sustainability

MDPI

Article

Analysis of the Impact of the COVID-19 Pandemic on the Future of Public Transport: Example of Warsaw

Marek Bauer [1,*] and Kinga Bauer [2]

[1] Department of Transportation Systems, Cracow University of Technology, 31-155 Krakow, Poland
[2] Department of Accounting, Cracow University of Economics, 31-510 Krakow, Poland; kinga.bauer@uek.krakow.pl
* Correspondence: mbauer@pk.edu.pl

Abstract: The COVID-19 pandemic is completely changing the transport customs of city residents. It has decreased the number of travels and has affected changes in the division of transport means. This article presents a case study of the city of Warsaw, attempting to describe the process of changes in the use of public transport in daily trips in the following months of the pandemic. Statistical data on the public transport offer, number of passengers, and tickets sold in 2017–2021, which are available in monthly and annual bulletins issued by the public transport organizer, were used. The knowledge base was supplemented with the results of surveys conducted among the city's residents. The obtained data were organized and analyzed using descriptive statistics methods. The study findings reveal that the lower use of public transport for travel during the COVID-19 pandemic is mainly due to the imposed limits on the number of passengers and is also linked to changes in the structure of the tickets purchased, especially a significant decrease in the sale of long-distance tickets, which implies the loss of a significant number of most valuable, regular users. It was also observed that the appraisal of public transport did not deteriorate, which allowed to expect with optimism the return of passengers after the pandemic. Therefore, a package of possible steps to be taken to restore confidence in public transport and to enable return of lost passengers is presented. The results of the analyses show how easily passengers can be lost and why it is so important to ensure the functioning of public transport even in crisis situations such as a pandemic. These results can also be applied in transport policy updates.

Keywords: COVID-19 pandemic; public transport; transport behaviors; revenues from tickets; passenger volumes

Citation: Bauer, M.; Bauer, K. Analysis of the Impact of the COVID-19 Pandemic on the Future of Public Transport: Example of Warsaw. *Sustainability* **2022**, *14*, 7268. https://doi.org/10.3390/su14127268

Academic Editors: Marianna Jacyna and Renata Żochowska

Received: 18 December 2021
Accepted: 8 June 2022
Published: 14 June 2022

1. Introduction

The COVID-19 pandemic has drastically changed the previous order of the world. Its most profound effect is the direct threat to the life and health of people on an unmatched scale. Almost 260 million people have been infected worldwide, and the total number of deaths has exceeded 5.1 million [1]. However, the number of people affected by the pandemic to a lesser or greater degree is much higher. The pandemic changed the lifestyle of the vast majority of residents, especially in places of high population concentration, such as cities [2]. The rules and conditions for fulfilling life needs have changed, including maintaining social ties, work performance, studying, and even spending free time. The global pandemic has significantly reduced economic activity and even led to threats to the financial stability of many countries [3–7]. Consequently, the COVID-19 pandemic could lead to many bankruptcies and insolvencies [8]. The pandemic also affected the sector of the economy that aims to enable realization of life objectives, that is, the transport of people and goods.

In the case of public transport, almost revolutionary changes occurred in the conduct of daily travel, particularly in urban areas [9]. With regard to functioning of the city transport system, the COVID-19 pandemic mainly caused three major changes in the use of transport:

- The number of travels made by the transport system users (residents and other users) has changed;
- The use of individual means of transport has changed; and
- The manner in which public transport is used by its users has changed.

The reduction in daily trips is closely related to the reasons for travel. When a significant part of the activity is shifted to virtual reality, the realization of life's needs can occur at the place of residence. This is what happened during the COVID-19 pandemic. At its various stages, according to the different decisions of the authorities of different countries, schools and colleges moved to remote or at least hybrid mode [10,11]. Although researchers analyzed the determinants of grade point average in the traditional mode of studying [12], it remains unknown how remote and hybrid modes will affect the performance of students. The labor market has also undergone significant changes [13–17], especially in the office sector [18]. During the COVID-19 pandemic, prospective employees realized that performing professional obligations from a home office is associated with disadvantages and should be rewarded by a salary premium [19]. The private life habits of the residents have also changed [20]. The online delivery market and the range of on-site services have grown [21].

The drop in the demand for public transport services has been a global phenomenon. According to the conducted analyses, some operators in the United Kingdom witnessed a decrease by 70% in this demand, and in the largest cities of China, Iran, and the USA, this decrease was 80–90%. In some cities such as Wuhan, the public transport was completely suspended. In contrast, in California and many Italian cities, it was limited to necessary travel [9]. Sweden recorded a 40–60% decrease in the number of passengers (depending on the region) [22]. A similar phenomenon was observed in Poland. Scientific research confirmed that government-imposed lockdown and social fears of COVID-19 caused a reduction in passengers' public transport demand in Poland [23]. A survey study conducted in the city of Gdańsk indicated abandonment or a marked reduction in the use of public transport during the pandemic. Among the respondents who reduced or abandoned the use of public transport, 75% planned to return to their previous mode of traveling after the end of the pandemic [24]. This implies a potentially permanent outflow of revenues from ticket sales from 25% of respondents who have limited their travels by public transport because they do not plan to return to their previous style of travel after the pandemic ends. A research study conducted in Stockholm concluded that the drop in demand depends on socioeconomic factors. The remedy for changes in transport behavior that affects revenues from ticket sales should be to adjust tariffs to the current conditions [25].

The abandonment or significant limitation of the use of public transport services is associated not only with the change in lifestyle and, for example, switching to remote work or learning, but also with the risk of coronavirus infection spread in public transport as suggested by the literature [26]. Reduction of the contribution of public transport in travel with the concomitant increase in the share of individual means of transport (car, bicycle, personal transport vehicles, e.g., electric scooters) was supported by incentives from the governments of individual countries. These activities were manifested, for example, by the opening of temporary bicycle paths in Bogota or promoting bicycle travel conditions for medical services and providing the location of docking stations near hospitals [9]. In the initial phase of the pandemic, during the isolation period, because of the reduced total travel volume, the greater use of private cars did not result in the increased number of kilometers traveled and congestion [27]. Moreover, the pandemic led to increased contribution of pedestrian and bicycle travels for professional, private, and recreational purposes [28].

During the isolation period and reduction in the use of public transport, increasing the share of individual forms of transport may also affect household finances, resulting in increased expenses on fuel, repairs of vehicles owned, or purchase of new vehicles. These issues, despite being significant from the social and economic standpoint, do not constitute the subject of the present study.

Considering that the indicated changes will have an impact on the number of tickets sold, there will be a reduction in the revenue of transport service providers. Therefore, the problem is also significant in terms of limiting revenues from ticket sales, which, as shown by studies from the pre-COVID-19 pandemic period, constituted a significant or even the main source of revenues for units responsible for implementing transport services in cities [29,30], and the drive to increase revenues was manifested through activities aimed at increasing the demand for public transport services [31]. During the pandemic, the considerable limitation of the use of means of public transport resulted in a decrease in its operator income and even financial issues [26].

It is commonly believed that the lower number of public transport users stems from the reduced travel demand and that personal safety considerations prompt people to select individual means of transport (car, bicycle, or personal transport vehicles) in their daily travels. Moreover, the fact that holding a ticket is a factor that can strongly affect the selection of the mean of transport, even in the situation of epidemic threat, is overlooked.

This article focuses mainly on a detailed presentation of changes in the number of public transport passengers in subsequent phases of the COVID-19 pandemic and in subsequent stages of the imposed passenger limits. Its purpose is to increase understanding of the process that may facilitate the introduction of measures to restore public confidence in public transport after the COVID-19 pandemic ends, which will enable the return of lost passengers.

2. Materials and Methods

The influence of the COVID-19 pandemic on the use of public transport by its users was discussed on the basis of a case study conducted for the city of Warsaw, the capital of Poland.

2.1. Case Study: Capital City of Warsaw (Poland)

Warsaw is a city with a surface area of 517 km^2 and is inhabited by 1.8 million people [32]. The public transport in Warsaw is managed by the Public Transport Authority, which organizes and supervises the functioning of the subway (two lines), streetcar, and bus transport throughout the Warsaw agglomeration. The superior function is fulfilled by the rail transport, implemented by companies: subway operator: Metro Warszawskie and streetcar operator: Tramwaje Warszawskie. Bus transportation is provided by many operators, the largest of which is Miejskie Zakłady Autobusowe. The transport system of the agglomeration also includes regional railways serviced by companies such as Szybka Kolej Miejska, Warsaw Commuter Railway, and Koleje Mazowieckie. In 2020, public transport vehicles realized a total transportation work of more than 238 million vehicle-km, of which subway trains completed more than 42 million vehicle-km, while streetcars completed more than 52 million vehicle-km [33].

According to the recent Comprehensive Traffic Study carried out in Warsaw in 2015 [34], on an average working day, the inhabitants made over 3.35 million journeys, and it was much more in 2019, with approximately 4.7 million journeys [35]. Public transport had and still has the largest share in daily journeys. The journeys made using public transport accounted for 47% of all journeys (2015), which placed Warsaw at the top of European cities with the highest contribution of public transport in travel. This is confirmed by various lists enabling the comparison of the division of transport tasks, including the reports of Deloittle [36] and numerous scientific publications such as: [37].

The city was not randomly selected for the analysis. Warsaw is the largest Polish city with the best development of public transport network, and it has allocated 18.3% of its budget to public transport in 2020 [38]. It is also a city where revenues from tickets, additional fines, and subsidies from municipalities with which it has signed contracts do not cover even 40% of the expenses for the purchase of public transport services, which in 2020 were record-high and amounted to over PLN 2.6 billion [39]. In the period 2017–2019, the percentage share of funds allocated for this purpose from the city budget amounted to 61–64%, and it increased to 75% in 2020 because of the pandemic (Figure 1).

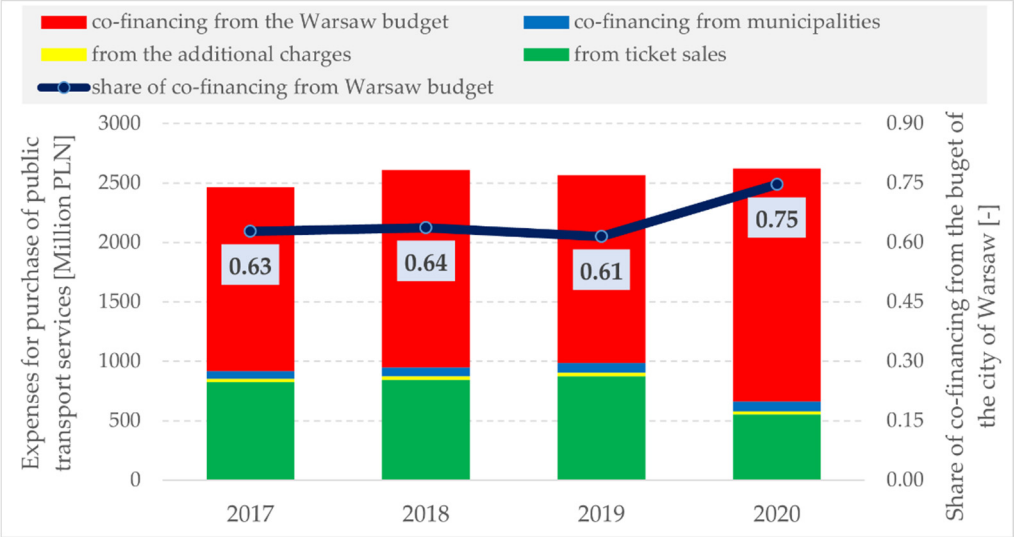


Figure 1. Coverage of expenses for the purchase of public transport services from 2017 to 2020 (author's own elaboration, based on [39]).

