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Proposal of the traffic service on the Žilina – Rajec railway line by using the innovative methods

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Abstract

Nowadays, there is a trend that creates individual car transport, which creates environmental burdens and congestion, which is reflected in the time loss of all transport participants. It is therefore important to develop public passenger transport and support alternative transport modes that are environmentally friendly. The development of electromobility and creation of integrated passenger transport systems are opportunities to find new possibilities to improve public passenger transport and the exchange of rail passenger transport. The article deals with the use of new progressive scientific methods in the context of improving the quality of passenger rail transport and improving transport services. First, the main basic principles of transport services and passenger rail transport are defined, followed by a review of the literature, which is followed by the proposed scientific principles and context. Secondly, the practical application of the proposed issue is demonstrated on the Žilina – Rajec railway line.

Keywords: Traffic potential; Traffic service; Scientific methods; Timetable

1. Introduction

Transport is very important sector of the national economy. It is necessary to analyse the transport chain in passenger and freight transport (Brumerčíková, E. et al., 2020). It is also important to support public passenger transport, as its performance has declined over the last few years at the expense of individual motoring, which is

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much more popular among the population of the state than public transport. However, the enormous increase in passenger cars is caused by a number of negative factors, in particular the creation of congestion and adverse environmental effects. Moreover, it is necessary to accept regulatory and environmental measures and take also number of effective measures to revive public passenger transport (Hrudkay, K. et al., 2019). One of the solutions is to improve it and to make it more attractive mainly by rationalizing and optimizing the timetables of each mode of transport. It is also necessary to ensure a higher synergy effect between partial transport modes and to create more transport links. (Banister D., 2008). The main transport system must be a rail transport system. High-quality and attractive timetables could significantly increase the interest of passengers to use public passenger transport and to optimize the transport chain in passenger transport and as a result to improve the passenger transport system. There are many professional and scientific procedures and methods to take measure, estimation of the mentioned problems and finally to find optimal solution for improvement (Dragićević, B. et al., 2018) (Čamaj, J et al., 2019).

Railway passenger transport problems, optimization and rationalization are addressed to many transport experts and scientists. For example, the book publication, "Railway Timetabling and Operations" by authors I. A. Hansen and J. Pachl(2014) describes analysis, modelling, simulation and performance evaluation. There are lots of useful information about the rationalization and optimization of railway transport operation. The scientific paper "Estimation of Transport Potential in Regional Rail passenger Transport by Using the Innovative Mathematical – Statistical Gravity Approach"published in scientific journal Sustainability by authors J. Gasparik et al. (2020)presents new methodology for determining traffic potential in railway passenger transport.Public transport rationalization and timetabling are mentioned in other publications (Niger, M., 2011)(Kuník, P., 2012) (Pellegrini P. et al., 2014)(Sun Q. et al., 2019).Similar research about railway vehicle circulation was done with issues of city bus transport, where main topics were vehicles scheduling and bus-drivers scheduling. Mathematical approaches of bus-drivers scheduling arethe main field of Stanislav Palúch's (2008, 2017, 2018) research where the author describes some mathematical algorithms that are used to optimize scheduling of bus-drivers and gives some model examples. Applications of flow-networks are elaborated in his publications. Other author Jaroslav Kleprlík (2007) deals with scheduling in general and in his publications, he suggests usage of the Hungarian method to solve transport optimization as the assignment problem. There are two subjects of the paper: mathematical approaches that were mentioned above and purpose in railway passenger transport.

There are a lot of theoretical and practical basis, unexplored processesin the field of planning, rationalization and optimization of therailway passenger transport system. The contribution is also focused on the proposal of the traffic service by means of new scientific methods, their principles, new connections and relationships. It is explained on the Žilina – Rajec railway line.

2. Use of new scientific methods to improve transport services

The main scientific-research part, which uses new scientific methods for traffic service improvement consists of five parts:

- level of vehicle occupation theory,
- description of the methodology for determining the transport potential,
- determining the transport potential on Žilina – Rajec railway line,
- modeling of traffic flows on the railway line Žilina - Rajec,
- proposal of the timetable variants of the mentioned railway line.

2.1. Level of vehicle occupation theory

Key element in railway passenger transport is a customer – traveller, who requires the transport from one place to another. Basic precondition for accomplishment the main requirement – transport, is making the complete offer which provides not only transport, but also other associated services. Practically, there are many associated criteria of transport, for example safety, duration, price, reliability, comfort and complementary services (Dolinayova, A. et al., 2017).

