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The role of current transport expenditure in mitigating the risk of modal shift during Covid-19 – Lessons from Polish cities

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ABSTRACT

This article shows that current expenditure allocated by local authorities for the routine maintenance of public transport (i.e., providing passengers with clean and frequent services) is crucial to effectively limit the modal shift from public transit to private cars during the Covid-19 pandemic. In our analysis, we define public transport as the bus, tram, metro and trolley operations which are ordered and funded by 11 local authorities in Poland; we also assume that the modal shift is reflected in the growth of traffic congestion. Taking into account these assumptions and considering the long-term financial data from 2010 to 2020, we then conduct hierarchical linear regression and state that cities with a higher share of current expenses in cities’ total annual transport expenditure have registered during the pandemic a lower number of weeks with congestion level exceeding the pre-pandemic level. We argue that this is due to the allocation of current expenditure to cleaning services and the transport service supply, which could have a significant impact on perceptions of crowding and safety on public transport. Both issues belong to the essential determinants of the quality of public transport services and could play a key role in mitigating the modal shift by reducing the fear of catching Covid-19. In contrast to this finding, we also show that investment expenditure (allocated to improvements of transport infrastructure) does not have any similar impact on the congestion during the pandemic. In this context, we emphasise that cutting spending on cleaning services and the transport supply service as a response to the reduced number of passengers would be more devastating for public transport than postponing new infrastructure investments. Based on the results achieved in the analysis, we provide recommendations for local authorities that can help implement new funding models and reframe local transport policy, namely: (1) close the funding gap resulting from lower revenues to local budgets, (2) provide resources for maintaining the infrastructure investments and adapting them to a “new normality”, (3) maintain the attractiveness of public transport post-Covid.

1. Introduction

The current pandemic has significantly changed urban life and raised questions about a possible shift in urban mobility from the dominating role of cars to greater importance on public transport services (Martin et al., 2012; Abdullah et al., 2020; Chocholac et al., 2020; Yaya et al., 2014). Covid-19 and related restrictions have reduced both the number of people using public transport (Barbieri et al., 2020; Budd & Ison, 2020; Saha et al., 2020) and the confidence in the safety of public transport (Tirachini & Cats, 2020). Moreover, they have resulted in weaker economic activity in cities, have led to the popularization of working from home (Sharifi and Khavarian-Garmir, 2020; Barbieri et al., 2021) and have created a financial burden for transit operators, who have often been forced to reduce the frequency of services (Bernhardt, 2020). Importantly, the changes occurring in the transportation sector during the pandemic have also questioned the effectiveness of financial tools for implementing less car-oriented policy.

Before Covid-19, expenditure on the quality of public transport (i.e. higher service supply and investments in a new infrastructure) was considered crucial for reducing congestion in cities and limiting the role of private cars in urban mobility, though the efficiency of such efforts was often questioned in a scientific debate (Beaudoin, Farzin, Lawell, 2015). This problem also applies to the effectiveness of expenses for transport during the current pandemic (Teixeira & Lopes, 2020). Their impact on transport behaviours is not recognized in the chaotic circumstances of Covid-19, nor is it clear how to limit the current and...
undesirable modal shift from public transport to the private car.

Our article fills this gap and looks for the optimal structure of transport expenditure enabling cities to effectively limit the modal shift during and after Covid-19. We distinguish between current and investment transport expenditure in cities’ total annual transport expenses and assume that current expenses have a greater impact on limiting the modal shift. Our focus on the current spending comes from its expected role in mitigating the shift by reducing the fear of catching Covid-19. Most of the current expenditure is usually spent on the routine maintenance of public transport, mainly cleaning services and a supply of transport services that allow for the reduction of crowds (Gubanski & Mikołajczyk, 2016). Both issues belong to the essential determinants of the quality of public transport services and are considered a primary tool for mitigating the risk of contamination. Thus, they may influence transport mode choices during the pandemic and successfully contribute to the restoration of confidence in public transport once the pandemic ends (Friman et al., 2020).

We also assume that the undesirable modal shift from public transport to a private car during Covid-19 will be reflected in the growth of congestion level in cities. Therefore, we use hierarchical linear regression models to check out how the share of current expenditure in transport budgets of 11 Polish regional capitals influences the number of weeks with congestion level exceeding the pre-pandemic level. Based on this, we verify the hypothesis that, during Covid-19, cities with the greater share of current expenditure in cities’ total annual transport expenses register lower number of weeks with congestion level exceeding the pre-pandemic level (which indicates lower modal shift from public transport to private cars).

In Poland, more than 80% of current expenditure funds almost 100% of the public transport services available within each city. These services include bus, tram, metro and trolley operations ordered by local authority, and that is what we mean by the “public transport” in this study. We investigate our research problem taking into account the long-term financial policy of local governments and assuming that these funding strategies shape the mobility preferences and the image of public transport for a long time. This strategy enables us to recommend the continuation or rejection of the pre-pandemic financial policy, especially regarding the efforts to limit a modal shift from public transport to private cars. All cities considered in the analysis got the same funding model of transport. In that model, both current and investment expenses are transferred from the local budget to the bodies conducting infrastructure investments or providing operations of public transport.

In the first part of this article, we argue that crowd management strategies and the quality of cleaning services in public transport influence people’s feelings of safety and may determine mobility preferences as well as perceptions of the quality of service in public transport during Covid-19. We also argue that both aspects strongly depend on the funding schemes of local governments. The second part of the article includes a description of methodology and data sources used to verify the research hypothesis. In the third part, we present results of the analysis, and, in the fourth part, conclusions and discussion with other works concerning the future of public transport in a post-pandemic reality are presented. In the fifth part, we describe the study limitations, and, finally, in the last section, we present recommendations arising from our study.

2. Literature review

2.1. Relationship between safety, quality of public transport and its attractiveness

Previous studies have stated that a successful transformation from car domination to a greater popularity of public transport could be achieved through various means, including respect for users’ needs and improvement in the quality of public transport (Matas 2004; Suzuki et al., 2003; Chocholac et al., 2020). The latter has been thoroughly investigated in many studies that focus on the complexity of the term “quality” (Karatepe et al., 2005; Pauley et al., 2006; Yaya, Fortia, et al., 2014). Although there has not been complete agreement on how to measure the quality of a public transportation system (Yannis & Georgi, 2008; Van’t Hart, 2012; Yaya et al., 2014), a few common aspects have constituted the core of the available definitions (Friman et al., 2020). They have referred to the classic Kano model with accessibility, availability, comfort, frequency, safety, and travel time treated as basic components of public transport quality (Sauerwein et al., 1996).

Objectively, better quality could be achieved by improving infrastructure and its parameters (Kampf et al., 2012; Kauf, 2016; Friman et al., 2020). More importantly, however, available definitions of quality have often referred to the gap between customers’ expectations and assessments of the received service (Berry et al., 1988; Yaya, Fortia, et al., 2014). Thus, the issue of the quality of public transportation services is inseparable from the social perceptions that create long-term attitudes to particular transport modes (Acker & Willox, 2009; Yaya et al., 2014b; Yannis & Georgi, 2008; Cascetta et al., 2014). Due to this fact, Sinha et al. (2020) emphasised that it is important to understand the user’s perception and identify variables that are most likely to influence mobility decisions. Previous studies on how passengers perceive quality have shown that safety, comfort and cleanliness, fare, time, affordability, reliability, accessibility of the service, accessibility of information, and service organisation are the most important determinants influencing transport mode choices (Popuri et al., 2011; d’Ovidio et al., 2014; Nutsugodo et al., 2018).

