THE SMART CITY CONCEPT TO INCENTIVIZE PUBLIC TRANSPORT IN THE V4 COUNTRIES IN THE POST-COVID-19 PERIOD

Milan Kubina, Oliver Bubelíny *

University of Zilina, Zilina, Slovakia

*E-mail of corresponding author: oliver.bubeliny@fri.uniza.sk

Resume

The attractiveness of public transport is not high and therefore it is obvious that private transport is the preferred mode of transport. The interest in public transport has declined even more since the outbreak of the COVID-19 pandemic, during which passengers feared the rapid spread of the disease in public vehicles. As a result, the habit of traveling individually has increased. This paper highlights the massive increase in private transport in the V4 Countries by the use of private vehicles and the related decrease in use of public transport. It also presents some of the relevant tools of the Smart City concept that could improve the use of public transport in cities. This paper is aimed at highlighting the current use of public bus transport (including public transport) in the V4 countries vis-a-vis the ongoing COVID-19 pandemic and highlighting the information and communication technology (ICT) - related means of incentivization.

Article info

Received 5 May 2022
Accepted 17 August 2022
Online 26 October 2022

Keywords:

public transport
management
smart city
strategy
COVID-19

Available online: https://doi.org/10.26552/com.C.2022.4.G15-G23

ISSN 1335-4205 (print version)
ISSN 2585-7878 (online version)

1 Introduction

Transport is one of the sectors that have major impacts on the environment of all countries. Industry emissions have been gradually declining since 1990, but the transport emissions are constantly on the rise. Overall, passenger cars, vans, trucks and buses account for 70% of the total greenhouse gas emissions generated by transport. The other 30% comes mainly from the aviation and shipping sectors. Road transport, therefore, has a significant environmental impact. Air pollution from traffic can be mainly seen in urban areas that are exposed to higher concentrations. Currently, the European Union is moving towards reducing the air pollution from transport, in particular through the introduction of fuel quality standards and the promotion of electromobility. The other traffic environmental impacts - high noise and landscape disturbance - should also be taken into account [1]. Cities, as well as individual countries, are committed to reducing the impact of transport on air quality through the adoption of European Union standards. Improving the air quality in cities creates a better climate for living in cities and conurbations. The significant increase in private transport and the low use of public transport is also a problem. The share of private transport in 2018 in Slovakia raised to 73.6%. The remaining share was taken by road, rail and public transport [2]. The OECD estimate indicates an ambitious opportunity to reduce the emissions produced by urban transport by 80% compared to 2015 if the right urban policies were adopted [3].

The COVID-19 pandemic has also caused a huge drop in passenger motivations to use the public transport. Quarantine mandates have significantly reduced mobility. Fears and anxieties about using the public transport have again sparked the increase in private transport. The solution to reducing emissions in cities is to create sustainable and reliable public transport. It is this type of transport that is currently greatly aided by the Smart City concept, which uses information and communication tools to make urban areas, including transport, more efficient. In addition to the Smart City concept, cities need to adopt other measures to promote the public transport, such as creating emission zones, expanding infrastructure for urban micromobility etc. [3].

Table 1 *Advantages and disadvantages of the public transport*

Advantages	Disadvantages
major reduction of air pollution	maybe slower
fewer traffic jams in cities	need to overcome the ‚Last kilometer'
high availability	lower comfort
less parking spaces	lower flexibility
higher safety	lower privacy
plenty of time while travelling	higher risk of infection

2 Theoretical review

Public transport, in general, can be considered as any transport for a fee paid to the operator. From the city and region perspective, the public transport should be designed to be friendly to inhabitants. Development of the motor transport and the availability of motor vehicles have made private transport the preferred mode over public transport. In the 90s of the 20th century, private transport began to rise already by up to 90%. Currently, this trend continues, although an increase in public transport passengers has also been observed since the COVID-19 pandemic. In her research, Steg pointed out that avid car users are the primary opponents of public transport. For them, the vehicle is a symbol of prestige and independence. Thus, the car is not only a means of transport for them, but it also represents certain cultural and psychological values. Conversely, casual car users had a much more positive attitude towards the public transport [4].