Other factors with significant impact are reliability, offer of travel possibilities, vehicle occupation and coherence of transport system. Reliability is relative, because it depends on transport time and distance, while it proportionally decreases with mode of transport combination, for example train-bus. The most reliable are direct connections. The offer of travel options has a great impact on the quality of the entire transport system and building modifications in passenger transport. It can be evaluated from spatial and temporal density. Spatial density means the number of tariff points per some area, while temporal density means the number of links per some time unit. The occupancy level of the vehicle compares the actual use of the vehicle with the maximum use of the vehicle.This relationship is expressed by comparing "transport power":

$$L_{VO} = \frac{\sum passkm}{\sum placekm} \quad (1)$$

where: L_{VO} – level of vehicle occupation,
Σ passkm – sum of the real “transport power” expressed by passenger-kilometres unit,
Σ placekm – sum of the maximum ‘transport power’ expressed by place-kilometres unit.

All transport companies want to achieve an approximate value of $L_{VO} = 1$, which means a high or total occupancy of the vehicle. High vehicle occupancy increases traffic exhaustion and has a bad impact on passengers' travel experiences. The recommended L_{VO}value for long-distance trains is 0.75.

Whole quality is defined as the ability to satisfy all customer requirements. Specific features of transport services are insignificance, impossibility of storage, inseparability, variability, complexity and uniqueness. The level of service quality can be perceived as a mismatch between expectations and perceptions. Customers – passengers have different priorities related to the quality of services. They usually remember low quality and high quality is a standard for them. The main challenge is to identify passengers' needs and satisfy them in all cases, because each transport is carried out under different conditions (Vojtek et al., 2020) (Černá et al., 2020).

2.2. Description of the methodology for determining the transport potential

Gravity models are the inspiration for the creation of the following relationship, which can be considered as a new progressive gravitational method applicable in regional rail transport.It is very important to take into account the principle arising from the gravitational model(Hoštáková, D. et al, 2019). The resulting proposed formula for calculating the transport potential (K_p) can be marked as a further modification of the Lill gravitational model. Its form is as follows (Gasparik, J. et al., 2020):

$$K_p = \frac{\sum_1^n \frac{A_n}{D_n}}{L} \quad (2)$$

where:
K_p – transport potential coefficient [population/km^2],
A_n– the number of inhabitants of the n-th seat of the monitored area [piece],
D_n– availability of the n-th railway station and stop – its distance from the centre or from its middle [piece],
L– length of the railway passenger transport route [km].

The transport potential is expressed by the coefficientK_p given as an index for the transport relation on the route with n settlements. A is the number of inhabitants (in thousand) of the monitored seat (municipality or city), D is distance(in km) from the railway station or stop from the seat from the centre or geographical centre of the neighboring seat.L is transport distance between the monitored area.The closer these settlements are, the higher their attractiveness.

The most significant benefit of the proposed relationship is the assessment of transport potential and subsequent more effective identification of bottlenecks on individual regional railway lines, while it is possible to assess whether the line has low transport potential due to low population density or problems with accessibility of railway stations and their longer distance from settlements. On these lines, it is also possible to assess the effectiveness of investments in railway infrastructure, whether, based on the transport potential, more extensive construction and reconstruction measures will pay off, or operational and organizational measures will be sufficient, etc. Based on the calculated values of K_p on several transport routes, it is possible to better compare these routes and then assess their importance based on the resulting hierarchy and thus the setting of priorities for possible modernization. Based on scientific opinions and brainstorming methods, the width of the intervals is as follows (Gašparík, J. et al., 2020).