According to some researchers, the social assessment of these attributes depends on contextual factors (e.g., available travel modes environment), trip characters, socio-demographic factors (e.g., age, income, and gender), an individual’s abilities or constraints (e.g., car ownership and possessing a driver’s license), various psychological factors (e.g., evaluations and motives) social norms (which influence the perception of societal and environmental importance of transport modes), behavioural beliefs (subjective probability that performing a behaviour will provide a certain experience) and the assessment of how these characteristics could contribute to the expression of social position and the achievement of social appreciation (Bourdieu, 1984; Ganzbehoon, 1988; Ajzen, 1991; Outwater et al., 2003; Acker & Willox, 2009; Weber, 2010; Dell’Olio et al., 2011; Pu & Juan, 2017; Hansson et al., 2019; Ingvardsen & Nielsen, 2019; Zhou, 2019; Chaisomboon et al., 2020; Mayo & Taboada, 2020). However, according to other studies, qualitative evaluation of the particular modes could be less symbolic and based more on the perception, calculation, and mitigation of various risks that might occur when using transport services. Safety incidents might affect behavioural beliefs and the overall assessment of public transport quality (Jevon & Kubota, 2006; Friman et al., 2020).

Therefore, safety seems to play a key role in shaping the attractiveness of public transport (Spears et al., 2013). Its position within the transport quality determinants has often been discussed using Maslow’s hierarchy of human needs (Maslow, 1943). According to this approach, some studies see safety as a base factor in Maslow’s pyramid of requirements. If a safe service is not offered by the public transport system, other advantages of the transit will not be of interest to the user choosing the transport mode, and there will be no opportunity for policymakers to create an attractive transport offer (Abenoz et al., 2017).
and subjective comfort in crowded spaces (Adamos et al., 2019). Although both issues have often been analysed regardless of safety, one can see close links between them under the circumstances of the pandemic. Covid-19 has drawn people’s attention to close and unavoidable contact with other people in crowded spaces, scarce methods to identify passengers who may be sick, and the existence of multiple surfaces that easily transfer germs (Gutiérrez et al., 2020; Koehl, 2020).

Available studies have left no doubt that Covid-19 has changed perceptions of safety, has reduced the attractiveness of the public transport services, and, as a result, has led to a mismatch between sustainable policy goals and users’ preferences (Tirachini & Cats, 2020). It is widely expected that fear of infection in crowded places may result in at least temporary detriment of public transport services and the renaissance of private car domination (Koehl, 2020). Indeed, although lockdown has caused the number of trips people made on all modes of transport to fall, the decline has been most significant in public transport (Molloy et al., 2020; Astroza et al., 2020; Pullano et al., 2020; Saladié et al., 2020). The attractiveness of public transportation services has been further reduced due to budget constraints and the lockdown rules, resulting in diminished service supply (Jenelius & Cebecauer, 2020; Tirachini and Cats, 2020).

Some authors expect the circumstances of the pandemic to be a ‘game-changer’ and modify people’s habitual routines. The abandonment of public transportation services could go hand in hand with the growing popularity of remote work and countryside residential locations (Gutiérrez et al., 2020; Tian et al., 2020). Future mobility behaviours may also be permanently affected if the role of public transport was to be reduced and a positive attitude to the private car was to be strengthened (Abdullah et al., 2020; Bucsky, 2020; de Haas et al., 2020). Zhang (2020) also emphasised that the virus could create a “new normal” due to the lack of methodologies addressing Covid-19 and future public health pandemics. Covid-19 also creates a new challenge for urban transport planners who should make journeys less risky and gain public trust (Zhang, 2020).

The first reactions to the new circumstances show, so far without empirical confirmation, that routine maintenance and organisation of public transport services will be primarily important in combating both the risk of contamination and the negative changes to the transportation market. One of the proposed solutions is to reschedule the daily activities of the local community to avoid peak hours and to spread demand for transport services over a longer period (Tirachini & Cats, 2020). At the same time, however, managing cleanliness is expected to be particularly important to mitigate the risk of being injected by viruses and to restore confidence in public transport. An equally significant issue regards the frequency of the service, which should be created in a way that eliminates crowds and ensures physical distancing on public transport (Bucsky, 2020). Otherwise, there is a high risk that the current situation may result in sustained growth of congestion and long-term deterioration of mass transit, despite the many efforts made before Covid-19 to promote the sustainable transport paradigm.

2.3. Structure of transport expenditure and its impact on the quality of public transport

The Covid-19 period is not the first time routine maintenance and organisation of public transport services became relevant. Both issues constitute an essential part of current (operational or running) expenditure which has got two different purposes. First, it allows for winter maintenance and lighting of roads. Second, the level of current spending significantly influences the ability to keep or increase the quality of service in public transport, including the frequency of service, its cleanliness, load factors, route planning, etc. (McGlade et al., 2007; Gubanski and Mikolajczyk, 2016). In practical terms, operational expenditure often covers the cost travelled by the fleet of the local public transport operator. The price of each kilometre considers the drivers’ salary, fuel consumption, the volume and technical maintenance of vehicle fleets, compensation of operational losses, insurance, and depreciation (Jackiewicz et al., 2010).

Besides, we could distinguish capital expenditure that is based on investment spending for the maintenance, improvement and enlargement of infrastructure in local transport. This category primarily covers investments in new tramlines and their renovation, construction of new roads and purchase or modernisation of rolling stock (Ardila-Gomez and Ortegon-Sanchez, 2016).

Our article, however, gives particular importance to the current expenditure. Contrary to the capital spending (which is often the mix of the expenses that come from the local budget, central state and the European Union funding programmes), the current expenditure is usually of local origin. It practically means that local governments obtain revenues based on local taxes and incomes (such as income and property taxes, parking fees etc.), and then they transfer a certain amount of money to the body responsible for local transport (Kocur-Bera, 2011). In many cases, revenues from sales of public transport tickets also belong to these incomes and are redistributed by local authorities to the public transport operators as a part of the current expenditure.

Experiences gathered across the countries show that revenues from ticket sales – a basic part of the current expenditure in many cities – are not enough to bear all costs of public transport maintenance. Due to this fact, there is often an additional part of current spending which takes the form of subsidy and could be understood as an extra support of local government. The subsidy covers the “difference between production costs of a good and revenues from sales to final users” (Fabbri, 1995). Thus, it aims to reduce financial deficits (Nash et al., 2002) and “restore profitability in the production of a good, in order to make it available in quantities and qualities otherwise not provided by the normal functioning of the market” (Fabbri, 1995). Sometimes, this additional part of the current expenditure is also perceived as an instrument that would lead to positive externalities in public transport (McGlade et al., 2007), including supply response in terms of higher frequencies decreasing scheduling costs of new and existing travellers (Van Goeverden et al., 2006). The subsidy could be granted in different ways, including direct payments from government budgets, tax exemptions and rebates, preferential market access, accelerated depreciation, limited liability, ‘soft’ loans, and special exemptions from regulatory requirements (McGlade et al., 2007).