The pandemic has brought great uncertainty to public transport with passengers' fear of a potential outbreak. As a result, the public transport is going through a major decline in general (rail, road, private, primarily urban transport). On the other hand, no significant increase in private transport was observed, primarily due to the introduction of quarantine mandates, which decreased the mobility of the population. Most employees worked from home and the students switched to online learning. A number of publications, focusing on public transport and COVID-19, have highlighted the significant impacts of individual governments concerning public transport. Wielechovski et al. pointed to the adverse impact of governmental measures on urban mobility. They also pointed out that the interconnection between the increase in individual cases and the use of public transport had not been confirmed [5]. Rasca highlights the impact of the measures on mobility in their article also. They point to the relationship of individual restrictive measures to the strong impact on the number of passengers in public transport (lockdown, open schools in some regions etc.) [3]. When deciding between the private transport or micromobility, people mainly took their feeling of safety into account. They saw public transport as an area where the disease could spread faster. Beck et al. in their study from Australia highlighted the relationship between the use of public transport and its safety from a hygienic perspective. People with greater concerns about hygiene showed less interest in using the public transport. For this reason, they perceived it as a risk [6]. Similar studies have been carried out in different European cities with very similar results. Residents use private transport more and their perception of public transport has deteriorated, e.g. in terms of comfort and quality [7-8].

Public transport has thus become a negatively perceived mode of transport in many cities around the globe. Given the many benefits of public transport, cities need to incentivize their residents to use it. Table 1 shows several general advantages and disadvantages of the public transport.

Most of the advantages above are the result of the large capacity of vehicles. A public transport vehicle can carry a number of passengers who would otherwise use cars. All this generates traffic jams, which in turn has a negative impact on air quality. Conversely, the disadvantages are a large number of people in the vehicle and the need to cover the "last kilometer" from the public transport stop.

The incentive for the residents towards the frequent use of public transport can come in the form of different tools rendered by the Smart City concept. In general, a Smart City can be defined as a city that uses information and communication means to improve the quality of life of its residents, support the economy and address the traffic problems in order to build a sustainable city with lower environmental impacts. The individual components of the Smart City can include smart economy, smart public administration, smart housing, smart population, smart transport and smart environment. Smart transport can be generally defined as a way of managing traffic in a city that can use information and communication means to ensure the smooth mobility of the city residents. These are the possibilities of building a sensor network, building the signal preference of public transport vehicles and solving micromobility issues. The deployment of information and communication means in the city traffic management brings valuable information to city officials in the form of real-time data collection. Subsequently, this facilitates ad-hoc decisions or other managerial decisions with regard to the strategic management of the city [9].

3 Materials and methods

This paper is aimed at highlighting the current use of public bus transport in the V4 countries *vis-a-vis* the ongoing COVID-19 pandemic and highlighting ICT-related means of incentivization. The view of use of the public transport is complemented by the view of registered motor vehicles in the V4 Countries. The term "V4 Countries" refers to the countries of the Visegrad Group: Slovakia, Czech Republic, Hungary and Poland. These are Slovakia's neighbors, which are part of the European Union. The following research questions were defined to produce this paper and achieve its goal.

RQ1: Did the COVID-19 pandemic - together with different governmental mandates - affect the volume of public transport in the cities of the V4 Countries?

RQ2: Is there a negative correlation between the use of public transport and private vehicles in the V4 Countries?

RQ3: Do any measures (tools) exist in the Smart Cities concept that can incentivize passengers to use public transport?

This paper uses data taken from the V4 Countries' statistical data. The period under examination was 2012–2020. The Statistical Office of the Slovak Republic does not keep accurate information on the number of people transported by the urban public transport; therefore the data for Slovakia are counted together with the suburban transportation. For the rest of the paper, a content analysis of scientific papers (assessment of public transport during the pandemic around the globe) was used, as well as other publications and websites that are directly focused on building the smart cities.

4 Results

The data collected were analyzed and presented in MS Excel. The data were normalized to a common reference scale in millions of passengers and millions of private cars. The data were subsequently used to analyze and provide answers to the presented research questions:

RQ1 Did the COVID-19 pandemic - together with different governmental mandates - affect the volume of public transport in the cities of the V4 Countries?

This research question can be divided into two sub-questions with a focus on public and private transport for easier interpretation:

- RQ1a: Did the COVID 19 pandemic and the relevant governmental measures affect the public transport?
- RQ1b: Did the COVID 19 pandemic and the relevant governmental measures affect the private transport concerning the number of registered vehicles in the V4 Countries?

With regard to RQ1a, it can be stated that the reduction in the number of public transport passengers was apparent in all the V4 Countries. Until the outbreak of the pandemic in 2020, the number of public transport passengers was fluctuating. In 2020, there was a massive drop due to the COVID-19 pandemic. This came due to the introduction of governmental measures, such as lockdown, quarantine mandates and the like, higher reluctance to use public transport due to hygienic safety, or increased use of non-motorized means of transport. Figure 1 shows the progress of the number of passengers in the V4 Countries.

