (Black sea). Corridor is passing cross the Czech Republic, Slovakia, Hungary, and Romania with a branch via the Bulgaria and Greece.

Entry point of RFC 7 on the railways network in Slovakia is cross-border station Kúty Gr. and exit point is cross-border station Štúrovo Gr. (alternative exit point are stations Rusovce, respectively Komárno). In the table 2, it is shown the stations that are on the corridor. In figure 5, it is shown the corridor map.

Table 2 Rail Freight Corridor 7 on the Slovakian railways network

Corridor	Route	Distance
RFC 7	Kúty št. hr. – Bratislava – Nové Zámky – Štúrovo št. hr.	300 km
RFC 7	Kúty št. hr. – Bratislavské spojky – Rusovce št. hr.	176 km
RFC 7	Kúty št. hr. – Bratislava – Nové Zámky – Komárno št. hr.	280 km

Source: authors

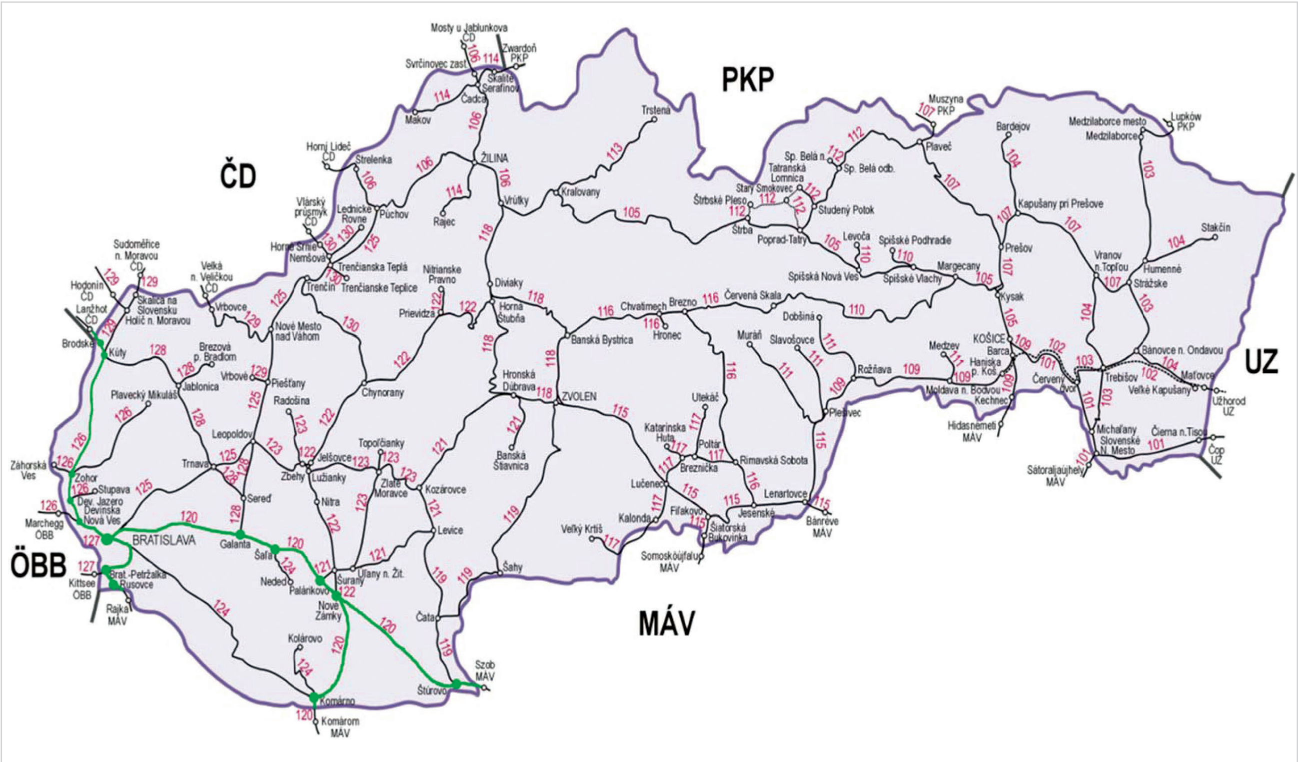

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Figure 5 Rail Freight Corridor 7 on the Slovakian railways network