The local origin of the current expenditure makes the public transport services sensitive to economic cycles, the overall financial health of local budgets, political changes and different priorities of local governments (Sakamoto and Belka, 2010). Therefore, local transport policies in particular cities may vary over time in terms of the level and detailed purpose of subsidies (Ardila-Gomez and Ortegon-Sanchez, 2016). For example, if the tax revenues go down, local governments often reduce subsidies for public transport operators who have to optimize their costs by technical or operational austerities (e.g., the annual performance of transit is diminished and the ticket prices grow, which shift the financial burden from operator to passengers and may reduce their number). The reduced public transport patronage leading to lower incomes from sales of tickets could bring similar effects, regardless of how these revenues are distributed (directly to the operator or indirectly as a transfer from local government). Such circumstances may result in a vicious circle of public transport deterioration, thus reducing its accessibility, attractiveness and quality. They also lead to differences in the structure of urban traffic and city-wide mobility behaviours, which allows researchers to distinguish car-oriented and transit-oriented cities (Klinger and Lanzendorf, 2016).

Covid-19 belongs to the factors that may favour the financial difficulties and reduce the ability or willingness of local authorities to fund public transport operations (Bernhardt, 2020). On the other hand, it is important to know whether long-term stability of the current expenditure could protect the demand for transit and prevent the growth of private car usage during the critical pandemic time. This question is justified because transport subsidies could effectively affect transport...
demand only in the long term, mainly due to their indirect impact on the social attitude towards public transport (McGlade et al., 2007). Therefore, the pandemic could influence mobility behaviours to different degrees, depending on the past transport policy at the local level.

3. Methodology

3.1. Sample

For the purpose of our analysis, we collected data on weekly congestion level during the pandemic from eleven regional capitals in Poland (Fig. 1). The analysis was limited to one particular country since we wanted to avoid the uncontrolled impact of lock-down restrictions that were diversified across Europe and resulted in a different impact on mobility behaviours. It also means that the movement restrictions and the rules of lock-down were the same in all considered cities, which makes it easier to conduct a comparative analysis. We analyzed 41 weeks from the middle of March to the end of December 2020.

In general, urban transport represents the major part of passenger transport in Poland in terms of passenger numbers. Karolak (2016) noted that public transport services exist in about 260 Polish cities and municipalities inhabited by 17 million people. Urban transport enterprises carry in the region of 3.7 billion passengers annually, which represents approximately 80% of the total number of passengers in the public transport sector (Karolak, 2016).

After a significant decline in passenger numbers under the post-socialist transformation in the 1990s, the public transport in Polish cities has been strengthened in subsequent years. This was due to the large investment projects funded by €3 billion from the European Union. Since Poland accession to the EU in 2004, local governments significantly improved the quality of transit by investing in bus, trolleybus, and tram systems, including purchases of bus fleets and tram rolling stock. Although these efforts weaken the pace of the decline, a significant increase in passenger traffic was not observed (Karolak, 2016), regardless of which city or town we consider.

In most cases, public transport services in Poland are provided by municipal operators or private companies upon the request of local authorities. Usually, revenues from fares go to the general budget of the local government and then are transferred to the operators together with the compensation of other uncovered costs. The principles of the support

Fig. 1. Spatial distribution of cities taken into account in the study.
for the operators are similar to the other countries. The transfers are based on the two different types of expenditure: current (operational) and investment (capital). These rules also concern the cities taken into account in this study.

The current spending usually covers the following types of costs:

- the price of kilometres travelled by fleet of the local public transport operator. In Poland, the price of each kilometre considers the drivers’ salary, fuel consumption, technical maintenance of rolling stock, insurance, and depreciation (Jackiewicz et al., 2010). This cost consumes around 82–89% of annual current spending per year (Gubanski & Mikolajczyk, 2016) and determines the frequency and quality of the public transport service (cleanliness, technical condition of fleet, etc.). Its significant share in the financial transfers from Polish local governments to the operators also means that the current spending is a typical “supply-side subsidy”.
- maintenance of existing roads and sidewalks (mainly winter maintenance, removing small damages etc.). Based on the official data gathered from “Statistics Poland” we could say that this category of costs is responsible for 12–18% of annual current spending.
- maintenance of bike infrastructure, such as bike rental systems (around 1% of annual current spending) (Gubanski & Mikolajczyk, 2016).

The capital investments are included in a separated category of financial transfers from local governments, which is entitled “investment spending”. Its primary role is to provide large lump sums required to build a new infrastructure for transport purposes. The investment spending also serves as an own contribution to the infrastructural projects funded by the European Union. The analysis of local budgets in Polish cities shows that, considering each city separately, approximately 60% of annual investment subsidy is devoted to infrastructure initiatives officially strengthening public transport (e.g., construction of new tramlines or purchase of rolling stocks). A further 35% includes mixed projects aimed at improving both public transport and roads (e.g., increase of road capacity combined with construction of new tram- or busline), while only the final 5% is spent on fully road-oriented investments. Thus, we could say that a vast majority of investment spending is more or less dedicated to transit-related investments. In our analysis, we primarily seek to evaluate the impact of current expenditure on the congestion level during Covid-19, yet the proposed methodology enables us to evaluate the role of investment spending as well.

3.2. Methods

Data analysis was performed using the IBM SPSS package, version 21. To verify the research hypothesis, we used a hierarchical linear regression model with a dependent variable based on the number of weeks in every city during which the congestion level exceeded the values registered one year ago. The first block of our model included only control variables reflecting the long-term and complex character of reasons that lead to congestion. We selected factors that shape transport behaviours, determine the capacity of the transport system and influence general travel demand in a longer temporal perspective. The second block included an additional variable regarding an average share of current expenditure in the cities’ total annual expenses for transport (the variable that allowed us to verify the research hypothesis). This predictor was based on data from 2011 to 2020, thanks to which we were able to verify the impact of long-term fiscal policy on the congestion level.

In our analysis, we assume that the long-term perspective is crucial to identify factors that contribute to the congestion level during Covid-19. Nevertheless, the popularity of private cars during the pandemic could be also determined by short term circumstances, strongly connected with spontaneous adaptation strategies of local governments and inhabitants. Therefore, further blocks of the model included two other variables reflecting possible changes in mobility behaviours due to un-expected pandemic disturbances. The first predictor refers to the suspension of selected bus- or tramlines during the pandemic, while the second variable measures the length of bike roads per 100 km². The suspension of selected lines during the pandemic and the length of bike roads were tested in the separated blocks due to the unsatisfactory statistical parameters of the block including both of them (Durbin-Watson value = 0.814, F(2,8) = 16.202, p > .05). Nevertheless, neither the short-term changes in the public transport offer nor the bike infrastructure predictor improved the model. They both were not statistically significant in explaining the outcome variable, and there was no impact of these variables on the significance of other predictors. They also did not increase the explained variance. Bearing that in mind, we omit the discussion of these short-term predictors further into the article (however, their distribution is presented in Appendix 1).

The conducted analysis considers only eleven cities because of the limited availability of data. A small sample size usually means that regression models should include a small number of predictors, while the congestion is a very complex phenomenon and its analysis needs more sophisticated approaches. Due to this limitation, we preceded the essential part of the analysis by conducting simple two-variable models to assess the impact of each predictor separately. All models used a bootstrap estimation method that allows for the avoidance of a lack of confidence in the estimations, especially if obtaining a significant number of observations is not possible (Gavilanes & Michael, 2019). Based on this, we identified predictors with statistically significant and insignificant impact on the dependent variable. One should note, however, that simple two-variable models are devoid of control variables and could show an illusory correlation between predictor and dependent variable. Therefore, in the second step, we developed a full hierarchical linear regression model with three blocks of control predictors that were presented above. The results achieved in both steps remains coherent. All predictors that were statistically significant in two-variable linear regression models retained their significance also in full multi-variable analysis.

