

**CHOSEN ASPECTS OF A SPATIALLY FUNCTIONAL ACCESSIBILITY BY PUBLIC TRANSPORT: THE CASE OF TRNAVA SELF-GOVERNING REGION (SLOVAKIA)**

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**Keywords:** rural area, public transport, accessibility, Trnava Self - Governing Region, Slovak Republic**Abstract:** The aim of the paper is to analyze transport possibilities of Trnava Self-Governing Region (TTSK) municipalities residents to its center (regional capital) by public transport. The authors of the paper have reviewed the current trends of public transport and discussed the optimization of their capacity and timetable scheduling in terms of continuity and parallelism of bus and train transport. The research methods included GIS tools, complex accessibility calculations based on the journeys published on slovakrail.sk and www.cp.sk on a Tuesday, February 6, 2018 at four key times (4:00, 7:30, 14:00, 24:00), which were compared by four aspects: distance traveled, travel time, number of transfers, comprehensive route accessibility by three types of transport: train, bus and combined transport. The results of the research have showed that there is a certain threshold value for travel distance, time and number of transfers, which affects the commuters to either not visit the regional capital or choose to travel by a car. It was confirmed, that every type of public transport in the territory of TTSK has areas where it is currently the main way for commuting to the regional city. The authors of the paper have provided a comprehensive picture of selected aspects of spatially functional accessibility by public transport and the characteristics of individual types of transport in terms of following the scheduled route timetables in the TTSK region during the selected key times.

## 1 Introduction

Different types of transport are key accelerators for the development of population mobility. According to the European Commission White Paper "Roadmap to a Single European Transport Area - Towards a competitive and resource efficient transport system", transport is a key element of the economy and society [1,2]. The European transport policy emphasizes on an increased use of more environmentally friendly types of transport, in particular rail transport.

During the first decade of the political transformation in Slovakia (after 1989), the reverse development of public transport services (road and rail) was observed, while the role of individual transport (cars) in society has increased significantly. Until 2014, the share of public transport for passenger transportation in the Slovak Republic was decreasing. This decadent state is more noticeable in rural areas, where transport routes have been reduced or canceled. The cancelation of bus and rail routes and the creation of a "more efficient" (inconvenient for

passengers) transportation system in the municipalities of the Slovak Republic was caused by several factors. The most important [3] are considered to be: i) questionable demarcation of higher territorial units, driven by political (not geographical) criteria; ii) the growing significance of individual car transport in both the commercial and private spheres; iii) structurally spatial changes in the labor market, which have caused considerable number of people to work from home or commute home on weekends only, as well people not working during typical work shifts (06:00-14:00, 14:00-22:00, 22:00-06:00, or 08:00-16:00).

Since 17 November 2014, public rail transport services in Slovakia have become a specific phenomenon with zero tariffs for selected groups of passengers, which contributed to the growing share of railways in passenger transportation. While bus transport is in the competence of 8 self-governing regions, railways are still the responsibility of the state [1].

The aim of the paper is to analyze transport possibilities of Trnava Self-Governing Region (TTSK) municipalities

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residents by public transport, review the current trends in a qualitative dominance of various types of public transport and discuss the optimization of their capacity and timetable scheduling in terms of continuity and parallelism of bus and train transport.

Dealing with these action poses a new question: "Which of these types of transport should be a priority for ensuring transport to the regional capital of TTSK?"

On the basis of new methodology presented by the authors of the paper the complex availability equation based on the comprehensive route accessibility proposed by the authors of the paper, the most convenient way has been suggested for transporting each municipality residents belonging to TTSK towards the regional capital Trnava at four key times has been suggested.

## 2 Theoretical background

Public passenger transport, understood as transport operated with – pre-determined and publish transport and tariff conditions, is accessible to any interested party-transport participant, regardless of their gender, age, nationality, ethnicity, etc. It is especially important as ecologically friendly alternative to individual car transport, for citizens who are unable to use a car [4,29]. Accessibility is, according to [5], a measure of the strength and extent of geographical relationships between citizens and their socio-economic activities. [6] in his work defines the spatial accessibility of regions as "the ease of reaching a region from other cities or regions.

The accessibility of Slovak cities in terms of correlations between settlement, transport network configuration and territorial division has been given more attention in the geographical community [7-10] than the availability of rural municipalities towards their natural centers [11] and [12]. Even in Czech geography, public transport and its spatial connections are mainly addressed in regional cities [13-16], and not in its regions [17].