Table 1. Determination of the modified intervals width particular traffic service ranges

Traffic service range	The interval of the resulting K_p value	Recommended number of pairs of all regional trains	Recommended number of seats for all train connections in both directions
I.	0 - 700	4	up to 500 seats
II.	701 - 1000	5-6	250 – 1500
III.	1001 - 1200	7-10	350 - 3000
IV.	1201 – 1400	11-15	550 – 6000
V.	1401 – 1600	16-20	1000 – 8000
VI.	1601 – 1800	21-25	2000 – 10000
VII.	1801 – 2000	26-30	4000 – 12000
VIII.	2001 – 2500	31-39	5000 – 15000
IX.	2501 – 3000	40-49	7000 – 20000
X.	3001 and more	50 and more	8 000 more

2.3. Determining the transport potential on Žilina – Rajec railway line

The practical application of the proposed methodology is indicated on the regional railway line Žilina - Rajec. It is a single-track railway line with stations Žilina, Bytčica, LietavskáLúčka and Rajec, where are mechanical station security devices with manually set exchanges. In the railway section Žilina –LietavskáLúčka there is a semi-automatic line security block and in the railway section LietavskáLúčka – Žilina there is a telephone communication.The maximum speed on the railway line is 60 km/h.

Table 2.Traffic potential on Žilina-Rajec railway line.

Tariff point	A	D	A/D
Bytčica	2046	0,60	3410,00
Lietavská Lúčka	1840	0,28	6571,43
Porúbka	491	0,65	755,38
Poluvsie	590	0,10	5900,00
Rajecké Teplice	3017	0,50	6034,00
Konská pri Rajci	1547	1,50	1031,33
Zbyňov	879	0,80	1098,80
Kľače	419	0,20	2095,00
Rajec	5777	0,60	9628,30
Total value A/D			**36 524,20**
Railway line length (km)			**21,00**
Total value K_p			**1 739,25**

As a part of the application of the proposed methodology, it will first be necessary to analyze the number of inhabitants and the distance of the railway station or stop from the city center or municipality. Subsequently it is possible to calculate the transport potential (K_p) for regional rail transport. Determination of the values of the number of inhabitants (column marked A), as well as the values of access (column marked D) and the subsequent calculation of the transport potential $K_p$for individual line sections is shown in tab. 2.

The regional railway line Žilina - Rajec with a length of 21 km requiresa value of the transport potential K_p= 1739.25 and therefore, basedon the proposed range, it is possible to include the railway line in level VI, which represents the recommended number of 21-25 pairs of connections with a transport capacity of 2,000 - 10,000 seats.

Table 3.Trafficserviceparameters of the Žilina – Rajec railway line

Railway line	FinalK_p value	Traffic service range	Recommended number of pairs of all regional trains	Recommended number of seats for all train connections in both directions
Žilina - Rajec	1739,25	VI	21 – 25	2 000 – 10 000

2.4. Modeling of traffic flows on the railway line Žilina - Rajec

Traffic flows can be divided in terms of traffic and traffic in terms of content. The first is passenger flows and the second is train flows. Traffic flows are comparable to fluid, gas or electricity flows. These flows are described by parameters, such as place, time and direction. Other useful parameters are speed, intensity, density and wavelength. The intensity q and the density h are disproportionately dependent on each other. Transport monitoring and the resulting analysis provide an interesting finding, that $q = q(h)$. This means that if we know the density at the selected place, we also know the intensity. In this research, the characteristics of traffic flows are their continuity are very important. If we have two places (stations or stops) x_1 and x_2, it would be possible to calculate the number of passengers between these two places at time t as well as $t+ \Delta t$. X_1 is a starting point and X_2 is the destination of the passenger flow. Size of the flow h (number of passengers) in time t and t+Δt is calculated separately. Important is the difference D that shows the flow change. The final difference that shows the change in passenger flows is calculated according to the formula (Černá, A. et al. 2014):

$$\int_{x_1}^{x_2} \big(h(x, t + \Delta t) - h(x, t)\big)dx \qquad (3)$$

Figure 1 shows the model values of the number of passengers on Žilina – Rajec railway line. The blue column represents the modelled number of boarding passengers, the red column represents the modelled number of disembarked passengers and the green line represents the train occupancy.