3.3. Dependent (outcome) variable

The most appropriate way to measure the impact of long-term current expenditure on modal shift during the pandemic is to identify changes in the public transport patronage. However, there are no confirmed calculations on the pandemic decrease in demand for public transport in Polish cities, since passengers often buy long-term tickets, while their actual use was not controlled constantly during Covid-19. Bearing that in mind, we used a substitute outcome variable based on the difference between 2019 and 2020 in terms of local congestion level. We assumed that congestion levels exceeding the pre-pandemic levels reflect modal shift from public transport to the private car and, thus, could be implemented when estimating the impact of long-term current spending on the pandemic transport preferences.

In general, congestion could be defined as a temporary situation in which the demand for road space exceeds the capacity of roads and extends the travel time. The imbalance between the demand and supply results from the concentration of travel in time and historically developed transportation space. In our analysis, we used dynamic statistics on weekly congestion levels from 11 Polish cities, which enabled an analysis of changes in car usage during the examined period. The data were extracted from the TomTom Traffic Index, which ranks weekly congestion levels in 416 cities across 57 countries. The Index data comes from more than 600 million drivers who use TomTom tech in navigation devices, in-dash systems, and smartphones around the world. A special version of the database, designed to provide insight into real-time traffic during Covid-19, allows for the analysis of congestion levels in every week since the beginning of the first national lockdown (in Poland, lockdown-type control measures came into force on 10–12 March 2020 and had been partially withdrawn by November 2020). Weekly statistics...
are calculated on the basis of data recorded for all hours of each day. The Index measures the congestion in each city separately, and informs how long a 30-minute trip took in any particular week compared to the same week in the previous year. The weekly value of the Index is expressed in percentage. For instance, a 53% congestion level in any particular week means that a 30-minute trip took 47% less time than a year ago (value registered in the previous year is a reference point and equals 100%).

In order to confirm the reliability of the Index, we collected real-time traffic data from the Intelligent Transport System (ITS), which is used in one of the examined cities (Wrocław). ITS data show the number of cars travelling through 50 crossings per day; they cover each week between the middle of March 2020 and the end of December 2020. We found that there is a significant and positive correlation between the Index in Wrocław and the data extracted from the local ITS (rho = 0.74, N = 41, p < .001) (Fig. 2). It is important to note that we narrowed down the ITS data to passenger cars. This was necessary because the Index does not distinguish between different types of vehicles and our study is focused on the popularity of private cars. A strong positive correlation between the ITS data and the Index confirmed that the latter could be used as an indicator of private car usage, even if heavy goods vehicles are also included in the Index’s statistics.

As shown in Fig. 3, the national lockdown significantly reduced the congestion level in those cities, which is confirmed by the minimum values of the Index. Nevertheless, the maximum values suggest that the congestion is not only returning to pre-pandemic levels but also exceeding the values registered one year ago (see the maximum values above 100%). We assumed that the congestion level above 100% demonstrates the modal shift from public transport to the private car, particularly as some economic sectors still have not returned to the pre-pandemic operating mode. Based on the available data, we calculated the number of weeks in every city during which the congestion level exceeded the value registered one year ago (see column 7 in Table 1). That was the outcome variable in our further analysis.

It should be mentioned that the outcome variable used in our model is discrete, while linear regression requires continuous quantitative dependent variable with normal distribution. However, discrete outcomes that have at least a moderate number of different values (e.g., 10 or more) could be used in linear regression models, since the method is quite robust to deviations from the Normality assumption (Madrigal, 1998). Regardless of this fact, our outcome variable follows a normal distribution, which was confirmed by Kolmogorov-Smirnov test for normality.

3.4. Predictors

When defining the list of predictors, we referred to the two different types of congestion according to the causes leading to its occurrence. The first type, recurrent congestion, is the result of factors that act periodically on the transportation system, such as daily commuting or weekend trips (OECD, 2007). The recurrent congestion results from the impact of long-term “drivers” operating at the macro level and including land-use patterns, the spatial distribution of economic activity, employment patterns, car ownership trends, long term financial policy, characteristics of transport infrastructure, regional economic dynamics, etc. (Kožlak et al., 2018). As a contrast, non-recurrent congestion is “caused by unexpected, unplanned or large events (e.g., road works, crashes, special events and so on) that affect parts of the transportation system more or less randomly and, as such, cannot be easily predicted or modelled” (OECD, 2007). The non-recurrent congestion is caused by “triggers” comprised of micro-level factors that are related to present traffic on the roadway.

In the article, we explain the congestion level by referring to macro-level circumstances that shape transport behaviours in a longer temporal perspective. Therefore, our model includes only those predictors belonging to the “congestion drivers”. In parallel, these variables enable us to control differences between cities. What is also important, values of all predictors were standardized before conducting the analysis.

The first predictor, which allows us to verify the research hypothesis, concerns the percentage share of current and investment expenditures in cities’ total annual expenses for transport. The main goal of current and investment expenditure is different. As already mentioned, Polish cities spend approximately 82–89% of the current expenses on routine maintenance of public transport, including cleanliness and service supply (Gubański & Mikolajczyk, 2016). Both aspects belong to the essential components of the public transport quality and strongly influence the feeling of safety among passengers (Yannis & Georgia, 2008). Service supply determines the level of crowding, while cleanliness ensures protection against infection. Appropriate management of these issues might reduce the negative perception of safety on public transport, thus limiting its deterioration during the pandemic.

Contrary to current expenses, investment expenditure allows for the development of new infrastructure projects in the area of transport, including investment in a fleet of vehicles, construction of tramlines, etc. Nevertheless, assuming that people will tend to shift their preference from public transport to private cars due to the fear of contamination (Abdullah et al., 2020), we believe that it is more important to focus on
current expenditure to limit the undesirable changes in transport preferences. In this context, one should also note that the two categories of expenditure – current and investment – account for the full amount of total transport expenses. This means that the second category is the reverse of the first. Bearing that in mind, the analysis of the share of current expenditure is enough to evaluate the role of both current and investment expenses in affecting the congestion level. Therefore, in a further analysis, we used a variable titled “average share of the current expenditure in total cities’ annual expenses for transport” (see Fig. 4).

The presented definition of recurrent congestion and its drivers indicates that the structure of annual transport expenses could significantly influence the traffic problems on roads. Nevertheless, the definition also suggests that the level of congestion is not a simple result of lock-down restrictions. Although these restrictions were the same in all considered cities, we could expect some differences in their impact on the travel demand due to the different character of local economies. The distribution of all control predictors is presented in Appendix 1, while Table 2 includes their definition.

As already mentioned, we also tested two predictors regarding the short-term circumstances of the pandemic. In our model (based on the outcome variable measuring congestion level in cities) these short-term effects could be measured by the changes in public transport patronage. However, as already emphasized, the lack of available data on patronage means that it could be used neither as a dependent variable nor as a predictor. To address this problem, we used two other simplified predictors describing the current pandemic situation and taking into account selected points in time, instead of trend analysis. There was no statistically significant impact of these variables on the model, so we did not discuss these factors in the results section. Nevertheless, below we provide their definitions with justification for including them in the initial analysis.

The first short-term predictor refers to the suspension of selected bus or tramlines during the pandemic. Some operators and local governments decided to reduce the public transport offer during Covid-19, which could have made transit less available and attractive for people. In this context, short-term changes in the offer would have a more significant impact on the travel behaviours than long term efforts to build passengers’ loyalty. For that reason, we decided to control the pandemic reductions in the offer when assessing the impact of long-term financial policy on the congestion level during Covid-19. Our model included variable 0–1 indicating whether the reductions were implemented in the considered cities (the predictor was based on: Straub, 2020).