The Polish literature [18] has been an inspirational publication for the aim of this study, where an example of canceled passenger rail routes in a transforming Poland highlighted the importance of public transport in connecting cities and settlements. The traffic congestion in Poland and other developed countries [19] and [20] is considered to be one of the most significant issues influencing living conditions of urban and regional residents.

It is noted, that this situation was caused not only due to the increase in the population's wealth, but also to the chaotically progressing suburbanization. The chaotic suburbanization and the related deterioration in accessibility by public transport is based on research in the Olcztyna region [21] and Krakow [22]. Another inspirational publication from a non-European environment has been [23].

## 3 Research methodology, data and research area

While [13] calculates the accessibility of public transport in terms of frequency (the sum of 3x long-distance trains per standard Wednesday, which stop in a given municipality + 1x regional trains per standard Wednesday, which stop in a given municipality + 2x the long haul buses per standard Wednesday, which stop in a given municipality + 1x regional coaches per standard Wednesday, which stop in a given municipality), the authors propose a calculation based on speed and reliability of passenger transport (the ratio of traveled distance and time multiplied by the number of routes). The proposed calculation procedure was named complex accessibility (kd) calculation and was applied in [11] and [12].

$$kd = \frac{s}{t \times p} \quad (1)$$

kd - complex accessibility,

s - distance traveled,

t - time traveled,

p - number of transfers.

For the purpose of complex accessibility calculation in this paper a standard Tuesday (February 6, 2018) was considered, thus eliminating the increasing trend of traffic before and after the holidays, but also the decreasing trend of traffic during them.

Transport journeys at four key times were selected: i) journeys leaving at 04:00 from municipalities with the earliest arrival in Trnava (important for tourists, long-distance travelers and commuters to work for morning shift); ii) journeys with the latest departure from municipalities arriving at 07:30 in Trnava (important for commuters to school, work, doctor office etc.); iii) journeys with the earliest arrival in municipalities leaving from Trnava at 14:00 (important for commuters from school, work, doctor office etc.); iv) journeys with the latest departure from Trnava arriving in municipalities by 24:00 (important for tourists, long-distance travelers, commuters from afternoon shift). In the case of time equality during the calculation, the number of transfers and a traveled distance was taken into account (lower is better).

Data used for railway journeys calculations were acquired only for municipalities with at least one tariff point – a railway station or a stop from the scheduled timetable published on [24]. The difference between a railway/bus station and stop has not been considered for the calculation purposes.

Data used for bus and combined transport services were with attention to the number of lines, routes, and bus operating companies acquired through a search engine at [25]. The default filter setting of the search engine was used to generate search results, the only exception was filtering out inner city transport buses. Combined transport combines the usage of both bus and train transport during journeys.

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Miroslava Trembošová; Alena Dubcová; Ľudmila Nagyová; Dagmar Cagáňová

#### 4 Research results

Trnava Self-Governing Region (TTSK) is located in the west part of the Slovak Republic and consists of 7 districts: Dunajská Streda (DS), Galanta (GA), Hlohovec (HC), Piešťany (PN), Senica (SE), Skalica (SI) and Trnava (TT). In the west it borders with the Bratislava self-governing region and Austria, in the north-west with the Czech Republic, in the north with the Trenčín self-governing region, in the east with the Nitra self-governing region and in the south with Hungary.

Trnava city, with a population of 65,382 (31.12.2017), as the regional capital of TTSK, concentrates important institutions such as faculty hospital basic secondary and university educational institutions, cultural institutions, public administration typical for the regional city, the state administration - police, jurisdiction and other services resulting from the nodal position of the regional city in relation to its background. There is a high concentration of industrial enterprises represented e. g. by car manufacturer Peugeot-Citroën, increased concentration of progressive activities and it is also an important bus and train hub of Slovakia. TTSK is a higher-level service center for seven districts with 491,904 residents (31.12.2017).