With regard to RQ1b, to analyze the private transport, it is possible to use the indicator of registered vehicles of individual countries. Figure 2 shows the increases in passenger motor vehicles (4-wheel motor vehicles used for passenger transport). It follows that the increase in the number of vehicles is not just the result of the pandemic. The increase in the number of registered vehicles happens constantly across the period under analysis. However, no significant increase in the number of registered vehicles was observed in 2020.

The reason why there was no sharp increase in motor vehicles may also be the introduction of lockdown and the resulting reduced mobility and small imports

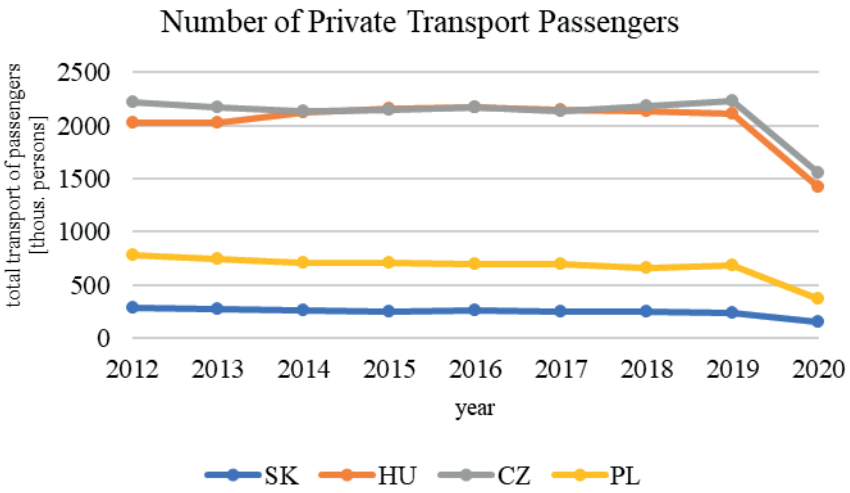

Figure 1 *Number of Private Transport Passengers, [7, 10-12]*

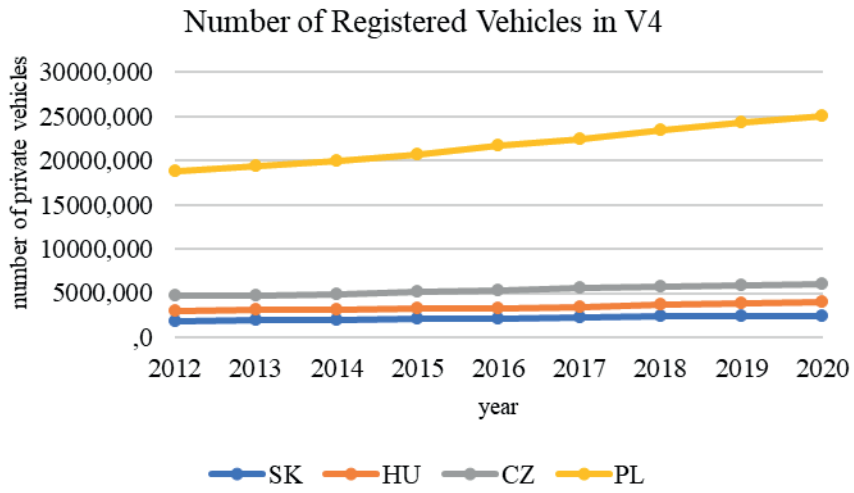

Figure 2 *Number of Registered Vehicles in V4, [7, 10-12]*

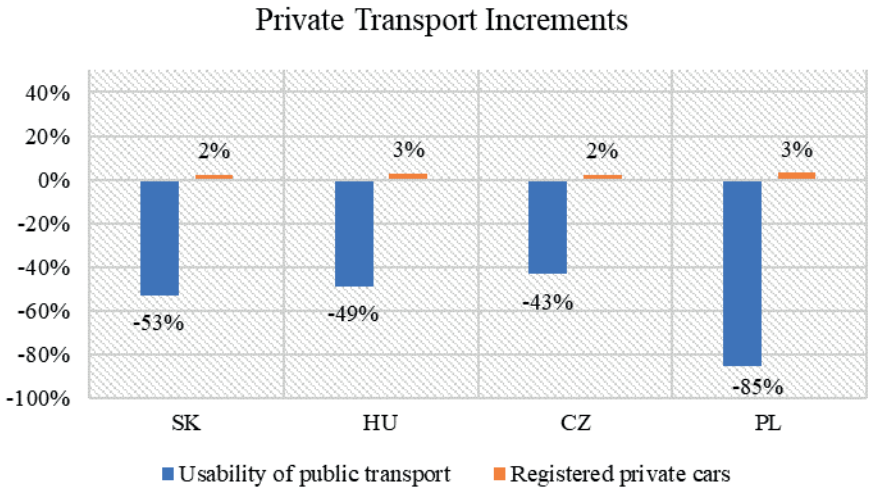

Figure 3 *Private Transport Increments, [7, 10-12]*

of used cars. Other reasons could be a job loss or fear of buying new vehicles. Figure 3 shows a comparison of the percentage shift of increments of registered vehicles and the number of transported passengers in the V4 Countries.