The above chart shows that Warsaw is a city that can lose a considerable amount of revenue following permanent reduction of public transport usage for travel. This does not only mean lost passengers but also severe economic effects. The fact that Warsaw is the only Polish city that offers such detailed data on the functioning of public transport in such a comprehensive and open manner was less important, but still significant in the selection of the city for the analysis.

2.2. Source of Data Used

The considerations presented in the article were based on official, publicly available monthly and annual bulletins [33] containing information on the functioning of public transport in Warsaw, published on the website of the Public Transport Authority, as well as publicly available reports on research on the transport behavior of the city's residents [40], periodically conducted as part of the Barometr Warszawski, organized by the Warsaw City Hall.

The monthly bulletins have been published since January 2017 and contain the following information on the functioning of public transport in Warsaw:

- organization of public transport (including specification of public transport lines, length and density of the network, amount of planned transport operations, scheduled number of vehicles serving the lines, locations for separate roadways, and lanes for public transport);
- implementation of transport (including performance of schedule tasks, list of irregularities in transport implementation, complaints and applications submitted by passengers, road events and vandalism, number of people entering the subway stations);
- commercial activity (including sales of tickets that include quantitative and type structure as well as sale channels, ticket control, and fine recovery efficiency, estimated number of people traveling without a ticket);
- explaining the used rolling stock of the urban communication (including number, division into size classes, vehicle equipment, differentiation of the rolling stock in terms of age and exhaust emission standards); and
- Park & Ride (P&R) and Bike & Ride (B&R) parking lots (location and number of spots on P&R and B&R parking lots, stop infrastructure for the public transport).

The present paper mainly uses data on the type and quantitative structure of tickets sold as well as the number of entries to subway line stations, divided according to types of validated tickets, in the period from January 2017 to June 2021. To understand the scale of the effect of the COVID-19 pandemic on the choices made by the residents, changes that

occurred in the years preceding the outbreak of the pandemic must be considered. This is particularly relevant when a city is still experiencing rapid development, which causes considerable changes in spatial management as well as enforces a continued development of the transport system. The analysis considered all available types of tickets: time-limit tickets (20 min), single tickets (regular, 75- and 90-min transfer and group tickets), short-term tickets (daily, weekend, and 3-day), and long-term tickets (30-day, 90-day, Senior tickets, Family 3 tickets, and employee tickets). The differentiation in terms of purchase channels was also considered: stationary ticket machines, mobile ticket machines, Internet sales, mobile ticket sales and other sales that include all possible points of sale.

The annual bulletins, apart from the annual data summaries reported on a monthly basis, also contain information on the transportation work (presented in vehicle-km) and punctuality of individual public transport subsystems, the value structure of tickets sold, and the number of passengers transported. These bulletins are supplements to monthly bulletins for the subsequent years of publishing statistical information on the functioning of urban communication, that is 2017–2020. The value structure of the tickets constitutes supplementation of the quantitative and type structure of tickets, which are part of monthly supplements. The number of passengers was estimated based on the ticket sales, assumed transfer coefficients, number of journeys per day, number of trips, and the amount of transport work performed. In this article, an estimated number of passengers transported by the available means of public transport was used: by agglomeration and regional rail (subway, Szybka Kolej Miejska, Warsaw Commuter Railway, Koleje Mazowieckie) as well as streetcars and public transport buses. On the other hand, the data on the value structure of tickets sold were given—as in the case of the analysis of data from monthly bulletins, classified into temporary, single, short-term, and long-term tickets.

The article further used the results of surveys carried out among the residents of Warsaw under the title Barometr Warszawski (In English: The Warsaw Barometer). These surveys are carried out since 2003, and two to four survey series have been realized each year. The survey includes the assessment of how residents feel about the city authorities and municipal services and the living conditions in the city, including safety, public transport, road condition, order and cleanliness, the quality of service provided to residents in the office, the quality of informing residents about issues important to them, public health, education, and sports, recreational, and cultural offerings. The respondents could also speak out on the frequency of using different means of transport and assess the quality of travel with those means of transport. An important element of the questionnaire are the questions regarding the directions of further development of the city in terms of investments and organization, including further development of the public transport system. Beginning from 2010, within the Barometr Warszawski, two series of studies are organized, which are typically conducted in June and November and are based on the CAPI method (Computer-Assisted Personal Interview, [41]) on a sample of 1100 respondents. An exception was made in 2020, when only one, September survey series was conducted. This was due to the restrictions related to the COVID-19 pandemic, but it is indeed a pity that the survey was not conducted in June, which could have provided more information on the variability of behavior and expectations of the residents during the ongoing pandemic. For the purpose of the present study, the data from surveys conducted in the period 2017–2020 were used, which were within the period of the issuance of the aforementioned bulletins containing information on the functioning of public transport.

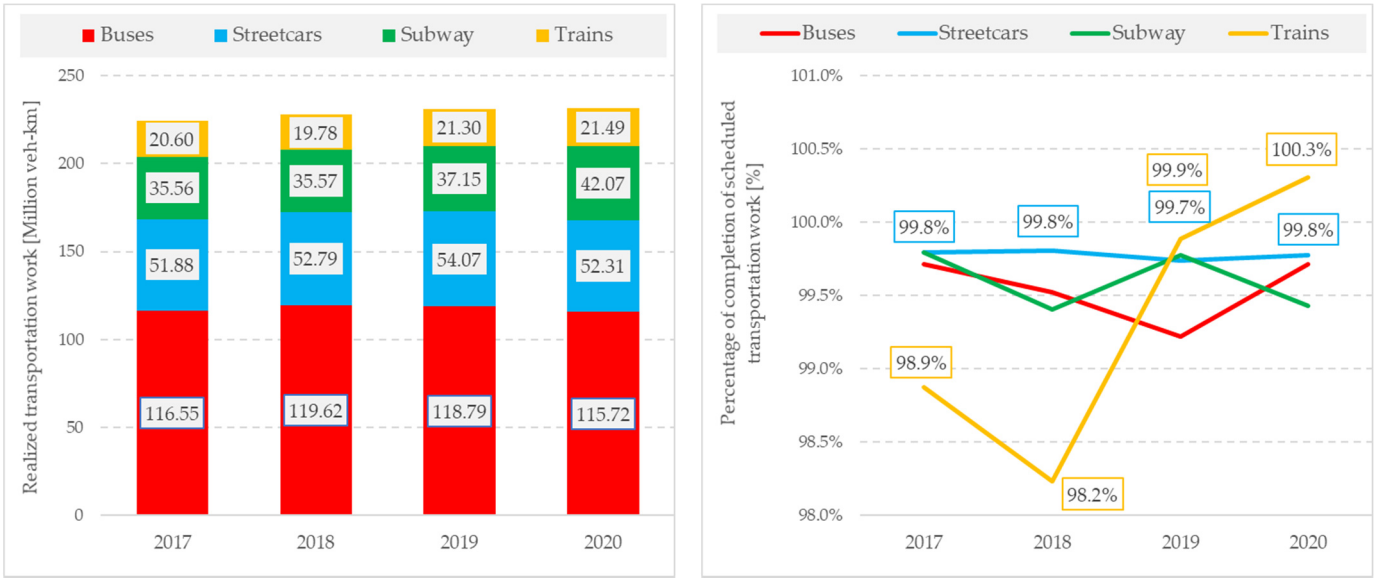
As one of the aims of the article is to show the scale of common changes in the use of public transport, the method of descriptive statistics was used to analyze the available data. According to the authors, this is a sufficient approach at the current stage of the research, in which the most important aspect is to understand the nature of the phenomenon of a sudden drop in the number of passengers and then a slow reconstruction of the passenger potential. Microsoft Office Excel and professional statistical software PQStat were used for statistical analysis [42].

3. Results

The COVID-19 pandemic has severely affected public transport operations. However, it is important to determine how great this impact is and whether it can be distinguished from other determinants of public transport use. For this purpose, we first determined the reference point, which is transportation offer, and then described the differences between the size of passenger flow before and during the COVID-19 pandemic and the number and structure of tickets sold, and finally whether the quality of public transport might be a factor in the scale of departures from public transport for daily trips.

3.1. Reference Point: Keeping the Public Transport Offer Unchanged

To analyze the impact of the COVID-19 pandemic on changes in the frequency of use of public transport, it was assumed that the work offered by the various subsystems, expressed in vehicle-km, remains constant. Fulfilling this condition implies that on a city scale, when no significant changes are made to the routes, the frequencies remain at a similar level. Figure 2 presents a comparison of the realized transport work between 2017 and 2020 (Figure 2a) as well as a comparison of the actual realization of the scheduled transportation work (Figure 2b).



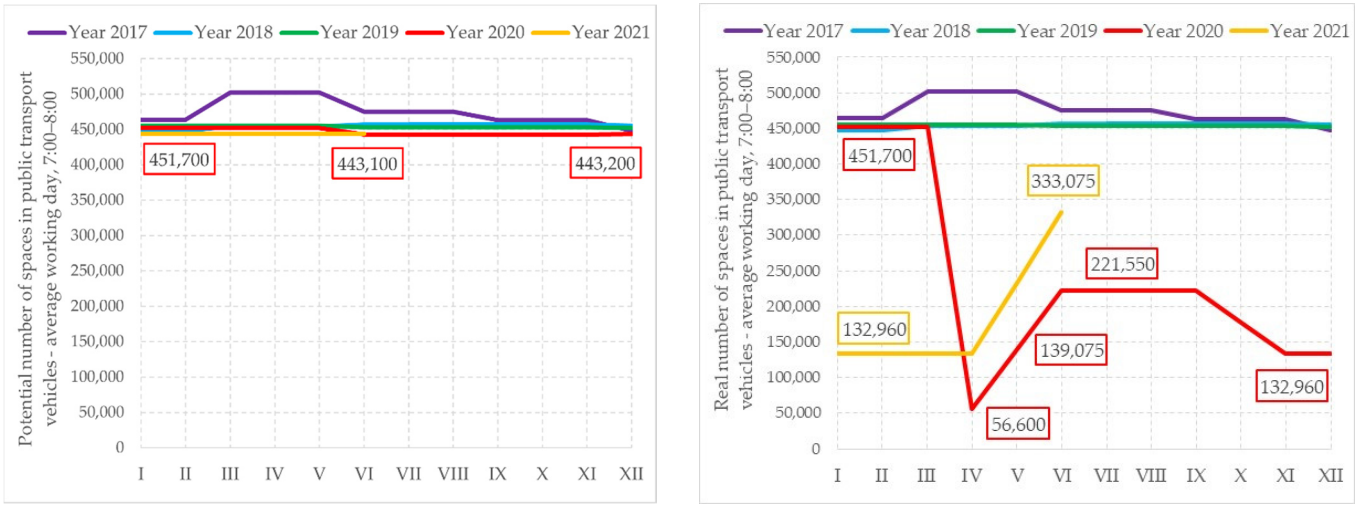
(**a**) (**b**)

Figure 2. Completion of the offered transportation work in Warsaw's public transport (bus, streetcar, subway and train), 2017–2020: (**a**) Transportation work [PT vehicle-km]; (**b**) Completion of offered transportation work [%] (author's own elaboration, based on [33]).

The total transportation work in the pandemic year 2020 increased by 1.2% as compared to that in the previous year, with an increase of 13% in the subway and a decrease of nearly 6% in streetcar and bus transportation combined. It should also be noted that in all the analyzed public transport subsystems, more than 99% of the planned transport work was realized. These results are better than those in the previous year. Therefore, it can be concluded that the availability of public transport vehicles did not change much during the pandemic.

