Centre for Research on Settlements and Urbanism

Journal of Settlements and Spatial Planning

Journal homepage: http://jssp.reviste.ubbcluj.ro/eng/index.html

First Year of COVID-19. The Impact of Pandemic Waves on Public Transport Usage in Cluj-Napoca, Romania

Titus-Cristian MAN[1], **Camelia-Florina ANDOR**[2], **Elena-Manuela BÎRSĂNUC***[3]

** Corresponding author*

[1] *Babeş-Bolyai University, Faculty of Geography, Department of Regional Geography and Territorial Planning, Cluj-Napoca, ROMANIA*

[2] *Babeş-Bolyai University, Faculty of Mathematics and Computer Science, Cluj-Napoca, ROMANIA*

[3] *Babeş-Bolyai University, Faculty of Geography, Doctoral School of Geography, Cluj-Napoca, ROMANIA*

titus.man@ubbcluj.ro https://orcid.org/0000-0001-9331-054X

camelia.andor@ubbcluj.ro https://orcid.org/0000-0002-1124-7805

elena.birsanuc@ubbcluj.ro https://orcid.org/0000-0003-0162-474X

DOI: 10.24193/JSSP.2022.2.02 https://doi.org/10.24193/JSSP.2022.2.02

Keywords: *COVID-19, transport ridership, ETL, transport user type, card validation, urban public transport*

ABSTRACT

The global pandemic of COVID-19 has had a significant influence on public transportation usage and service provision. As many countries begin to return to normality, new public transportation planning standards are being developed. Considering these new standards, there is a critical shortage of understanding the possible impact of the pandemic on public transportation systems and models that can help service planning face these challenges. This paper analyzes data collected in Cluj-Napoca (Romania), from late-February 2020 to late-March 2021. As local authorities began to remove restrictions aimed at limiting the propagation of the SARS-CoV-2 virus, the study investigates the travel changes in various modes of transportation, travel plans, and user categories. Results confirm that low-income groups depend on public transit the most; consequently, they had considerably lower declines in usage during the COVID-19 pandemic. This study also identifies various daily average patterns of demand for public transportation in Cluj-Napoca throughout each stage of the pandemic. All of these data contribute to extending the global understanding about COVID-19's influence on transport usage by comparing these outcomes with the ones from other cities. They offer pertinent information for transportation authorities to develop adaptation policies to a major event like this pandemic. Although there is still apprehension about using public transportation, the collected data show that the regular public transport users from before the pandemic have been gradually returning to their transport of choice once the restrictions have been relaxed (March-May 2020).

1. INTRODUCTION

On March 11, 2020, the World Health Organization (WHO) declared COVID-19 a pandemic, prompting many countries to impose social distancing regulations or planned lockdowns (Afifi et al., 2020; Xu and Li, 2020). Schools, shops, workplaces, public transportation, and many other sectors were influenced by the social distancing measures (Anderson et al., 2020; Lewnard and Lo, 2020). During the COVID-19 pandemic, most states reported a significant drop in public transportation usage (Aloi et al., 2020; Beck and Hensher, 2020; Beck, et al., 2020; De Haas et al., 2020; Bucsky, 2020; Budd and Ison, 2020; De Vos, 2020; Islam et al., 2020; Jenelius and Cebecauer, 2020; Teixeira and Lopes, 2020; Tiikkaja and Viri, 2021). Scholars have been debating how to sustain urban mobility for a long time, with many studies concluding that transportation decision-making should be merely a reflection of sustainable development and city quality of

life, since most cities face increasing motorization and mobility demands (Foltynova et al., 2020; Canitez et al., 2020). In this regard, the pandemic has contributed to the understanding of the necessity of active mode of transportation (bicycles) in addition to the increasing desire to utilize private cars. Several cities that increased their cycling networks to relieve demand on public transportation during this period (New York, Oakland, Milan, Paris, Bogota, and Brussels) were documented (Budd and Ison, 2020; Nurse and Dunning, 2020; Zhang, 2020). The main characteristics of public transport systems influencing the decisions regarding transport mode for a person are connectivity, prices, journey time, comfort, security, timeliness, dependability, directness, multimodality, sustainability (Witter, 2010; Mozos-Blanco et al., 2018). Additionally, social characteristics (car ownership, age, social status, member of a vulnerable group, gender) are factors that are proved to directly influence mobility choices.

In this context, assessing the effects of the COVID-19 pandemic (Fatmi, 2020; Kuzemko et al., 2020; Pase et al., 2020; Ahangari et al., 2020) on transportation patterns (Deponte et al., 2020; Dyer and Kolic, 2020; Saini and Saini, 2020) demands multidisciplinary research (Pullano et al., 2020; Nian et al., 2020) in order to attain a multidimensional (Alamo et al., 2020; Aleta et al., 2020), and comprehensive view (Linka et al., 2020; Warren and Skillman, 2020; Chang et al., 2021).

Despite the fact that lockdowns and a growth in teleworking have greatly limited movement, some individuals have adjusted their transportation habits, changing to personal vehicles and cycling. Some studies suggest that public transport needs to shift structurally, and the road back to pre-pandemic conditions will be difficult and complex (Dunning and Nurse, 2021). Long-term consequences may also lead to the development of more substantial changes connected to smart working (implying Artificial Intelligence, cloud data processing, etc.) and also other everyday activities, decreasing travel requirements. As a general trend, in the early stages of COVID-19 pandemic due to governmental regulations and public health concerns, public transportation service providers around the world have limited their operation schedule, cancelled certain services, and closed specific facilities (Askitas et al., 2020; Aloi et al., 2020; Jenelius and Cebecauer, 2020).

