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Baseline Model to Increase Railway Infrastructure Capacity on a Single-Track Section: a Case Study

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Abstract: Providing the railway infrastructure is a prerequisite for achieving the quality of public passenger transport, not only from a national perspective but also within a regional level. Based on transportation capacity knowledge, railway tracks capacity and headway can be determined. Subsequently, it is possible to examine the railway sections capacity and select a measure in order to increase this capacity.

Keywords: Railway track capacity, integrated transport system, public transport, single-track, double-track

1. Introduction

For a long time, individual regions of the Slovak Republic have been trying to find effective ways to harmonize and, especially, to make public passenger transport more attractive, and thus, attract new customers. Providing the railway infrastructure represents a prerequisite to achieve a high-quality public passenger transport, which could be considered as a cornerstone of the entire transport system, not only in the national, but also in the regional conception.

Generally, transport is an important aspect of economic development and an integral part of everyday life in modern society. Currently, all products are measured in monetary terms; therefore, new saving solutions are permanently going to be developed. In the area of public passenger transport, activities are lead to create integrated transport systems which result in money savings as well as time and a synergy between each other occurs.

In order to provide rapid, high-quality and safe railway transport, it is also necessary to deploy new railway vehicles in the required amount, in regions where these are efficiently used in terms of traffic flow intensity.

2. Mid-South Functional Region

The Mid-South functional region includes the Banska Bystrica self-governing region with population over 650,000. In terms of occupied area, it is the largest self-governing region in the Slovak Republic. The metropolis of the Banska Bystrica region is the city of Banska Bystrica. The second largest city in this region is Zvolen, located 18 km south from the metropolis and, thus, creates an important area in relation to the traffic flows. Basic demographic data on the Mid-South functional region is summarized in Table 1 [1,2].

Table 1 Demography of the Mid-South functional region. Source: [1,2]

	Banska Bystrica self-governing region	Banska Bystrica	Zvolen
Population [inhabitants]	656,813	79,368	43,100
Area [km^2]	9,454.44	103.38	98.73
Population density [inhabitants/km^2]	69.47	767.73	436.54
Number of cities	24	x	x
Number of municipalities	516	x	x

2.1 Organization of Transport

The Mid-Southern region have not harmonized railway and bus transport as a whole, not even in the most utilized Banska Bystrica - Zvolen direction, where the modes of transport compete with each other. Due to the relative isolation of this region from other regions, it is possible to take advantage of a lower number of relationships between customers and carriers to establish an integrated transport system [3].

Railway regional transport is more utilized between Banska Bystrica - Zvolen and sections of Horna Stubna, Ziar nad Hronom, Brezno and Lucenec. In the remaining area, regional bus transport, which has a high transport performance 35 km/inhabitant per year, is dominating. As a consequence of passengers decrease, the cost increases from 15 to 20 €/inhabitant per year over the past 6 years [2,3].

2.2 Area Zvolen – Banska Bystrica

Between the stations of Banska Bystrica and Zvolen, electrified single-track line, connecting the largest centers in the region, is the most frequented. Due to its throughput (operating efficiency), timetable design, which would be fully in compliance with the transport needs of suburban and long-distance transportation, is not allowed. This area is a prerequisite for a significant increase of suburban transport due to increased need of population mobility [1-3].

In the commute area, there are all tariff points along the railway line with great importance of the Banska Bystrica and Zvolen stations. Currently, insufficient throughput can be eliminated by using regional or long-distance trains for suburban transport needs. The strong competition of road transport is another threat for region's suburban railway transport [2].

In order to improve the interconnection of these centers, as well as the traffic point of the Banska Bystrica self-governing region with the city of Bratislava, it is necessary to build a second line or a double-track line for smooth crossing. This would solve interval suburban railway transport, which would serve as the basis of the future integrated transport system Banska Bystrica - Zvolen [1-3].