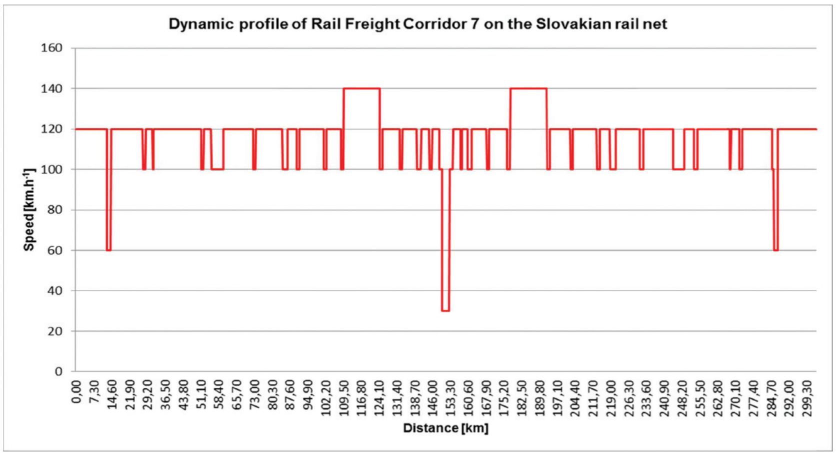

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Figure 6 Dynamic profile of Rail Freight Corridor 7 on the Slovakian railways network

Speed profile of rail freight corridor 7 is shown in figure 6. Maximum track speed on the rail corridor is 140 km.h-1, but significant part of rail line has maximum speed 120 km.h^{-1}. In some points of line, it is maximum speed less, restriction is in the railway station. Railway station has restrictions because of its technical base (tracks, switches) are old and it needs the reconstruction. Nevertheless, the technical base of rail freight corridor 7 in Slovak part has relatively good technical condition for rail operation (based on the directive EU 913/2010) [5] [7].

On the rail freight corridor 7 in the Slovakia, it is common rail operation – passenger and freight – and also is double track line. Analysis of transport volume on the corridor is in figure 7 and 8. Analysis of transport volume on the rail freight corridor has been processed for even and odd direction separately.

2.3. Characteristic of rail freight corridor 9

Rail freight corridor 9 connects Czech Republic and Slovakia. The beginning point of rail freight corridor 9 is cross-border station Čierna nad Tisou and exit point from Slovak railways network is cross-border station Lúky pod Makytou Gr. In table 3, it is preview of corridor network in Slovakia.

Table 3 Rail Freight Corridor 9 on the Slovakian railways network

Corridor	Route	Distance
RFC 9	Lúky pod Makytou št. hr. – Žilina –Košice – Čierna nad Tisou št. hr.	408 km

Source: authors

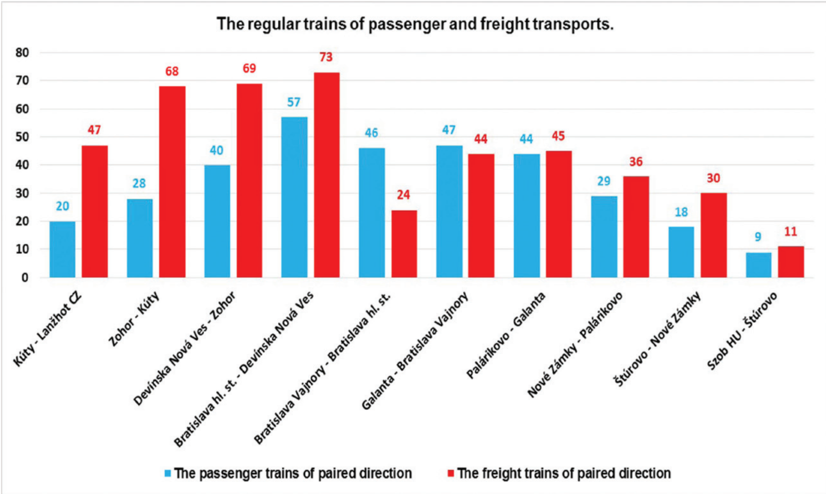

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Figure 7 The regular trains of passenger and freight transports