The second added predictor refers to the length of bike roads per 100 km². Many current analyses show that Covid-19 has created new mobility patterns and has led to unexpected growth in bike use. Bicycles gained higher popularity during Covid-19, but their long-term attractiveness and impact on the structure of traffic may be strongly determined by the availability of comfortable infrastructure. Thus, we assumed that cities with better-developed bike infrastructure would register a lower increase of congestion during the Covid-19.

4. Results

The data used in the study met all assumptions that are required to use the regression method (Jobson, 2012). An analysis of standard residuals showed that the data contained no outliers (Model I: std. residual min = −1.199, std. residual max = 1.243; Model II: std. residual min = −1.008, std. residual max = 1.375). Tests to see if the data met the assumption of collinearity indicated that multicollinearity was not a concern (see VIF values in Table 3). The data included in the models also met the assumption of independent errors (Durbin-Watson value in Model I = 2.806; in Model II = 2.301). In all models, the histogram of

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**Table 2**

Descriptive statistics for weekly congestion levels in examined cities.

| City          | N (number of weeks) | Minimum congestion level (%) | Maximum congestion level (%) | Mean of the congestion level (%) | Standard deviation of the congestion level | Number of weeks with congestion level exceeding the values registered one year ago |
|---------------|---------------------|------------------------------|------------------------------|----------------------------------|--------------------------------------------|-----------------------------------------------------------------------------|
| Białystok    | 41                  | 52                           | 128                          | 91                               | 20                                         | 13                                                                          |
| Bydgoszcz    | 41                  | 43                           | 108                          | 81                               | 20                                         | 7                                                                          |
| Kraków       | 41                  | 35                           | 117                          | 73                               | 21                                         | 2                                                                          |
| Gdańsk       | 41                  | 41                           | 124                          | 86                               | 24                                         | 13                                                                         |
| Katowice     | 41                  | 43                           | 110                          | 79                               | 19                                         | 4                                                                          |
| Łódź         | 41                  | 54                           | 113                          | 87                               | 17                                         | 11                                                                         |
| Lublin       | 41                  | 54                           | 142                          | 90                               | 22                                         | 12                                                                         |
| Poznań       | 41                  | 41                           | 93                           | 66                               | 14                                         | 0                                                                          |
| Szczytno     | 41                  | 40                           | 143                          | 89                               | 27                                         | 15                                                                         |
| Wrocław     | 41                  | 34                           | 107                          | 68                               | 19                                         | 2                                                                          |

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**Fig. 4.** The average share (in %) of current transport expenses in total annual transport expenses in studied cities.
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Table 2 (continued)

| Control variable                                                                 | Definition and justification for its use                                                                 |
|---------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|
| current transport expenses. What is more, some aspects of the quality could have an impact on mobility preferences during the pandemic, which justifies our efforts to explore the role of current expenditure in the context of Covid-19. |

The following article aimed to verify the role of transport expenditure in affecting congestion levels during the Covid-19 pandemic. We used data from eleven of Poland’s regional capitals and verified the impact of long-term fiscal policy, assuming that longer temporal perspectives are crucial to explain transport behaviour also during Covid-19. We found that, during the pandemic, cities with a higher share of standardised residuals indicated that the data contained approximately normally distributed errors, as did the normal P-P plot of standardised residuals, which showed that points were not completely on the line, but close. The scatter plots of standardised residuals showed that the data met the assumptions of homogeneity of variance and linearity. The data also met the assumption of non-zero variances.

The first model (Table 3) predicted the number of weeks with congestion level exceeding the pre-pandemic level based only on the control variables. A significant regression equation was found (F(5,5) = 5.695, p < .05), with an R²Adjusted = 0.701. According to the model, only the number of cars registered in the city per capita significantly influenced the number of weeks with congestion exceeding the pre-pandemic level (β = -1.254, t(5) = -3.861, p < .05). The direction of this relationship suggests that the more registered cars, the lower number of weeks with the congestion level exceeding the pre-pandemic level.

The second model (F(6,4) = 17.612, p < .01, R²Adjusted = 0.909) included an additional variable that refers to the share of current expenses in cities’ total transport expenditure. The model shows that this extra variable has proven to be statistically significant (β = -0.464, t(4) = -3.519, p < .05) in predicting the number of weeks with congestion exceeding the pre-pandemic level. The added predictor also significantly contributed to the model and improved the portion of explained variance (the change of R²Adjusted from 0.701 to 0.909, though this value should be considered carefully due to the small sample size). One should note, however, that the number of cars registered in the city per capita remained statistically significant and had slightly more impact on the number of weeks with congestion exceeding the pre-pandemic level (β = -1.061, t(4) = -5.652, p < .01). Nonetheless, based on the results obtained, we can say that the greater value of both predictors, the lower the number of weeks with congestion level exceeding the pre-pandemic level.

Model II provided empirical evidence that the traffic level is significantly influenced by the emphasis of local authorities on current expenses in the transport area. Cities in which the contribution of current expenses to total annual transport expenses was higher registered lower number of weeks with congestion exceeding the pre-pandemic level.

It is particularly noteworthy that these results are a mirror image of the analysis regarding the share of investment expenditure in cities’ total transport expenses. This point to the conclusion that the greater share of investment expenditure in cities’ total annual transport expenses did not reduce congestion levels during the pandemic. Keeping this in mind, we can positively verify the research hypothesis and state that, in regard to the necessity of limiting the usage of private car during Covid-19, long-term policy focused on current expenditure was more effective in mitigating the pandemic growth of congestion, contrary to the investment-oriented strategies with the leading role of infrastructure improvements.

5. Discussion and conclusions

The following article aimed to verify the role of transport expenditure in affecting congestion levels during the Covid-19 pandemic. We used data from eleven of Poland’s regional capitals and verified the impact of long-term fiscal policy, assuming that longer temporal perspective is crucial to explain transport behaviours also during Covid-19. We found that, during the pandemic, cities with a higher share of...
current expenses in cities’ total annual transport expenditure have registered a lower number of weeks with congestion level exceeding the pre-pandemic level.

Current expenses are usually assigned for routine maintenance of public transport, including cleaning services and the service supply. Therefore, the presented analysis supports the claim (Hensher, 2020; Tirachini and Cats, 2020) that increasing service supply and adjusting services to cleanliness standards will be particularly important to affect the post-Covid mode choice and make public transportation services more attractive to people who have lost confidence in public spaces during the pandemic.

This primary conclusion also shows that cutting spending on routine maintenance of public transport would, potentially, be no less devastating for sustainable transport policy than Covid-19 has been. Due to the significant fall in the number of passengers using public transport (Abdullah et al., 2020), there is a risk of political pressure to optimise the efficiency of the transportation services and their cost (Gutiérrez et al., 2020). Moreover, the circumstances of the pandemic have negatively impacted the condition of local budgets and have shifted the attention of local governments to other social needs. Therefore, many local authorities could have significant difficulties finding public funds to support the transformation of public transport towards future needs and challenges. The potential long-term outcome of these changes could be a vicious circle of continuously declining ridership and quality of public transport (Bucksy, 2020). This is particularly challenging for cities located in Central Eastern Europe, due to their cultural and political post-socialist legacy. Urban transport policy that is implemented by Central Eastern European (CEE) cities is often influenced by values and preferences of local authorities that do not put a strong emphasis on a sustainable approach (Rubicki, 2012; Beim, 2013). As a result, the pandemic circumstances could be a great excuse for many CEE local governments to redefine transport policy goals by reducing the supply of public transport services and promoting car-oriented infrastructure.