The TTSK route network has a convergent shape and consists of a dense network of roads in total length of 1951.041 km [26]. According to collected data [27], TTSK contains 67.24 km of motorways, 22.93 km of expressways, 268.084 km of I class roads, 535.873 km of II class roads and 1056,912 km of III class roads. Currently, TTSK has agreed on a framework contract with three bus operating companies providing services in public interest (suburban bus service on the territory of TTSK) operating 93 routes. Specifically, ARRIVA Trnava, a. s. operates 31 routes, Slovenská autobusová doprava Dunajská Streda, a. s. covers 45 routes and SKAND Skalica, s. r. o. manages 17 routes. Ten railway lines run through the territory of TTSK. They create a 347 km long rail network with 62 tariff points, composed of 30 stations and 32 stops. The railway lines run through 55 municipalities of TTSK, which is 21.9 % of the total of 251 municipalities. Railway lines on the territory of TTSK create an odotropic type of network [11].

##### 4.1 Spatially functional analysis of TTSK residents transport accessibility by public transport

Early in the morning, the results confirmed the priority position of bus transport. In the Fig 1, several areas can be

identified: Záhorie, north of the TT, PN and HC districts, the area around the town Sered' and the west of the DS district. Main reasons for the obtained results within the area of Záhorie are: i) train transport is not available as only few municipalities have train station/stop, ii) combined transport is not convenient as the first morning buses from the surrounding municipalities are not synchronized with the train departures, and iii) at the same time, the quality of road infrastructure is better in comparison with the railway infrastructure on lines 114 and 116. In the northern part of the TTSK region (i. e. districts TT, HC and PN), good road infrastructure leading primarily to Trnava and small number of functional train tariff points accessible by buses (for combined transport) contributed to the major usage of bus transport. The surrounding of the town Sered' is typical by frequent and convenient train and combined journeys. Most municipalities in this area have a direct journeys with Trnava in the morning. On the other hand, the train is only available in Gáň, Sered' and Križovany nad Dudváhom, where bus and train journeys do not follow each other. This situation creates complications and makes combined transport impossible.

The west of the Dunajská Streda district is a typical gravitational area of bus routes to Šamorín and Bratislava. These bus stations are not in close proximity to the railway stations. For this reason, from Bratislava bus station, the journey to Trnava is better by long haul bus than by train, to which travelers need to move by using Bratislava public transport.

On the other hand, the quality of the journeys in the early morning is brought by the railways due to the arrival of their employees. In most municipalities with a train tariff point, the train route was more favorable or equivalent to the bus. The exceptions are: i) Pusté Úľany with more convenient bus lines as the road is more direct, ii) Buková with a remote train stop and the fact that the first train to Trnava does not stop there, iii) municipalities between Leopoldov and Piešťany, which are offered only one complicated journey with Trnava through Piešťany, iv) line 114 from which surroundings leads better road infrastructure. In addition, the Figure 1 also shows some areas where combined transport is preferred. Especially the surroundings of Galanta with a built transfer terminal with short transfer times and relatively well-timed train and bus timetables, while the direct bus journey with Trnava is poor. Similar parameters were observed in the south from Dunajská Streda, with the integrated transport terminal in Dunajská Streda, as well as near Piešťany with the integrated transport terminal in Piešťany.

**CHOSEN ASPECTS OF A SPATIALLY FUNCTIONAL ACCESSIBILITY BY PUBLIC TRANSPORT: THE CASE OF TRNAVA SELF-GOVERNING REGION (SLOVAKIA)**