2.3 Transport Flow Between Zvolen and Banska Bystrica

In tables 2 and 3, the traffic flows between get in and get out points are summarized. The traffic flow of passengers is divided into two time slots: afternoon and evening. The transport rush (peak) and saddle periods are repeated in reverse order. Passenger flows are processed per day and individually per each direction [2,3].

Table 2 Passengers traffic flows – direction into Banska Bystrica. Source: [2,3]

Track number	Track direction	Railway track section	Number of passengers
170	Zvolen – Banska Bystrica	Zvolen – Sliac spa	1,086
		Sliac spa – Velká Luka	1,141
		Velká Luka – Hronsek	1,142
		Hronsek – Vlkanova	1,184
		Vlkanova – Radvan	1,259
		Radvan – Banska Bystrica town	1,133
		Banska Bystrica town – Banska Bystrica	613

Table 3 Passengers traffic flows – direction into Zvolen. Source: [2,3]

Track number	Track direction	Railway track section	Number of passengers
170	B. Bystrica – Zvolen	Banska Bystrica – Banska Bystrica town	826
		Banska Bystrica town – Radvan	1,462
		Radvan – Vlkanova	1,561
		Vlkanova – Hronsek	1,401
		Hronsek – Velká Luka	1,362
		Velká Luka – Sliač spa	1,356
		Sliac spa – Zvolen	1,328

3. Railway Infrastructure between Zvolen and Banska Bystrica

The track section connecting Zvolen and Banska Bystrica is 21 km long and consists of the line 170 Zvolen - Vrutky. For this section, the capacity optimization of the integrated transport system construction is solved.

The traffic management is decentralized, which means that the management is provided by the transport staff directly in railways operating buildings. All the operating buildings are constantly occupied without the transport service lockout.

Zvolen and Banska Bystrica are connected by single-track line. The railway infrastructure, which connects Zvolen and Banska Bystrica, is electrified with an alternating current system of 25 kV, 50 Hz. According to the Železnice Slovenskej Republiky (ŽSR) railway tracks categorization, the whole Zvolen – Banska Bystrica section is included among tracks of 1st category [1].

Fig. 1 depicts a track section scheme showing stations and stops located on this section as well as the branch (turning) tracks from the railway stations Zvolen and Banska Bystrica and the course speed of a given session.

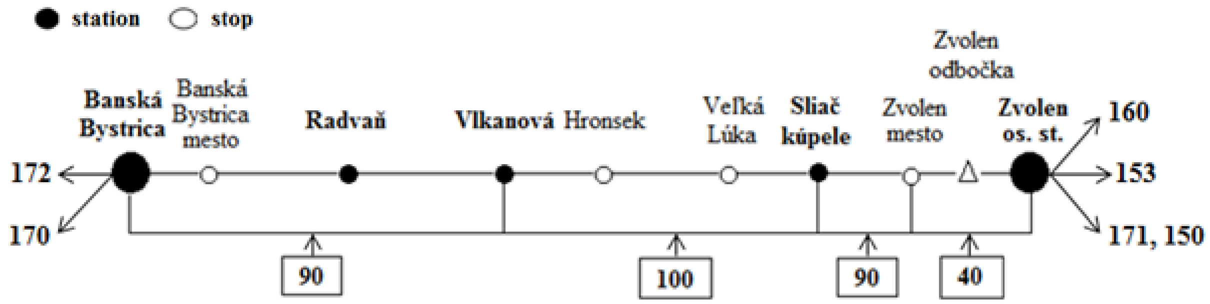

Fig. 1 Banska Bystrica - Zvolen track section scheme. Source: authors

4. Proposal of Railway Infrastructure Capacity Increase for the Integrated Transport System Needs

Following the analysis of the passenger flows, the railway infrastructure capacity between Zvolen and Banska Bystrica is assessed. It is a single-track section and, therefore, it is necessary to optimize the infrastructure capacity in the context of fixed interval services within the planned Integrated Transport system (ITS) [4-9].