Scholars have approached the impact of COVID-19 on public transportation from two perspectives (Pozo et al., 2022): (1) addressing the responses and actions adopted by public authorities (Tirachini and Cats, 2020) in order to minimize the risk of contagion, and (2) analyzing the effects of the COVID-19 pandemic in public transport using various data sources (surveys, location-based tracking data, fleet management systems, applications for transit navigation, mobile applications, and data from transport companies) for mobility patterns estimation (Askitas et al., 2020; Wei et al., 2021; Pozo et al., 2022; Zhang et al., 2022) in several countries and metropolitan or urban areas: United States (Liu et al., 2020), Australia (Beck et al., 2020), Chile (Astroza et al., 2020), Turkey (Shakibaei et al., 2020), Switzerland (Molloy et al., 2020), Sweden (Jenelius and Cebecauer, 2020), Hong-Kong (Zhang et al., 2021), Spain – Madrid Community (Pozo et al., 2022), and Spain – Santander (Aloi et al., 2020).

The goal of this research is to look into the consequences of the COVID-19 pandemic on mobility practices in Cluj-Napoca and Cluj Metropolitan Area (CMA), Romania (Fig. 1), particularly in terms of public transportation routine for travel and commuting needs. CMA is comprised of 23 territorial administrative urban and rural units (including Cluj-Napoca, third largest city of Romania) with a total area of 2,000 sqkm, a population of 450,000, and 5 territorial administrative units with more than 10,000 residents. Based on real time reports from Smart Card Data (SCD) systems we used information regarding ticket/card validations between February 2020 and March 2021 to give a data-driven analysis of the influence of COVID-19 on the demand for public transportation in CMA. This time span includes the de-escalation stages of the pandemic in Romania.

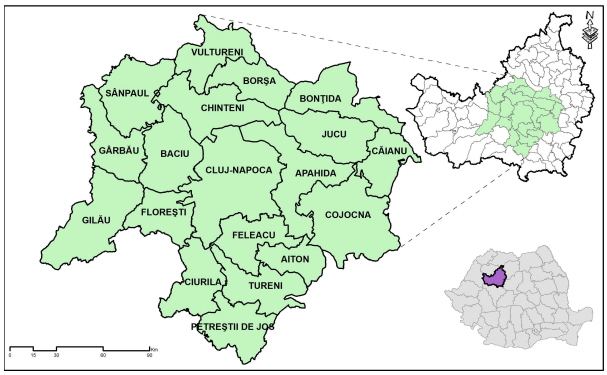

Fig. 1. Study area: Cluj-Napoca and Cluj Metropolitan Area, Romania.

2. MATERIALS AND METHODS

2.1. Data

Public transportation ridership data were provided by the metropolitan transportation company of Cluj (CTP – Compania de Transport Public) as daily SQL (Structured Query Language) dump files. Specific characteristics of the passengers were extracted using database queries in order to determine: number of passengers per day, number of passengers/routes, number of passengers per time interval, social status of the passengers. The analyzed interval was divided in three specific periods: pre-pandemic (February 27, 2020 – March 15, 2020), state of emergency – national lockdown (March 16, 2020 – May 15, 2020), state of alert (May 16, 2020 - March 31, 2021).

2.2. The Extract-Transform-Load Process

This section presents the ETL (Extract-Transform-Load) process. All source data was available as data dumps. The database management system (DBMS) used was MariaDB (see more information on MariaDB at https://mariadb.org/) since all data contained in the data dumps was originally stored in this DBMS.

We designed an ETL data processing pipeline with the purpose of extracting, cleaning, transforming and loading all data into its destination database, where the analysis process takes place. The ETL data processing pipeline consists of three phases: a). Extraction phase: we restored all the data dumps necessary, one data dump at a time. Each data dump contains data registered for a distinct date of a year; b). Transformation phase: the data was cleaned and transformed, one batch at a time (a batch refers to the data from a single restored dump); c). Loading phase: each cleaned and transformed batch was then loaded into the destination database, also known as data warehouse.

In the following, we present the detailed description of the ETL data processing pipeline.

2.3. Extract-Transform-Load Data Processing Pipeline

2.3.1. Extraction Phase

The data dump is restored. After restoring the data dump, its data is available inside a database that contains various tables.

2.3.2. Transformation Phase

At this step, all data contained in the batch is cleaned and transformed. From the restored data dump, we select data about tickets and card validations. The selected data is cleaned, transformed and then stored in the staging database. The name of the staging database is transport staging. This database contains two staging tables, in which data about tickets and card validations will be temporary stored. The database commands used to create the staging database and its tables can be found in Appendix 1.1, while the procedure that cleans, transforms and stores in the staging database the selected data from the restored dump is available in Appendix 1.2.

2.3.3. Loading Phase

In this phase, the resulting cleaned and transformed data from the previous step is loaded into the destination database, also known as data warehouse. The destination database is called transport and contains one table. All data about tickets and card validations will be stored in this table for data analysis purposes. The database commands used to create the destination database and its table can be found in Appendix 2.1, while the procedure that loads the cleaned and transformed batch of data from the staging database into the destination database is available in Appendix 2.2.

