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Regional Differences in the Impact of the COVID-19 Pandemic on the Demand for Bus Transport in the Slovak Republic

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Abstract: The COVID-19 pandemic and the anti-pandemic measures taken have significantly affected the activities of the society and the associated need for mobility, as well as the transport behaviour of inhabitants. The goal of this research is to assess the impact of the COVID-19 pandemic on the change in the demand of residents for suburban bus transport (SBT) services in the regions of Slovakia. Due to the impact of the pandemic of COVID-19, there was a decrease in the number of passengers transported by SBT as well as a decrease in the supply of bus services offered in all the regions under study. The decrease in the number of passengers in the pandemic year was caused not only by COVID-19 and the anti-pandemic measures, but also by the reduction in the supply of SBT. The research confirmed the relation between the reduction in the offer of SBT and the decrease in passenger demand.

Keywords: Bus transport, COVID-19, demand, supply

1. Introduction

The pandemic of COVID-19 has affected almost every part of social life and economic activity since its outbreak. Countries all around the world have adopted various measures to stop the spread of the COVID-19 pandemic [1,2]. The given measures were adopted to prevent the spread of the disease; on the other side, they have caused a decline in economic growth and the functioning of the economy [3,4] as well as a considerable decline in mobility and the usage of public passenger transport (PPT) services [5-7]. According to the latest EUROCONTROL report [8] from October 2021, there was a 21% drop in demand for air transport in Europe compared to the same period in 2019. In April 2020, the London Underground saw a nearly 96% drop, and a year later, in April 2021, a 52% decrease was

recorded. The reference period was April 2019 [9]. Many European cities have experienced a decrease in the range of PPT services, e.g., in Spain, up to 88% drop in supply was recorded compared to pre-pandemic levels [10].

The first cases of the new COVID-19 virus appeared in China, where there were investigated the applied policies and the impacts of the pandemic on urban transport area and proposed measures that can be taken in the efforts to stop the spread of the risk of COVID-19 [11,12]. Research into the impacts of the COVID-19 pandemic on PPT, demand and passenger behaviour has been carried out in several countries. In Poland, the lower usage of PPT during the COVID-19 pandemic was mainly due to the set limits on the number of passengers and a significant decrease in the sale of long-distance tickets [13]. The development of PPT services in Poland was predicted using a questionnaire survey [14]. In Toronto, COVID-19 caused a decrease in demand for PPT, but on the contrary, an increase in mobility was recorded in the case of car transport [15]. In Zurich, due to the impact of the pandemic, there were significant changes in the distribution of transport performance in favour of walking, cycling and the usage of passenger cars [16]. Based on available data from Spain, researchers [17] found out that the number of trips by public and private transport dropped significantly by 95 % and 86 % compared to the pre-pandemic levels. The results of research conducted in Santander show a 76% drop in mobility in individual car transport and a much larger drop in mobility of up to 93 % in public transport [18].

In Spanish cities, measures need to be taken in public transport to guarantee safety from the virus and to return to normal conditions [19]. The research on the changes in passenger demand for PPT caused by the impact of COVID-19 was carried out in the Finnish city of Tampere, where a 70% decline in the number of transported people was recorded at the beginning of the year 2020 [20]. The development of the number of passengers transported by PPT in the city of Agder (Norway) was predicted during the period of COVID-19 using the Tsetlin machine learning algorithm [21]. The number of routes per passenger were reduced by 50 % during the restriction of movement [22]. Travel times increased, and the time of the first trip of the day shifted to later hours, resulting in a more even distribution of passenger demand throughout the day. In Sweden, COVID-19 has hit public transport hardest compared to other modes of transport and caused a significant drop in the number of passengers [23]. Based on the data from GPS in Switzerland, the average daily travel distance decreased by 60 %, while in the case of PPT, there was a decrease of more than 90 % [24]. The results of a study conducted on the changes in passenger behaviour caused by COVID-19 in several countries in South Eastern Europe show that the selection of a mode of transport depends mainly on the age and social and health status of the respondents [25]. In April in 2020, the number of carried persons in Slovakia fell by 73 % on average compared to April 2019 [26].