On the basis of the knowledge of a set of possible measures to increase the railway tracks throughput (permeable performance) and of the railway infrastructure condition in the assessed track section, the following alternative measures are developed:

- Construction of a double-track line for smooth crossing,
- Construction of the second line throughout the entire assessed section.

4.1 Methodology of Perspective Throughput Calculation

The calculation of the perspective practical throughput in the limiting section is based on assumptions as in the calculation using statistics and mathematical probability and consists of two calculation tables [9,10].

The calculation of the throughput performance was performed by the methodology of the ŽSR according to Internal Regulation D24 (ŽSR D24 1965), which is applied to the perspective train graph schedule diagram, which means without the need to create a train graph schedule diagram. The methodology consists in finding a limiting interstate section. Then, occupation times for individual probability of train sequences in limiting interstate section are determined and multiples of train numbers in individual sequences are calculated [9-12].

By multiplying the respective occupation times and the number of trains in individual sequences, the total occupancy time (T_{obs}) is calculated. T_{obs} is increased about 10% due to the reserve order. Subsequently, unit occupancy time of the average train (t_{obs}) is calculated and required buffer time according to the provisions of Regulation D24 is determined [13]. The practical throughput of the section (n) is determined according to the:

$$n = \frac{T_{occ} - (T_E + T_{ois})}{t_{occ} + t_{gapp}} \qquad (1)$$

where: n = practical throughput [trains/day = t/d]; T_E = total time needed for regular scheduled examinations [d]; T_{ois} – occupation time of an inter-station section by regular siding, operating and service trains not included in the number of trains [d]; t_{occ} = average occupation time per train [d]; t_{gap} – required time gaps per train [d].

To evaluate the results on a comparable basis, the same methodology was used for the current state and post-modernization (upgrade) state. The throughput for the double-track line is determined separately per each direction. Due to the slight difference between the driving time of trains in even and odd directions, it is sufficient to perform a calculation for one direction (in this case, impaired direction). 60 minutes of lockout time (T_{vyl}) are taken into consideration and the permanent activities time is not considered. The range of train traffic is assessed according to the current train graph schedule diagram 2016/2017 [14-17].

4.2 Throughput Indicators in the Current State

To determine the number of train paths for each train typologies, after examining the possibilities of creating the symmetric cycle train graph schedule diagram, it is necessary to quantify the practical throughput of the assessed section [8-12].

As mentioned, calculation of the track section throughput is solved using the methodology of the ŽSR. For this purpose, facts by analyzing the elements of the Train Graph Schedule (TGS) diagram in 2015, such as interstate section occupation times, station and track intervals, and so on were identified. In Table 4, numbers of established routes for passenger and freight trains and total and free capacity in the Zvolen - Banska Bystrica section are processed [10-15].

Table 4 Numbers of established routes in TGS per 24 hours. Source: [3]

Track number	Track section	Train type	Number of connections							
			Regular – in TGS		As needed – in TGS		Free capacity		Capacity	
			E	O	E	O	E	O	E	O
118 D	Zvolen – Banska Bystrica	Passenger	39	32	1	1	11		102	
		Freight	5	5	5	7				

Table 5 shows the throughput indicators in the current state. Between Zvolen and Banska Bystrica, the current throughput is determined at 109 trains per 24 hours.

Table 5 Zvolen – Banska Bystrica track section throughput (in 2017). Source: [3]

Track section	Direction	Total number of trains	T_{occ}	T_{gapp}	N_{add}	N_{ar}	D_o	C_p	t_l
			t_{occ}	t_{gapp}	p	t_{fix}	b		
Zvolen - Banska Bystrica	E	40	1,102	338	11	7	0.61	79.7	60
	AN	7	10.39	3.19	**102**	0	6.6		x
	E	38	x	x	x	x	x	x	x
	AN	7	x	x	x	x	x		x