During the pandemic, however, it was observed that the availability of vehicles does not necessarily mean the availability of space for passengers. Figure 3a presents a comparison of the total number of spaces on public transportation (subway, streetcar, bus, and rail) from 2017 to 2021 for a hypothetical situation in which there would be no pandemic, on an average weekday during the morning peak hour. Except for 2017, the

numbers are close to each other. For example, for June 2018, there were 1% fewer total spaces available in June 2019 and 3% fewer in June 2020 and 2021.

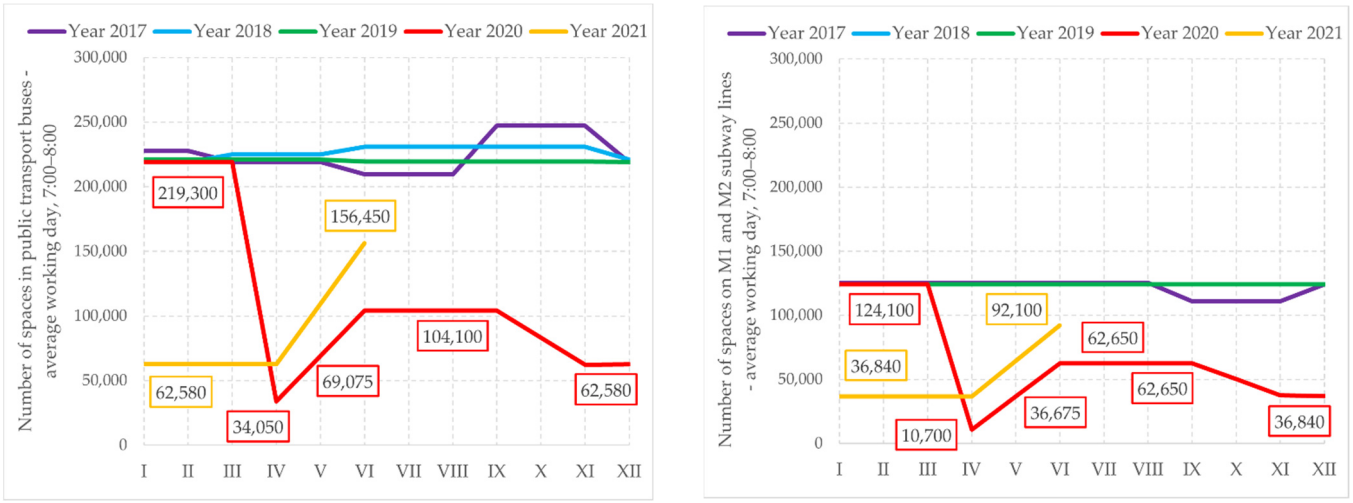


(**a**) (**b**)

Figure 3. Comparison of the total offered number of spaces (sitting and standing) in Warsaw's public transport vehicles (bus, streetcar, subway, and train) during the average working day and during the morning peak hour (7 a.m. to 8 a.m.), 2017–2020 [sps/h]: (**a**) No restrictions; (**b**) Real situation—reduced passenger capacity limits (own elaboration, based on [33]).

The passenger limits on public transport vehicles introduced during the pandemic, however, reduced the number of seats on offer [43]. The scale of the restrictions was varied. At the very beginning (from 25 March 2020), the maximum number of people in a public transport vehicle could not exceed half of the seats. Nearly 2 months later (as of 18 May), the limit on the number of passengers was raised to 30% of the nominal capacity (total seats and standing spaces), and 2 weeks later (as of 1 June), it was further increased to 50%. Another change occurred on 17 October, when the 30% passenger limit was reinstated, which was in effect until 14 May 2021, when the limit was raised to 50% of the nominal capacity. Subsequent limit changes occurred in the last month considered in this analysis. First, on 5 June, the limits were increased to 75% of the capacity, and on 26 June, the public transport passenger limits were eliminated (this change was not included in the analysis because of its short duration in the analyzed period until 30 June 2020). Changes in the total number of spaces offered in public transport vehicles as a result of the restrictions are shown in Figure 3b.

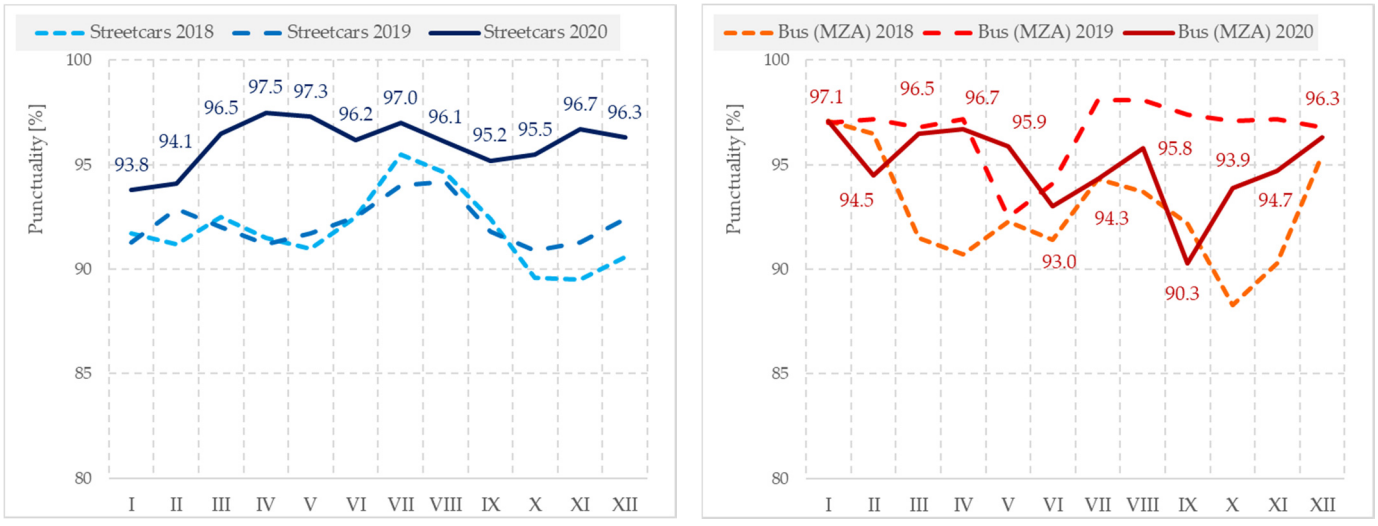
The limits introduced affected different public transport subsystems to varying extents. In the initial stage, when vehicle limits were based on the number of seats, rail transport (subway and streetcar) was the most affected. In April 2020, the period of the most radical restrictions, only 12.5% of total spaces were available: 8.6% in subways, 10.5% in streetcars, and 15.5% in buses. In the later stages of the restrictions, when the limits were related to the total number of spaces, the negative impact of the pandemic on public transport operations was mainly related to accessibility. The reduction in the number of available spaces was more severe for buses, which have the highest share of the transportation work. Consequently, bus service, which generally has a lower frequency than rail service (subway and streetcar), was particularly hard hit by reduction in spaces, as accessibility to the whole public transport system had declined. The differences in the number of available spaces on subways and buses are shown in Figure 4.



(**a**) (**b**)

Figure 4. Comparison of the number of offered spaces in bus and subway transport during the average working day and during the morning peak hour (7 a.m. to 8 a.m., 2017–2020 [sps/h]: (**a**) Buses; (**b**) Subway (author's own elaboration, based on [33]).

The quality of transport services was also considered, as it is important in the process of choosing the means of transport for daily trips. The available data on the punctuality of streetcars and buses in Warsaw were used [33]. It should be noted, however, that only one bus operator was considered: Miejskie Zakłady Autobusowe, which carries the highest number of vehicle-km. As a measure of punctuality, the statistical punctuality index was used to determine the share of punctual departures. The results of the index in the period 2018–2020 are presented in Figure 5.



(**a**) (**b**)

Figure 5. Punctuality of public transport means in Warsaw, 2018–2020 [%]: (**a**) Streetcars; (**b**) Buses (only Miejskie Zakłady Autobusowe) (author's own elaboration, based on [33]).

Generally, higher values of punctuality index were obtained for streetcar transport, which to a greater extent than bus transport makes use of separate lanes and priority in traffic signals. However, by far, the best results in the analyzed period were obtained in the pandemic year 2020 (on average: 96% on-time departures and a 4 pp. increase compared to that in 2018), and especially during the period of greatest restrictions (over

97% on-time departures). For bus transport, in 2020, there was a 1.7 pp. decrease in the value of the index compared to that in 2019, but a 2.1 pp. increase in relation to that in 2018. Moreover, throughout the analyzed period, monthly values were characterized by significant variability, for example, in 2020, the values ranged from 90.3% (September) to 97.1% (January).

This is undoubtedly influenced by fewer passengers and shorter dwell times at bus stops. Nevertheless, it can be concluded that quality was not a reason for passengers to reduce their use of public transport.

3.2. Number of Passengers Carried

The COVID-19 pandemic resulted in lower mobility of city residents, especially at the beginning, when the mechanism of virus spread was not yet known. A similar trend was noted in Warsaw. In 2020, at different stages of the pandemic, the number of trips relative to the pre-pandemic period was lower by up to nearly 25%, according to the already mentioned [35]), as shown in Table 1.

Table 1. Number of daily trips in the capital city of Warsaw—before and during COVID-19 pandemic (author's own elaboration, based on [35]).

Period	Before Pandemic April–June 2019	During 1st Phase of Pandemic March 2020	During 2nd Phase of Pandemic April 2020	During 3rd Phase of Pandemic May–June 2020
Number of daily trips	4,653,501	3,544,438	3,498,091	4,231,528
Decrease	-	23.8%	24.8%	9.1%

The decrease in the number of total trips was significant, but it was observed that during the third phase of the pandemic, the number of trips made began to approach the baseline. However, this was not fully reflected in the trips made by public transport. The annual statement shows that compared to the previous year, the total number of journeys made by public transport decreased by 40%. This is closely related to the restrictions imposed by the Polish government in response to the COVID-19 pandemic.

This implies that the public transport offer was significantly reduced, which in addition to the epidemiological threat may be another factor strongly discouraging potential passengers. This is particularly important for Warsaw, whose public transportation is based on the rail system.

A summary of the number of passengers carried in 2017–2020, categorized by subway, streetcar, bus, and agglomeration/regional rail (Szybka Kolej Miejska, Warsaw Commuter Railway, Koleje Mazowieckie—together) is presented in Figure 6.

The largest decrease in passenger numbers was recorded for streetcars and buses—43% and 41%, respectively; for heavy rail, it was much less: 33% (subway) and 34% (other railway means). Thus, it is apparent that the fastest public transport subsystems are less prone to losing passengers. The most worrying aspect, however, is the slowing down of the growing trend. Indeed, between 2017 and 2019, the total number of passengers increased by as much as 5%, which, at the scale of more than 1.1 billion trips per year, was a non-negligible effect.

Due to the availability of data for analysis, a more detailed approach was used for the subway network in Warsaw [44]. The network consists of two lines, where the M1 line with a total length of 23.1 km has been fully implemented (completed in 2008), while the M2 line with a planned length of 22.9 km is under construction—to date, the central sections with a total length of 13.1 km (57% of the final length) have been implemented. The data on the number of people entering the stations of two subway lines (M1 and M2) on a monthly basis was used. Thus, information was obtained on the entire assumed analysis period from January 2017 to June 2021 (Figure 7).