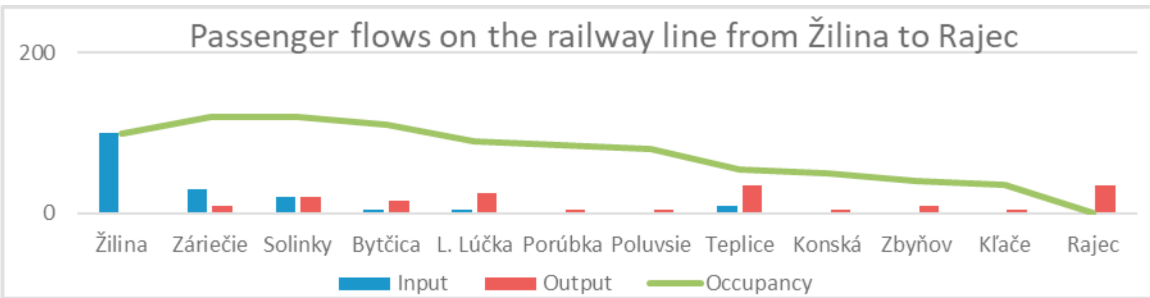

Fig. 1. Passenger flows on the railway line from Žilina to Rajec

The modelled data show that the individual trains are the busiest in the section Žilina – Bytčica. Therefore, it would be appropriate to introduce the special city trains in this section, which will divert traffic flows on the busiest section, and thus additional trains will not be needed, especially in peak traffic times, significantly overcrowded (Čamaj et al.,2019). Another advantageous operating concept is the introduction of a special zone traffic service, which is represented by regional express trains, which will be stopped at Žilina-Záriečie, Rajecké Teplice and Rajec stations. These trains will be occupied only by those passengers travelling to Rajecké Teplice and Rajec. This concept of operation is especially suitable for transport peaks to avoid overcrowding of individual trains.

2.5. Proposal of the timetable variants of the mentioned railway line

Subsequently, it is necessary to design a timetable on the railway line. However, based on the current state of railway infrastructure capacity, it can be stated that the minimum planned range of transport service, which represents 25 pairs of connections (at least 21 pairs of regional trains) it is not possible to ensure the required quality and operational efficiency on the line. The basic timetable for both directions includes hourly train departures in each direction. There are 20 trains per day in each direction. The advantage of this timetable is simplicity for passengers, as they always know that maximum waiting time for the next train is one hour. The disadvantage of this timetable is that there are no extensions during peak periods, so the trains could be overcrowded or the capacity of the selected trains should be higher. The minimum number of vehicles for this timetable is two but there must be another to increase capacity and backup vehicle. The recommended number of vehicles is 4.

km	Train	3500	3502	3506	3510	3514	3518	3520	3522	3524	3526	3530	3534	3538	3542	3546	3550	3552	3554	3556	3558
0	**Žilina**	4:00	4:50	5:50	6:50	7:50	8:50	9:50	10:50	11:50	12:50	13:50	14:50	15:50	16:50	17:50	18:50	19:50	20:50	21:50	22:50
2	Žilina - Záriečie	4:04	4:54	5:54	6:54	7:54	8:54	9:54	10:54	11:54	12:54	13:54	14:54	15:54	16:54	17:54	18:54	19:54	20:54	21:54	22:54
5	Žilina - Solinky	4:08	4:58	5:58	6:58	7:58	8:58	9:58	10:58	11:58	12:58	13:58	14:58	15:58	16:58	17:58	18:58	19:58	20:58	21:58	22:58
6	Bytčica o	4:10	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00
6	Bytčica	4:11	5:07	6:07	7:07	8:07	9:07	10:07	11:07	12:07	13:07	14:07	15:07	16:07	17:07	18:07	19:07	20:07	21:07	22:07	23:07
7	Lietavská Lúčka	4:15	5:10	6:10	7:10	8:10	9:10	10:10	11:10	12:10	13:10	14:10	15:10	16:10	17:10	18:10	19:10	20:10	21:10	22:10	23:10
10	Porúbka	|	5:15	6:15	7:15	8:15	9:15	10:15	11:15	12:15	13:15	14:15	15:15	16:15	17:15	18:15	19:15	20:15	21:15	22:15	23:15
13	Poluvsie	|	5:19	6:19	7:19	8:19	9:19	10:19	11:19	12:19	13:19	14:19	15:19	16:19	17:19	18:19	19:19	20:19	21:19	22:19	23:19
15	Rajecké Teplice o	4:25	5:22	6:22	7:22	8:22	9:22	10:22	11:22	12:22	13:22	14:22	15:22	16:22	17:22	18:22	19:22	20:22	21:22	22:22	23:22
15	Rajecké Teplice	4:26	5:23	6:23	7:23	8:23	9:23	10:23	11:23	12:23	13:23	14:23	15:23	16:23	17:23	18:23	19:23	20:23	21:23	22:23	23:23
16	Konská pri Rajci	|	5:25	6:25	7:25	8:25	9:25	10:25	11:25	12:25	13:25	14:25	15:25	16:25	17:25	18:25	19:25	20:25	21:25	22:25	23:25
18	Zbyňov	|	5:27	6:27	7:27	8:27	9:27	10:27	11:27	12:27	13:27	14:27	15:27	16:27	17:27	18:27	19:27	20:27	21:27	22:27	23:27
19	Kľače	|	5:30	6:30	7:30	8:30	9:30	10:30	11:30	12:30	13:30	14:30	15:30	16:30	17:30	18:30	19:30	20:30	21:30	22:30	23:30
21	**Rajec** o	4:33	5:33	6:33	7:33	8:33	9:33	10:33	11:33	12:33	13:33	14:33	15:33	16:33	17:33	18:33	19:33	20:33	21:33	22:33	23:33