Different findings can be provided in the case of investment expenditure, whose share in total transport expenses is the reverse of the current expenditure contribution. This means that a higher share of investment expenses in total transport expenditure has increased the likelihood of an increase in congestion. We propose at least three potential explanations of this paradox. First, the main goal of many infrastructure investments is to extend the public transport network and to provide inhabitants with up-to-date infrastructure, including stops, new rolling stock, and information systems (Beim & Haag, 2014; Geurs & Outh, 2016). Such improvements are not a key challenge in the context of Covid-19, which requires ensuring social distancing and transport safety (Campisi et al., 2020). Second, local authorities sometimes ignore the opinion of citizens who are not satisfied with the key attributes of infrastructure improvements. This negatively affects the support to use public funding for public transport and does not lead to its popularisation (Calvo-Poyo et al., 2020). Third, in some cases, the investment expenditure does not affect congestion levels due to the conservative nature of municipal mobility policymaking. Kłkowski and Bassens (2018) emphasise that many local transport policies still follow a neoclassical approach and put a strong emphasis on car-oriented solutions, contrary to the sustainable mobility paradigm with its criticism towards car dominance.

Another conclusion arising from the study concerns the role of other macro-level circumstances which reflect socio-economic differences between cities and shape the congestion over a longer period. We confirmed the impact of long-term financial policy on the congestion level during Covid-19, but the land-use, economic conditions and employment patterns remained statistically insignificant in our study. It seems that they do not cover the circumstances of the pandemic which are exceptional and shift our attention to the role of trust, safety perception and quality in public transport. We only found that the higher number of registered cars per capita, the lower number of weeks with congestion exceeding the pre-pandemic level. This relationship is not surprising due to several different reasons. First, it could mean that the pandemic restrictions and the transformation of jobs into teleworking lead to more visible reductions in car traffic in cities where a higher proportion of the population integrated their existence with private cars. If such people travel less, the general car usage will be lower as well. As a result, we could say that the higher motorization rate gives better opportunities to limit car usage when lockdown and remote working is widely implemented. In parallel, it also means that only a few people could buy the car and significantly change their mobility habits during Covid-19.

We also tested the impact of short-term reductions in the public transport offer and the availability of bike infrastructure. These interventions were not correlated with a higher number of weeks during which the congestion level exceeded the pre-pandemic level. It suggests that long-term transport policy has got a primary impact on the mobility preferences during Covid-19. We could also hypothesize that the offer reduction leads, in the first place, to the growth in bicycle usage. This hypothesis corresponds to some studies emphasising that public transport has lost some popularity to bikes during Covid-19 (Abdullah et al., 2020; Buck and Nurse, 2021). However, our study did not confirm that bicycles have a significant impact on the structure of traffic during the pandemic. Such findings are in line with the second group of publications which suggest that Covid-19 has significantly improved the popularity of bikes, but their contribution to the modal split is still low (Bucksy, 2020).

6. Study limitations

Our analysis includes several methodological simplifications and limitations which should be eliminated in other similar studies. First, we suggest that multivariable models with a far richer data set than the one presented in this article would be more useful when identifying determinants of congestion levels. For this reason, we recommend using more local-oriented indicators which would enrich the research findings and allow to better control differences between cities. Alternative datasets would include data on the confirmed number of jobs transformed into remote work, the spatial distribution of non-remote jobs, cities’ topography, the structure of local economies and a detailed

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Table 3
Regression models identifying the impact of current expenditures on the congestion level.

| Model | B     | t   | VIF | Model | B     | t   | VIF |
|-------|-------|-----|-----|-------|-------|-----|-----|
| (Constant) | 7.818 | –   | 19.956 | (Constant) | 7.818 | –   | 15.956 |
| Density of public transport routes (km per 1 km²) | -2.266 | -0.421 | -1.700 | 2.05 | -1.902 | -0.353 | -2.559 | 0.09 |
| Population density (per 1 km²) | -0.828 | -0.154 | -0.560 | 2.52 | -0.941 | -0.175 | -1.152 | 2.53 |
| Number of cars per capita | -6.751 | -1.254* | -3.861 | 3.53 | -5.710 | -1.061** | -5.652 | 3.87 |
| Average gross wage | 1.671 | 0.310 | 0.966 | 3.45 | 1.772 | 0.329 | 1.854 | 3.46 |
| Number of business entities | 0.990 | 0.184 | 0.643 | 2.74 | 1.903 | 0.354 | 2.138 | 3.00 |
| The share of current expenditure in cities’ total annual transport expenses | – | – | – | – | – | – | – |

* p < 0.05; ** p < 0.01.

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picture of the capacity of main and supplementary transport corridors. A more comprehensive analysis would also consider historical data on the evolution of demand for public transport during the pandemic, and the changes in modal split regarding daily commuting or weekend trips. The improved datasets should also lead to alternative models with the outcome variable identifying the determinants of the number of passengers during the pandemic.

Another limitation was the fact that available and comparable data on transport expenditure was limited to Polish cities. Therefore, we were not able to extend the analysis beyond the cases from Poland. Unfortunately, only eleven Polish cities are covered by TomTom Traffic Index, and such a small number of observations leads to a risk of overfitting the model (Austin & Steyerberg, 2015; Henley et al., 2020; Jenkins & Quintana-Ascensio, 2020). We counteracted the negative effects of the small sample size by implementing a bootstrap procedure. Nevertheless, using a bigger sample in future research projects is strongly recommended.

More specific datasets would also allow the use of more sophisticated methodology, for instance, structural equation modelling (SEM). SEM approach tests and evaluates multivariate causal relationships and differs from other modelling approaches as it pays close attention to the direct and indirect effects on pre-assumed causal relationships (Fan et al., 2016). This alternative method provides several possibilities that are not achievable in traditional linear regression models. First, Fan et al. (2016) indicate that SEMs are very useful in measuring a causal relationship among predictors, where one predictor can influence an outcome directly and indirectly through another predictor. For instance, land use patterns could influence the congestion level directly by generating the demand for travel in the given area. However, their impact on the congestion could be also observed indirectly, based on the personal mobility choices. These mobility decisions depend not only on spatial characteristics of the city (objective circumstances) but also on cultural orientations and attitudes of inhabitants towards different means of transport. In this context, land-use patterns could be considered a stand-alone driver of congestion or mediated by the indicator reflecting personal attitude towards the car, public transport, bicycle walking, car sharing, etc. The flexibility of SEMs allows to include such mediations in the analysis, thus identifying reasons for the congestion level and the interrelations between them more effectively.

The second advantage of SEMs refers to their ability to measure more abstract concepts, for which direct measurements or units may not exist (Fan et al., 2016). For example, we used the number of cars registered in the city per 1000 inhabitants, assuming that the motorization rate is one of the key factors determining the congestion level. Although it is allowed, we are aware that this predictor could be replaced by a more complex latent variable measuring the popularity of the private car. There are no direct measurements of popularity, but its value could be derived from other related variables, such as local modal split, average spendings of the households on car exploitation, and, as already mentioned, qualitatively measured cultural attitudes towards a car or public transport. SEMs allow the use of such latent variables, providing more comprehensive insight into the nature of the mobility decisions of inhabitants.