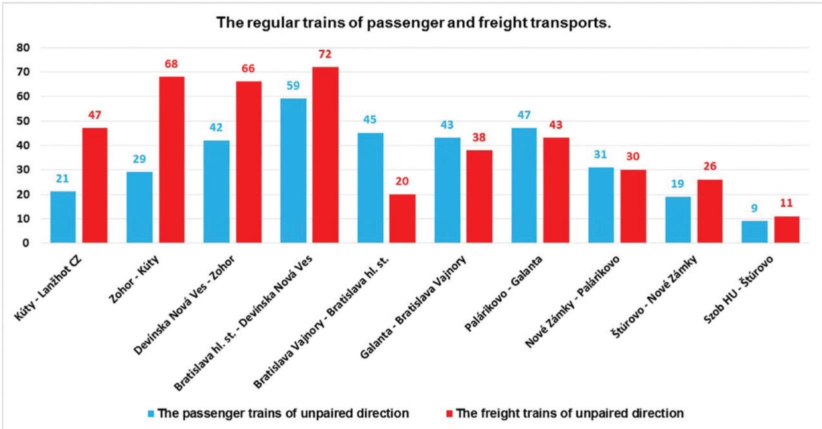

Figure 8 The regular trains of passenger and freight transports

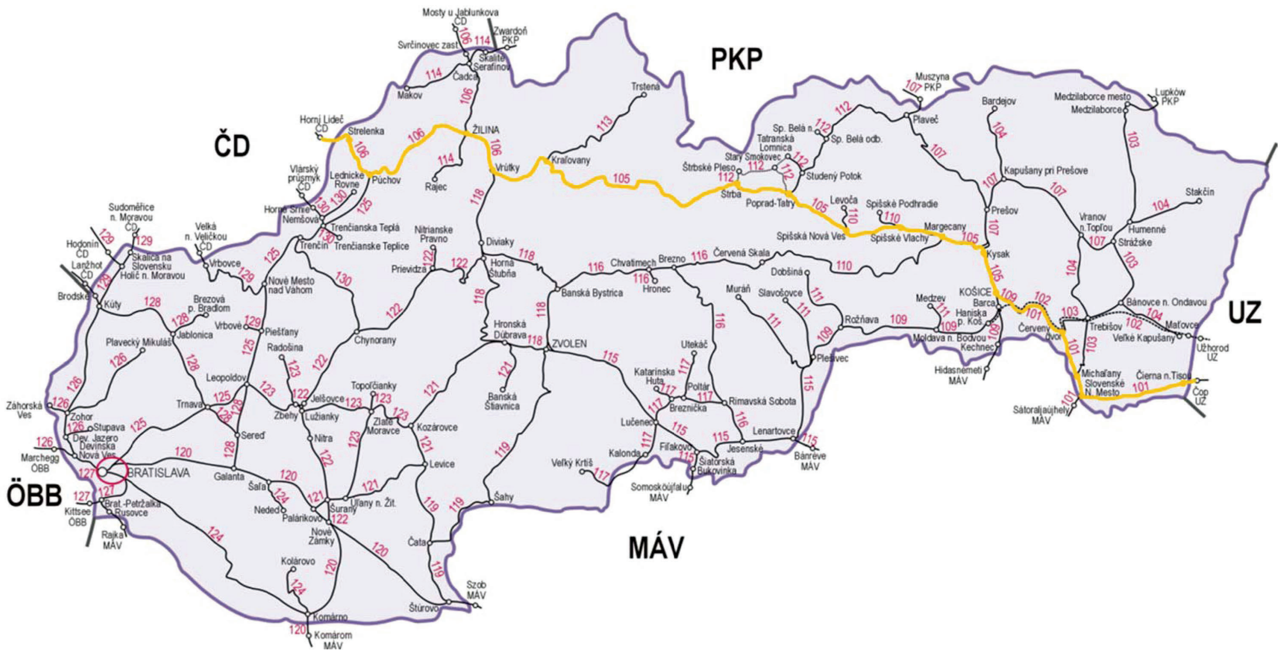

Figure 9 Rail Freight Corridor 7 on the Slovakian railways network

Speed profile (in Figure 10) of rail freight corridor 9 is very diverse. This corridor is also main rail line in Slovakia, but technical