km	Train	3501	3505	3509	3513	3517	3519	3521	3523	3525	3529	3533	3537	3541	3545	3549	3551	3553	3555	3557	3559
0	**Rajec**	4:37	5:37	6:37	7:37	8:37	9:37	10:37	11:37	12:37	13:37	14:37	15:37	16:37	17:37	18:37	19:37	20:37	21:37	22:37	23:37
2	Kľače	4:40	5:40	6:40	7:40	8:40	9:40	10:40	11:40	12:40	13:40	14:40	15:40	16:40	17:40	18:40	19:40	20:40	21:40	22:40	|
3	Zbyňov	4:42	5:42	6:42	7:42	8:42	9:42	10:42	11:42	12:42	13:42	14:42	15:42	16:42	17:42	18:42	19:42	20:42	21:42	22:42	|
5	Konská pri Rajci	4:45	5:45	6:45	7:45	8:45	9:45	10:45	11:45	12:45	13:45	14:45	15:45	16:45	17:45	18:45	19:45	20:45	21:45	22:45	|
6	Rajecké Teplice o	4:46	5:46	6:46	7:46	8:46	9:46	10:46	11:46	12:46	13:46	14:46	15:46	16:46	17:46	18:46	19:46	20:46	21:46	22:46	23:44
6	Rajecké Teplice	4:47	5:47	6:47	7:47	8:47	9:47	10:47	11:47	12:47	13:47	14:47	15:47	16:47	17:47	18:47	19:47	20:47	21:47	22:47	23:45
8	Poluvsie	4:50	5:50	6:50	7:50	8:50	9:50	10:50	11:50	12:50	13:50	14:50	15:50	16:50	17:50	18:50	19:50	20:50	21:50	22:50	|
11	Porúbka	4:54	5:54	6:54	7:54	8:54	9:54	10:54	11:54	12:54	13:54	14:54	15:54	16:54	17:54	18:54	19:54	20:54	21:54	22:54	|
14	Lietavská Lúčka	5:00	6:00	7:00	8:00	9:00	10:00	11:00	12:00	13:00	14:00	15:00	16:00	17:00	18:00	19:00	20:00	21:00	22:00	23:00	23:56
15	Bytčica o	5:03	6:03	7:03	8:03	9:03	10:03	11:03	12:03	13:03	14:03	15:03	16:03	17:03	18:03	19:03	20:03	21:03	22:03	23:03	23:59
15	Bytčica	5:04	6:04	7:04	8:04	9:04	10:04	11:04	12:04	13:04	14:04	15:04	16:04	17:04	18:04	19:04	20:04	21:04	22:04	23:04	0:00
16	Žilina - Solinky	5:06	6:06	7:06	8:06	9:06	10:06	11:06	12:06	13:06	14:06	15:06	16:06	17:06	18:06	19:06	20:06	21:06	22:06	23:06	0:02
19	Žilina - Záriečie	5:10	6:10	7:10	8:10	9:10	10:10	11:10	12:10	13:10	14:10	15:10	16:10	17:10	18:10	19:10	20:10	21:10	22:10	23:10	0:06
21	**Žilina** o	5:14	6:14	7:14	8:14	9:14	10:14	11:14	12:14	13:14	14:14	15:14	16:14	17:14	18:14	19:14	20:14	21:14	22:14	23:14	0:10