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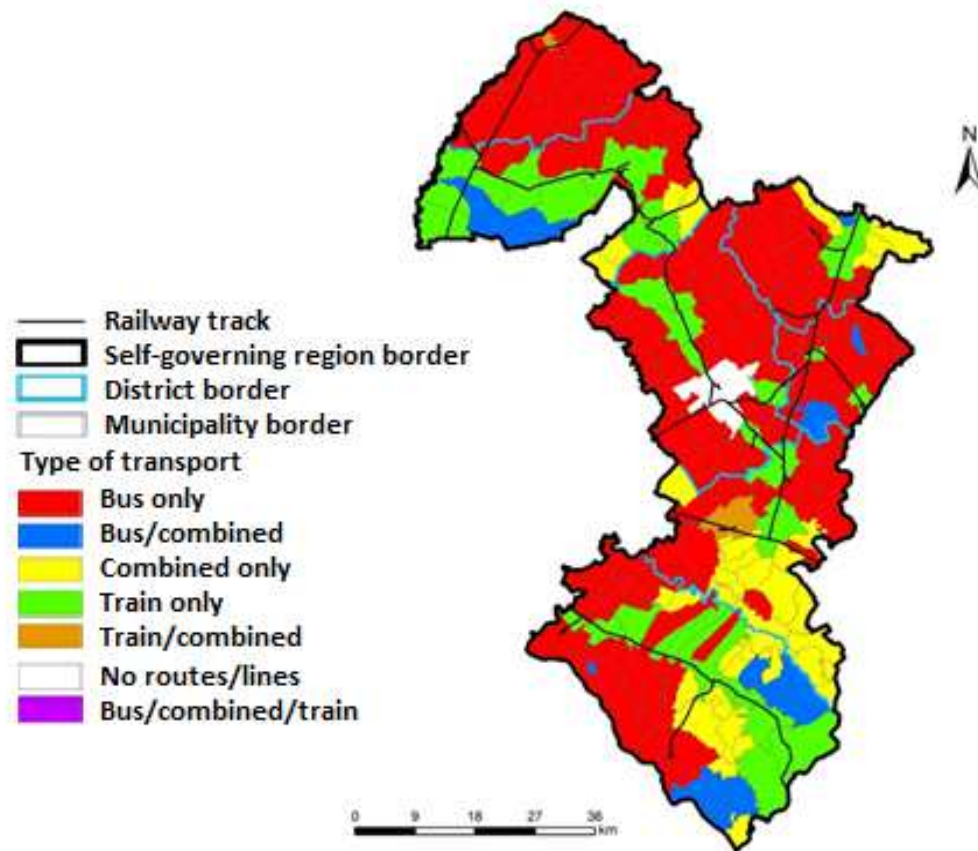


Figure 1 The best journeys to the regional capital Trnava from the municipalities of TTSK at the time 4:00

The Figure 2 shows a few changes in comparison with the previous figure. First of all, the surroundings of Gbely are more oriented towards train and combined transport. This is due to the situation (at around 6:00) in municipalities with a railway point, where it is already worthwhile for bus operating companies to transport people from places where it was pointless at 4:00. Thereafter, these people are transported by a train that arrives in Trnava at 7:21. This way, trains can compete

significantly with buses, which are slower due to poor road infrastructure in the section from Gbely to Senica.

Thanks to the alternative route through Galanta, a significant part of the municipalities of the Dunajská Streda district, which had a favorable rail or combined transport at 4:00, was reoriented to bus or combined transport. A similar process occurred in Sered' and Gáň, where the bus arrival time in Trnava (7:30) is more convenient, rather than train arrival time (7:21), which result in higher complex accessibility.



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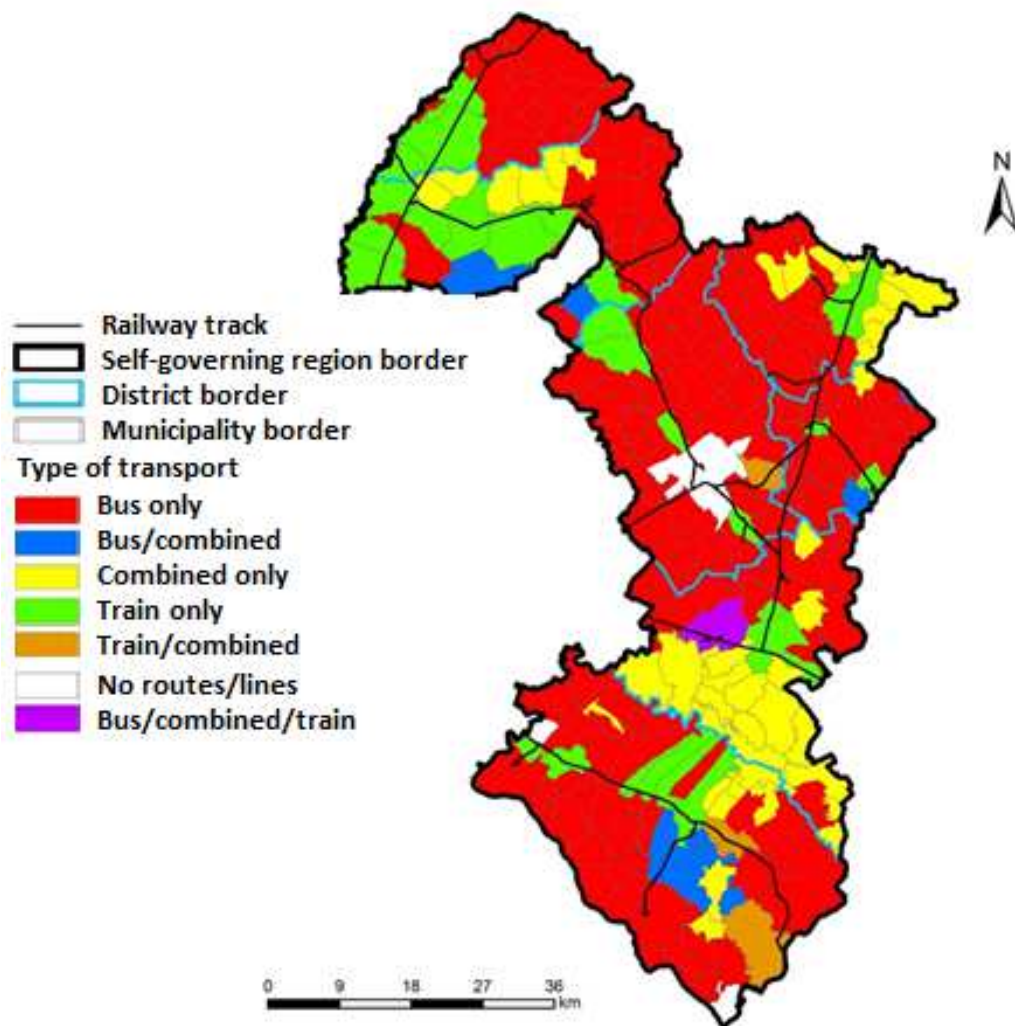