conditions of corridor are bad. In the future, it will be repaired, based on the conditions of agreement AGTC, and then, it can be assumed to improve technical specifications [5].

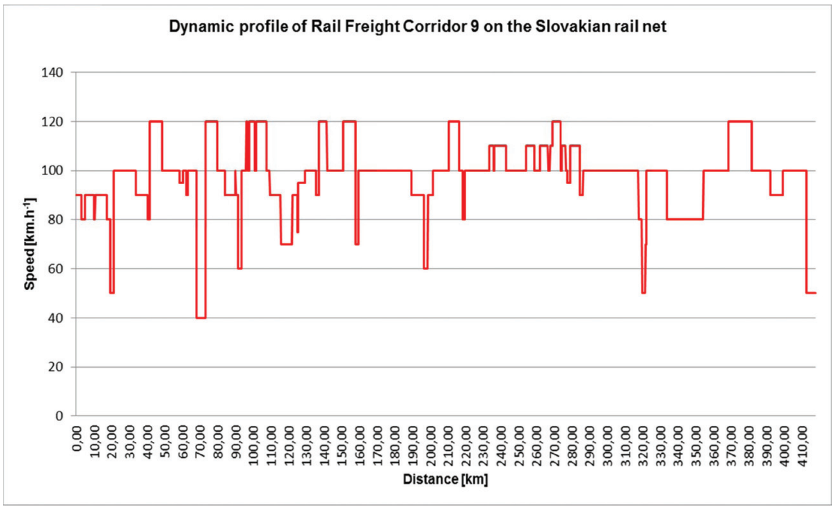

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Figure 10 Dynamic profile of Rail Freight Corridor 9 on the Slovakian railways network