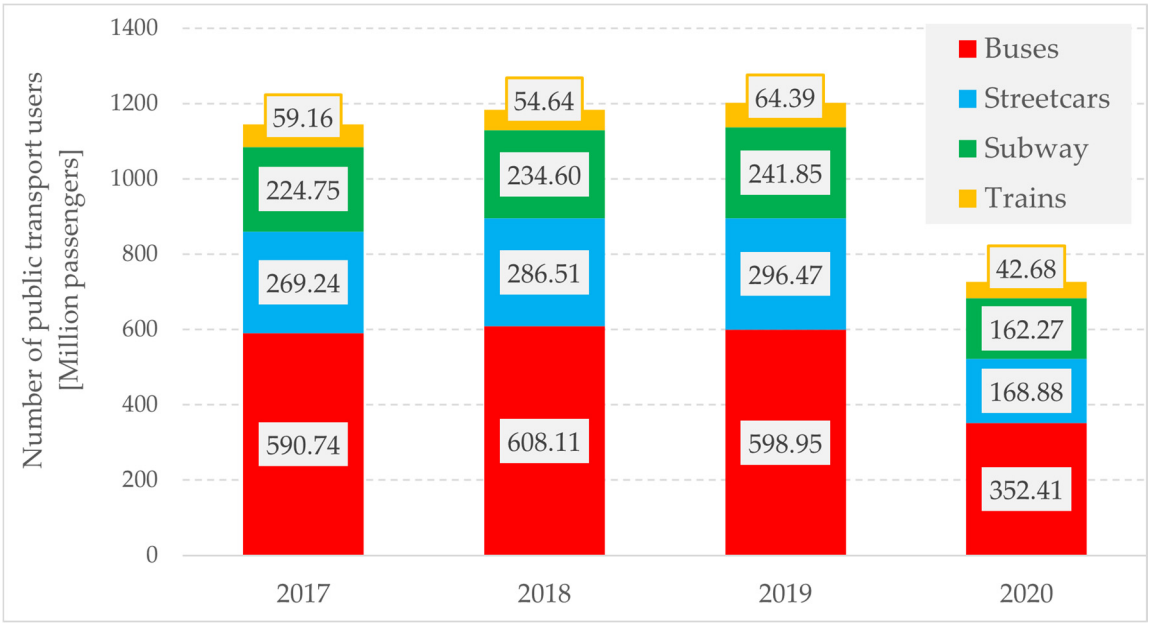
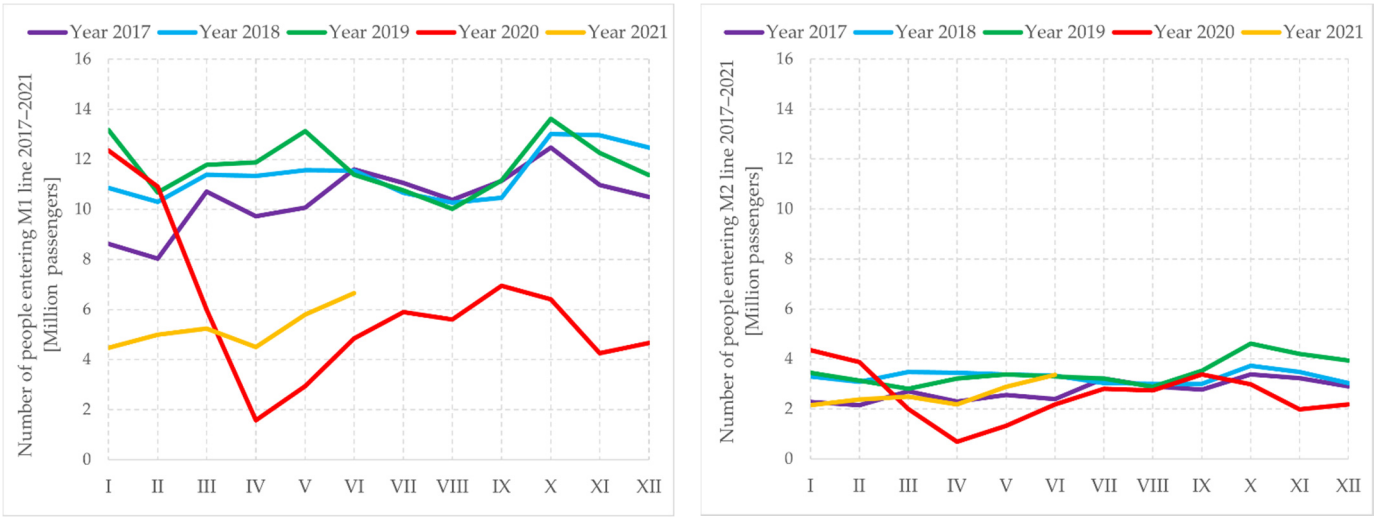


Figure 6. Number of passengers carried from 2017 to 2020 (author's own elaboration, based on [33]).



(**a**) (**b**)

Figure 7. Number of people entering subway line stations between January 2017 and June 2021: (**a**) Line M1; (**b**) Line M2 (author's own elaboration, based on [33]).

For the M1 line, on which the monthly passenger numbers occasionally exceeded even 13 million before the COVID-19 pandemic, major drops in users were recorded. While there are considerable similarities between the 2017–2019 performance, the sharp decrease in passenger numbers in April 2020 (decrease by as much as 87% compared to April 2019) is evident, as is the strenuous attempt to compensate for the loss, which culminated in September 2020, when the loss in relation to September 2019 was 38%. In contrast, in November 2020, the loss of passengers increased again, this time to a level of 65%, and then, there was a renewed increase in passenger numbers—in June 2021, the M1 line recorded passenger flows that were 42% lower than that in June 2019. The situation was different on the M2 line, which has not yet reached its full capacity. In this case, the reference point is completely different. The maximum monthly passenger numbers before the pandemic only exceeded the value of 4 million in the autumn-winter 2019/2020 period. During the

pandemic, the passenger numbers decreased by a maximum of 79% (comparison: April 2019 and 2020), and at the end of the study period, in June 2021—despite the pandemic—there was a 2% increase in passenger numbers (compared to that in June 2019).

3.3. Structure of Ticket Sale

The next step of the analysis estimates the number of tickets of different types purchased by passengers between 2017 and 2020.This considers the classification of tickets discussed in Section 2.2 (Figure 8).

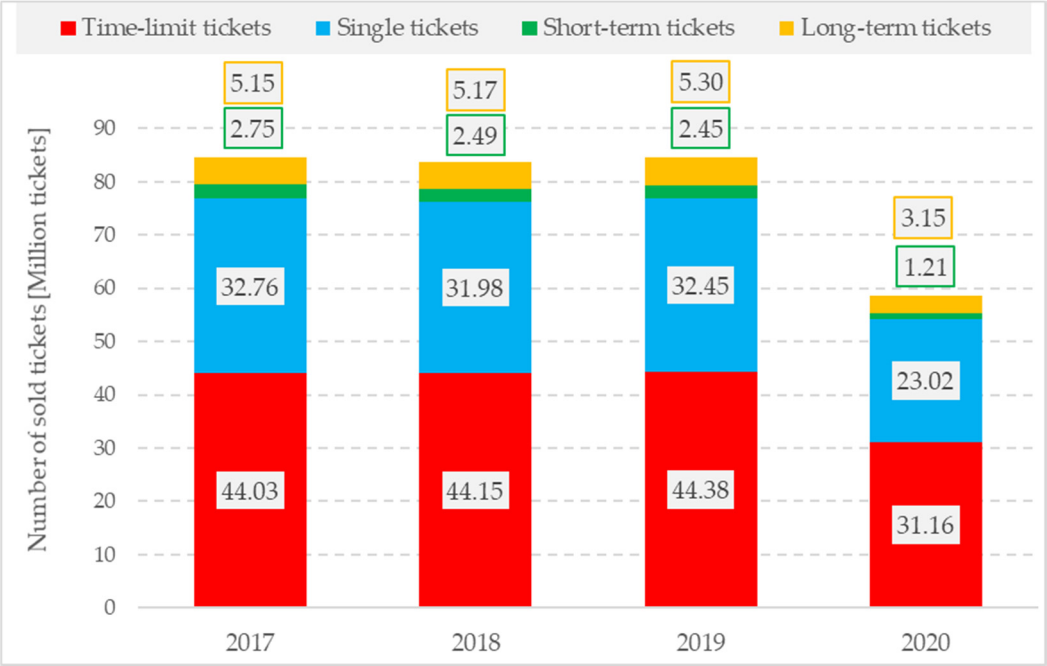


Figure 8. Number of tickets sold from 2017 to 2020 (author's own elaboration, based on [33]).

In terms of the absolute number of tickets sold during the analysis period, 2017 was a record year, with nearly 84.7 million total tickets sold. A very similar result was achieved in 2019 with 84.6 million tickets and slightly less in 2018 with 83.8 million tickets. In 2017, single and long-term tickets were mostly sold, while in 2019, passengers mostly purchased temporary and short-term tickets. Compared to 2017–2019, sales in the pandemic year of 2020 were significantly lower. At that time, 30% fewer timed tickets and 29% fewer single tickets were sold than in 2019. However, the largest percentage decrease in sales was observed for short-term and long-term tickets: 50% and 41%, respectively. Figure 9 presents trends in ticket sales from January 2017 to June 2021. For better visibility of the results, a tenfold reduced scale of the vertical axis was used in Figure 9c,d. Otherwise, it would be difficult to visualize the differences between the successive years.

Since the beginning of the COVID-19 pandemic and the implementation of public transport restrictions (March 2020), there was a decrease in the number of sales of all ticket types considered: time-limit, single, short-term and long-term tickets. Throughout 2020, until January 2021, sales of each type of ticket were lower than those in 2017–2019. However, starting from February 2021, the number of single tickets sold began to reach the level of 2019, and in June 2021, it achieved a record in the entire analyzed period of 2017–2021. On the other hand, in May and June 2021, sales of time-limit tickets also reached the level of 2019. Unfortunately, for short-term tickets and especially long-term tickets, the number of tickets sold was still much lower than that in 2019—by 32.5% and 35.0%, respectively (comparison of June 2019 and June 2021).