Fig. 2. Basic timetable with no extensions

As can be seen from figure 1, the highest occupancy of railway vehicles is in the section from Žilina to Bytčica, because this section passes through the city center. Capacity in this section should be increased by new trains, which should only run in the sections during transport peaks in the morning and in the afternoon. This solution extends the overall transport service because there are more trains. There are 30 trains running in each direction per day so the transport service is about 50% higher, but only in the section from Žilina to Bytčica, which is critical in term of occupancy.

km	Train		3526	3528	3530	3532	3534	3536	3538	3540	3542	3544	3546	3548	3550	3552	3554	3556	3558
0	Žilina	_	12:50	13:20	13:50	14:20	14:50	15:20	15:50	16:20	16:50	17:20	17:50	18:20	18:50	19:50	20:50	21:50	22:50
2	Žilina - Záriečie	_	12:54	13:24	13:54	14:24	14:54	15:24	15:54	16:24	16:54	17:24	17:54	18:24	18:54	19:54	20:54	21:54	22:54
5	Žilina - Solinky	_	12:58	13:28	13:58	14:28	14:58	15:28	15:58	16:28	16:58	17:28	17:58	18:28	18:58	19:58	20:58	21:58	22:58
6	Bytčica o	_	13:00	13:30	14:00	14:30	15:00	15:30	16:00	16:30	17:00	17:30	18:00	18:30	19:00	20:00	21:00	22:00	23:00
6	Bytčica	_	13:07		14:07		15:07		16:07		17:07		18:07		19:07	20:07	21:07	22:07	23:07
7	Lietavská Lúčka	_	13:10		14:10		15:10		16:10		17:10		18:10		19:10	20:10	21:10	22:10	23:10
10	Porúbka	_	13:15		14:15		15:15		16:15		17:15		18:15		19:15	20:15	21:15	22:15	23:15
13	Poluvsie	_	13:19		14:19		15:19		16:19		17:19		18:19		19:19	20:19	21:19	22:19	23:19
15	Rajecké Teplice o	_	13:22		14:22		15:22		16:22		17:22		18:22		19:22	20:22	21:22	22:22	23:22
15	Rajecké Teplice	_	13:23		14:23		15:23		16:23		17:23		18:23		19:23	20:23	21:23	22:23	23:23
16	Konská pri Rajci	_	13:25		14:25		15:25		16:25		17:25		18:25		19:25	20:25	21:25	22:25	23:25
18	Zbyňov	_	13:27		14:27		15:27		16:27		17:27		18:27		19:27	20:27	21:27	22:27	23:27
19	Kľače	_	13:30		14:30		15:30		16:30		17:30		18:30		19:30	20:30	21:30	22:30	23:30
21	Rajec o	_	13:33		14:33		15:33		16:33		17:33		18:33		19:33	20:33	21:33	22:33	23:33

km	Train	3501	3503	3505	3507	3509	3511	3513	3515	3517	3519	3521	3523	3525	3527	3529	3531	3533	
0	Rajec	4:37		5:37		6:37		7:37		8:37	9:37	10:37	11:37	12:37		13:37		14:37	_
2	Kľače	4:40		5:40		6:40		7:40		8:40	9:40	10:40	11:40	12:40		13:40		14:40	_
3	Zbyňov	4:42		5:42		6:42		7:42		8:42	9:42	10:42	11:42	12:42		13:42		14:42	_
5	Konská pri Rajci	4:45		5:45		6:45		7:45		8:45	9:45	10:45	11:45	12:45		13:45		14:45	_
6	Rajecké Teplice o	4:46		5:46		6:46		7:46		8:46	9:46	10:46	11:46	12:46		13:46		14:46	_
6	Rajecké Teplice	4:47		5:47		6:47		7:47		8:47	9:47	10:47	11:47	12:47		13:47		14:47	_
8	Poluvsie	4:50		5:50		6:50		7:50		8:50	9:50	10:50	11:50	12:50		13:50		14:50	_
11	Porúbka	4:54		5:54		6:54		7:54		8:54	9:54	10:54	11:54	12:54		13:54		14:54	_
14	Lietavská Lúčka	5:00		6:00		7:00		8:00		9:00	10:00	11:00	12:00	13:00		14:00		15:00	_
15	Bytčica o	5:03		6:03		7:03		8:03		9:03	10:03	11:03	12:03	13:03		14:03		15:03	_
15	Bytčica	5:04	5:34	6:04	6:34	7:04	7:34	8:04	8:34	9:04	10:04	11:04	12:04	13:04	13:34	14:04	14:34	15:04	_
16	Žilina - Solinky	5:06	5:36	6:06	6:36	7:06	7:36	8:06	8:36	9:06	10:06	11:06	12:06	13:06	13:36	14:06	14:36	15:06	_
19	Žilina - Záriečie	5:10	5:40	6:10	6:40	7:10	7:40	8:10	8:40	9:10	10:10	11:10	12:10	13:10	13:40	14:10	14:40	15:10	_
21	Žilina o	5:14	5:44	6:14	6:44	7:14	7:44	8:14	8:44	9:14	10:14	11:14	12:14	13:14	13:44	14:14	14:44	15:14	_

