Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Impacts of COVID-19 and pandemic control measures on public transport ridership in European urban areas – The cases of Vienna, Innsbruck, Oslo, and Agder

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ABSTRACT

The study uses the case of two regions with small and medium sized cities (Agder in Norway and the greater Innsbruck area in Austria) and two European capitals, Vienna and Oslo, to showcase the impact of the COVID-19 pandemic on public transport ridership in northern and central Europe. The comprehensive timeline of actions taken by governments and public transport providers in Austria and Norway, and their impact on public transport ridership in the first and second waves of the pandemic form the basis of a descriptive study.

Comparing the data, a strong negative impact on the public transport patronage in the first wave of the pandemic was found, despite a comparable low number of cases per 100,000 inhabitants. Furthermore, a smaller impact of the second wave of the pandemic on the ridership was registered. The study provides valuable first insights on how the pandemic affected different settlement types. It also documents, in detail, the measures taken by two distinct European countries to curb the pandemic infection rates and how these actions impacted public transport patronage.

The results pointed in the direction of a need for further analysis of aspects such as "fresh fear" and "lingering fear" in relation to the effect of a pandemic on public transport. Data availability limitations show the necessity of upgrading and aligning ridership and ticketing monitoring systems across Europe, to allow for better understanding of pandemic impacts on public transport in a more unified manner.

Introduction

At the end of December 2019, the first cases of an unknown pneumonia were reported in Wuhan, China; it was later identified in January 2020 as the novel coronavirus (SARS-CoV-2 or COVID-19). According to medical research, the virus is transmitted via respiratory droplets and requires certain proximity between individuals (Wilder-Smith A and Freedman, 2020). The virus proved to be highly contagious, and the World Health Organization (WHO) declared it to have reached the status of an epidemic by the end of January 2020 and a pandemic in March 2020 (De Vos, 2020). Regarding the effects of COVID-19 on the public transport (PT) networks worldwide, WHO stated that *"The real and perceived risks of exposure to the virus have transformed the greatest plus of mass transport – the ability to move large numbers of people rapidly, efficiently and affordably – into a liability"* (ITF/OECD, 2020, p. 2).

To slow the spread of the virus, most countries in Europe adopted measures that were intended to decrease social contact in everyday life. These measures affected the transport networks in general, as well as mobility behavior in particular. Even though the prevention measures taken are very similar among European countries (for example, nationwide lockdowns and remote work for a variety of office jobs and even education), the effects on the transport system seem to differ (Bucsky, 2020; de Haas et al., 2020; Zhang et al., 2021). There are also regional differences within the countries with regard to the effect of the measures taken on the modal split and mobility behavior (Jenelius & Cebecauer, 2020). Furthermore, the chronology of the pandemic has presented three major waves so far in Europe (Whitworth, 2020). Analyzing public transport (PT) ridership data, the three waves seem to have different effects on PT patronage. These effects seem to be dependent not only on measures taken by governments and PT authorities, or on the number of registered COVID-19 cases in a

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country, but also on the size of the urban community serviced and point in time related to the start of the pandemic.

As small and medium-sized cities (SMCs) are commonly confronted with a reduced public transport market share and high car ownership and dependency (Holmgren et al., 2008; Pojani et al., 2015), it was expected that the impact of the pandemic would be consistent and persistent for these urban forms. On the other hand, metropolises such as Vienna or Oslo, where sustainable transport modes are dominant and car ownership is low compared to the rest of the urban areas in Austria or Norway, were expected to recover more easily in the aftermath of the lockdown.

The lack of novel viruses epidemic events in the recent history of Europe means that data on measures taken by governments to curb the level of contagion are limited compared to other regions of the world, such as Asia (Dye & Gay, 2003; Lam et al., 2003). The European Commission has attempted to collect the national events and measures taken by European governments (ECML Covid, 2020). The lists of measures provided on the platform are not extensive and no comparison between the timelines in different countries is possible. Moreover, the relation between the COVID-19 pandemic and human mobility has not been analyzed on the platform. Examples of research presenting the pandemic chronology for specific countries have mainly focused on the first wave of the pandemic (Göncüoğlu et al., 2020). Currently, most research treating the topic of human mobility in relation to the pandemic has focused on the disease-spreading aspects (Hadjidemetriou et al., 2020). If the systematic impact of the pandemic and the national containment measures are observed in relation to the PT use, even less data is available for both the 2003 SARS epidemic in Asia and for the current COVID-19 pandemic around the world. Such data is essential both in the current pandemic management decisions, offering perspective on the efficacy and impact of specific actions, but also for ensuring the preparedness of national governments and PT providers for similar future events.