Figure 2 The best journeys to the regional capital Trnava from the municipalities of TTSK with the arrival time before 7:30

The Figure 3 shows a significant change in comparison with the maps of morning journeys, especially in two aspects: i) almost complete orientation of the districts of Dunajská Streda and Galanta to the bus transport, ii) a strong orientation of Záhorie region to combined or train transport. In the district of Dunajská Streda, this change was caused by the time-consuming regional train to Bratislava with 22 minutes break to following train to Trnava. In the case of Záhorie region, the significant factor is that trains from Trnava to the mentioned direction depart

at 14:06 following shortly after the arrival of other regional trains from surrounding municipalities. Buses leave Trnava usually around 14:30, due to the shifts in the Zavar logistics park, which creates long break within the journey. The bus transfers in Cerová-Lieskové, Šajdíkove Humence, Borský Mikuláš and Šaštín-Stráže that follow the train from Trnava have simple, unequipped bus stops (sometimes even without shelters), but the timing of the buses is well-planned, thus creating an easy distribution to municipalities which are far from the tariff points.

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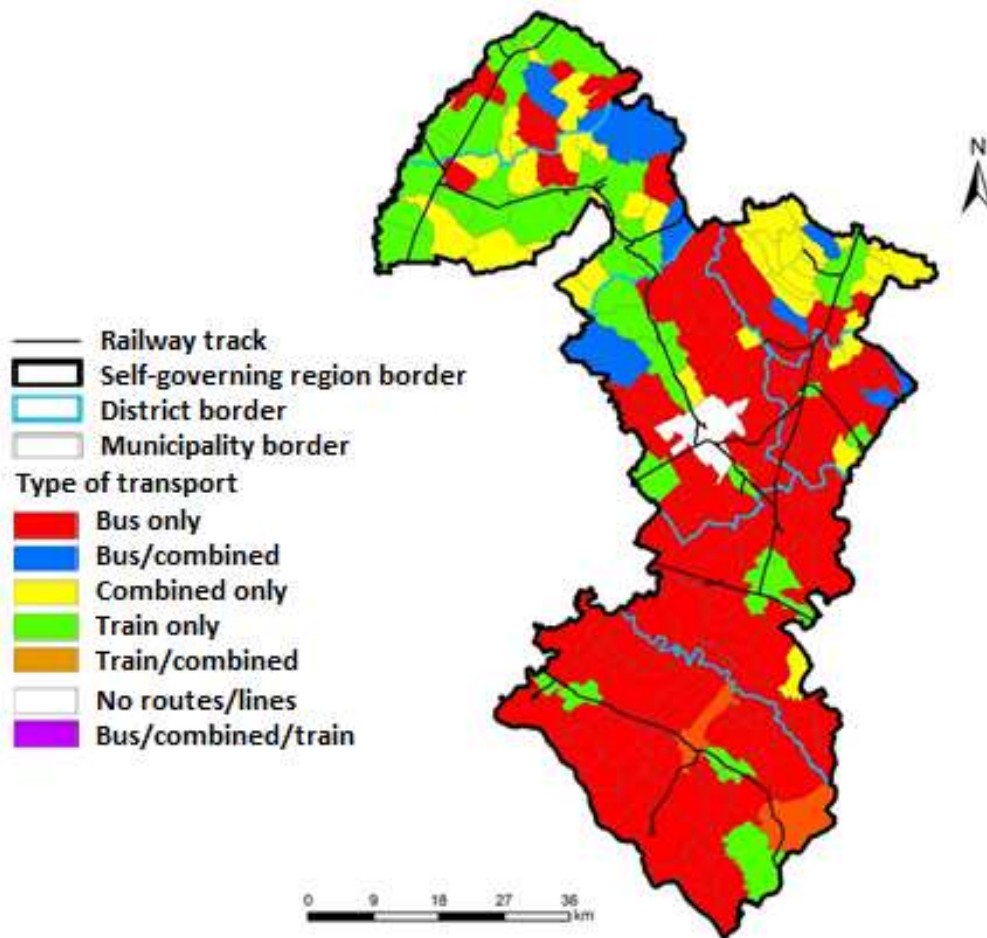