From the above, it can be stated that the increments of new vehicles were relatively low. However, the drop in the use of public transport in 2020 compared to 2019 was significant. In 2020, motor vehicles raised by 2% in Slovakia, which means that additional 46409 vehicles were registered in the country. However, vehicle registration is not the only indicator of the number of motor vehicles; it is also the number of vehicles imported into the country from abroad. Hungary recorded a 3% increase in 2020, an increase of more than 100, 000 vehicles, the Czech Republic a 2% increase, which represents an increase of more than 120,000 vehicles and in Poland, it was an increase of more than 700,000 vehicles. Figure 4 shows the percentage change (increments in individual years) of registered vehicles across the V4 Countries. Conversely, Poland experienced the most significant decline. The differences in the declines in public transport could just have led to a variety of governmental pandemic regulations. Some countries have taken measures lasting a longer period of time (e.g. longer school closures, which drastically reduces city mobility). Different countries have also experienced different pandemic developments.

The RQ1 research question can be answered with respect to its sub-questions RQ1a and RQ1b. The RQ1a question, whether the COVID-19 pandemic had an impact on public transport in the V4 Countries, can be answered with a resounding yes. Drastic restrictions on movement of population through the quarantine mandates and lockdowns, or working from home, have significantly reduced the number of public transport passengers, which is indicated in Figure 1 and Figure 3, showing the apparent drop in the number of public transport passengers. On the other hand, the RQ1b sub-question cannot be answered with a definite yes. The increasing trend in the number of registered vehicles is apparent in the long run. However, since 2017, the

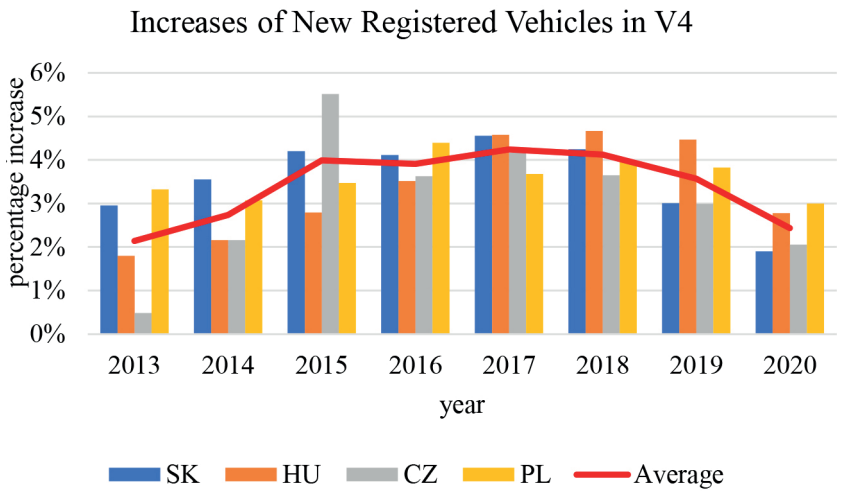

Figure 4 *Increases of New Registered Vehicles in V4, source: [7, 10-12]*

Table 2 *Results of linear regression*

Country	Pearson coefficient (R)	P-value
Slovakia	-0.79	0.010863
Czech Republic	-0.48	0.184542
Hungary	-0.47	0.192737
Poland	-0.73	0.023747

growth has been gradually slowing down and the increments of registered vehicles are becoming smaller every year. The mean value of the V4 Countries has been declining since 2017. This trend continues even during the COVID-19 pandemic. For this reason, it is not possible to state whether the pandemic had an impact on decline in registered vehicles in the V4 Countries.

RQ2: Is there a negative correlation between the use of public transport and private vehicles in the V4 Countries?

The data were evaluated using correlation and regression analysis. The relationship between the long-term and constant growth of motor vehicles lowering the use of public transport can be confirmed by a negative correlation of variables. Pearson's sample correlation coefficient was used for this confirmation:

$$r_{x,y} = \frac{\overline{x \cdot y} - \overline{x} \cdot \overline{y}}{\sqrt{\overline{x^2} - (\overline{x})^2} \cdot \sqrt{\overline{y^2} - (\overline{y})^2}}, \quad (1)$$

where:

r is Pearson koeficient,

x is number of transported passengers by public bus transport,

y is number of vehicles.