One should also note that the presented study considers only CEE cities that still undergo imitative modernisation processes (Ziółkowski, 2000). They absorb contradictory cultural and economic patterns that emerged in Western Europe at different times but were imported to CEE countries at the same time (Malikowski, 2015; Chapain and Strzyżek-Wicz, 2017). This cultural context is significantly different in comparison to the Western European cases, even if both Western and Eastern European cities officially move towards the same sustainable approach. This could affect not only the local transport policies but also values and preferences of local inhabitants, including their attitude to public transport during the pandemic. Therefore, more comparative studies are needed to avoid false conclusions on the relationship between public transport quality and the congestion level in regions other than Central Eastern Europe.

7. Recommendations for post-Covid transport policy

A crucial role of the current expenditure also raises a question on how to secure the desired level of financial transfers from the local government. Existing models of public transport funding are different across the countries, but most of them are based on fares and support granted from the local budget. These budgets are made up of various taxes and there is no direct link between the source of incomes and their final allocation (Polia̧k et al., 2018). Therefore, the proportion of expenditure on transport purposes is not constant and varies from budget cycle to budget cycle (TCRP, 2003). It is also very sensitive to economic circumstances and the political priorities of the local establishment. This issue gains a significant relevance in the context of financial shortcomings during and after Covid-19. As we have mentioned earlier, the current spending is necessary to protect the demand for public transport, but the availability of funds may be very limited in the post-pandemic period. Not only has the pandemic reduced revenues from fares, but it has also led to lower profits of local governments from the other sources. Even if people go back to public transport, it would be difficult to predict whether changes in the labour market and consumer preferences will return to business as usual. As a result, if working from home and using digital services becomes the norm for many, there would be structural changes or even a permanent decline in the use of public transport (Vickerman, 2021).

Notwithstanding the mentioned issues, there are some opportunities to maintain or even increase the current expenditure, provided that local governments implement innovative business models in funding the transportation sector. Another opportunity comes from the modified tax regulations at the national level. Considering both solutions, we propose a set of recommendations that would protect public transport services against the reductions in the supply of services and their quality. All recommended solutions rely on the assumption that the post-Covid reality would be a “new normality” with a long-term need for funding packages that are unable to be withdrawn whilst patronage is still depressed (Bray, 2020). Our recommendations also define a research agenda for further transportation studies. It is important to note that the proposed strategies refer to solutions not widely implemented in various local contexts. Therefore, interdisciplinary analysis of economic, social and legal aspects would allow experts to better define the applicability of these solutions at the local level.

7.1. Financial solutions

The first possible solution is to define new forms of obtaining funds from public sources. A Transit Cooperative Research Program (TCRP, 2003) identifies about 20 alternative sources of funding, with special attention to fees for using road infrastructure and parking levies. Nevertheless, despite promising opportunities provided by these particular extra taxes, their implementation could be constrained due to the social resistance against additional payments, especially if they come from car exploitation. Local authorities can mitigate this risk by implementing less controversial solutions, such as excise duties to selected goods, casino revenues, vehicle registration fees, cigarette tax, and property tax. These additional revenues still not have been widely used before the pandemic, so they may increase the capacity of local governments to finance public transport. Using alternative financial solutions would also allow local authorities to avoid postponing necessary infrastructure investments to collect resources for the current exploitation of the already existing system.

particularly, the last of all mentioned taxations, the property tax, seems to be promising for transit funding due to the high recovery rates from the investments on the real estate market. This tool is based on the assumption that users of properties may benefit from the fact that the territory, where their properties are located, is served by public
passenger transport or well connected by other means of transport (Poliak et al., 2018). Therefore, they have to pay the extra tax that is transferred afterwards to public transport operators. Another opportunity comes from an employment levy based on the contribution of employers who benefit from access to markets and labour provided by the transport system. In some countries, however, local authorities cannot diversify the local tax base, which may restrict the possibilities for supporting the local transport system.

Another solution would be based on modified contracts between local governments and the public transport operators. Currently, many services are contracted for a short period and their costs are disproportionately high compared to the costs of preparing a bid for a large scheme (Bray, 2020). It means that long-term contracts could reduce unit costs, thus protecting public transport against cutting spending. Long-term bids also stabilize the public transportation offer and facilitate the building of trust among passengers, thus mitigating the risk of undesirable changes in the transport preferences of inhabitants (Bray, 2020; Shaheen and Wong, 2021). Moreover, this recommendation corresponds with results arising from our study. Longer contracts with lower unit costs allow saving resources and then shifting them to a higher supply of public transport services.

7.2. New business models

Local authorities and public transport operators could also test new business models connected with a real estate market. For example, Mass Transit Railway Corporation in Hong Kong acts as a transit operator, real estate developer and multinational transportation company in one. The operator invests money in housing and shopping centres located particularly around stations, which increases the attractiveness of public transport and provides new subsidies for transit (Majid, 2021). If real estate investments are not achievable for the public bodies, they could develop business models based on Wi-Fi access through buses or goods delivery via transit vehicles (Shaheen and Wong, 2021). The complementary option is the public–private partnership model (PPPs), which is based on the opportunity to attract additional financial resources through the involvement of the private sector, thereby reducing pressure on the public sector (Kharwal and Khandelwal, 2021). For instance, cities in India use the PPPs formula to introduce and scale bus services together with private entities. In such a scenario, local authorities plan and manage bus services, while the private sector is responsible for introducing cost-effective bus operations and maintenance. This cooperation allows increasing the number of services because the private operators generate additional revenues from real estate development, advertisement, branding, etc. (Kharwal and Khandelwal, 2021).

The PPPs formula of cooperation is still evolving, and one could expect that the circumstances of the pandemic will facilitate new types of contracts. Currently, available models are based on net-cost contracts (in which the operator provides a specified service for a specified period and retains all revenue. The authority pays a subsidy to the operator if the bus services in an area are unprofitable. If the services are profitable, the authority pays the operator a royalty) and gross contract (where local governments pay the operator a specified sum to provide a specified service for a specified period) (see: PPIAF, 2011). Although PPPs are widely used in some countries, many local authorities have avoided this model and have cooperated only with the public operator. It has often excluded competitiveness from the local transport, thus generating ineffectiveness in the planning activities and limiting efforts to yield additional revenues. The circumstances of the pandemic could change the attitude of local governments towards PPPs and make this formula more popular across the countries.

7.3. Organizational and marketing solutions

The mentioned tools sometimes require significant changes in the local and national regulations, which needs political consensus around the future shape of mobility. Therefore, local authorities should also identify light solutions to be implemented at the operational level without modifying legal circumstances. Rethinking the structure of service provided to the passengers according to the post-pandemic trends is one of the possibilities (Vickerman, 2021). The first opportunity to be considered is flattened demand in peak periods which required additional vehicles, staff and services to serve the short, sharp peaks in commuter travel before Covid-19. Currently, these services would be shifted to other parts of the day to reduce the crowd, serve leisure and discretionary trips, or provide a more flexible offer that better fits to dispersed needs of inhabitants (Renard, 2021). A detailed picture of the local labour market also would help to understand who is not working from home and should be served at first (Bray, 2020).

The next option leads to a new approach in the marketing activities of operators and transport managers. Timokhina et al. (2020) found that the core consumers’ values influence the attitude of inhabitants towards different means of transport during the pandemic. Based on this conclusion, they emphasized that the transportation bodies should differentiate social and marketing programs to promote the competitiveness of public transport in the minds of consumers. The best way to achieve this goal is to conduct the marketing segmentation and then create and communicate values that are consistent with the value orientations of consumers (Timokhina et al., 2020). This strategy also concerns the issue of gaining social acceptance for solutions that were used to decrease the fear of infection among passengers, such as decontamination, infrared sensors to measure the body temperature, etc. What is more, the implementation of effective marketing strategies may be crucial to promote flexible models of delivery of transport services. Their role in post-pandemic reality perhaps will be increasingly important to maintain the attractiveness of public transport in meeting the fragmented demand.