Fig. 3. Extended timetable with "city line"

The advantage of this extension is that there are more trains, so there could be new passengers. The disadvantage of this extension is that the capacity of the railway line is used to the maximum during rush hours, so there is no gap for freight trains and in case of delays, certain problems may arise.

In the third variant, there are 18 pairs of passenger trains in both directions, three regional express trains in the even direction and two regional express trains in the odd direction. This range can be ensured by means of four trainsets. The concept of this variant is based on the hourly rate of passenger trains that cross with priority at the Lietavská Lúčka or Bytčica railway station. An example of the third proposed variant of the timetable, also with graphic marking of the trainsets, is shown in figure 4.

km	Train	REX 3580	3500	3502	3504	3506	3508	3510	3512	3514	3516	REX 3582	3518	3520	REX 3584	3522	3524	3526	3528	3530	3532	3534
0	**Žilina**	**4.21**	5.03	6.21	7.14	8.14	9.14	10.14	11.14	12.14	13.14	**14.17**	14.28	15.22	**16.17**	16.28	17.14	18.21	19.14	20.14	21.14	22.21
2	Žilina - Záriečie	**4.25**	5.07	6.25	7.18	8.18	9.18	10.18	11.18	12.18	13.18	**14.21**	14.32	15.26	**16.21**	16.32	17.18	18.25	19.18	20.18	21.18	22.25
5	Žilina - Solinky	I	5.11	6.29	7.22	8.22	9.22	10.22	11.22	12.22	13.22	I	14.36	15.30	I	16.36	17.22	18.29	19.22	20.22	21.22	22.29
6	Bytčica	I	5.14	6.40	7.25	8.25	9.25	10.25	11.25	12.25	13.25	I	14.39	15.33	I	16.39	17.25	18.32	19.25	20.25	21.25	22.32
7	Lietavská Lúčka o	I	5.16	6.42	7.27	8.27	9.27	10.27	11.27	12.27	13.27	I	14.41	15.35	I	16.41	17.27	18.34	19.27	20.27	21.27	22.34
7	Lietavská Lúčka	I	5.25	6.43	7.35	8.35	9.35	10.35	11.35	12.35	13.35	I	14.42	15.36	I	16.42	17.35	18.35	19.35	20.35	21.35	22.35
10	Porúbka	I	5.29	6.47	7.39	8.39	9.39	10.39	11.39	12.39	13.39	I	14.46	15.40	I	16.46	17.39	18.39	19.39	20.39	21.39	22.39
13	Poluvsie	I	5.33	6.51	7.43	8.43	9.43	10.43	11.43	12.43	13.43	I	14.50	15.44	I	16.50	17.43	18.43	19.43	20.43	21.43	22.43
15	Rajecké Teplice	**4.41**	5.37	6.55	7.47	8.47	9.47	10.47	11.47	12.47	13.47	**14.37**	14.54	15.48	**16.37**	16.54	17.47	18.47	19.47	20.47	21.47	22.47
16	Konská pri Rajci	I	5.39	6.57	7.49	8.49	9.49	10.49	11.49	12.49	13.49	I	14.56	15.50	I	16.56	17.49	18.49	19.49	20.49	21.49	22.49
18	Zbyňov	I	5.41	6.59	7.51	8.51	9.51	10.51	11.51	12.51	13.51	I	14.58	15.52	I	16.58	17.51	18.51	19.51	20.51	21.51	22.51
19	Kľače	I	5.44	7.02	7.54	8.54	9.54	10.54	11.54	12.54	13.54	I	15.01	15.55	I	17.01	17.54	18.54	19.54	20.54	21.54	22.54
21	**Rajec**	**4.47**	5.47	7.05	7.57	8.57	9.57	10.57	11.57	12.57	13.57	**14.43**	15.04	15.58	**16.43**	17.04	17.57	18.57	19.57	20.57	21.57	22.57