For this coefficient, the higher the number is, the stronger the linear relationship between the variables becomes and vice versa. The results of the calculated Pearson correlation coefficient for individual V4 Countries are shown in Table 2. The coefficient was highly negative in Slovakia and Poland. Hungary and the Czech Republic have a correlation coefficient halved, which really means that in addition to this private transportation increase impact; there are other undefined variables with the same effect. With regard to the created ANOVA model, which represents the analysis of variance, it is possible to monitor the p-value (the level of model significance). Within the veracity of individually created models for the individual country dependencies, it is possible to draw a conclusion. In Slovakia and Poland, the models are statistically significant; in other models, statistical significance was not confirmed.

It can be argued that other factors enter into the relationship of these dependencies, such as the availability of public transport services, the possibility of using micromobility (e-scooters, bicycle-sharing), or dissatisfaction with the quality of public transport - low safety, poor onward connections etc.

As a result of this examination, the research question can be answered affirmatively. A degree of dependency exists between these relationships. However, it is necessary to add that other variables enter into this dependence that has not been examined. This is confirmed by the Pearson coefficient itself, but also by the results of the analysis of variance and the ANOVA model.

RQ3: Do any measures exist in the Smart Cities

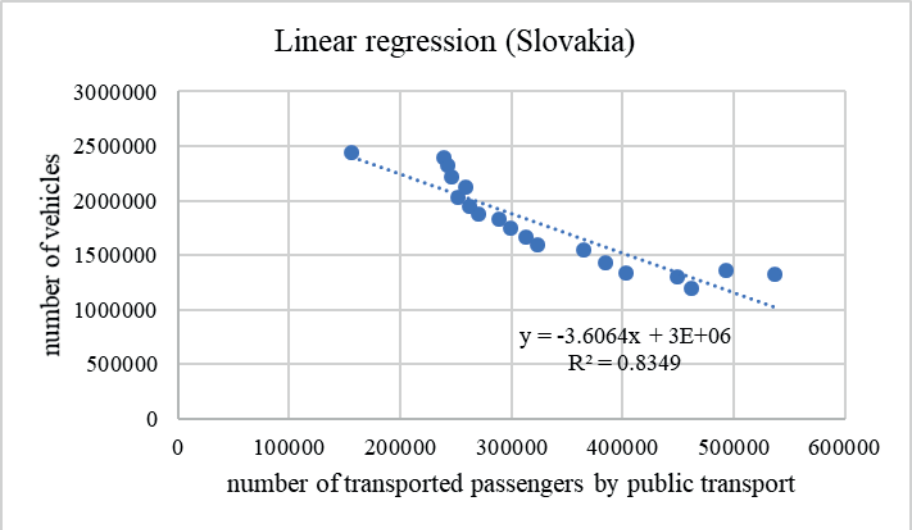

Figure 5 *Example of Linear Regression (case Slovakia)*

concept that can incentivize passengers to use public transport?

The effects of information and communication means are observed everywhere. The term and concept of the Smart City deal with use of these resources in practical terms. The goal is definite - to facilitate different management processes in the city, as well as to improve the quality of life of the residents, considering the long-term city sustainability. Internet of Things tools create the space for generating large amounts of data for further analysis and the basis for further decision-making processes. In order to incentivize residents to use public transport more intensively, it is necessary to take such measures that can simplify the purchase of transport tickets, provide route search and speed up the transport itself. Such measures may include:

5 Mobility as a service (MaaS)

This type of service comes as a brand new business model to cities. It integrates services of different kinds into one comprehensive platform. The MaaS provider facilitates different transport options and aligns them with customers' requirements. This includes primarily public transport, but it also integrates bicycle sharing, e-scooter sharing, availability of taxis, sharing of motor vehicles etc. A major added value is availability of the city mobility application for customers. Through a single platform, a customer is able to satisfy their transportation needs in several ways by making a payment through this application. This streamlined city transport planning and payment is a clear benefit for the customer. On the other hand, the MaaS provider can collect a huge amount of information and data that can then be used to improve their services. The basic goal of this service is to provide passengers arriving in the cities with a suitable alternative to the private mode of transport [13]. An important part of the functionality of this service is the existing infrastructure - 3G/4G/5G networks and their security, daily updated information on the availability of individual services, timely information on updating schedules, availability of payment systems [14]. To meet the demanding service infrastructural requirements, the cooperation of individual service representatives is key, such as the city management, telecommunication companies, payment service providers, public transport providers and providers of shared services [15]. Another important part is the city's data service providers providing the website and MaaS mobile application. It is this component that is essential to generate a large volume of data, which is used for further analysis and subsequent management. Carrier and shared service providers are key stakeholders to MaaS. With regard to this type of service, third parties, such as Uber, are coming under the spotlight [16].