Figure 3 The best journeys from the regional capital Trnava to the municipalities of TTSK at the time 14:00

The map of the journeys from Trnava with the latest departure (Figure 4) brings a completely different result. The usage of train transport is preferable only in the south-east of the district of Dunajská Streda, the towns of Galanta and Sládkovičovo and several municipalities along lines 116 and 110. The reason is that the last buses have later departure time than the last trains. On the other hand, a large part of the districts of Senica, Skalica and Dunajská Streda residents chose combined transport, as direct bus

transport from Trnava was not provided to municipalities situated away from the main roads from Trnava past 22:30. The later journeys by combined transport were more preferable. Passengers chose combined transport despite the long distance between the train station and bus station in Bratislava and Senica, which was inconvenient at peak times. Combined transport proved to be advantageous in the vicinity of Galanta again.

**CHOSEN ASPECTS OF A SPATIALLY FUNCTIONAL ACCESSIBILITY BY PUBLIC TRANSPORT: THE CASE OF TRNAVA SELF-GOVERNING REGION (SLOVAKIA)**

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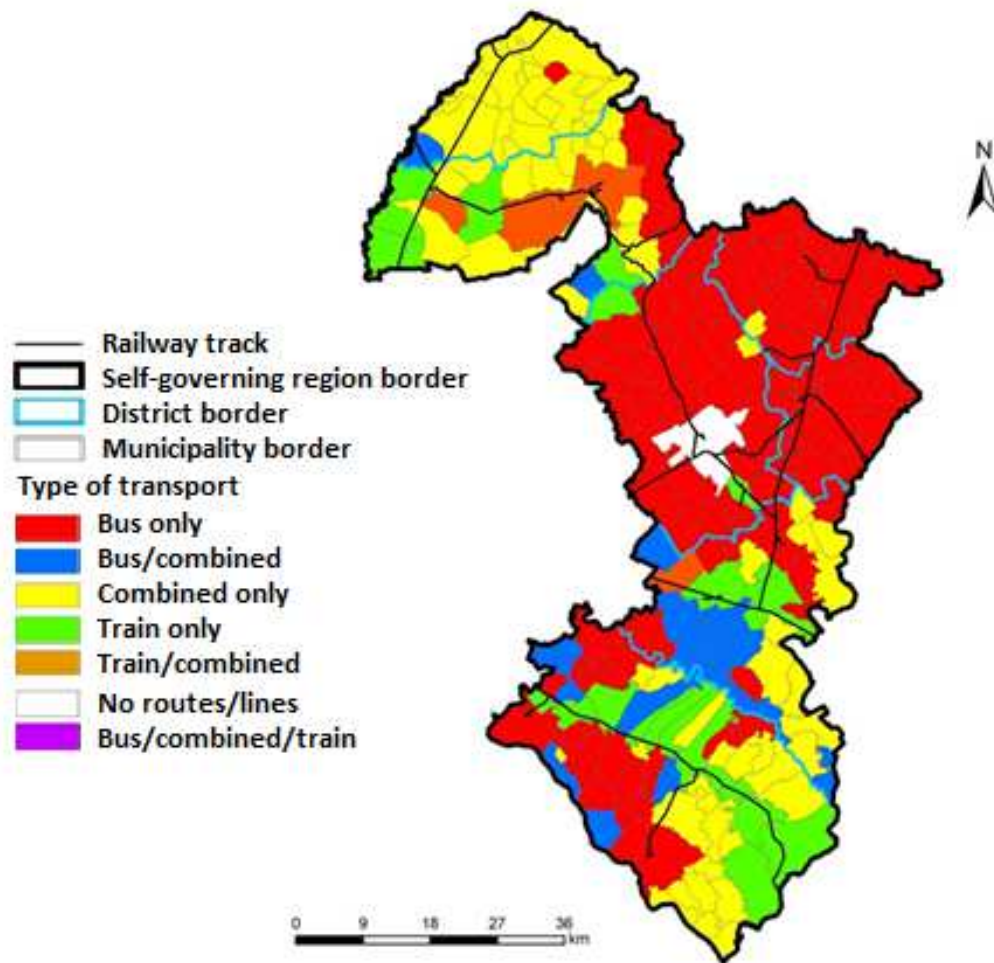