Explanations: E = even train direction; O = odd train direction; T_{occ} = total occupation time of the interstation section by all trains [d]; t_{occ} = occupation time per one train [d]; T_{gapp} = total gaps time [d]; t_{gapp} = gaps time per one train [d]; N_{add} = number of additional routes; p = practical permeability [t/d]; N_{ar} = number of added routes; t_{fix} = time of fixed operations per train [d]; D_o = occupation degree; b = backups time [d]; C_p = coefficient of the permeability utilization; t_l = lockouts time [d]

Analysis of the current state of the railway infrastructure capacity between Zvolen and Banska Bystrica indicates that it is possible to deploy additional 11 train connections within 24 hours. This free capacity is given by the limiting section between the stations of Zvolen and Sliac. However, for an integrated transport system, it is necessary to increase capacity at peak periods, when demand for transport is the highest, especially in the morning and afternoon peaks, which are set from 5:00 to 9:00 and from 14:00 to 21.00 for our model proposal needs. Therefore, the infrastructure capacity needs to be partially divided into such peak and saddle periods and it is necessary to determine the number of free train paths within a peak period [16-18].

Table 6 Throughput indicators within morning traffic peak. Source: authors

Track section	Direction	Total number of trains	T_{occ}	T_{gapp}	t_l	P_{real}
			t_{occ}	t_{gapp}	p	t_{fix}
Zvolen - Banska Bystrica	E	9	2,068	97.79	0	**16**
	AN	0	8.89	6.11	**18**	0
	E	7	x	x	x	x
	AN	0	x	x	x	x

In Table 7, throughput indicators within a morning peak from 5:00 to 9:00 are processed. Thus, to determine the practical throughput, the calculation time is 240 minutes. From calculation of the practical throughput, it is clear that the maximum number of trains in a given timeframe is 18 within traffic peak periods. Currently, the actual number of trains is 16, which represents using the 88.89% of capacity of limiting critical section. This number causes a relevant quality reduction in a given section and at a given time [18,19].

Table 7 Throughput indicators within afternoon traffic peak. Source: authors

Track section	Direction	Total number of trains	T_{occ}	T_{gapp}	t_l	P_{real}
			t_{occ}	t_{gapp}	p	t_{fix}
Zvolen - Banska Bystrica	E	18	6,551	127.5	0	**31**
	AN	0	7.50	4.11	**33**	0
	E	13	x	x	x	x
	AN	0	x	x	x	x

According to a similar approach, throughput indicators within afternoon peak from 14:00 to 21:00 are summarized. Thus, to determine the practical throughput, the calculation time is 360 minutes. From calculation of the practical throughput, it is clear that the maximum number of trains in a given timeframe, which can be deployed in the section, is 33 within peak periods. Currently, the actual number of trains is 31, which represents using 93.93% of capacity of limiting critical section. This extremely high number causes a significant reduction of quality in a given section and at a given time [20,21].

Table 8 Throughput perspective capacity for train graph schedule diagram 2017/2018. Source: [3]

Track number	Track section	Limited interstate section	Perspective capacity		
			T_c		k_z
			t_{pr} (Pn)	n_{vyhl}	T_{stal}
118 D	Zvolen – Banska Bystrica	Sliac – Zvolen	1,440	x	0.81
			10	117	x

Explanations: T_c = calculation time in minutes, t_{pr} (Pn) = drive time of average Pn train, n_{vyhl} = perspective capacity, k_z – throughput backup coefficient, T_{stal} = time of permanent operation.

4.3 Calculation of Zvolen - Banska Bystrica Section Throughput after Construction of a Double-Track Line for Smooth Crossing

In case of insertion of a double-track line into a single-track railway line in the Zvolen - Banska Bystrica section, it is necessary to specify its minimum length with the appropriate safety device [4,13,22].

$$L_k = \frac{(\tau_{pv}^A + \tau_{pv}^B)*(v_1 * v_2)}{(v_1 + v_2)*0.06} = \frac{(2+2)*(40*40)}{(40+40)*0.06} = 1{,}333.83 \quad (2)$$

where: L_k = the minimum distance of the double-track liner for smooth crossing [m]; v_1 = speed of the first train [km/h]; v_2 = speed of the second train [km/h]; τ_{pv}^A = interval of successive entrances in the railway operating building A; τ_{pv}^B = interval of successive entrances in the railway operating building B [8-11].