6 Park and ride

It is a parking lot, or a system of parking lots, which are located on the city outskirts connected to the public transportation network. Residents coming to the cities thus park their vehicles on the city outskirts and continue to the city by using the public transport. The advantage of this type of parking is that it reduces the number of motor vehicles entering the city center, which improves air quality and the quality of life of city residents in general. On the other hand, it saves time for drivers to find a parking space. Thus, the time it takes them to get to their destination may be the same. Macziosek and Kurek [17] made an analysis of the use of such car parks in Krakow, Poland. They highlighted the importance of building such parking lots and the right incentivization of drivers, e.g. through free parking if they purchase a public transport ticket. In their research, they also pointed out that the most important element for the use of this type of car park is the

proximity of the public transport spot at the destination and the quality of public transport itself. This system, together with the MaaS interconnection, can ideally affect the number of vehicles in downtowns. Such car parks exist in all V4 Countries. In Slovakia, it is built mainly in locations around the capital with a connection to the railway directly to the city center].

7 Public transport preference and bus lanes

Another measure that can be used in individual cities is giving preference to public transport vehicles with traffic lights. Traffic jams and slowdowns at traffic lights are common problems. Again, the problem is the high intensity of private transport, which significantly affects the fluidity of public transport. In the end, its attractiveness is reduced by for instance frequent delays. Another possibility is to build a sensor network on light signals with controllers and transmitters installed in public transport vehicles, which signals when a public transport vehicle is arriving at an intersection and prioritizes it with traffic lights. Several tactics that govern such intersections exist. It can be done in the form of suspending the green lights in the intended path of the approaching public transport vehicle or accelerating the switching of different traffic lights to improve the fluidity of public transport. Many tactics that can switch traffic lights exist and they depend mainly on the use of the intersection and the intensity of the private and public traffic in it [18].

A more fundamental option is to create public transport lanes, which can speed it up and get faster to intersections. However, the basic problem lies in the existing infrastructure, which significantly limits the construction of new lanes in cities (e.g. surrounding buildings, urban greenery etc.).

It is also possible to take restrictive measures with regard to urban mobility. These may include, for instance, the **creation of low emission zones.** Motor vehicles that do not meet the defined requirements are not allowed to enter these zones. It can be a specific emission class (euro 4-6), or it can only be vehicles that are powered by an alternative type of fuel. Many European cities are currently making decisions to build such zones. The aim is primarily to create good and clean air in downtowns. Air quality can also be observed through the Smart City concept, through sensors installed in different parts of the city. According to a case study from Madrid, after the introduction of the low-emission zone, the air quality in the city has significantly improved and the noise, generated by the traffic, was reduced. Other restrictions may include the adoption of parking restrictions, making changes in parking policies, or increasing parking fees [19].

The answer to the RQ3 research is that the Smart City concept has many tools that can be used to increase the share of public transport in cities. However, the implementation of these measures depends on the established city strategy. However, this also depends on other attributes, such as the financing of individual measures, the complexity of interconnection of individual stakeholders, the relative limitedness of the infrastructure, political beliefs etc. Then, it is up to the individual cities and their representatives to what extent they will try to rebuild the city in line with the concept. However, it can be proven that in the city the results after implementation are observable relatively quickly [19].

8 Discussion and conclusion

This paper was aimed at highlighting the current use of public bus transport in the V4 countries *vis-a-vis* the ongoing COVID-19 pandemic and highlighting ICT-related means of incentivization. Three research questions were posed with regard to its goal, related to individual and public transportation amidst the ongoing COVID-19 pandemic. The results are positive answers to individually defined questions. The V4 Countries recorded a decline in the number of public transport passengers. On the other hand, the number of registered cars in the countries is constantly increasing, although, in recent years, the increase has a declining nature. The link between the reductions in vehicle registration in relation to the pandemic has not been shown. The relationship between the number of passengers transported by public transport and the number of registered vehicles in the V4 Countries was also examined. Looking at each country individually, there was a minor dependence between the two variables. However, this minor dependence also pointed to the fact that other variables also affect this relationship; namely the availability of motor vehicles, the use of micromobility/bicycle sharing. The last question regarded the City Smart concept. The impact of information and communication means is also apparent in the urban sphere. They bring new possibilities for managing all the parts of the city in line with this concept. Its actual development in cities depends on individual representatives and their interest in deployment. If they were to opt-in, then they would have to comply with several strategic principles from the strategic management perspective [20-21]. It is mainly about planning, project preparation, project implementation and at the same time, implementation follow-ups according to a suitable methodology [22]. The deployment of the entire concept means a real change for the city and several fundamental actions would have to be implemented from a managerial point of view. These include finding sufficient financial resources to create sufficient technical and technological infrastructure in the city (includes the installation of various types of sensors, security cameras etc.). However, the advantage remains that the well-built infrastructure is then suitably applicable in several city management areas.