Figure 4 The best journeys from the regional capital Trnava to the municipalities of TTSK with the latest departure

The authors of this paper conclude from the results of the investigation that the bus was the most efficient type of transport within the Trnava Self-Governing Region. In the first morning journeys, 53.36 % of TTSK residents and almost 70 % of municipalities considered bus transport as the most advantageous way of transport; 62.47 % of residents and 71.32 % of municipalities preferred bus transport to travel to Trnava at 7:30; 56.91 % of residents and 65.33 % of municipalities preferred bus transport at the 14:00 departure time and 56.68 % of residents and 62.55 % of municipalities preferred bus transport for the latest journey from Trnava in comparison with the train and combined transport. According to the calculations, the bus was convenient especially for smaller municipalities.

The train transport reached the highest efficiency according to the number of residents (36.69 %) at the first morning journey to Trnava. However, according to the amount of percentage points of TTSK municipalities (17.93 %) the highest value was obtained at the 14:00 departure time. This means, that the morning train transport was more efficient for larger municipalities and train transport at 14:00 was more efficient for smaller municipalities.

Combined transport showed the highest values at the latest departure time from Trnava with 20.38 % for the TTSK population and 26.9 % for the municipalities, specifically the smaller municipalities of TTSK (Table 1).

Another important aspect related to the quality of public transport services was direct lines. The direct lines without transfers have the best chance to compete with individual transport. According to the collected data, 101 municipalities within TTSK had direct bus journeys (40.3 %) with Trnava (both directions, within 24 hours), in total 1327 journeys. Most frequent lines are with the Trakovice village with 111 direct journeys. On average, there were 13 direct bus journeys per 24 hours per municipality. On the other hand, 24 municipalities of TTSK (9.6%) had direct train routes with the regional capital with total 428 journeys, which is almost 18 journeys per 24 hours per municipality. The village of Leopoldov had the most frequent direct train journeys with Trnava, 76 journeys in 24 hours. Final evaluation of the accessibility of the regional capital by direct line was that the train transport had 38 % higher number of journeys than bus transport.



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Table 1 The most effective way of transport provided by public transport between the regional capital Trnava and the TTSK municipalities at four key times

The most effective way of transport	Number of TTSK municipalities		Number of TTSK residents		
	Abs.	%	Abs.	%	
<b>Bus, Train, Combined</b>					
The first morning arrival to TT	Bus	174	69,33	265 495	53,36
	Train	40	15,93	<b>182 538</b>	<b>36,69</b>
	Combined	37	14,74	49 542	9,95
Arrival to TT at 7:30	Bus	<b>179</b>	<b>71,32</b>	<b>309 656</b>	<b>62,47</b>
	Train	26	10,36	118 159	23,84
	Combined	46	18,32	67 846	13,69
Departure from TT at 14:00	Bus	164	65,33	277 899	56,91
	Train	<b>45</b>	<b>17,93</b>	145 713	29,84
	Combined	42	16,74	64 722	13,25
The latest departure from TT	Bus	157	62,55	285 990	56,68
	Train	29	11,55	115 738	22,94
	Combined	<b>65</b>	<b>26,9</b>	<b>102 847</b>	<b>20,38</b>