This ETL data processing pipeline was used to process each data dump. After all data dumps were processed, the resulting data was ready for analysis in the destination database. Consequently, the statistical analysis focused on identifying changes in transport usage for different social groups (students, seniors, low-income and vulnerable people) and for different pandemic stages (pre-pandemic, state of emergency, state of alert, during weekdays and weekends).

3. RESULTS AND DISCUSSION

The research is focused on alterations of public transport ridership in CMA induced by the introduction of social-distancing restrictions because of the COVID-19 pandemic. These changes are analyzed through a statistical approach of the changes in ticket type usage and user demographics, as well as in daily transport patterns during both weekdays and weekends. Given the restriction policies adopted in CMA, we foresee a decrease in daily public transport ridership, as well as changes in user types and demographics.

3.1. Analysis of total ridership

The daily number of validations in Cluj-Napoca's public transportation system is depicted in Figure 2.

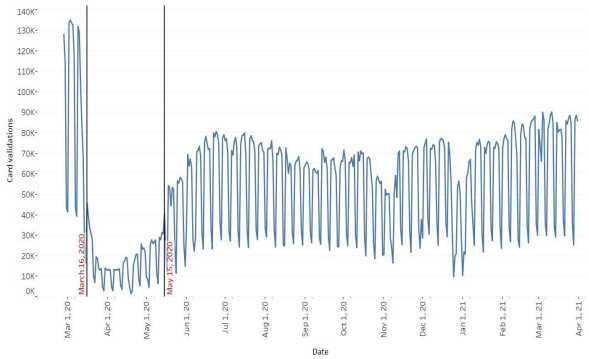

Fig. 2. Daily number of travels using public transport *(data source: CTP, 2021).*

The start and the end of the national lockdown and the issuance of the State of Emergency in Romania are indicated by the vertical lines. Additionally, the several COVID-19 pandemic stages and waves in Romania can be identified in the chart. It is clear that daily ridership sharply decreased just before the State of Emergency was declared, continued to decline during the emergency period (with the fewest validations), and then slowly started to increase again.

Additionally, we can see the anticipated weekend impact (fewer validations on Saturdays and Sundays), the seasonal effect of the holiday season in July - August 2020, and how validations began to gradually improve in September, revealing values that were still significantly less than those recorded prior to the pandemic eruption. Autumn 2020 and winter season 2020 marked the second wave of COVID-19 in Romania, with decreasing values of card validations. A similar trend is registered at the beginning of February 2021 due to travels and vacations in the holiday season. However, even when the demand for public transportation starts to progressively increase as the de-escalation stages begin, the number of card validations barely reached the half of its pre-pandemic level.

3.2. Analysis of ridership change per ticket type

Figure 3 illustrates how COVID-19 altered public transportation usage based on the type of ticket purchased. While in pre-pandemic period the average number of daily card validation was of 89,919 during the state of emergency, due to lockdown and limited services availability (operational schedule, operational frequencies on transport lines, cancelation on come transport lines) (CTP, 2020), this number decreased to 16,604 rides/day (March 16, 2020 – May 15, 2020) and during the state of alert, it increased to more than 55,000 daily card validations.

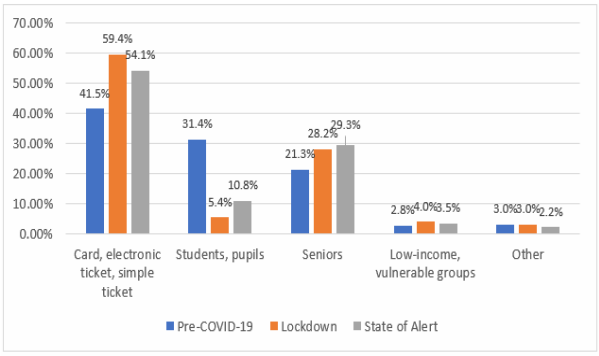

Fig. 3. The variation in the daily number of validations by user type (percent of total daily ridership).

By examining the precise ridership displayed by each user type, we may be able to learn key information about the unique responses of various demographic groups to the COVID-19 pandemic. In this regard, we detect several temporal differences in ridership change and note that the decline in demand for public transportation was not consistent throughout this group of individuals. For adolescents, children, seniors, low-income, and disadvantaged groups, CTP offers reduced rate tickets. The variation in the daily number of validations by user type compared to the baseline level is shown in Figure 3 for three stages: pre-pandemic, state of emergency and state of alert.

While in pre-pandemic conditions a high percent of public transport users were students and pupils (31.4%), this percentage drastically reduced during both state of emergency (less than 6%) and state of alert (less than 11%). The September 2020 reopening of schools and institutions led to a persistent upward trend till late-November 2020, when the second wave of COVID-19 was registered in Romania.

As the greatest risk category, seniors witnessed the second-largest decline in the usage of public transportation (Figure 4) during state of alert, but maintaining a high percentage from total number of commuters. However, it is the first group of users who make extensive use of public transport as soon as the restrictions were lifted showing the dependence on the public transport system.