From previous calculation, it is clear that the length of the double-track line must be at least 1.334 m. After analysis of the track section, the best possible position for double-track line is in the limiting interstation section. In our case, it is the section of Zvolen - Sliac spa stations. The distance between these points is 6,112 m which suits our requirements for the construction of a double-track line [13,15,23].

Table 9 Indicators for characteristics of throughput of the Zvolen - Banska Bystrica section after construction of the double-track line. Source: authors

Track section	Direction	Total number of trains	T_{occ}	T_{gapp}	N_{add}	D_o	C_p	t_l
			t_{occ}	t_{gapp}	p	b		
Zvolen - Banska Bystrica	E	40	361	1,019	x	0.26	69.92	60
	AN	7	4.20	11.85	**123**	8.9		x
	E	38	x	x	x	x	x	x
	AN	7	x	x	x	x		x

4.4 Calculation of the Section Throughput after the Second Line Construction

A new railway line construction has a positive impact in terms of increasing the assessed section capacity. For such construction measures, the throughput is increased by more than 100%. When making decisions about construction of double-track sections, it is necessary to equip the entire section, not only with a new railway line, but also a new railway safety device, which has a positive impact on this throughput performance as well [5, 8, 24-26].

After the second line construction, determining throughput performance is much easier compared to single-track sections: e.g. the throughput is determined separately for each path direction [4-9].

$$n = \frac{T_{occ}-(T_E+T_{ois})}{t_{occ}+t_{gapp}} = \frac{1{,}440-(30+10)}{(5+4)} = 155 \text{ t/d} \tag{2}$$

where: n = practical permeability [trains per day = t/d]; T_E = total time needed for regular scheduled examinations [d]; T_{ois} = occupation time of an inter-station section by regular siding, operating and service trains which are not included in the number of trains [d]; t_{occ} = average occupation time per train [d]; t_{gap} = required gaps time per train [d].

4.5 Comparing the Capacity of Each Variants

Following the calculations in the previous chapters, it is necessary to evaluate the individual proposed measures. Figure 2 shows the comparison of the practical throughput performance of particular track section for the current state (without measures) and after the proposed measures: double-track line and second line construction (double-tracking) within the whole section.

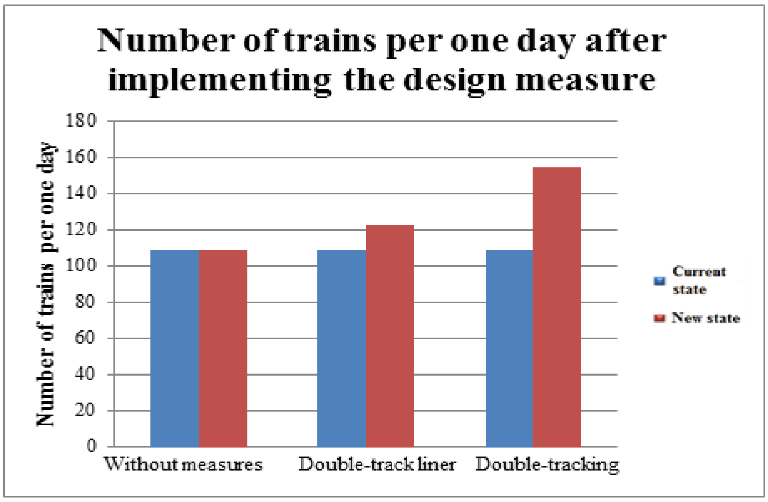

Fig. 2 Comparison of throughputs: current and after upgrade. Source: authors

After the construction of a double-track line in a limiting critical section, the throughput increases from 102 to 123 trains per day, this allows to create fixed interval transport services between individual cities [17,19,25,26].