## 5 Conclusions

According to [1], the organization of the public transport should reflect changes in the spatial organization of society and country systems. The most important changes are suburbanisation in the proximity of the largest cities and towns [22], changes in economic positions of centers, etc. The big differentiation in the availability and density of spatial links of the functional region (the so-called low availability of region) causes negative consequences for the overall region development [21]. Poor accessibility may result in low level of education, unemployment and low level of social capital [21,28-30].

The authors of the paper have reviewed the current trends in a qualitative dominance of various types of public transport in TTSK. Comprehensive picture of the transport individual types characteristics in terms of following the scheduled route timetables in the TTSK region during the selected key times was provided. The main sorting element for the accessibility evaluation of TTSK municipalities was the presence of railways on their territory or the distance from it. The disadvantage of the train transport is that the lines are linked to existing railway infrastructure (lines and stations). The train routes order within the territory of Slovakia is subject to approval at the level of the Ministry of Transport, Construction and Regional Development of the Slovak Republic (the relevant departments [3]) [3] points out that this system is not optimal in terms of coordination among various types of transport. Regional bus transport brings both advantages and disadvantages. On the one hand, the bus can get almost anywhere, serves usually 2-3 more stops in the municipality than train, is less limited to the capacity of the infrastructure and the loss of profits due to black passengers is lower. On the other hand, the bus transport is slower, more endangered to traffic jams, accidents and has less passenger capacity per one vehicle driver. Combined transport by using both bus and train combines the advantages and disadvantages of the two above-mentioned types of transport. Its advantage is that combined transport enables to avoid routes that are problematic in terms of traffic jams and increases the

frequency of the journeys, and at the same time, the combined transport helps to bring the advantages of the train transport to municipalities that are positioned further from the railway station. The disadvantage is required space for bus turnovers near the train station and on the willingness of bus operating companies to adjust their timetables to the departure of trains and to modify their routes to closer proximity of the train station.

The authors of this paper have realized that not all four solved times are equally necessary for passengers and that people do not travel only to a regional capital. The number of transfers is also important factor. There exists a certain threshold value for travel distance, time and number of transfers, which affects the commuters to either not visit the regional capital or choose to travel by a car. From the collected data can be concluded that these limits are at a distance of 150 km, with a time interval of 2 ½ hours, at a maximum of 3 transfers. However, the number of direct journeys is important factor, where, on average, train transport achieved a better result.

Generally, it was predicted, that every type of public transport in the territory of TTSK has areas where it is currently the main way for commuting to the regional capital.

It is difficult to judge which type of public transport should be promoted primarily for the most efficient route. However, in Slovakia, several bus operating companies complain about the introduction of free train services for certain population groups, causing them loss of customers. As a result, they cancelled journeys, sometimes whole routes, even in places where passengers do not have an option to use train. The authors have realized that the lines need to be optimized in terms of continuity and parallelism but no limited to the minimum necessary journeys.

This paper ought to inspire other experts to explore the quality of transport in other regions of the Slovak Republic. At the same time, it may be an impulse for improvement of the public transport operating companies' services and timetable scheduling.



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Miroslava Trembošová; Alena Dubcová; Ľudmila Nagyová; Dagmar Cagaňová

Public transport is also recording changes after the covid crisis. Predicting future developments in this sector is rather complicated. However, already at present is monitored and felt an obvious decline in transport with this form of transport and the strengthening of individual transport. At the expense of public transport, there is strong pressure to create cycle paths in cities such as Paris, where they plan to reduce the number of passenger parking spaces by 20% by 2024, when the Summer Olympics will take place, but not to encourage public transport but to create cycle paths and new infrastructure for safe bicycle transport in city. Such projects will again slow down the development of public transport, seriously affect its functioning and it is possible that even in the TTSK region, the situation of transport will return to the years of the first decade of the 21st century.

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**CHOSEN ASPECTS OF A SPATIALLY FUNCTIONAL ACCESSIBILITY BY PUBLIC TRANSPORT: THE CASE OF TRNAVA SELF-GOVERNING REGION (SLOVAKIA)**

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