Some authors have investigated the effect of measures taken to stop the spread of COVID-19 and the pandemic on the passenger behaviour [27-34]. More than half (57%) of studies dealing with the measures or effects of the COVID-19-related measures focus on social impacts, with the huge economic and environmental consequences accounting for about 17 % each [32]. Another research defines advice to eliminate the impact of COVID-19 on population mobility [33]. Social distancing and control of vehicle occupancy rate can be considered the most effective measures to protect against the disease [34]. Research into the influence of COVID-19 on micromobility using statistical approaches was conducted to highlight the reason for the preference of alternative modes of transport and the health impacts and concerns related to COVID-19 disease [35]. This paper analyses the effect of the COVID-19 on changes in residents' requirements for suburban bus transport (SBT) in the regions of Slovakia. The aim is to identify the groups of passengers whose mobility was most significantly affected by COVID-19.

2. Data and Methods

In the conditions of Slovakia, self-governing regions are the customers of transport services. The territory of the Slovak Republic consists of 8 self-governing regions: Bratislava, Trnava, Nitra, Trenčín, Banská Bystrica, Žilina, Košice, and Prešov. Mobility in SBT is expressed by the number of transported persons by the type of fare. An analysis of passenger demand in the regions of Slovakia was carried out, for the purposes of which the regions were divided into two groups according to the structure of the available data. The first alternative was research on changes in passenger trips based on the provided annual data (Trnava, Nitra, Trenčín, Banská Bystrica, Žilina, Košice, Prešov). The second alternative of research on changes in mobility is based on monthly data on passenger demand (Banská Bystrica, Žilina, Prešov). The supply in SBT is represented by the transport performance of buses in SBT expressed in kilometres.

2.1 Average Interannual Changes in Supply and Demand Before the Outbreak of the COVID-19 Pandemic

In addition to COVID-19, the change in supply and demand in 2020 was caused by other factors that affected the development of supply and demand even before 2020. For the calculation of the changes in the volume of SBT supply and passenger demand between 2013 and 2020, several methods and formulas were used. The average interannual change formula was used to evaluate the changes in supply and the number of transported passengers before the outbreak of the COVID-19 pandemic. It is based on the structure of the provided annual data on supply and demand [35]. The change in time series values between consecutive years can be calculated using the following formula:

$$I_t = \frac{V_t}{V_{t-1}}, \quad [-] \tag{1}$$

where: t is period, t = 2,3, ..., n [-]; l_t is the indicator of change [-], V_t is the value of the variable for period t [-], V_{t-1} is the value of the variable for period t-1 [-]. Using indexes of interannual changes of values, it is possible to calculate the average index of changes in values in the observed period using equation (2):

$$\overline{I}_t = \sqrt[n-1]{I_2 . I_3 \dots . I_n} = \sqrt[n-1]{\frac{V_2}{V_1} . \frac{V_3}{V_2} \dots . \frac{V_n}{V_{n-1}}} = \sqrt[n-1]{\frac{V_n}{V_1}}, \quad [-] \tag{2}$$

where: $\overline{I}_t$ is the average indicator of change in time series values [-]; n is the number of members of the time series [-]; V_1 is the value of the 1st member of the time series [-]; V_n is the value of the n-th member of the time series [-]. Using equation (2), it is possible to calculate the average percentage change of the time series values in the observed period using the following formula:

$$\overline{K_t} = \left(\overline{I}_t . 100\right) - 100 = \left(\sqrt[n-1]{\frac{V_n}{V_1}} . 100\right) - 100 = \left(\sqrt[n-1]{\frac{V_n}{V_1}} - 1\right) . 100, \quad [\%] \tag{3}$$

where: $\overline{K_t}$ is the average gap of values in percentage [%].

2.1.1 Interannual Changes in Supply and Demand Due to the Pandemic - Changes in 2020 Compared to the Year 2019

The impact of COVID-19 on passenger demand and supply in 2020 can be calculated using the index of the change in 2020 in comparison with 2019, which is expressed as follows:

$$ICovid = \frac{V_{2020}}{V_{2019}}, \quad [-] \tag{4}$$

where: *ICovid* is the impact of the pandemic on the supply, or passenger demand [-]; V_{2020} is the value of the supply, or demand in 2020 [-]; V_{2019} is the value of the supply, or demand in 2019 (before the pandemic) [-]. The conversion into a percentage enables obtaining the formula for calculating the percentage share in supply or demand in the year 2020 compared to 2019:

$$ICovid = \frac{V_{2020}}{V_{2019}} . 100, \quad [\%] \tag{5}$$

2.2 The Impact of the COVID-19 Pandemic on Changing Supply and Demand

Supply and demand in the pandemic year 2020 were also affected by other factors of demand that affected its evolution even before the outbreak of the pandemic (fare, wages, population, quality of transport service, etc.). The net impact of COVID-19 on the percentage change in supply and change in demand for SBT in the regions of Slovakia was determined similarly to the calculation in [36] for the Žilina region. The development before the pandemic was calculated using formula (3). The net impact of COVID-19 on supply and demand was calculated using formulas (3) and (5) and the following formula (6) was achieved:

$$NICovid = ICovid - \overline{K_t} = \frac{V_{2020}}{V_{2019}} . 100 - \left(\sqrt[6]{\frac{V_{2019}}{V_{2013}}} - 1\right) . 100 = \left(\frac{V_{2020}}{V_{2019}} - \left(\sqrt[6]{\frac{V_{2019}}{V_{2013}}} - 1\right)\right) . 100, \quad [\%] \tag{6}$$

where: *NICovid* is the net influence of COVID-19 on the assessed indicator (on demand or supply) [%]; V_{2013} is the value of the variable (demand or supply) in 2013 [-].

2.3 Correlation Analysis

Correlation Analysis can be used for examining the relationship between two variables X and Y or values of two time series of different variables. Correlation coefficient ($r_{x,y}$) can be used according to formula (7):

$$r_{x,y} = \frac{n \cdot \sum xy - \sum x \cdot \sum y}{\sqrt{[n \cdot \sum x^2 - (\sum x)^2] \cdot [n \cdot \sum y^2 - (\sum y)^2]}}, \quad [-] \tag{7}$$

where: *n* is the number of ordered pairs of variable values X a Y [-]; *x* is the value of variable X (supply) [-]; *y* is the value of variable Y (demand) [-].

3. Results and Discussion

In the article [35], the authors examine the impact of measures taken against the spread of the pandemic in Slovakia on the number of passengers transported in suburban bus transport in Žilina self-governing region. Research was also conducted on the impact of COVID-19 on the change in supply of PPT in Slovakia, the results of which are published in [37]. The goal of the research is a more comprehensive evaluation of the impact of the COVID-19 pandemic on population mobility using SBT from the perspective of a region. During the COVID-19 pandemic, mobility was limited by the measures taken against its spread, which also had an impact on the demand of groups of residents for SBT. In general, the demand for SBT in the regions of Slovakia has had a decreasing trend in recent years. Due to the influence of the COVID-19 pandemic, the number of passengers fell even more significantly in the pandemic year of 2020. We have used a data on supply and demand in SBT from 2013 to 2019, i.e., the data on demand of groups of passengers, overall demand, as well as the scope of SBT supply from the customers of transport services.

The total number of trips by SBT in 2020 shows a significant year-on-year decrease. Based on equations (1) and (2), equation (3) was derived. Subsequently, using formula (6) derived on the basis of formulas (3) and (5), we determined the impact of COVID-19 on the overall passenger demand in the areas of Slovakia. Equation (4) is equivalent to equation (5) and expresses the relative interannual change without unit expression, equation (5) is the year-on-year percentage change. The results are shown in Table 1. The largest drop in demand due to the pandemic was recorded in Prešov. During the year 2020, self-governing regions as funding bodies for SBT services responded to falling demand and the measures taken by the government to reduce the spread of COVID-19 by adjusting the scope of the SBT service offer. Using equations (3), (5) and (6), we determined the impact of the COVID-19 pandemic on changes in SBT supply in the self-governing regions. The calculated changes in SBT supply by regions in Slovakia are shown in Table 1.

Table 1 Changes in the demand and supply for SBT in the regions of Slovakia. Source: authors

	Žilina	Trnava	Trenčín	Nitra	Banská Bystrica	Košice	Prešov
Average annual change in demand between 2013 and 2019 (%)	-3.46	-3.38	-3.69	-3.90	-9.79	-2.63	-0.74
Interannual change in demand in 2020 (%)	-39.62	-40.33	-35.4	-35.77	-38.26	-36.77	-41.09
Interannual change in demand due to the pandemic in 2020 (%)	**-36.16**	**-36.95**	**-31.71**	**-31.87**	**-28.47**	**-34.14**	**-40.35**
Average annual change in supply between 2013 and 2019 (%)	0.07	-0.13	-0.58	-1.05	-6.36	0.44	0.89
Interannual change in supply in 2020 (%)	-6.34	-8.35	-2.2	-2.72	-7.08	-4.88	-12.12
Interannual change in supply due to the pandemic in 2020 (%)	**-6.41**	**-8.22**	**-1.62**	**-1.67**	**-0.71**	**-5.32**	**-13.01**

To graphically represent the relation between the change in supply and the change in demand for SBT in each region, a two-dimensional scatter plot was used. The chart of the relationship of changes in supply and demand for SBT due to COVID-19 in 2020 by regions in Slovakia is presented in Fig. 1.