The aim of the infrastructure is to collect a lot of usable data, which through a suitable system leads to long-term sustainability and competitiveness of the city and provides the city with an advantageous position in relation to other stakeholders [22-23].

From the transport perspective, the aim of the Smart City concept is to incentivize the public transport through a sound infrastructure. Subsequently, the quality of the selected public transport provider and miscellaneous city micromobilities - based on the sharing of electric scooters or bicycles - also contribute to this. Intelligent velomobility and modern e-velomobility, i.e. electrically-powered bicycles, also come to the fore as a part of the Smart City concept [21]. This mode of transport also contributes to reducing emissions in the city and the only question left is to motivate residents and visitors to use them. Smart City as a transport concept must be adopted gradually with regard to functioning of the city ecosystem. It is necessary to emphasize the conviction of the city officials and the willingness to develop the city. However, city officials are often elected for only a certain period and therefore, they refuse to take unpopular measures, which would ultimately have a significant positive effect. These include car prohibitions to enter downtowns, the construction of city outskirts car parks connected to public transport grid, or the digitization of car parks with the temporary exclusion of their operation. However, the communication of this development is the actual communication with the residents who must be informed of these planned changes. It is also essential to involve all other stakeholders [24-25].

Smart City, as a concept for improving the quality of life of the residents, is also a transport solution. Its advantage is the possibility of making public transport more attractive, mainly by simplifying the search for onward connections, purchasing travel tickets and preferring the public transport vehicles at traffic lights. It is necessary to emphasize that it is not only the Smart City concept that is aimed at incentivizing the use of public transport. It is also about, for instance, constantly increasing travel comfort, adjusting onward connections, availability of stops, raising hygiene standards. The future that cities face truly lies in public transport to create a clean environment improving the quality of life of its residents. Cities will thus face the important task of creating a place for people to live that will increase their overall attractiveness. In general, other stakeholders, such as the local or state government, will need to prioritize public transport in order to reduce emissions. After demanding technological and infrastructural solutions and implementation of the concept, the role of cities will thus also include the need to shift the opinion of their residents towards the public transport to become an attractive and comfortable mode of transport.

References

[1] European Environment Agency [online]. 2020. Available from: https://www.eea.europa.eu/themes/transport/intro

[2] Enviroportal [online]. 2019. Available from: https://www.enviroportal.sk/indicator/detail?id=761&print=yes

[3] OECD iLibrary [online]. 2021. Available from: https://www.oecd-ilibrary.org/sites/316ba973-en/index.html?itemId=/content/component/316ba973-en

[4] STEG, L. Can public transport compete with the private car? *IATSS Research* [online]. 2003, **27**, p. 27-35. ISSN 0386-1112. Available from: https://doi.org/10.1016/S0386-1112(14)60141-2

[5] WIELECHOVSKI, M., CESKA, K., GRZEDA, L. Decline in mobility: public transport in Poland in the time of the COVID-19 pandemic. *Economies* [online]. 2020, **8**(4), 78. ISSN 2227-7099. Available from: https://doi.org/10.3390/economies8040078

[6] BECK, M. J., HENSHER, D. A., NELSON, J. D. Public transport trends in Australia during the COVID-19 pandemic: an investigation of the influence of bio-security concerns on trip behaviour. *Journal of Transport Geography* [online]. 2021, **96**, 103167. ISSN 0966-6923. Available from: https://doi.org/10.1016/j.jtrangeo.2021.103167

[7] Passenger transport - time series - Czech statistical office [online] [accessed 2021-11-15]. Available from: https://www.czso.cz/csu/czso/passenger_transport_time_series

[8] EISENMANN, C., NOBIS, C., KOLAROVA, V., LENZ, B., WINKLER, C. Transport mode use during the COVID-19 lockdown period in Germany: the car became more important, public transport lost ground. *Transport Policy* [online]. 2021, **103**, p. 60-67. ISSN 0967-070X. Available from: https://doi.org/10.1016/j.tranpol.2021.01.012

[9] SHARIF, R. A., POKHAREL, S. Smart city dimensions and associated risks: review of literature. *Sustainable Cities and Society* [online]. 2022, **77**, 103542. ISSN 2210-6707. Available from: https://doi.org/10.1016/j.scs.2021.103542