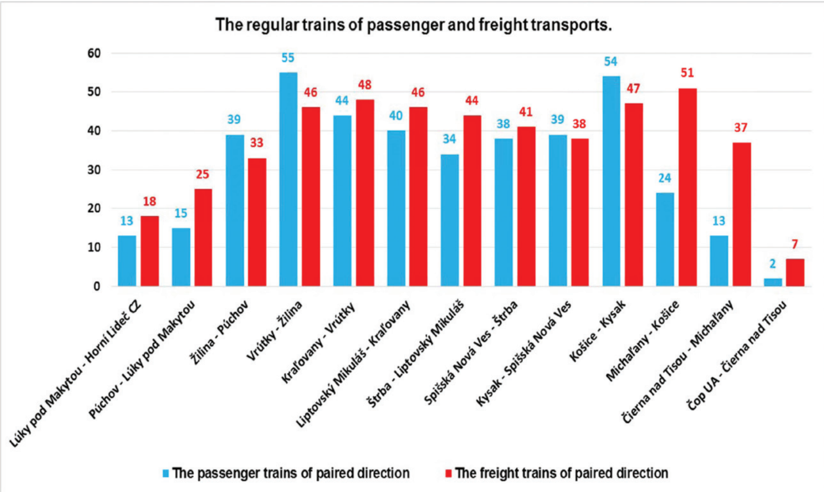


Figure 11 The regular trains of passenger and freight transports

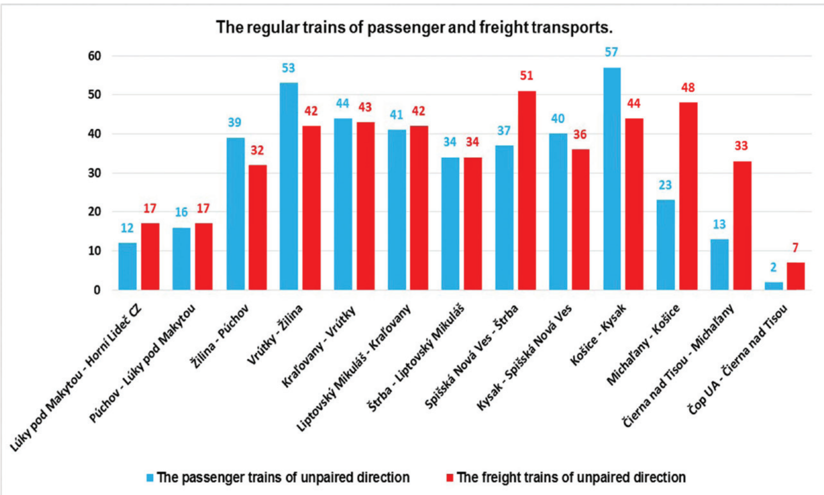


Figure 12 The regular trains of passenger and freight transports

Rail operation on the rail freight corridor 9 is common (passenger and freight) as well as RFC 5 and RFC 7. Transport volume on the rail freight corridor 9 is showed in figures 11 and 12. This corridor is double track line and analysis of transport volume has made separately for each direction.

3. THE METHODOLOGY FOR DETERMINING THE THROUGHPUT EFFICIENCY OF TRACK LINES

For railway transport, it is a routine to refer to line capacity as line throughput efficiency. Sometimes, we also use an abbreviated form of line throughput [4].

There are many definitions in this area, however, the most substantive one is: "Throughput is defined as efficiency expressed in number of trains that can be operated on railway infrastructure without compromised required quality of railway traffic" [2], [9]. This definition specifies the scope of train service with respect to its quality. This firstly emphasizes importance of transport service quality and a fact that transport is executed mostly in stochastic conditions [4].

To define the throughput efficiency, the following method can be used [10], [11]:

- Graphic,
- Analytical,
- Simulation.

Graphic method for measuring practical throughput efficiency consists in designing timetable of railway service. Clearances (buffer times) between individual trains or groups of trains that should contribute to possibility to implement the designed timetable within the whole section it has been compiled for, should be preserved. If following the delineation of a required number of lines of individual train types in the designed timetable such big number of time clearances appears, that would allow (including buffer time) an easy integration of other (additional) train paths, these shall be included in the timetable. Practical throughput efficiency shall then be defined as a sum of all train paths [4].

Analytical method of identifying practical throughput efficiency results from knowledge of data on number of trains according to individual types and familiar elements of timetable. Knowing the occupation time of intermediate section and probable sequence of trains allows calculation of a total occupation time and knowing the principle of distribution of buffer times (clearances) allows defining probable practical throughput efficiency. The benefit of the method is its close similarity to distribution of trains in timetable. It is appropriate for calculation of throughput in the prospective timetable including stochastic operating conditions. Its drawback consists in too much effort [4], [8], [13].

With the development of computer technology, simulation tools become frequent. With a *simulation method* required timetable of railway service is designed and simulation of a real operation identifies occupation times and timetable stability while evaluating time necessary for elimination of a primary delay.

For determination the throughput efficiency rail freight corridor in Slovakia was used graphic method, respectively graphic method was used to determination of occupation time track lines of corridors [4].