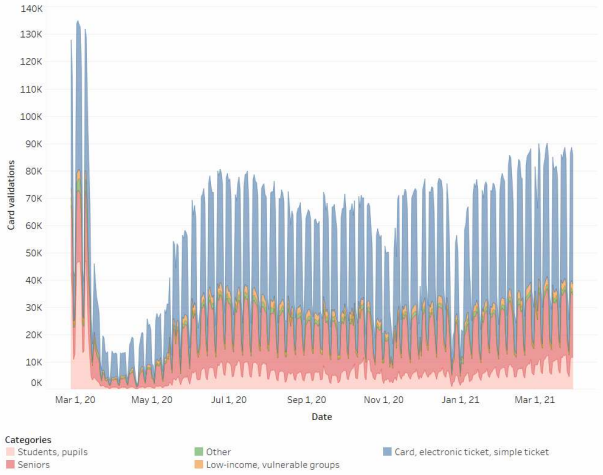

Fig. 4. Daily number of travels using public transport by user categories *(data source: CTP, 2021)*.

Moreover, the number of travels by paper tickets increased in lockdown (state of emergency) compared to the period before the COVID-19 pandemic (Fig. 5) and continued to be preferred by a larger number of people during the state of alert. Thus, a shift towards more adjustable tickets is noticed, as the regularity of daily travels is altered by local policies designed to combat the pandemic. This travel choice reflects a new pattern of the local mobility behaviour that is based more on occasional travels and less on regular, subscription-based travels.

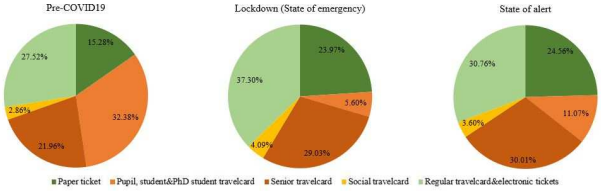

Fig. 5. Share of travels using public transport by ticket type *(data source: CTP, 2021)*.

One of the most intriguing conclusions of this research is that throughout the most challenging months of the pandemic (March and April 2020) and during the de-escalation phase, the number of card validations for low-income and vulnerable groups have suffered the least decline. This finding is consistent with other studies that found low-income and historically

disadvantaged populations were more reliant on public transit (Pozo et al., 2022).

Another important finding focused on travel behaviour is revealed by the analysis of occasional transport tickets (usually individual paper-based tickets). The usage of these showed a positive trend in the early stages of COVID-19 pandemic. Moreover, in the early stages of state of alert (May-July 2020) the number of occasional travellers was higher than the number of commuters using electronic tickets and travel cards illustrating not only a non-constant usage of public transport services, but also a lack of confidence in the sanitation conditions provided by public transportation system (Shakibaei et al., 2020).

3.3. Analysis of ridership change per travel time

In addition to the general weekly patterns previously displayed, in this section we look at the temporal variations in the use of public transportation over the course of a day (Fig. 6). The objective is to investigate the various public transport demand mobility patterns in relation to the COVID-19 pandemic evolution in Cluj-Napoca.

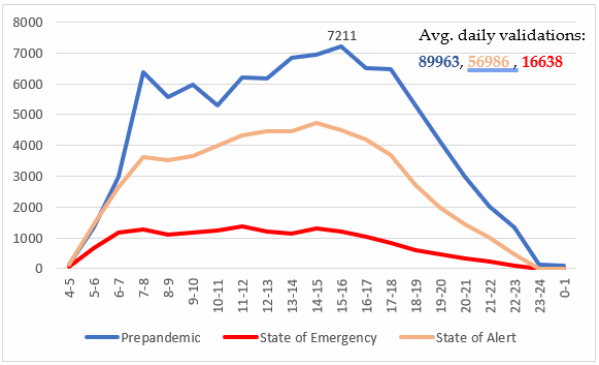

Fig. 6. The average daily riding patterns *(data source: CTP, 2021).*

Two relevant patterns can be depicted from the chart analysis. First, it is a quite notable drop in the average number of validations/day: with more than 80% during the State of Emergency and with almost 40% during the State of Alert. Second, we determined that the shapes of travel patterns are significantly varied. Even if the morning commute peak is much diminished, it still manifests at the expected time. Additionally, the midday peak is still there but has a diminished amplitude; in fact, the peak between 15 and 16 is relocated one hour earlier (14 to 15), becoming the highest ridership for the whole day. In the afternoon (17-18), the third peak nearly vanishes.

When the analysis is restricted only to weekdays (Monday-Friday) (Fig. 7) the above-mentioned patterns are even more visible (a drop of 82% card validation during lockdown, and 42% during the State of Alert). Additionally, it can be noticed the existing trend in the early hours of the day (4-5 a.m., 5-6 a.m.), when the number of commuters before and after the lockdown is almost equal, which states that there are specific labour groups (essential activities not qualified for remote work) highly dependent on public transport services.

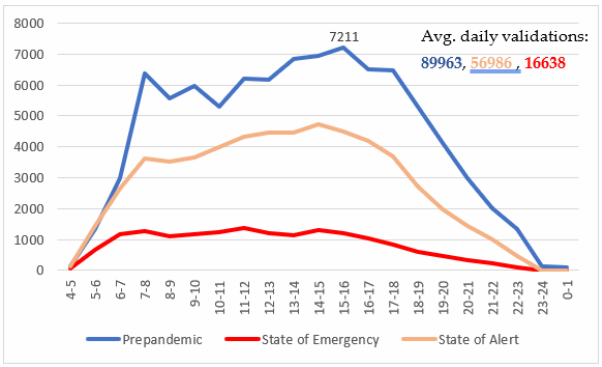

Fig. 7. The average daily riding patterns (Monday to Friday) *(data source: CTP, 2021).*

Figure 8 illustrates the travel patterns over the weekend. As expected, beside the highest decrease of card validations (83.5%) compared against travel patterns prior to COVID-19, the general trend before and after lockdown is similar, being related to the general behaviour during weekends (midday activities).