[10] Transport - Hungarian central statistical office [online]. 2021. Available from: https://www.ksh.hu/transport

[11] Urban transport - Poland [online]. 2021. Available from: https://bdl.stat.gov.pl/BDL/dane/podgrup/temat

[12] Summary indicators for transport and mail - Statistical Office of the Slovak Republic [online]. 2021. Available from: http://datacube.statistics.sk/#!/view/sk/VBD_SK_WIN/do1003rs/v_do1003rs_00_00_00_sk

[13] What is MaaS? - MaaS Alliance [online] [accessed 2021-11-15]. Available from: https://maas-alliance.eu/homepage/what-is-maas/

[14] KUBINA, M., KOMAN, G. Big data technology and its importance for decision-making in enterprises. *Communications - Scientific letters of the University of Zilina* [online]. 2016, **18**(4), p. 129-133. ISSN 1335-4205, eISSN 2585-7878. Available from: https://doi.org/10.26552/com.C.2016.4.129-133

[15] VODAK, J., SOVIAR, J., LENDEL, V. Identification of the main problems in using cooperative management in Slovak enterprises and the proposal of convenient recommendations. *Communications - Scientific letters of the University of Zilina* [online]. 2013, **15**(4), p. 63-67. ISSN 1335-4205, eISSN 2585-7878. Available from: https://doi.org/10.26552/com.C.2013.4.63-67

[16] The rise of mobility as a service - Deloitte review [online]. 2017. Vol. 20. Available from: https://www2.deloitte.com/content/dam/Deloitte/nl/Documents/consumer-business/deloitte-nl-cb-ths-rise-of-mobility-as-a-service.pdf

[17] MACIOSZEK, E., KUREK, A. The use of a park and ride system - a case study based on the city of Cracow (Poland). *Energies* [online]. 2020, **13**, 3473. ISSN 1996-1073. Available from: https://doi.org/10.3390/en13133473

[18] MOGHIMI, B., KAMGA, C. Transit signal priority in smart cities. In: *Models and technologies for smart sustainable and safe transportation systems* [online]. DE LUCA, S., DI PACE, R., FIORI, CH. (eds.). 2021. ISBN 978-1-83880-823-5, eISBN 978-1-83880-824-2. Available from: http://dx.doi.org/10.5772/intechopen.94742

[19] LEBRUSAN, I., TOUTOUH, J. Using smart city tools to evaluate the effectiveness of a low emissions zone in Spain: Madrid Central. *Smart Cities* [online]. 2020, 3, p. 456-478. eISSN 2624-6511. Available from: https://doi.org/10.3390/smartcities3020025

[20] RASCA, S., MARKVICA, K., IVANSCHITZ, B. P. Impacts of COVID-19 and pandemic control measures on public transport ridership in European urban areas - the cases of Vienna, Innsbruck, Oslo and Agde. *Transportation Research Interdisciplinary Perspectives* [online]. 2021, **10**, 100376. ISSN 2590-1982. Available from: https://doi.org/10.1016/j.trip.2021.100376

[21] BEHRENDT, F. Why cycling matters for Smart Cities. Internet of bicycles for intelligent transport. *Journal of Transport Geography* [online]. 2016, **56**, p. 157-164. ISSN 0966-6923. Available from: https://doi.org/10.1016/j.jtrangeo.2016.08.018

[22] MORA, L., DEAKIN, M., REID, A. Strategic principles for smart city development: a multiple case study analysis of European best practices. *Technological Forecasting and Social Change* [online]. 2019, **142**, p. 70-97. ISSN 0040-1625. Available from: https://doi.org/10.1016/j.techfore.2018.07.035

[23] HOLUBCIK, M., VODAK, J., SOVIAR, J. How to manage business in collaborative environment – a case study of multinational companies. *Communications in Computer and Information Science* [online]. 2018, **877**, p. 299-311. ISSN 1865-0929, eISSN 1865-0937. Available from: https://doi.org/10.1007/978-3-319-95204-8_26

[24] ECHANIZ, E., RODRIGUEZ, A., CORDERA, R., BENAVENTE, J., ALONSO, B., SANUDO, R. Behavioural changes in transport and future repercussions of the COVID-19 outbreak in Spain. *Transport Policy* [online]. 2021, **111**, p. 38-52. ISSN 0967-070X. Available from: https://doi.org/10.1016/j.tranpol.2021.07.011

[25] SOVIAR, J., HOLUBCIK, M., VODAK, J. Regional cooperation ecosystem: case of the Zilina self-government region (Slovak republic). *Sustainability* [online]. 2018, **10**, 2219. ISSN 2071-1050. Available from: https://doi.org/10.3390/su10072219