7.4. Technological innovations and stimulating new types of customers’ demand

The market trends mentioned above could be successfully identified only if the public transport sector is better integrated with new digital technologies that allow operators to understand the dynamic structure of travel patterns and user demand. Such technological solutions open new opportunities to permanently redesign and reallocate services, according to real social needs. Together with good business models, they would also make the transit less expensive to operate, thus providing some financial savings to local authorities.

Therefore, although current expenditure is crucial to maintain the role of public transport during and after the pandemic, its primary role should not result in the marginalization of investment spending in local transport policy. We argue that the investment expenditure for infrastructure projects should be rather adapted to the post-Covid “new normality” with the wide implementation of digital technologies. First of all, new digital solutions allow controlling the risk of infection and identifying outbreaks through social tracing. Moreover, they are an essential part of innovative approaches, such as mobility-as-a-service, Demand Responsive Transport and micro-transit services. The primary goal of these approaches is to facilitate better community planning, improved transportation services, better urban logistics and e-commerce (Earley and Newman, 2021). These strategies also pay close attention to integrated multimodal systems and could help connect isolated communities, implement community- and customer-centric services, and increase the integration of sectoral transport (e.g., across health, education, tourism etc.) (Renard, 2021).

To this end, they use digital channels with smart payment methods that enable users to plan, book, and pay for multiple types of mobility services at the community level (Smith, 2020; Mladenović, 2021; Santos and Nikolaev, 2021). In this way, the innovative digital solutions provide new opportunities to make public transport more flexible during and after the pandemic, which is necessary to meet the increasingly diversified needs of the inhabitants.
The presented ideas have the potential to close the funding gap resulting from the shifted priorities of local governments, reduced revenue from fares, and more car-oriented modal split during the pandemic. Their primary advantage is the fact that they would attract new passengers or at least provide local authorities with new revenue streams to maintain or increase current expenditure for transport purposes. Such innovative approaches may alleviate the financial effects of Covid-19, thus mitigating the risk of cutting spending on cleaning services and the transport supply service as a response to the lower number of passengers. They also enable to reduce the undesirable modal shift and allow local operators to avoid costs of re-starting suspended services, as well as re-training fired staff.

Appendix 1. Distribution of predictors considered in the analysis

| Density of public transport routes (km per 1km²) | Number of business entities registered in the city | Average monthly gross wage (per 1,000 inhabitants) | Number of cars per capita | Employment rate (number of employees per 1000 workers) | Length of roads (per 100 km²) | Average annual number of passengers in public transport services (in min) | Length of bike routes (per 100 km²) | Suspension of selected PT lines during the pandemic |
|-----------------------------------------------|-----------------------------------------------|-----------------------------------------------|--------------------------|--------------------------------------------------|---------------------------------|-----------------------------------------------|---------------------------------|-----------------------------------------------|
| Białystok                                    | 4.30                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Bydgoszcz                                    | 1.10                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Gdańsk                                       | 1.30                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Katowice                                     | 2.80                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Kraków                                       | 4.10                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Lublin                                       | 2.50                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Łódź                                          | 2.10                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Poznań                                       | 1.50                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Szczecin                                     | 1.50                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Warsawalia                                   | 2.30                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |
| Wrocław                                     | 1.80                                          | 34844                                         | 5127                     | 2904                                             | 474                             | 2.85                                           | 371                             | 60                                            | 156                                           | Yes                                      |

References

Abdullah, M., Dias, C., Muley, D., Shahin, M., 2020. Exploring the impacts of COVID-19 on travel behavior and mode preferences. Transp. Res. Interdisciplinary Perspectives 8 (July), 100255. https://doi.org/10.1016/j.trip.2020.100255.

Abenoza, R.F., Cats, O., Susilo, Y.O., 2017. Travel satisfaction with public transport: Determinants, user classes, regional disparities and their evolution. Transp. Res. Part A: Policy Practice, 95 (May 2020), 64–84. doi: 10.1016/j.trap.2016.11.011.

Acker, V. Van, Witlox, F., 2009. Introducing the lifestyle concept in travel behavior research. Proceedings of the BIVEC-GIBET Transport Research Day, 27-05-2009, Brussels, 707–725. https://biblio.ugent.be/publication/1849595/file/6759664.pdf.

Adamos, G., Nathanail, E., Jackiva, I.Y., Budilović, A., 2020. The theory of planned behavior. Organ. Behav. Hum. Decis. Process. 50, 199–211.

Aguilera-Ruiz, J., Beim, M., 2013. Transport i komunikacja w polskich miastach – gdzie leży problem? Retrieved on 15 January 2020 from: https://obiekty.pl/pl/tras transport-i- komunikacja-w-polskich-miastach/.

Azeez, M.A., 2020. Decline in ridership, adapted timetables and disinfection-robots – The impact of Corona/Covid-19 on public transport – Urban Transport Magazine. Retrieved January 28, 2021, from https://www.urban-transport-magazine.com/en/decline-in-ridership-adaptedtimetables-and-disinfection-robots-the-impact-of-c o rona-covid-19-on-public-transport/.

Barbieri, D.M., Lou, B., Passavanti, M., Hui, C., Hoff, I., Lesa, D.A., Sikka, G., Chang, K., Gupta, A., Yang, K., Banerjee, A., Maharaj, B., Lam, L., Ghasemi, N., Naik, B., Wang, F., Foroutan Mirhosseini, A., Naseri, S., Liu, Z., Qiao, Y., Tucker, A., Wijayaratna, K., Peprah, P., Adomako, S., Yu, L., Goswami, S., Chen, H., Shu, B., Hessami, A., Abbas, M., Agarwal, N., Rashidi, T.H., Pakpour, A.H., 2021. Impact of COVID-19 pandemic on mobility in ten countries and associated perceived risk for all transport modes. PLoS ONE 16 (2), e0245886. https://doi.org/10.1371/journal. pone.0245886.

Beaudoin, J., Hosse Forzin, Y., Lawell Lin, C., 2015. Public transit investment and sustainable transportation: a review of studies of transit’s impact on traffic congestion and air quality. Res. Transp. Econ. 52, 15–22.

Beecroft, M., 2019. The future security of travel by public transport: a review of evidence. Res. Transp. Business Manage. 32 (September), 100388 https://doi.org/10.2478/ rtbm-2019-0031.

Beim, M., 2013. Transport i komunikacja w polskich miastach – gdzie leży problem? Retrieved on 15 January 2020 from: https://obiekty.pl/pl/tras transport-i- komunikacja-w-polskich-miastach/.

Beim, M., 2020. Decline in ridership, adapted timetables and disinfection-robots – The impact of Corona/Covid-19 on public transport – Urban Transport Magazine. Retrieved January 28, 2021, from https://www.urban-transport-magazine.com/en/decline-in-ridership-adaptedtimetables-and-disinfection-robots-the-impact-of-co rona-covid-19-on-public-transport/.

Benjamin, L.L., Parasuraman, A., Zeithaml, V.A., 1988. SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. J. Retail. 64 (1), 12–40.

Bourdieu, P., 1984. Distinction: A Social Critique of the Judgement of Taste. Harvard University Press.

Berry, L.L., Parasuraman, A., Zeithaml, V.A., 1988. SERVQUAL: a multiple-item scale for measuring consumer perceptions of service quality. J. Retail. 64 (1), 12–40.