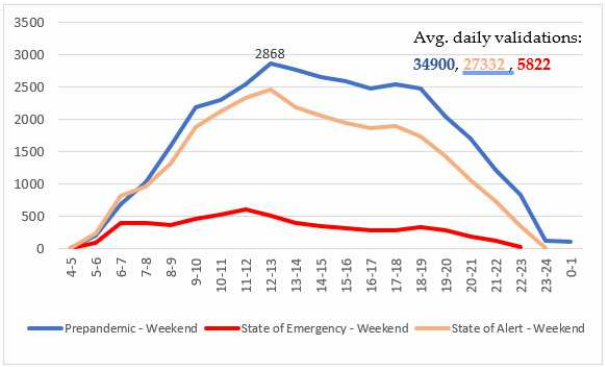

Fig. 8. The average daily riding patterns (Weekends) *(data source: CTP, 2021).*

The analysis of daily average card validations (Fig. 9) during February 27, 2020 – March 31, 2021, aggregated every 60 min., showed average daily card validation by most important categories of public transport. Thus, the highest decrease in card validations is determined in the group of students and pupils, as a direct consequence of online education and learning. These values are minimal during lockdown, slightly higher after May 2020, but still very far from those registered prior to the COVID-19 outbreaks (less than 25% from the baseline in every time interval). Showing some variations in the daily averages, the group of seniors has a similar travel pattern in all the stages of pandemic waves, with late-morning and midday activities.

The average number of card validations for seniors showed a sudden decline when lockdown was declared (25-75% depending on the time of the day), however during the state of alert this number recording similar values to those determined before March 16,

2020 (less than 10%). A similar trend is registered in the group of commuters that are using travel cards, electronic tickets and simple tickets, showing that the public transportation system in CMA was recovering, being directly related with the economic activities, commuting for work or university/school.

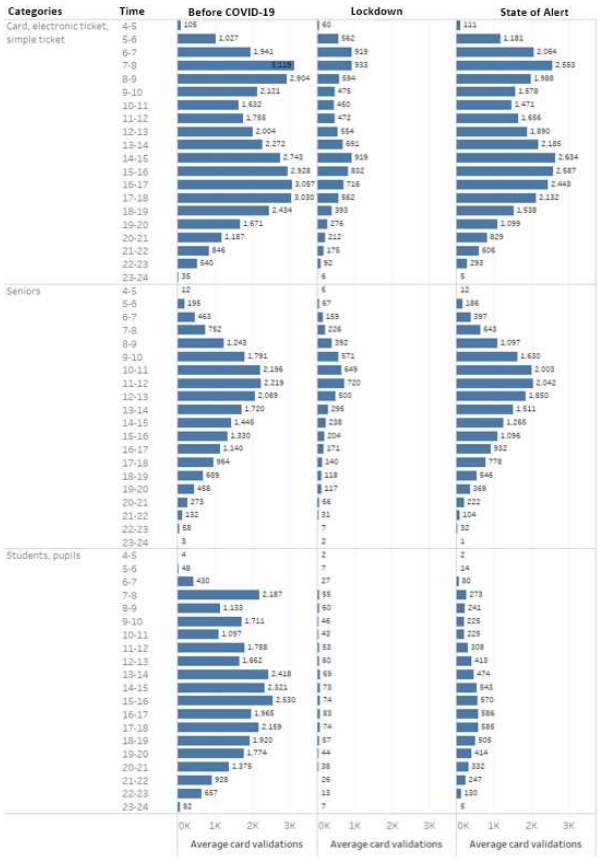

Fig. 9. Daily average card validations *(data source: CTP, 2021).*

4. CONCLUSIONS

Globally, COVID-19 is altering travel patterns and reducing demand for public transportation. The influence of the pandemic and stay-at-home measures on public transport services in the Cluj-Napoca and Cluj Metropolitan Area was examined in this paper using data from card and ticket validation. Our research shows that during the period of social-distancing restrictions that followed the pandemic peak of the first and second wave, ridership decreased by approximately 90%. From that point on, it increased extremely slowly before approximately regaining half of its pre-pandemic levels in September 2020 and 75% by March 2021.

Additionally, we adjusted this study to the various modes of transportation, ticket categories, and user demographics. We further demonstrated that, due to the unclear COVID-19 scenario, those individuals who were compelled to continue riding public transportation to get to their places of employment during the pandemic preferred to shift to more adjustable ticket types (simple ticket).

Results for various user groups indicate that younger individuals have lower transportation needs due to closed schools and colleges and fewer leisure activities, while older population, as the most exposed group to pandemic, significantly reduced their outdoor activities during lockdown. Seniors, low-income and vulnerable groups experienced smaller drops during state of alert showing how heavily dependent these groups are on public transit.