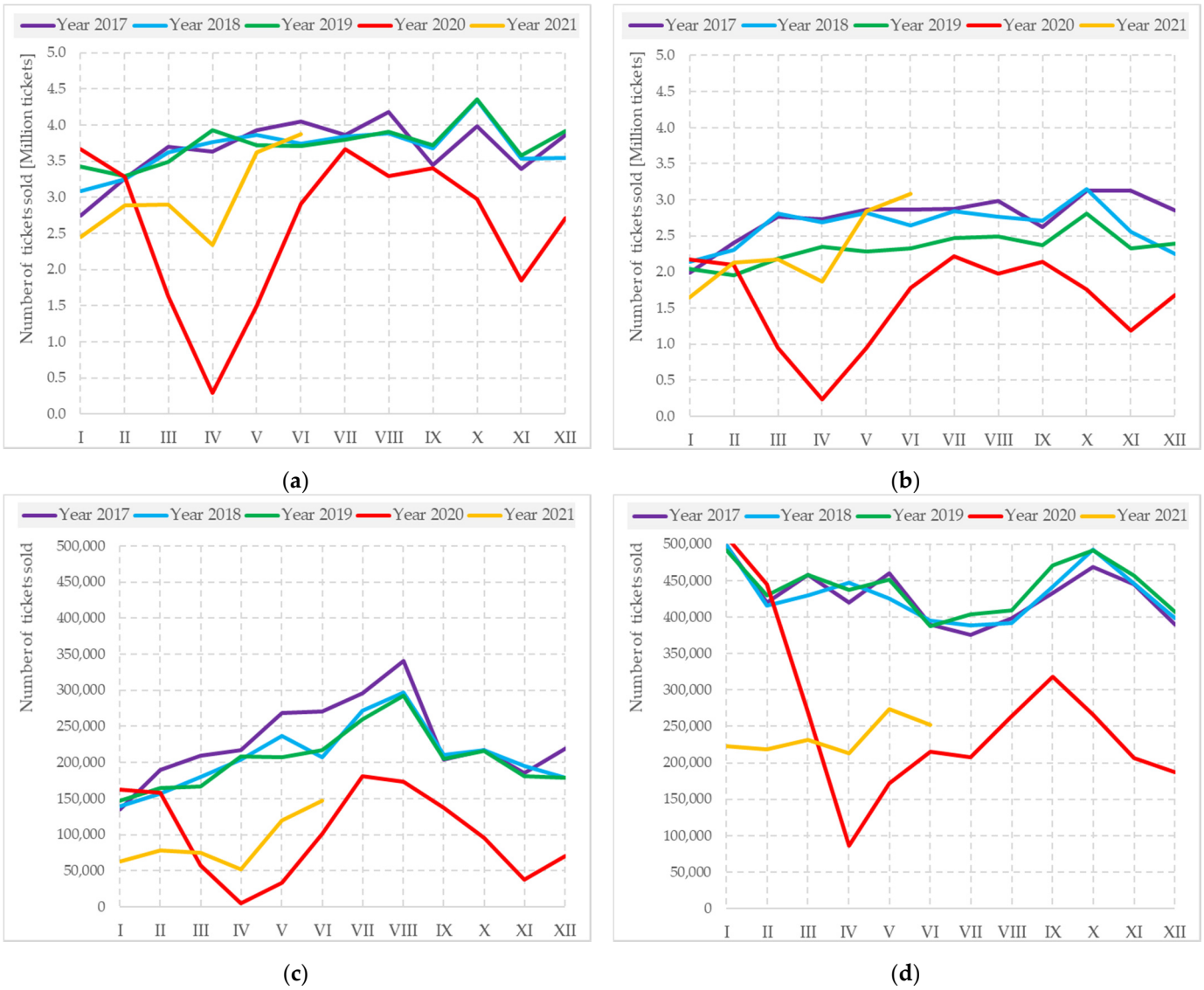


Figure 9. Number of tickets sold from January 2017 to June 2021: (**a**) Time-limit tickets (20 min); (**b**) Single tickets (regular, 75 and 90 min transfer and group tickets); (**c**) Short-term tickets (daily, weekend, and 3-day); (**d**) Long-term tickets (30-day, 90-day, Senior tickets, Family 3 tickets, and employee tickets) (author's own elaboration, based on [33]).

A further analysis checked the tickets used by passengers of the Warsaw subway. People who are entitled to free travel (pupil card holders, honorary blood donors, and others) were excluded. This information started to appear in bulletins [33] from January 2019 for the M2 line and from January 2020 for line M1. A summary of the number of entrances to subway stations according to the type of ticket held is shown in Figure 10. For better visibility of the results, the 10d plot uses a 10-fold larger scale. Subway is the fastest mode of urban transportation and is extremely competitive with other modes of transportation. Therefore, it is not surprising to see such a significant number of regular users with long-term tickets. A shorter comparison period than that used in previous analyses makes it difficult to interpret the results on the more frequently used M1 line. However, there is a general tendency for an increase in the number of entrances to subway stations in 2021, compared to the previous year (excluding the first 2–3 months, before the COVID-19 pandemic). The M2 line, on the other hand, was used by more passengers with time-limit and single tickets in 2021. In contrast, for the first time in June 2021, the number of entries with long-term tickets reached the pre-pandemic level.

The value structure of tickets sold was also analyzed for the period 2018–2020 (no data available for 2017 in bulletins [33]). Clearly, this structure differed significantly from the volume structure of tickets (Figure 11).

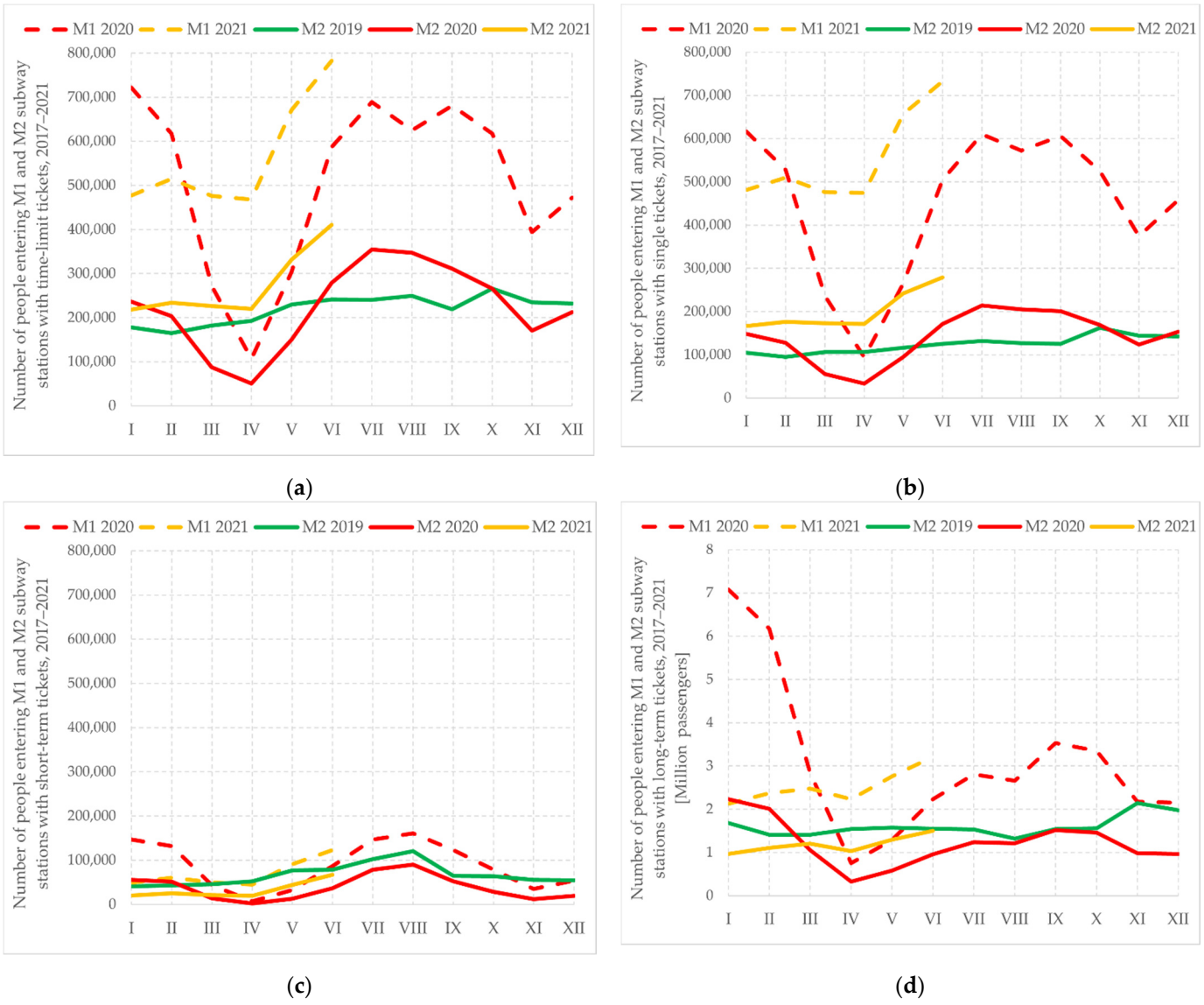


Figure 10. Number of persons entering M1 and M2 subway stations according to the type of tickets of tickets sold from January 2019 to June 2021: (**a**) Time-limit tickets (20 min); (**b**) Single tickets (regular, transfer, and group tickets); (**c**) Short-term tickets (daily, weekend, and 3-day); (**d**) Long-term tickets (30-day, 90-day, senior tickets, family 3 tickets, and employee tickets) (author's own elaboration, based on [33]).

Compared to 2019, the total ticket revenue in 2020 was decreased by as much as 40%. This decrease was across all four ticket types and was proportional to the decrease in ticket sales. In the time before the pandemic, the largest revenue came from long-term ticket sales; in 2019, it was as high as 69% of all ticket revenue. This trend did not change in 2020 either, and long-term ticket revenue was still the largest at 66%. This comparison fully shows how important, from the point of view of the city, is the effort to popularize long-term tickets.

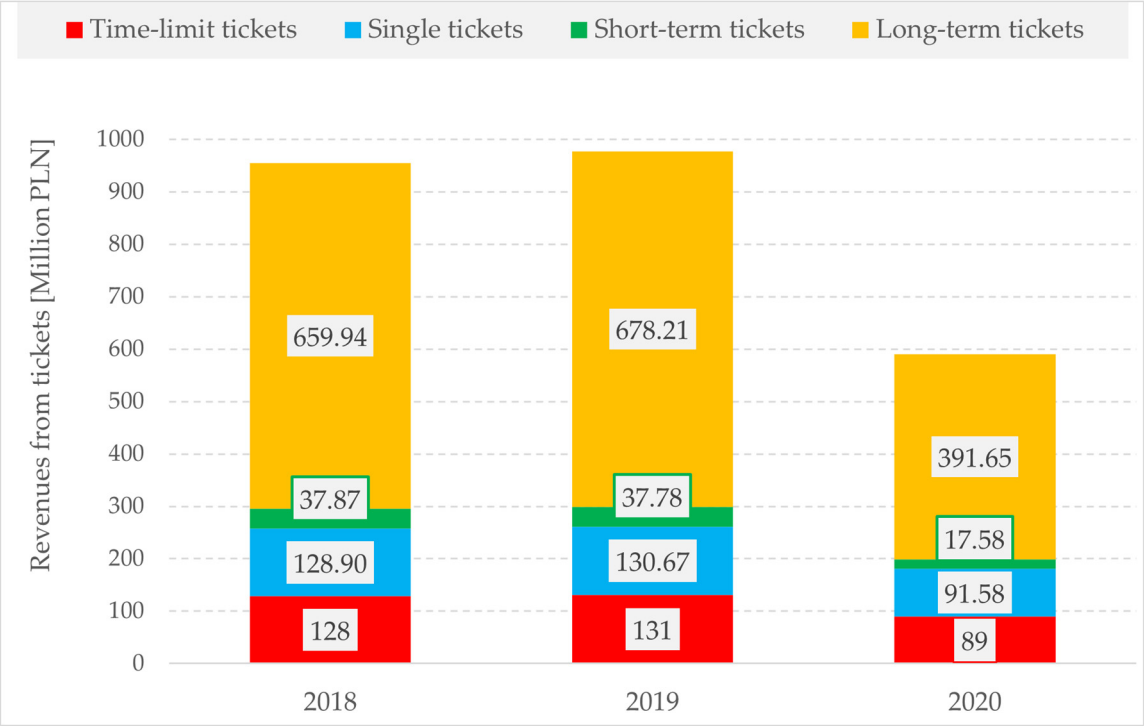


Figure 11. Revenues from tickets from 2018 to 2020 (author's own elaboration, based on [33]).

3.4. Residents' Assessment of Public Transport in Comparison with Other Means of Transport

Objective data on the number of passengers and the number and structure of tickets sold are complemented by user evaluations of the transport system. Ultimately, it is people's individual decisions about their choice of transport modes that result in greater or lesser use of those modes for travel. These decisions are based on subjective quality judgements made on the basis of personal experience. The best approach to obtain reliable information on travel is through Comprehensive Travel Studies, which were conducted in Warsaw in the years 1980, 1993, 1998, 2005 and for the last time in 2015. The COVID-19 pandemic prevented performing another series of surveys. Therefore, in this article, we decided to use the results of the Warsaw Barometer [40], which has been conducted continuously since 2003 and also during the pandemic—the last survey was conducted in September 2020. This is research conducted on a much smaller scale and is less accurate than the Comprehensive Travel Studies; nevertheless, it enables to obtain basic data on the evaluation and degree of utilization of various modes of transportation as well as on the opinions of the city's residents concerning the directions of its further development. Each time, the survey sample amounts to 1100 residents, which on the one hand allows for obtaining results that are insufficient for use in modeling the transportation system, but on the other hand is reliable enough to indicate the directions of the city's development.