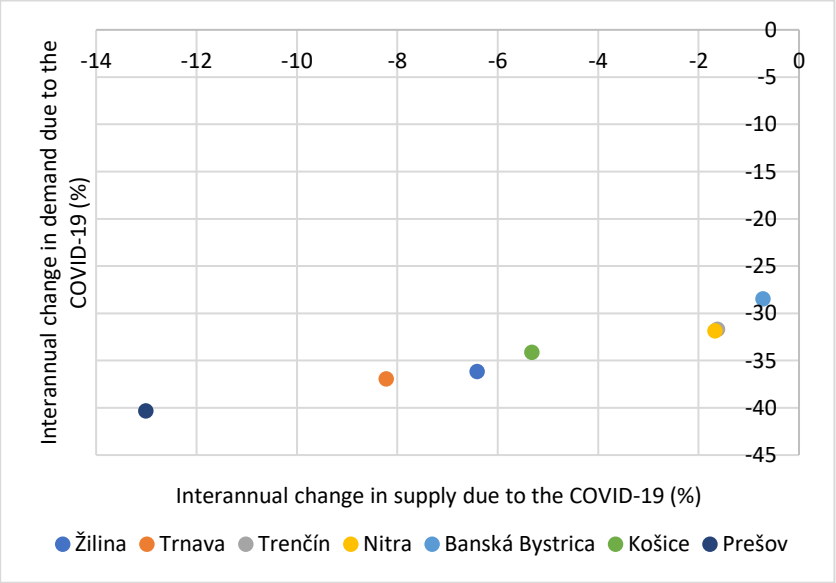

Fig. 1 The chart of the relationship of changes in supply and in demand for SBT by the regions in Slovakia. Source: authors by using the data on self-governing regions

The correlation coefficient according to equation (7) between the change in supply and the change in total demand caused by the COVID-19 in 2020 in the regions of Slovakia reaches a value of 0.97001. The research confirmed a significant direct relationship between a change in supply and a change in aggregate demand. The supply of bus services is an important driver of demand. The supply-demand relationship can be represented by a single-criteria regression function. The independent parameter is the supply of SBT, the dependent parameter is the demand for SBT. Figure 2 shows the functional dependence of the change in demand on the change in supply of SBT

because of COVID-19 determined based on changes in supply and demand in the regions of Slovakia in 2020.

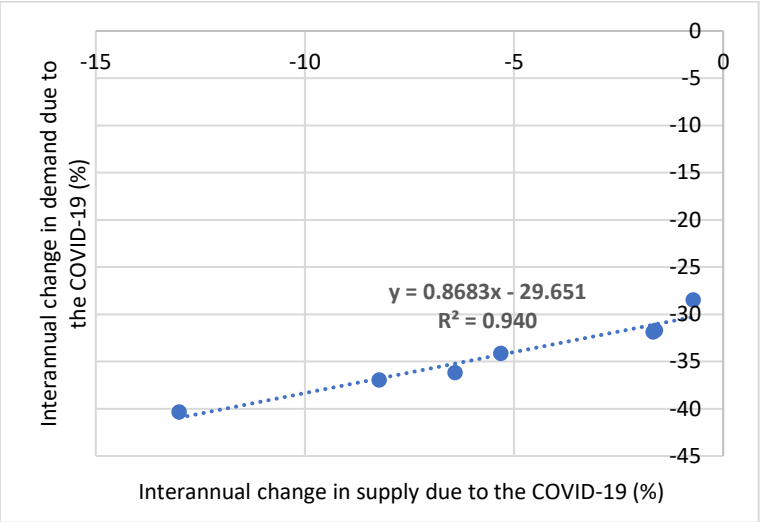

Fig. 2 Functional dependence of the change in demand from the change in supply in SBT due to the COVID-19. Source: authors by using the data of self-governing regions