The resulting statistics also show separate daily average characteristics of demand for public transportation during the several COVID-19 pandemic phases in the Cluj Metropolitan Area. It is important to note, for instance, that during the State of Alert period, the morning peak (related to commuting time) was significantly diminished, but appeared at the same time interval as before the pandemic; the midday peak was still present but shifted one hour earlier, while the afternoon peak was not detectable in the general trend of ridership.

The main limitation of this study resides in data availability and the adaptation of local policies to limit the impact of pandemic waves (work-from-home, online education, restrictions for basic services providers).

The aim of this study was formulated from both perspectives, considering impact of mobility changes on both users and providers of urban public transportation. We believe that our results fulfil the proposed goal to identify the consequences of the COVID-19 pandemic on mobility practices in Cluj-Napoca. Since each country in the world was impacted by the COVID-19 pandemic in different ways (and at different times) and adopted different strategies to combat the pandemic waves, with different effects on transport ridership, a comparison on the impact of the COVID-19 pandemic on the urban public transportation usage would be a subject to a different study with different goals.

Further research should examine how individuals modify their mobility behaviour in public transportation over time as the pandemic continues (since the data for this paper was prepared, two more pandemic waves occurred in Romania – late September 2021 and early February 2022), helping to understand how it has changed since the COVID-19 pandemic.

5. ACKNOWLEDGEMENTS

Author Contributions: all authors had equal contribution to the paper.

REFERENCES

Afifi R. A., Novak N., Gilbert P. A., Pauly B., Abdulrahim S., Rashid S. F., Ortega F., Rashida A. (2020), 'Most at risk' for COVID19? The imperative to expand the definition from biological to social factors

for equity. Preventive Medicine, 139, 106229. DOI: 10.1016.j.ypmed.2020.106229

Ahangari S., Chavis C., Jeihani M. (2020), Public Transit Ridership Analysis during the COVID-19 Pandemic. medRxiv.
DOI: https://doi.org/10.1101/2020.10.25.20219105

Alamo T., Reina D., Mammarella M., Abella A. (2020), Covid-19: Open-Data Resources for Monitoring, Modeling, and Forecasting the Epidemic. Electronics, 9, 827. DOI: https://doi.org/10.3390/electronics9050827

Aleta A., Martín-Corral D., Piontti A. P. Y., Ajelli M., Litvinova M., Chinazzi M., Dean E. N., Halloran M. E., Jr I. M. L., Merler S. (2020), Modelling the impact of testing, contact tracing and household quarantine on second waves of COVID-19. Nature Human Behaviour, 4, 964–971. DOI: https://doi.org/10.1038/s41562-020-0931-9

Aloi A., Alonso B., Benavente J., Cordera R., Echániz E., González F., Ladisa C., Lezama-Romanelli R., López-Parra Á., Mazzei V., Perrucci L., Prieto-Quintana D., Rodríguez A., Sañudo R. (2020), Effects of the COVID-19 Lockdown on Urban Mobility: Empirical Evidence from the City of Santander (Spain). Sustainability, 12, 3870. DOI: https://doi.org/10.3390/su12093870

Anderson R. M., Heesterbeek H., Klinkenberg D., Hollingsworth T. D. (2020), How will country-based mitigation measures influence the course of the COVID-19 epidemic? The Lancet, 395(10228), 931–934. DOI: https://doi.org/10.1016/S0140-6736(20)30567-5

Askitas N., Tatsiramos K., Verheyden B. (2020), Lockdown strategies, mobility patterns and COVID-19 [online]. URL: https://ssrn.com/abstract=3619687. Accessed 26.06.2022

Astroza S., Tirachini A., Hurtubia R., Carrasco J. A., Guevara A., Munizaga M., Figueroa M., Torres V. (2020), Mobility changes, teleworking, and remote communication during the COVID-19 pandemic in Chile. Transport Findings, July. DOI: 10.32866/001c.13489

Beck M. J, Hensher D. A., Wei E. (2020), Slowly coming out of COVID-19 restrictions in Australia: Implications for working from home and commuting trips by car and public transport. Journal of Transport Geography, 88, 102846. DOI: 10.1016/j.jtrangeo.2020.102846

Beck M., Hensher D. A. (2020), Insights into the impact of COVID-19 on household travel and activities in Australia—The early days of easing restrictions. Transport Policy, 99, 95–119. DOI: https://doi.org/10.1016/j.tranpol.2020.07.001

Bucsky P. (2020), Modal share changes due to COVID-19: The case of Budapest. Transportation Research Interdisciplinary Perspectives, 8, 100141. DOI: https://doi.org/10.1016/j.trip.2020.100141

Budd L., Ison S. (2020), Responsible Transport: A post-COVID agenda for transport policy and practice. Transportation Research Interdisciplinary Perspectives, 6, 100151.
DOI: https://doi.org/10.1016/j.trip.2020.100151

Canitez F., Alpkokin P., Kiremitci S. T. (2020), Sustainable urban mobility in Istanbul: Challenges and prospects. Case Studies on Transport Policy, 8(4), 1148-1157. DOI: https://doi.org/10.1016/j.cstp.2020.07.005

Chang S., Pierson E., Koh P. W., Gerardin J., Redbird B., Grusky D., Leskovec J. (2021), Mobility network models of COVID-19 explain inequities and inform reopening. Nature, 589, 82–87. DOI: https://doi.org/10.1038/s41586-020-2923-3