5. Conclusion

The railway track section Zvolen - Banska Bystrica represents the connection of two important traffic points, centers of major economic units and creates significant interconnection within them. This railway connection poses considerable demands on the quality and capacity of the infrastructure, especially in terms of its use to operate a primary service as a part of an integrated transport system.

The proposed measures can significantly contribute to create suitable timetable for passenger trains between the cities of Zvolen and Banska Bystrica, which can enhance the attractiveness of the planned integrated transport system.

References

[1] Ministry of Transport, Construction and Regional Development of the Slovak Republic. (2013). Operational Program Integrated Infrastructure 2014 – 2020, 5th revised draft. Bratislava, Slovak Republic.

[2] Ministry of Transport, Construction and Regional Development of the Slovak Republic. (2013). Strategic Plan for Development of Transport Infrastructure of the Slovak Republic by 2020. 1st phase. Bratislava, Slovak Republic.

[3] ŽSR – Railways of the Slovak Republic. (2016). Book of the railway tracks throughput of the ŽSR for the TGS 2016/2017. Bratislava, Slovak Republic).

[4] Jiang, M., Li, H.Y. & Meng, L.Y. (2016). Harmony Assessment of Network Transportation Capacity in Urban Rail Transit. In International Conference on Electrical and Information Technologies for Rail Transportation - Electrical Traction, 28-30 August 2015 (pp. 721-728). Zhuzhou. China: Springer. DOI: 10.1007/978-3-662-49370-0_75.

[5] Lai, Y.C., Huang, Y.A. & Chu, H.Y. (2014). Estimation of rail capacity using regression and neural network. Neural computing & Applications, 25(7-8), 2067-2077. DOI: 10.1007/s00521-014-1694-x.

[6] Kontaxi, E. & Ricci, S. (2009). Techniques and methodologies for carrying capacity evaluation: Comparative analysis and integration perspectives. Ingegneria Ferroviaria, 64(12), 1051-1080. ISSN 0020-0956.

[7] Malavasi, G., Molkova, T., Ricci, S. & Rotoli, F. (2014). A synthetic approach to the evaluation of the carrying capacity of complex railway nodes. Journal of Rail Transport Planning & Management, 4(1-2), 28-42. DOI: 10.1016/j.jrtpm.2014.06.001.

[8] Kampf, R., Lizbetin, J. & Lizbetinova, L. (2012). Requirements of a transport system user. Komunikacie, 14(4), 106-108. ISSN 1335-4205.

[9] Li, G.C., Li, B.R., Ju, M.Y. & Zhang, Z.J. (2017). Discussion on Integrated Traffic Planning (ITP) of New Tourism Town upon Sustainable Development and Livable Request. In 14th World Conference on Transport Research (WCTR), 10-15 Jul 2016 (pp. 3402-3415). Shanghai, China: Elsevier Science Bv. DOI: 10.1016/j.trpro.2017.05.231.

[10] Ližbetin, J., Černá, L. & Ľoch, M. (2015). Model evaluation of suppliers in terms of real company for selected criteria. Nase More, 62(3), 147-152. DOI: 10.17818/NM/2015/SI11.

[11] Abramovic B., Zitricky, V. & Biskup V. (2016). Organisation of railway freight transport: case study CIM/SMGS between Slovakia and Ukraine. European Transport Research Review, 8(4). DOI: 10.1007/s12544-016-0215-7.

[12] Gašparík, J. & Pečený, Z. (2009). Train graph schedule diagram and throughput of network. (1st ed.). Žilina: EDIS, Slovak Republic. ISBN 978-80-8070-994-5.

[13] Janos, V. & Kriz, M. (2016). Infrastructure parameters affecting capacity of railways in TEN-T. In Scientific Student Conference on Interoperability of Railway Transport (IRICoN), 04 May 2016 (pp. 22-25). Prague, Czech Republic: Czech Technical University. DOI: 10.14311/APP.2016.5.0022.