Calculation throughput efficiency was based on the analysis of traffic diagram and consisted from nest steps [4]:

- In the limited line track section are drawn other trains (in conditions of Slovak railways type of drawn train is freight train, this type of train is average train for calculating the capacity consumption), that can be transmitted on the whole track line. In drawing additional trains is taken into account throughput of all station in track line and also the observance of all norms of time (travelling time of train, stations and track lines interval and other). To the train diagram are not drawn rail sidings trains and interferences trains. Total trains are then intended by the formula:

$$N = N_{rt} + N_{dt} \quad [trains] \tag{1}$$

where: N – number of trains [train], N_{rt} – number of regularly trains [train], N_{dt} – number of drawn trains and additional trains paths [train].

- To determine the total occupation time of limited section the track line, it was used the graphic method to determine occupation time.

Graphic method for occupation time is illustrated as follows [4]:

To empty traffic diagram (specifically into limited section), they are drawn all trains (also added) in the order they follow each other. By the construction train paths, we do not accept adjacent track line sections. Trains follow each other in the shortest a standardized time. After the last train, we again draw first train. Total occupation time is deducted from the timeline traffic diagram between zero (where began drawing the first train) and dimension of last train, always the same line in traffic diagram. In figure 13, it is illustrated the sample of graphic method to determine of occupation time.

- after the finding total occupation time (T_{ot}), it is calculated the average occupation per one train path t_{otpt}:

$$t_{otpt} = \frac{T_{ot}}{N} \quad [min.] \tag{2}$$

where: t_{ot} – average occupation per one train [min], T_{ot} – total occupation time [min], N – number of trains

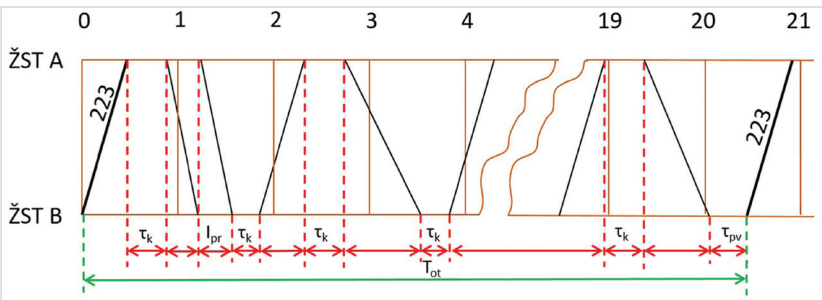
Then, it is necessary to calculate the buffer time per one train. Formula for determination of buffer time is:

$$T_{bt} = T - T_{ot} \quad [min] \tag{3}$$

and then

$$t_{btpt} = \frac{T_{bt}}{N} \quad [min.] \tag{4}$$

where: T_{bt} – total buffer time, T – computing time [1 440 min.], T_{ot} – total occupation time, t_{btpt} – buffer time per one train, N – number of trains



Source: authors

Figure 13 Graphic method to determine of total occupation time

- the final step of the methodology is to calculate the throughput efficiency:

$$n = \frac{T-(T_{sm}+T_{fo})}{t_{otpt}+t_{btpt}} \quad [trains] \qquad (5)$$

where: n – throughput efficiency [trains], T – computing time [1 440 min.], T_{sm} - supplement for maintenance [min], T_{fo} - fixed occupation [min], t_{otpt} - average occupation per one train path [min], t_{btpt} - buffer time per one train path [min]

4. THE CALCULATION RESULTS OF THROUGHPUT EFFICIENCY ON THE RAIL FREIGHT CORRIDOR IN SLOVAKIA

The calculation of the throughput efficiency has a significant impact on the organization of transport operation in track lines. Sufficient capacity is important for organizing continuous and safe transport.

Calculation of throughput efficiency was applied to individual rail freight corridors on the Slovakian railways network. Throughput efficiency is determined for each track line section separately. For better overview of consumption capacity, it was also calculated coefficient of throughput efficiency. The coefficient was determined based on formula:

$$c_{cte} = \frac{N}{n} * 100 \, [\%] \qquad (6)$$

where: c_{cte} – coefficient of throughput efficiency [%], n – throughput efficiency [trains], N – number of scheduled trains in traffic diagrams [trains]

Table 4 contains calculated throughput efficiency of rail freight corridor 5. First track line section Skalité - Čadca is only single track line for that a value of throughput efficiency is together for both directions. The highest consumption of corridor capacity is only approximately 55 %, nevertheless, common operation – passenger and freight transport.