Compania de Transport Public (CTP) (2020-2021), www.ctpcj.ro

de Haas M., Faber R., Hamersma M. (2020), How COVID-19 and the Dutch 'intelligent lockdown' change activities, work and travel behaviour: Evidence from longitudinal data in the Netherlands. Transportation Research Interdisciplinary Perspectives, 6, 100150. DOI: https://doi.org/10.1016/j.trip.2020.100150

De Vos J. (2020), The effect of COVID-19 and subsequent social distancing on travel behavior. Transportation Research Interdisciplinary Perspectives, 5, 100121.
DOI: https://doi.org/10.1016/j.trip.2020.100121

Deponte D., Fossa G., Gorrini A. (2020), Shaping space for ever-changing mobility. Covid-19 lesson learned from Milan and its region. TeMA Journal of Land Use, Mobility and Environment, Special Issue: COVID-19 vs. City-20.
DOI: https://doi.org/10.6092/1970-9870/6857

Dunning R., Nurse A. (2021), The surprising availability of cycling and walking infrastructure through COVID-19. Town Planning Review, 92(2), 149–155. DOI: https://doi.org/10.3828/tpr.2020.35

Fatmi M. R. (2020), COVID-19 impact on urban mobility. Journal of Urban Management, 9, 270–275. DOI: https://doi.org/10.1016/j.jum.2020.08.002

Foltýnová H. B., Vejchodská E., Rybová K., Květoň V. (2020), Sustainable urban mobility: One definition, different stakeholders' opinions. Transportation Research Part D: Transport and Environment, 87, 102465.
DOI: https://doi.org/10.1016/j.trd.2020.102465

Islam S., Ferdous Z., Potenza M. N. (2020), Panic and generalized anxiety during the COVID-19 pandemic among Bangladeshi people: An online pilot survey early in the outbreak. Journal of Affective Disorders, 276, 30-37. DOI: https://doi.org/10.1016/j.jad.2020.06.049

Jenelius E., Cebecauer M. (2020), Impacts of COVID-19 on public transport ridership in Sweden: Analysis of ticket validations, sales and passenger counts. Transportation Research Interdisciplinary Perspectives, 8, 100242.
DOI: https://doi.org/10.1016/j.trip.2020.100242

Dyer J., Kolic B. (2020), Public risk perception and emotion on Twitter during the Covid-19 pandemic. Applied Network and Science, 5, 99. DOI: https://doi.org/10.1007/s41109-020-00334-7

Kuzemko C., Bradshaw M., Bridge G., Goldthau A., Jewell J., Overland I., Scholten D., Van De Graaf T., Westphal K. (2020), Covid-19 and the politics of sustainable energy transitions. Energy Research and Social Science, 68, 101685. DOI: https://doi.org/10.1016/j.erss.2020.101685

Lewnard J. A., Lo N. C. (2020), Scientific and ethical basis for social-distancing interventions against COVID-19. The Lancet. Infectious Diseases, 20(6), 631–633. DOI: https://doi.org/10.1016/S1473-3099(20)30190-0

Linka K., Peirlinck M., Costabal F. S., Kuhl E. (2020), Outbreak dynamics of COVID-19 in Europe and the effect of travel restrictions. Computer Methods in Biomechanics and Biomedical Engineering, 23, 710–717. DOI: 10.1101/2020.04.18.20071035

Liu L., Miller H. J., Scheff J. (2020), The impacts of COVID-19 pandemic on public transit demand in the United States. PLoS One, 15(11).
DOI: 10.1371/journal.pone.0242476

Molloy J., Tchervenkov C., Schatzmann T., Schoeman B., Hintermann B., Axhausen K. W. (2020), MOBIS-COVID-19/25: Results as of 19/10/2020 (post-lockdown). Arbeitsberichte Verkehrs- Und Raumplanung, p. 1570

Mozos-Blanco M. Á., Pozo-Menéndez E., Arce R., Baucells-Aletà N. (2018), The way to sustainable mobility. A comparative analysis of sustainable mobility plans in Spain. Transport Policy, 72, 45–54. DOI: https://doi.org/10.1016/j.tranpol.2018.07.001

Nian G., Peng B., Sun D., Ma W., Peng B., Huang T. (2020), Impact of COVID-19 on Urban Mobility during Post-Epidemic Period in Megacities: From the Perspectives of Taxi Travel and Social Vitality. Sustainability, 12, 7954.
DOI: https://doi.org/10.3390/su12197954

Pase F., Chiariotti F., Zanella A., Zorzi M. (2020), Bike Sharing and Urban Mobility in a Post-Pandemic World. IEEE Access, 8, 187291–187306. DOI: 10.1109/ACCESS.2020.3030841

Pozo R. F., Wilby M. R., Díaz J. J. V., González A. B. R. (2022), Data-driven analysis of the impact of COVID-19 on Madrid's public transport during each phase of the pandemic. Cities, 127. DOI: https://doi.org/10.1016/j.cities.2022.103723

Pullano G., Valdano E., Scarpa N., Rubrichi S., Colizza V. (2020), Population mobility reductions during COVID-19 epidemic in France under lockdown. The Lancet, 2(12), E638-E649.
DOI: https://doi.org/10.1016/S2589-7500(20)30243

Saini V., Saini N. (2020), Air travel in COVID-19 pandemic. Journal of Patient Safety and Infection Control, 8(1), 29-32. DOI**:** 10.4103/jpsic.jpsic_12_20