[14] Kendra, M., Babin, M. & Barta, D. (2012). Changes of the infrastructure and operation parameters of a railway line and their impact to the track capacity and the volume of transported goods. In Conference on Transport Research Arena, 23-26 April 2012 (pp. 743-752). Athens, Greece: Elsevier Science Bv. DOI: 10.1016/j.sbspro.2012.06.1052.

[15] Putallaz, Y. & Rivier, R. (2004). Strategic evolution of railway corridor infrastructure: dual approach for assessing capacity investments and M&R strategies. In 9th International Conference on Computer Aided Design, Manufacture and Operation in the Railway and Other Advanced Transit Systems, 17-19 May 2004 (pp. 61-72). Dresden, Germany: WIT Press. ISSN 1462-608X.

[16] Wang, J.F., Yu, Y., Kang, R.W. & Wang, J.G. (2017). A Novel Space-Time-Speed Method for Increasing the Passing Capacity with Safety Guaranteed of Railway Station. Journal of advanced transportation, Article number UNSP 6381718. DOI: 10.1155/2017/6381718.

[17] Poliaková, B. (2011). Conditions and proposals of tariff integration for the integrated transport systems in the Slovak Republic. Transport and telecommunication, 12(2), 39-49. ISSN 1407-6160.

[18] Haith, J., Johnson, D. & Nash, C. (2014). The case for space: the measurement of capacity utilisation, its relationship with reactionary delay and the calculation of the capacity charge for the British rail network. Transport planning and technology, 37(1), 20-37. DOI: 10.1080/03081060.2013.844906.

[19] Bindzár, P. (2010). Project of integrated transport in the city of Košice. In SYM-OP-IS 2010: 37 (Simpozijum o operacionim istraživanjima: zbornik radova: Tara), 21-24 September 2010 (pp. 345-348). Beograd: Medija Center Obrana, Serbia. ISBN 978-86-335-0299-3

[20] Hu, J.Q., Li, H.Y., Meng, L.Y. & Xu, X.Y. (2013). Modeling capacity of urban rail transit network based on bi-level programming. In ASME 2013 Joint Rail Conference, 15-18 April 2013 (article number V001T08A001). Knoxville, Tennessee: The American Society of Mechanical Engineers. ISBN 978-0-7918-5530-0.

[21] Poliaková, B. & Kubasáková, I. (2014). The problematic implementation of integrated transport systems in Slovakia. Autobusy: technika, eksploatacja, systemy transportowe, 5, 104-110. ISSN 1509-5878.

[22] Rosová, A., Balog, M. & Šimeková, Ž. (2013). The use of the RFID in rail freight transport in the world as one of the new technologies of identification and communication. Acta Montanistica Slovaca, 18(1), 26 -32. ISSN 1335-1788.

[23] Kull, R.C. (2007). Increasing US freight rail network capacity with ECP braking and PTC systems. In ASME/IEEE Joint Rail Conference/ASME Internal Combustion Engine Division Spring Technical Conference, 13-16 March 2007 (pp. 83-87). Pueblo, Colorado: The American Society of Mechanical Engineers. ISBN 978-0-7918-4787-9.

[24] Lucchini, L., Rivier, R. & Emery, D. (2000). CAPRES network capacity assessment for Swiss North-South rail freight traffic. In 7th International Conference on Computers in Railways, 11-13 September 2000 (pp. 221-230). Bologna, Italy: WIT Press. ISBN 1-85312-826-0.

[25] Stopka, O., Bartuska, L. & Kampf, R. (2015). Passengers' evaluation of the integrated transport systems. Nase More, 62(3), 153-157. DOI: 10.17818/NM/2015/SI12.

[26] Bindzár, P. (2011). Some Knowledge from Implementing Integrated Transport on East Slovakia. In Transport and Logistics: Carpathian Logistics Congress - 9th special issue, 27-30 September 2011 (pp. 411-416). Podbanské, High Tatras, Slovak Republic. ISSN 1451-107X.