km	Train	3501	REX 3581	3503	3505	3507	3509	3511	3513	3515	3517	3519	3521	3523	3525	3527	3529	3531	3533	3535	REX 3583
0	**Rajec**	4.59	**5.51**	6.09	7.09	8.09	9.09	10.09	11.09	12.09	13.09	14.01	15.08	16.01	17.09	18.07	19.09	20.09	21.09	22.07	**23.09**
2	Kľače	5.02	I	6.12	7.12	8.12	9.12	10.12	11.12	12.12	13.12	14.04	15.11	16.04	17.12	18.10	19.12	20.12	21.12	22.10	I
3	Zbyňov	5.04	I	6.14	7.14	8.14	9.14	10.14	11.14	12.14	13.14	14.06	15.13	16.06	17.14	18.12	19.14	20.14	21.14	22.12	I
5	Konská pri Rajci	5.07	I	6.17	7.17	8.17	9.17	10.17	11.17	12.17	13.17	14.09	15.16	16.09	17.17	18.15	19.17	20.17	21.17	22.15	I
6	Rajecké Teplice	5.09	**5.58**	6.19	7.19	8.19	9.19	10.19	11.19	12.19	13.19	14.11	15.18	16.11	17.19	18.17	19.19	20.19	21.19	22.17	**23.16**
8	Poluvsie	5.13	I	6.23	7.23	8.23	9.23	10.23	11.23	12.23	13.23	14.15	15.22	16.15	17.23	18.21	19.23	20.23	21.23	22.21	I
11	Porúbka	5.17	I	6.27	7.27	8.27	9.27	10.27	11.27	12.27	13.27	14.19	15.26	16.19	17.27	18.25	19.27	20.27	21.27	22.25	I
14	Lietavská Lúčka o	5.21	I	6.31	7.31	8.31	9.31	10.31	11.31	12.31	13.31	14.23	15.30	16.23	17.31	18.29	19.31	20.31	21.31	22.29	I
14	Lietavská Lúčka	5.22	I	6.32	7.32	8.32	9.32	10.32	11.32	12.32	13.32	14.31	15.38	16.31	17.32	18.37	19.32	20.32	21.32	22.38	I
15	Bytčica	5.26	I	6.36	7.36	8.36	9.36	10.36	11.36	12.36	13.36	14.42	15.42	16.42	17.36	18.41	19.36	20.36	21.36	22.42	I
16	Žilina - Solinky	5.29	I	6.39	7.39	8.39	9.39	10.39	11.39	12.39	13.39	14.45	15.45	16.45	17.39	18.44	19.39	20.39	21.39	22.45	I
19	Žilina - Záriečie	5.32	**6.14**	6.42	7.42	8.42	9.42	10.42	11.42	12.42	13.42	14.48	15.48	16.48	17.42	18.47	19.42	20.42	21.42	22.48	**23.32**
21	**Žilina**	5.36	**6.18**	6.46	7.46	8.46	9.46	10.46	11.46	12.46	13.46	14.52	15.52	16.52	17.46	18.51	19.46	20.46	21.46	22.52	**23.36**

Fig. 4. Extended timetable with "fast trains"

3. Conclusion

Mobility is a part of everyday activities in cities, regions and between them. The increasing number of cars and trucks on the expanding transport infrastructure is causinga number of problems that need to be addressed in terms of impacts on the whole area. To meet this goal, it is necessary to propose specific measures to improve the transport system and to accept new progressive elements for the rationalization and optimization of the traffic service. The paper analyzes new scientific principles of determining transport services by determining the transport potential and new elements of traffic flowsmodeling. The practical application has been implemented on the Žilina – Rajec railway line. Three variants of the timetable were proposed on the line. The proposed concept should become a key global technology forregional railways. It should help optimize passenger transport in cities and surrounding regions. It points to the subsequent need to rationalize timetables and optimize specific types of public passenger transport. Related to this is the development of integrated transport systems, the creation of new transport connections, the development of electromobility and other safe and environmentaly friendly transport systems. These visions may be the subject of further research and scientific outputs.

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