Shakibaei S., De Jong G. C., Alpkökin P., Rashidi T. H. (2020), Impact of the COVID-19 pandemic on travel behavior in Istanbul: A panel data study. Sustainable Cities and Society, 65, 102619. DOI: 10.1016/j.scs.2020.102619

Teixeira J. F., Lopes M. (2020), The link between bike sharing and subway use during the COVID-19 pandemic: The case-study of New York's Citi Bike. Transportation Research Interdisciplinary Perspectives, 6, 1100166.
DOI: https://doi.org/10.1016/j.trip.2020.100166

Tiikkaja H., Viri R. (2021), The effects of COVID-19 epidemic on public transport ridership and frequencies. A case study from Tampere, Finland. Transportation Research Interdisciplinary Perspectives, 10, 100348. DOI: https://doi.org/10.1016/j.trip.2021.100348

Tirachini A., Cats O. (2020), COVID-19 and public transportation: Current assessment, prospects, and research needs. Journal of Public Transportation, 22(1), 1-21. DOI: 10.5038/2375-0901.22.1.1

Warren M. S., Skillman S. W. (2020), Mobility Changes in Response to COVID-19. arXiv. DOI: https://doi.org/10.48550/arXiv.2003.14228

Wei Y., Wang J., Song W., Xiu C., Ma L., Pei T. (2021), Spread of COVID-19 in China: Analysis from a city-based epidemic and mobility model. Cities, 110, 103010.
DOI: https://doi.org/10.1016/j.cities.2020.103010

Witter R. (2010), Public Urban Transport, Travel Behaviour and Social Exclusion - The Case of Santiago De Chile. In Proceedings of the 12th WCTR, Lisbon, Portugal, 11–15 July 2010

Xu S., Li Y. (2020), Beware of the second wave of COVID-19. The Lancet, 395(10233), 1321-1322. DOI: 10.1016/S0140-6736(20)30845-X

Zhang H., Li P., Zhang Z., Li W., Chen J., Song X., Shibasaki R., Yan J. (2022), Epidemic versus economic performances of the COVID-19 lockdown: A big data driven analysis. Cities, 120, 103502. DOI: https://doi.org/10.1016/j.cities.2021.103502

Zhang J. (2020), Transport policymaking that accounts for COVID-19 and future public health threats: A PASS approach. Transport Policy, 99, 405–418. DOI: https://doi.org/10.1016/j.tranpol.2020.09.009

Zhang N., Jia W., Wang P., Dung C.-H., Zhao P., Leung K., Su B., Cheng R., Li Y. (2021), Changes in local travel behaviour before and during the COVID-19 pandemic in Hong Kong. Cities, 112, 103139. DOI: https://doi.org/10.1016/j.cities.2021.103139

APPENDIX 1.1

```
create database transport_staging;
use transport_staging;
create table carduriaux
(
id int primary key auto_increment,
cardseries varchar(8) not null,
transportLine varchar(7) not null,
description varchar(254) not null,
data date not null,
ora INT not null,
minut INT not null,
dups int not null,
timp varchar(8)
```

```
as (CONCAT(CONCAT(ora,'-'),ora+1)) virtual
);
create table bileteaux
(
id int primary key auto_increment,
old_id int not null,
transportLine varchar(7) not null,
description varchar(254) not null,
data date not null,
ora INT not null,
minut INT not null,
timp varchar(8)
as (CONCAT(CONCAT(ora,'-'),ora+1)) virtual
);
```

APPENDIX 1.2

```
use transport_staging;
create procedure clean_and_transform()
begin
truncate table carduriaux;
insert into carduriaux (cardseries, transportLine, description, data, ora, minut, dups) select cardSeries, transportLine, description, date(exactTime) as data, hour(exactTime) as ora, minute(exactTime) as minut, COUNT(*) as dups from avl.cardvalidation c where cardSeries is not null and transportLine is not null and transportLine <> "" and transportLine <> 'TRANZIT' and description is not null and exactTime is not null
and date(exactTime) between '2020-02-27' and '2021-12-31'
group by cardSeries, transportLine, description, date(exactTime), hour(exactTime), minute(exactTime) order by cardseries, transportLine, description, data, ora, minut;
truncate table bileteaux;
insert into bileteaux (old_id, transportLine, description,data, ora, minut)
select id, case transportLine when '' then 'TRANZIT' else transportLine end as transportLine, 'Bilet hartie' as description, date(exactTime) as data, hour(exactTime) as ora, minute(exactTime) as minut
from avl.paperticketyvalidation p2 where date(exactTime) between '2020-02-27' and '2021-12-31' order by data, ora, minut;
end
```

APPENDIX 2.1.

```
create database transport;
use transport;
create table carduribilete
(
id int primary key auto_increment,
transportLine varchar(7) not null,
description varchar(254) not null,
data date not null,
ora int not null,
minut int not null,
timp varchar(8) not null
);
```

APPENDIX 2.2.

```
use transport;
create procedure load_data()
begin
insert into carduribilete (transportLine,description,data,ora,minut,timp)
select transportLine, description, data, ora, minut, timp from transport_staging.carduriaux
order by data, ora, minut;
insert into carduribilete (transportLine,description,data,ora,minut,timp)
select transportLine, description, data, ora, minut, timp from transport_staging.bileteaux order by data, ora, minut;
end
```