The results of throughput efficiency of rail freight corridor 7 are shown in table 5. Table 5 contains calculated throughput efficiency of rail freight corridor 7. Capacity consumption on the corridor is not so high. The corridor track line is used only on the 33.3 % (or 55 % on the section Kúty – Bratislava).

Table 6 contains the calculated throughput efficiency of rail freight corridor 9. Rail freight corridor 9 is basic tack line in Slovakia. Therefore, the capacity consumption on this corridor is low. The highest value of capacity consumption is 50 %.

5. CONCLUSION

Application results of the methodology for determining the throughput efficiency are sufficiently capacity of rail freight corridors, nevertheless, on the corridors, passenger and freight trains are operated. Common operation has not great influence to capacity consumption on the rail freight corridors on the net of Slovakian railways. In case of increase the transport volume (passenger or freight), the rail infrastructure has a possibility to ensure safety and continuous rail operation [2], [4], [14].

Currently, Slovak railways repairs railway infrastructure on the Slovakia and reconstructed track line Bratislava – Žilina is part of rail freight corridor 5. At the reconstruction, Slovak railways made a decision about building new track interlocking system on the reconstructed line. Slovak railways cancelled

Table 4 Throughput efficiency of Rail Freight Corridor 5

Track line	Limited track line section	Capacity [trains]		C_{ccte} [%]	
		Even direction	Odd direction	Even direction	Even direction
Skalité – Čadca	Čadca – Skalité	46	77	20.9	
Čadca – Žilina	Čadca – Žilina	165	165	36.4	37.6
Žilina – Púchov	Žilina – Púchov	128	126	49.8	48.6
Púchov – Bratislava hl. st.	Trnava – Bratisalava Rača	192	184	43.8	47.3
Bratislava hl. st. – Devínska Nová Ves	Devínska Nová Ves – Bratislava hl. st.	188	196	54.8	55

Source: authors

Table 5 Throughput efficiency of Rail Freight Corridor 7 (authors)

Track line	Limited track line section	Capacity [trains]		C_{ccte} [%]	
		Even irection	Odd irection	Even irection	Even irection
Kúty – Bratislava hl. st.	Devínska Nová Ves – Bratislava hl. st.	188	196	54.8	55
Bratislava hl. st. –Štúrovo	Bratislava hl. st. – Bratislava Vajnory	173	171	35.4	33.3

Source: authors

Table 6 Throughput efficiency of Rail Freight Corridor 9 (authors)

Track line	Limited track line section	Capacity [trains]		C_{ccte} [%]	
		Even direction	Odd direction	Even direction	Even direction
Čierna nad Tisou – Košice	Čierna nad Tisou –Michaľany	91	88	37.4	36.3
Košice – Kraľovany	Košice – Kysak	173	170	49.7	50.6
Kraľovany – Púchov	Žilina – Púchov	128	126	49.8	48.6
Púchov – Lúky pod Makytou	Púchov – Lúky pod Makytou	178	169	17.4	16.5

Source: authors

automatic block interlocking system and are building new interlocking system based on the shunt station. This new track line interlocking system not increases the capacity of railway infrastructure as would be expected. Next problem is the construction of train paths in the traffic diagram on the future, if there were to achieving the aims of the White Paper of EU - Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system. When the traffic flows in the ideal case move from road transport to railways in Slovakia too, and then, the currently capacity of rail infrastructure would be inadequate [2], [13-15].

Based on the analysis in the article, we can say that the capacity of rail freight corridors in Slovakia is low and railway infrastructure do not need the great financial measures on the fulfillment the aims of Regulation (EU) 913/2010. However, the Reconstruction of railway infrastructure in the Slovak republic is necessary for modernization and creation for one interoperability common rail market in the European Union [2], [16], [17].

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