The decrease in supply of SBT caused a further decrease in passenger demand for SBT. A 1% reduction in the supply caused by COVID-19 resulted in an average 0.8683% decrease in passenger demand in 2020. Based on data for the period 2013-2020, the authors evaluated the impact of COVID-19 on passenger mobility in 2020 in the regions of Slovakia by applying equation (6). The greatest decrease in mobility was recorded in the tariff group of children under 6 years of age. The smallest decrease in mobility in the given tariff group was recorded in Nitra (-33.58 %); the largest decline in the given passenger groups was in Žilina, where the decrease in mobility caused by the pandemic was 48.43 %. The next group is children under 15 years of age - the smallest drop in mobility was recorded in Trnava (-39.29 %), while the largest drop in terms of this group of passengers was recorded in Prešov (-47.17 %). As for pupils and students aged 16 to 26, the smallest decrease was recorded in Banská Bystrica (-40.04 %) and the largest decrease in Prešov (-60.48 %). The decrease in mobility for these groups of passengers is caused by the fact that during the pandemic waves in 2020, instruction at primary, secondary schools and universities in Slovakia was online for most of the school year. There was also a significant decrease in passenger movement due to the pandemic for other travellers over 60 years of age, where the decrease was due to government measures to stop the spread of COVID-19 (lockdown). The smallest drop in mobility in the analysed groups of passengers was recorded in the group of passengers transported for full fares, where mobility decreased from 21.27 % (Banská Bystrica) to 29.61 % (Trnava). Interannual changes in demand for SBT influenced by COVID-19 by groups of passengers in 2020 in the regions of Slovakia in percentage are shown in Table 2.

Table 2 Interannual changes in demand for SBT due to the COVID-19 pandemic by groups of passengers in 2020 in the regions of Slovakia (%). Source: authors

Group of passengers	Region						
	Žilina	**Trnava**	**Trenčín**	**Nitra**	**Banská Bystrica**	**Košice**	**Prešov**
Children (up to 6 years of age)	-48.43	-40.9	-39.97	-33.58	-36.73	-44.47	-37.05
Children (from 6 to 15 years of age)	-44.4	-39.29	-46.30	-40.54	-40.04	-43.76	-47.17
Pupils and students (from 16 to 26 years of age)	-50.99	-50.41	-46.30	-48.76	-40.93	-48.78	-60.48
Full fare	-23.24	-29.61	-22.36	-23.1	-21.27	-23.63	-26.46
ŤZP, ŤZP-S license holders, ŤZP-S guide	-36.86	-33.8	-39.97	-27.36	-26.26	-29.49	-28.56
Citizens over 60 years old	-37.64	-38.89	-39.86	-34.56	-34.57	-35.38	-38.42
Total	**-36.16**	**-36.95**	**-31.71**	**-31.87**	**-28.47**	**-34.14**	**-40.35**

4. Limitation of Research

For the purposes of the research and this study, data from 7 out of 8 regions was obtained for the year 2020. The data for the Bratislava Region was not included. As the COVID-19 pandemic continued in Slovakia in 2021, the data on supply and demand for SBT for this year was not obtained. During 2020, changes and developments in pandemic measures occurred to which groups of passengers responded with changes in mobility. It would be ideal to investigate the changes based on monthly demand data in 2020; however, the data for the year 2020 are only available for two regions (Žilina, Banská Bystrica). Therefore, it was not possible to carry out this type of research for all regions. We published research on changes in demand caused by the pandemic in 2020 on a monthly basis in the Žilina Region in [36]. Tariff rates and tariff conditions, including groups of passengers and fare types, are within the competence of the regions.

5. Conclusion

The COVID-19 pandemic caused a decrease in the number of people transported by SBT as well as a decrease in supply of SBT in all the investigated regions. Despite the anti-pandemic measures taken at the national level, the impact of COVID-19 on the mobility of passengers was different, with the largest drop in demand being recorded in Prešov, and the smallest in Banská Bystrica. The decrease in the number of transported passengers in 2020 was due to pandemic and anti-pandemic measures, as well as the decrease in the supply of SBT. The research confirmed the relationship between the decrease in the supply of SBT and the decrease in passenger demand. The supply fell most in Prešov (by 13.1 %) and least in Banská Bystrica (by 0.71 %). There is a significant direct relationship between the change in supply and the change in demand due to the COVID-19 pandemic in the self-governing regions. The correlation coefficient between these variables reaches a value of 0.97001.

The findings from research on changes in demand and in supply in the pandemic year 2020 can be used to make decisions about the provision of bus service, its scope and quality in the future in the event of other outbreaks of pandemics requiring the same or similar anti-pandemic measures. Even the reduction in the supply of SBT during the pandemic may cause an important decline in passenger demand. This change showed inelasticity in Slovakia, as a 1% decrease in supply caused a 0.86% decrease in demand. Further research in the field of demand for SBT in Slovakia could be focused on the transport behaviour of the inhabitants and their changes due to the pandemic.

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