Due to the results of the Barometr Warszawski, information is available on the frequency of use of different modes of transport before and during the COVID-19 pandemic. Although the simplest comparison would be to compare the results of 2019 and 2020, in the view of the very dynamic development of the city, this would be a very cursory approach, as it would not consider the halted dynamics of changes observed in the period preceding the pandemic. Therefore, it was decided to analyze the period 2017–2020, similar to the analysis of the number of passengers and the structure of tickets sold. During this period, the 2017–2019 surveys were conducted in two series: in June and November, while in 2020, exceptionally, only in September.

First, the frequency of use of different modes of transportation was analyzed. Trips made by public transport (according to the Barometr Warszawski methodology, combined: subway, streetcar, and bus), night public transport, car—as a driver and passenger, as well

as private bike and Veturilo public bike—were considered. Summaries from 2017–2020 based on Barometr Warszawski reports are presented in Figure 12.

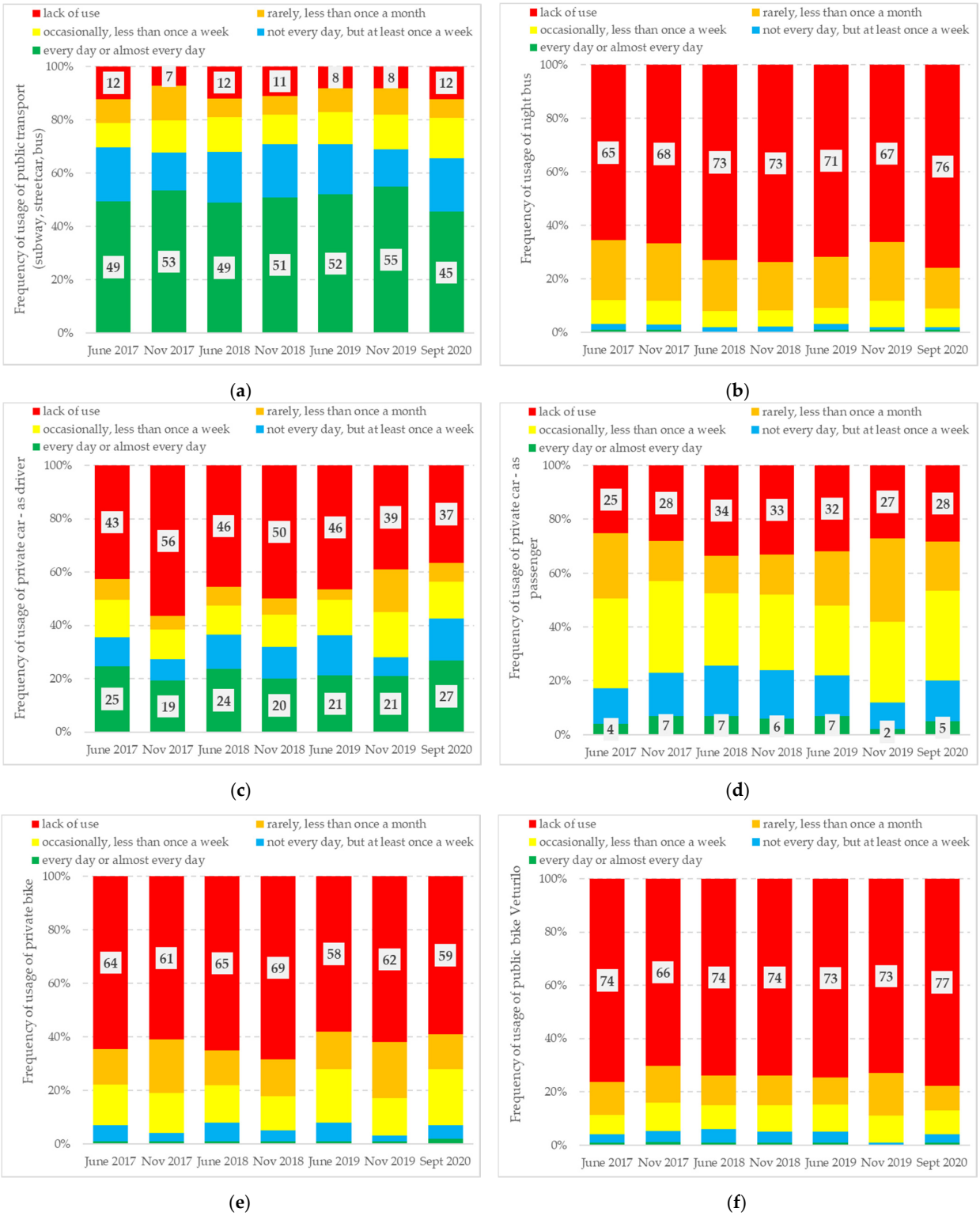


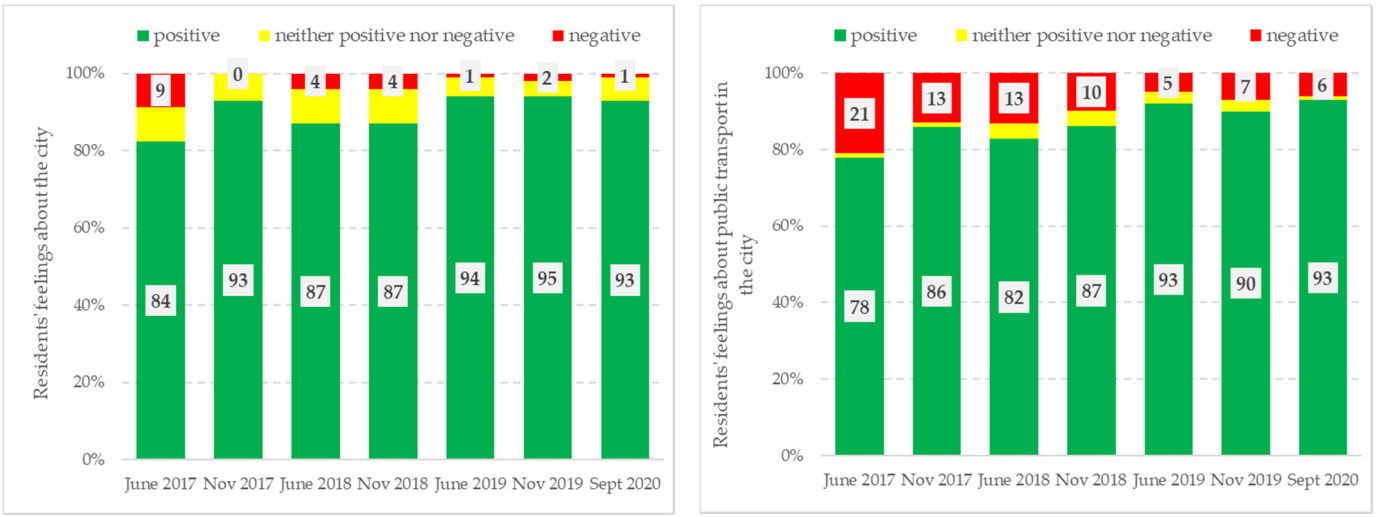
Figure 12. Frequency of the use of different means of transport by Warsaw residents, based on the results of the Barometr Warszawski, 2017–2020: (**a**) Public transport (subway, streetcar, and bus); (**b**) Night public transport (bus); (**c**) Private car—as driver; (**d**) Private car—as passenger; (**e**) Private bike; (**f**) Public bike Veturilo (author's own elaboration, based on [40]).

The above results reveal that in 2020, there was a significant decrease in daily use of public transport (by as much as 10 pp.) in favor of occasional use. This is the lowest share since 2017. Importantly, the share of people who avoided the use of public transport increased by 4 pp. as compared to that in 2019. The share of people not using night transport also increased.

In the case of trips made by car, the pandemic has reinforced the trend of increasing use of this mode of transport (as a driver). However, the scale of the increase is worrying—the share of people declaring to use a car every day increased by 6 pp., and the share of those declaring to use one at least once a week—by another 9 pp. At the same time, the share of those who do not use a car decreased by 2 pp.—in this case, a continuation of the trend was observed. On the other hand, no significant differences were observed in the frequency of using a car as a passenger.

With the decrease in the share of frequent use of public transport, the expected effect of the pandemic would be an increase in the share of cycling, and the Barometr Warszawski results partially confirmed this hypothesis. A slight increase in the occasional use of private bicycles was noted, while in the case of city bicycles, a decrease in the frequency of use was observed.

Since less use of public transport was found, it made sense to determine how public transport is perceived by users. For this purpose, the evaluation of public transport was compared with the general evaluation of life in the city. In this case, the respondents indicated whether their feelings were positive or negative, without further evaluation. They could also evade the answer and indicate a neutral rating. The results for the period 2017–2020 are presented in Figure 13.



(**a**) (**b**)

Figure 13. Assessment of the quality of life in the capital city of Warsaw, based on the results of the Barometr Warszawski, 2017–2020: (**a**) Residents' feelings about living in the city; (**b**) Residents' assessment of public transport (author's own elaboration, based on [40]).

A slight difference was observed between positive perceptions about living in a city and evaluation of public transport. Compared to 2017, there was a significant increase in such opinions in both cases, with the share of positive public transport ratings being more noticeable. Relative to the averaged ratings from the June and November surveys, ratings of living conditions in the city increased by 4.5 pp., and by as much as 11 pp. for public transport, However, a direct comparison with the year preceding the pandemic showed practically unchanged satisfaction levels—there was an average decrease of 1.5 pp. for living conditions in the city, while there was an average increase of 1.5 pp. for public transportation—(taking into account the average from the June and November surveys).

In both cases, the changes did not exceed the error of estimating the share of people who rate positively, which was only 1.5%. Therefore, it can be suggested that the perception of public transport is not significantly different from the perception of living conditions in the city. In contrast, the lack of a decline in the proportion of positive public transportation ratings during the pandemic indicates that residents are not linking less frequent use of public transportation to a decline in its quality (e.g., ride comfort mostly increased as a result of passenger reduction), but to the occurrence of the COVID-19 pandemic.

Therefore, it was considered worthwhile to compare the ratings of different modes of transport to unequivocally conclude that the decrease in the frequency of public transport use is an effect of the COVID-19 pandemic. For this purpose, the ratings of travel by different modes of transport (public transport, car, and bicycle) were compared. A summary of the average ratings determined from the Barometr Warszawski reports for the period 2017–2020 is shown in Figure 14.

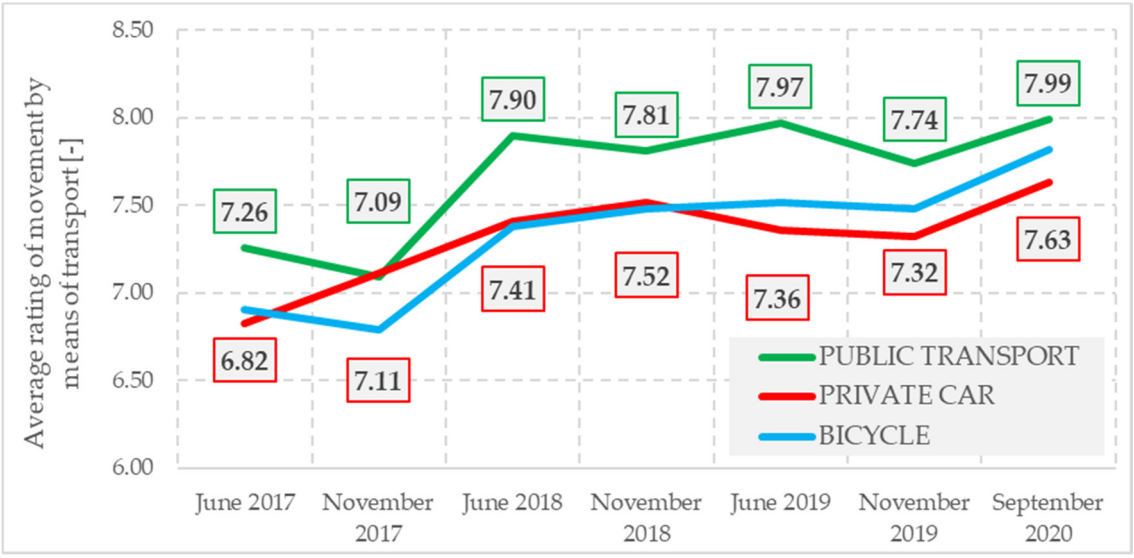


Figure 14. Residents' assessment of the quality of travelling around Warsaw by different means of transport: public transport (subway, streetcar, and bus), private car, and bicycle 2017–2020 (author's own elaboration, based on [40]).

From the figure, it is apparent that compared to the November 2019 survey, during the pandemic, the average rating for travelling by public transportation increased by as much as 0.25, whereas compared to the June 2019 survey, it remained almost unchanged. Importantly, however, an upward trend was noted. A similar trend was also observed for trips made by car and bike. The convergence with public transport ratings is very apparent for car trips.

4. Discussion

The results presented in Section 3 are summarized in the summary of the changes in passenger numbers and ticket revenue from 2018 to 2020 (for which full data were collected), as shown in Table 2.

The results of the conducted analyses give a certain picture of the phenomenon of decrease in the number of passengers who prefer public transport. That this decline will occur was obvious—especially with such a negative portrayal of public transport as a system responsible for virus transmission (which was not true). A more important aspect was the scale of passenger outflow (almost 40 pp.), which was strongly related to the scope of restrictions. It appears that public transport users were more deterred by the restrictions than by the virus itself. This is important because there is a strong correlation between the number of tickets sold and the number of passengers carried and the ticket revenue.

This implies that in addition to the negative social effect, there is a negative economic aspect, which unfortunately may result in a reduction in the range of transport services or an increase in ticket prices after the pandemic, at a time when the quality of the public transport offer will be the key to recover lost passengers.

Table 2. Summary statement of changes in passenger counts and ticket revenue in 2020 relative to that in 2018 and 2019 (author's own elaboration).

Indicator	Difference 2020–2018	Difference 2020–2019
Share of people using public transport at least once a week [%]	−4.5 pp.	−5.0 pp.
Number of passengers [prs/year]	−38.7%	−39.6%
Number of tickets sold [tickets/year]	−30.1%	−30.8%
Revenue from tickets [PLN/year]	−38.2%	−39.6%
Revenue per one ticket [PLN]	−11.5%	−12.8%
Revenue per one passenger [PLN]	0.8%	−0.1%

The key question raised in the article is, what will be the future of public transport after the COVID-19 pandemic ends? The answer is not simple because it is not known when the current pandemic will end and whether it is not one of many that will occur in the coming years. Therefore, we can talk more about scenarios than clear predictions. It is clear that regardless of accidentality, cities worldwide must be prepared to handle similar situations in the future. The current COVID-19 pandemic is not only a threat to human life and health, but it is also a giant testing ground that should be used to be better prepared for possible similar disasters in the future. It is a good time to start drawing conclusions, including those related to the functioning of the transport system in which—especially in the larger cities—the main role will still be played by public transport. First, it is necessary to know the nature of the pandemic, including in particular the mechanisms of virus spread, with particular emphasis on vehicles and the infrastructure of public transport. Today, it is already known that public transport has a relatively small share in virus transmission. This is confirmed, among others, by a study performed by the Robert Koch Institute [45]. Dissemination of knowledge about the ways and places of infection is crucial as it reduces the probability of applying apparently effective restrictions. The drastic decrease in passenger flow in the first months of the pandemic in Poland (April–June 2020) as a result of the imposed restrictions should serve as a warning against taking impulsive decisions, including the possible future application of restrictions on the number of passengers without a factual, professional analysis of the problem.

A return to the pre-pandemic situation seems possible, but it will certainly not be easy. The quality of public transport and its ability to recover passengers will be the key. This is evidenced by the previously presented ratings of public transport quality by Warsaw residents, which were still very high during the pandemic (93% satisfactory in September 2020). Thus, quality will not be a barrier, provided it is maintained or increased, in all aspects of public transport, from accessibility and reliability to the comfort and ticket prices.

There are, however, reasonable doubts about the chances of returning to old models of public transport development [46]. However, in addition to these doubts, there are also new opportunities to look at the shaping of transport behavior, to a greater extent than before considering the issues of health and sense of satisfaction of transport system users [47,48].

What, then, are the conditions that public transport must fulfill to perform its function after the COVID-19 pandemic? It will be crucial to undertake or continue to undertake measures to increase the attractiveness of public transport in terms of planning and design of infrastructure for public transport as well as in terms of traffic and transport organization [49]. This will enable to maintain or even improve its quality in all the most important aspects of operation [50–54]. This will entail providing:

- high availability to public transport in terms of space and time (proximity and ease of access to stops, range of daily services in response to social needs, satisfactory frequency, adapted to the various public transport subsystems);
- high level of public transport reliability (acceptable time of the entire travel (door-to-door) and its individual stages, invariability of the travel duration, high punctuality and regularity, low failure rate);
- high level of travel comfort (at each stage of the journey: convenient access to stops, friendly stop infrastructure, comfortable boarding, modern rolling stock, rare cases of vehicle overcrowding, high level of passenger information: at the stop, in the vehicle, on the Internet, in the phone);
- high level of personal safety (including the risk of infection during a pandemic) and transportation safety at every stage of travel (safe access, safe road and stop infrastructure, rapid response capabilities of emergency services);
- favorable tariff system that favors permanent public transportation users (relatively cheap season tickets for residents, ensuring the profitability of regular use of public transportation, and ticket integration with other forms of public transportation); and
- passenger-convenient transport network (line routing adapted to current needs, high level of time and space synchronization at interchanges, connection with P&R and B&R systems).

These groups of basic aspects of public transport performance were confronted with the results of the measurements and surveys of Warsaw, as discussed in Section 3. Only the aspect of safety was excluded, which is actually the factor whose impact on reducing passenger numbers and ticket revenue is being studied. Moreover, there are no data on the sources of COVID-19 infection in public transport in Warsaw. Groups of aspects were assigned evaluation indicators as well as changes in the values of indicators in the pandemic year 2020 in relation to the year immediately preceding the COVID-19 pandemic and the year 2018.

Comparisons were made between values and levels of annual performance in terms of the transportation work, punctuality, and the number of vehicle spaces offered, considering the restrictions introduced due to the COVID-19 pandemic (as a measure of availability). Vehicle capacity was also used as a measure of comfort, wherein the numbers of passengers transported were compared with respect to the nominal capacity of the vehicles (not including limits). The share of the most cost-effective long-term tickets was also compared as well as the level of resident satisfaction with public transportation in Warsaw. A summary of indicator evaluations is presented in Table 3.

Table 3. Comparison of indicators in years 2018–2020 (author's own elaboration).

Group of Features	Indicator	Difference 2020–2018	Difference 2020–2019
Availability	Transportation work [vehicle-km/year]	1.7%	0.1%
	Service capacity [sps/h]	−47.2%	−47.1%
Reliability	Completion of the scheduled transportation work [%]	0.3 pp.	0.2 pp.
	Punctuality index [%]	3.1 pp.	1.1 pp.
Comfort	Number of passengers per one space in public transport vehicles [prs/space/month]	−37.6%	−38.6%
User cost	Share of long-term tickets sold [tickets/year]	−2.8 pp.	−3.0 pp.
Convenience	Share of residents satisfied with public transport [%]	8.5 pp.	1.5 pp.

As shown in the table, the only factor that decreased in 2020 in comparison with that in previous years is the number of spaces offered in vehicles, which was artificially lowered because of COVID-19-related limits, on average by nearly half in comparison with that

in previous years. In contrast, the amount of work increased as well as the percentage of work carried out. Punctuality has improved, comfort has risen (although due to artificial restrictions), and the overall evaluation of public transport is satisfactory. This implies that there are no qualitative reasons for the decline in passenger interest in public transport. Thus, it is reasonable to conclude that the factor negatively influencing the number of journeys by public transport in Warsaw is the feeling of threat to personal safety and the related limits on the number of passengers. In fact, it is difficult to say what discouraged people from using public transport more: the actual risk of infection or the imposed limits on the number of people allowed to be inside public transport vehicles at the same time.

Paradoxically, during the pandemic, an improvement in the public transport offer in Warsaw was observed (an increase in transport work) as well as an increase in its quality (punctuality), despite a significant return to the initial number of daily trips. This has been achieved by maintaining a high level of traffic privileges for surface transportation vehicles (streetcars and buses), which cooperate well with the rail subsystems (subways, urban and regional rail). Thus, there is capital to increase the number of passengers and return to the trend of increasing passenger numbers that occurred in 2017–2019. Tariff policy also will be equally important here. It will influence, on the one hand, the pace of the eventual return of passengers and, on the other hand, the impact on profits from ticket sales, thus enabling the maintenance or expansion of the transport offer.

Therefore, there is a chance that passenger numbers will increase once the pandemic has receded. Some symptoms of this process have already been observed a few months after the start of the pandemic. After the initial shock of the infections, the number of journeys in Warsaw grew steadily, and in the first half of 2021, there were already significant reasons for optimism. It can also be expected with a high degree of probability that it will be easier to organize public transport, should the pandemic recur or another one emerges.

This article presents a detailed description of changes in the number of passengers as a result of the COVID-19 pandemic, with an attempt to identify the causes and consequences of this state of affairs. As the pandemic is not yet over, it is not possible to summarize its final effects. However, the authors hope to complete the post-pandemic research by considering statistical data and the opinion of residents after the pandemic. This will then allow the determination of the balance of the pandemic and its long-term consequences for public transport.

Author Contributions: Conceptualization, M.B. and K.B.; methodology, M.B.; software, M.B.; validation, K.B.; investigation, M.B. and K.B.; resources, K.B.; data curation, M.B.; writing—original draft preparation, K.B.; writing—review and editing, M.B.; visualization, M.B.; supervision, M.B.; project administration, M.B.; funding acquisition, M.B. and K.B. All authors have read and agreed to the published version of the manuscript.

Funding: The publication was co-financed from the subsidy granted to the Cracow University of Technology and from the subsidy granted the Cracow University of Economics—Project nr 3938/2022.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: All data used is publicly available on the following websites: https://www.ztm.waw.pl/en/statistics (accessed on 10 December 2021) and https://um.warszawa.pl (accessed on 10 December 2021).

Conflicts of Interest: The authors declare no conflict of interest.

References

1. WHO. Coronavirus (COVID-19) Dashboard. Available online: https://covid19.who.int/ (accessed on 29 November 2021).
2. Van Bavel, J.J.; Baicker, K.; Boggio, P.S.; Capraro, V.; Cichocka, A.; Cikara, M.; Crockett, M.J.; Crum, A.J.; Douglas, K.M.; Druckman, J.N.; et al. Using social and behavioural science to support COVID-19 pandemic response. *Nat. Hum. Behav.* **2020**, *4*, 460–471. [CrossRef] [PubMed]

3. Boot, A.W.; Carletti, E.; Haselmann, R.; Kotz, H.H.; Krahnen, J.P.; Pelizzon, L.; Schaefer, S.; Subrahmanyam, M.G. *The Coronavirus and Financial Stability*; SAFE Policy Letter No. 78; Leibniz Institute for Financial Research SAFE: Frankfurt am Main, Germany, 2020.
4. Barro, R.J.; Ursúa, J.F.; Weng, J. *The Coronavirus and the Great Influenza Pandemic: Lessons from the "Spanish Flu" for the Coronavirus's Potential Effects on Mortality and Economic Activity*; No. w26866; National Bureau of Economic Research: Cambridge, MA, USA, 2020.
5. Sarkodie, S.A.; Owusu, P.A. Global assessment of environment, health and economic impact of the novel coronavirus (COVID-19). *Environ. Dev. Sustain.* **2021**, *23*, 5005–5015. [CrossRef] [PubMed]
6. Bedrunka, K.; Mach, Ł.; Kuczuk, A.; Bohdan, A. Identification and analysis of structural fund support mitigating the effects of the COVID-19 pandemic in the EU—A case study of health unit funding. *Energies* **2021**, *14*, 4976. [CrossRef]
7. Ghiani, E.; Galici, M.; Mureddu, M.; Pilo, F. Impact on electricity consumption and market pricing of energy and ancillary services during pandemic of COVID-19 in Italy. *Energies* **2020**, *13*, 3357. [CrossRef]
8. Cochrane, J.H. *Coronavirus Monetary Policy. Economics in the Time of COVID-19*; Baldvin, R., di Mauro, B.W., Eds.; Centre for Economic Policy Research: London, UK, 2020; pp. 105–108.
9. UITP. *Public Transport Authorities and COVID-19. Impact and Response to a Pandemic*; International Association of Public Transport: New Zealand, Australia, 2020. Available online: https://www.lek.com/sites/default/files/PDFs/COVID19-public-transport-impacts.pdf (accessed on 20 November 2021).
10. Watermeyer, R.; Crick, T.; Knight, C.; Goodall, J. COVID-19 and digital disruption in UK universities: Afflictions and affordances of emergency online migration. *High. Educ.* **2021**, *81*, 623–641. [CrossRef] [PubMed]
11. Ahlburg, D.A. COVID-19 and UK universities. *Politic. Q.* **2020**, *91*, 649–654. [CrossRef] [PubMed]
12. Kurek, B.; Górowski, I. Importance of gender, location of secondary school, and professional experience for GPA—A survey of students in a free tertiary education setting. *Sustainability* **2020**, *12*, 9224. [CrossRef]
13. Bernstein, J.; Richter, A.W.; Throckmorton, N.A. *COVID-19: A View from the Labor Market*; Working Paper 2010; Federal Reserve Bank of Dallas: Dallas, TX, USA, 2020. [CrossRef]
14. Hoenig, K.; Wenz, S.E. Education, health behavior, and working conditions during the pandemic: Evidence from a German sample. *Eur. Soc.* **2021**, *23* (Suppl. 1), S275–S288. [CrossRef]
15. Lemieux, T.; Milligan, K.; Schirle, T.; Skuterud, M. Initial impacts of the COVID-19 pandemic on the Canadian labour market. *Can. Public Policy* **2020**, *46*, S55–S65. [CrossRef]
16. Schmid, L.; Wörn, J.; Hank, K.; Sawatzki, B.; Walper, S. Changes in employment and relationship satisfaction in times of the COVID-19 pandemic: Evidence from the German family Panel. *Eur. Soc.* **2021**, *23* (Suppl. 1), S743–S758. [CrossRef]
17. Hall, M.C.; Prayag, G.; Fieger, P.; Dyason, D. Beyond panic buying: Consumption displacement and COVID-19. *J. Serv. Manag.* **2021**, *32*, 113–128. [CrossRef]
18. Von Gaudecker, H.M.; Holler, R.; Janys, L.; Siflinger, B.; Zimpelmann, C. Labour Supply in the Early Stages of the COVID-19 Pandemic: Empirical Evidence on Hours, Home Office, and Expectations 2020. Available online: https://ssrn.com/abstract=3579251 (accessed on 20 November 2021).
19. Kurek, B. Expected Salary Premium for a Home Office—A Survey of Accounting and Controlling Students. In Proceedings of the 38th IBIMA Conference, Seville, Spain, 3–4 November 2021.
20. Biroli, P.; Bosworth, S.; Della Giusta, M.; Di Girolamo, A.; Jaworska, S.; Vollen, J. Family life in lockdown. *Front. Psychol.* **2021**, *12*, 687570. [CrossRef] [PubMed]
21. Dsouza, D.; Sharma, D. Online food delivery portals during COVID-19 times: An analysis of changing consumer behavior and expectations. *Int. J. Innov. Sci.* **2020**, *13*, 218–232. [CrossRef]
22. Jenelius, E.; Cebecauer, M. Impacts of COVID-19 on public transport ridership in Sweden: Analysis of ticket validations, sales and passenger counts. *Transp. Res. Interdiscip. Perspect.* **2020**, *8*, 100242. [CrossRef] [PubMed]
23. Wielechowski, M.; Czech, K.; Grzęda, Ł. Decline in mobility: Public transport in Poland in the time of the COVID-19 pandemic. *Economies* **2020**, *8*, 78. [CrossRef]
24. Przybylowski, A.; Stelmak, S.; Suchanek, M. Mobility behaviour in view of the impact of the COVID-19 pandemic—Public transport users in Gdansk case study. *Sustainability* **2021**, *13*, 364. [CrossRef]
25. Almlöf, E.; Rubensson, I.; Cebecauer, M.; Jenelius, E. Who continued travelling by public transport during COVID-19? Socioeconomic factors explaining travel behaviour in Stockholm 2020 based on smart card data. *Eur. Transp. Res. Rev.* **2021**, *13*, 31. [CrossRef]
26. Budzynski, M.; Luczkiewicz, A.; Szmaglinski, J. Assessing the risk in urban public transport for epidemiologic factors. *Energies* **2021**, *14*, 4513. [CrossRef]
27. De Vos, J. The effect of COVID-19 and subsequent social distancing on travel behavior. *Transp. Res. Interdiscip. Perspect.* **2020**, *5*, 100121. [CrossRef]
28. Czódörová, R.; Dočkalik, M.; Gnap, J. Impact of COVID-19 on bus and urban public transport in SR. *Transp. Res. Proced.* **2021**, *55*, 418–425. [CrossRef]
29. Buehler, R.; Pucher, J. Making public transport financially sustainable. *Transp. Policy* **2011**, *18*, 126–138. [CrossRef]
30. Bauer, K.; Bauer, M. Influence of Seasonality on the Value of Revenues from Ticket Sale in Public Transport. In *Digitalization in Finance and Accounting*; Springer Proceedings in Business and Economics; Springer: Berlin/Heidelberg, Germany, 2021; pp. 255–264. [CrossRef]

31. Matas, A. Demand and revenue implications of an integrated public transport policy: The case of Madrid. *Transp. Rev.* **2004**, *24*, 195–217. [CrossRef]
32. Statistics Poland. Local Data Bank. Available online: https://bdl.stat.gov.pl/BDL/start (accessed on 10 November 2021).
33. Public Transport Authority in Warsaw. Available online: https://www.ztm.waw.pl/en/statistics/ (accessed on 5 November 2021).
34. Kulpa, T.; Szarata, A. Development of the Transport Model for the Masovian Voivodeship. In *Contemporary Challenges of Transport Systems and Traffic Engineering*; Lecture Notes in Networks and Systems; Springer: Berlin/Heidelberg, Germany, 2017; pp. 193–203. [CrossRef]
35. Olszewski, P.; Brzeziński, A.; Dybicz, T.; Jesionkiewicz-Niedzińska, K.; Osińska, B.; Szagała, P.; Szymański, Ł. Modeling of mobility Changes Caused by the COVID-19 Pandemic in Warsaw on the Basis of Data on SIM Card Movements. Presented at the XIII Conference Communication Problems of Cities under Conditions of Vehicular Congestion, Poznan-Rosnowko, Poland, 22–24 September 2021. (In Polish)
36. The 2020 Deloitte City Mobility Index. Available online: https://www2.deloitte.com/xe/en/insights/focus/future-of-mobility/deloitte-urban-mobility-index-for-cities.html (accessed on 10 November 2021).
37. Hebel, K.; Wołek, M. Change trends in the use of passenger cars on urban trips: Car-pooling in Gdynia. *Sci. J. Sil. Univ. Technol. Ser. Transp.* **2017**, *96*, 37–47. [CrossRef]
38. Mayor of the Capital City of Warsaw for 2020. *Report on the Implementation of the Budget of the Capital City of Warsaw for 2020*; Warsaw, Poland, 2021. Available online: https://bip.warszawa.pl/Menu_przedmiotowe/budzet_polityka_finansowa_v2/wykonanie_budzetu/2020/Sprawozdanie_z_wykonania_budzetu/Kompendium/default.htm (accessed on 10 December 2021). (In Polish).
39. Public Transport Authority in Warsaw. Report 2020. Available online: https://www.ztm.waw.pl/wp-content/uploads/2021/03/Raport_roczny_2020-1.pdf (accessed on 8 November 2021).
40. Available online: https://um.warszawa.pl/ (accessed on 8 November 2021).
41. Nikolić, T.M.; Pantić, S.P.; Paunović, I.; Filipović, S. Sustainable travel decision-making of Europeans: Insights from a household survey. *Sustainability* **2021**, *13*, 1960. [CrossRef]
42. Więckowski, T. *PQStat Software*, version 1.6.8; PQStat: Poznan, Poland. Available online: https://pqstat.pl/ (accessed on 10 November 2021).
43. Bauer, M.; Dźwigoń, W.; Richter, M. Personal safety of passengers during the first phase COVID-19 pandemic in the opinion of public transport drivers in Krakow. *Arch. Transp.* **2021**, *59*, 41–55. [CrossRef]
44. Available online: https://www.metro.waw.pl/metro-w-warszawie (accessed on 20 November 2021).
45. Buda, S.; an der Heiden, M.; Altmann, D.; Diercke, M.; Hamouda, O.; Rexroth, U. Infektionsumfeld von erfassten COVID-19-Ausbrüchen in Deutschland. *Epidemiol. Bull.* **2000**, *38*, 3–12.
46. Vickerman, R. Will COVID-19 put the public back in public transport? A UK perspective. *Transp. Policy* **2021**, *103*, 95–102. [CrossRef]
47. Budd, L.; Ison, S. Responsible transport: A post-COVID agenda for transport policy and practice. *Transp. Res. Interdiscip. Perspect.* **2020**, *6*, 100151. [CrossRef]
48. Zhang, J.; Hayashi, Y. Impacts of COVID-19 on the Transport Sector and Measures as Well as Recommendations of Policies and Future Research: Analyses Based on a World-Wide Expert Survey. Available online: https://ssrn.com/abstract=3611806 (accessed on 10 December 2021).
49. White, P. *Public Transport: Its Planning, Management and Operation*, 1st ed.; Routledge: London, UK, 2016. [CrossRef]
50. Vuchic, V.R. *Urban Transit: Operations, Planning, and Economics*, 1st ed.; John Wiley & Sons Inc.: Hoboken, NJ, USA, 2005; pp. 534–540.
51. Bauer, M.; Kisielewski, P. The influence of the duration of journey stages on transport mode choice: A case study in the city of Tarnow. *Sustainability* **2021**, *13*, 5922. [CrossRef]
52. Gołębiowski, P.; Żak, J.; Kisielewski, P. The selected problems of public transport organization using mathematical tools on the example of Poland. *Teh. Glas.* **2020**, *14*, 375–380. [CrossRef]
53. Jacyna, M.; Kotylak, P. Decision-making problems of collective transport development in terms of sustainable urban mobility. *J. KONBiN* **2020**, *50*, 359–375. [CrossRef]
54. Popova, O.; Gorev, A.; Shavyraa, C. Principles of modern route systems planning for urban passenger transport. *Transp. Res. Proced.* **2018**, *36*, 603–609. [CrossRef]