The present paper provides a comparison between the calendar of the pandemic events and measures in Austria and Norway and the impact these measures had on PT ridership in two urban forms: metropolises (Vienna and Oslo) and networks of small cities and towns (Innsbruck region in Austria and Agder region in Norway). Norway and Austria are two countries with similar timelines in relation to the pandemic development. The cases selected from the two countries are similar in terms of size and governmental policies in promoting PT use, geographic likeness (between Agder and Innsbruck), and also have similar developments in the COVID-19 chronology of events. Using the data collected from the PT providers in the four selected urban areas, we aim to answer the following questions:

- How was PT ridership impacted in comparable European urban areas?
- Is there a difference in impact on PT ridership between urban forms of different sizes?
- How does the length of the pandemic affect the loss of ridership for PT?
- What data are missing for understanding the cause for loss of ridership in the PT system?

Answering these questions would support researchers and governments in better understanding the impact of pandemics on travel behavior. It would also shed light on the impact pandemic containment measures have on the PT sector.

The remainder of the paper is organized as follows. Section 2 presents the urban areas selected and data used for the analysis, together with the methods employed, while the findings are presented in Section 3. Section 4 engages in a discussion of the findings, concluding with the main points and the answers identified for the questions posed.

Literature review

Currently, research presenting the impact of COVID-19 on PT ridership is limited, with most of the available scientific publications referring to the impact of the pandemic's first wave (Ahangari et al., 2020; Barbieri et al., 2020; Bucsky, 2020; Chen & Pan, 2020; Jenelius & Cebecauer, 2020; Mogaji, 2020; Warren & Skillman, 2020). Previous research on the spread of coronaviruses in relation to transport refers to contagion in PT. (Browne and Ahmad, 2016) performed a systematic review on "The roles of transportation and transportation hubs in the propagation of influenza and coronaviruses". For ground transport, the authors found that the overall risk of infection rose with the duration of the travel and seating proximity, but "*no significant association to seating proximity to an index case was observed*" (Browne & Ahmad, 2016, p. 12). Studying the transmission of the COVID-19 virus in passenger trains in China, Hu et al. found that *"the transmission risk shows significant differences with co-travel time and seat location"*, where "*travelers adjacent to the index patient had the highest attack rate*" Hu et al. (2020, p. 1).

For the severe acute respiratory syndrome coronavirus (SARS-CoV), the case of Taipei City identifies the impact of the "fresh fear" effect on metro ridership, with *"an immediate loss of about 1200 underground ridership"* for each new case reported in the beginning of the pandemic (Wang, 2014, p. 8), even though no lockdown had been imposed. Underground ridership gradually increased in the final stage of the epidemic, but the *"ridership in Taipei did not resume back to normal levels"* (Wang, 2014, p. 8). Novel European level research shows that, in the first wave of the COVID-19 pandemic, when the population was confronted with information about this new virus, this strongly affected PT ridership and the mode share (Almlöf et al., 2020; Aloi et al., 2020; Bucsky, 2020; Jenelius & Cebecauer, 2020). Some of the main reasons identified for this behavior are the agglomeration in PT, the behavior of other passengers, and the fear of becoming infected (Przybylowski et al., 2021). An analysis of mobility data of various countries in Europe showed that *"the confinement measures explain up to 90% of the mobility patterns"* in those countries (Santamaria Serna et al., 2020, p. 7). Studies published after September 2020, such as Jenelius and Cebecauer (2020), consider the post lock-down period of the pandemic as well, showing a ridership recovery trend that coincides with the end of the first wave of the pandemic. No published studies treating the impact of the second wave of the pandemic on PT ridership in Europe have been currently identified.

Studies from other continents have focused heavily on the impact of the lockdown period on mobility and spread of the disease. In China, ridership levels in 2020 were half of what they were in 2019 (ITF/OECD, 2020), and a study shows that Chinese cities that set preventive measures (among others suspending intra-city public transport) reported one-third fewer cases in the first week of their outbreaks compared to cities with no measures set by that time (Tian et al., 2020). In the USA, Yilmazkuday (2020) found that inter-county travel, by any means of transport, is correlated with an increase in COVID-19 cases. In Australia, Beck and Hensher evaluated the effects of working from home on commuting travel behavior, concluding that *"working from home will be a key determinant on commuting behavior"* Beck and Hensher (2020, p. 16). Another Australian study presented the impact of the second wave of the pandemic on human mobility, showing a 73–85 percent reduction of traffic in PT hubs in the cases considered (Boroujeni et al., 2021). For the post-pandemic period, an estimation on the number of daily public transport trips to be serviced after COVID-19 is given by the ITF/OECD (2020); in some cities, teleworking was anticipated to cause a 30 percent reduction in trips.

Current research has concentrated on the spread of the virus in PT, the effects on specific transportation networks and differences within a country. So far, there have been limited insights into the importance of

the urban form for PT passenger loss. Furthermore, information is lacking on the direct influence of measures set by the authorities on the transportation network, as there are hardly any comparative studies that could indicate correlations between applied measures and PT ridership variations.

Methods

To answer the research questions, it is necessary to compare the effect of the pandemic on PT ridership values in regions from different European countries, on one hand, and in different urban forms, on the other. In choosing the countries, various criteria such as a comparable travel behavior of the population (mode share, car dependency), similar transport environmental goals and policies set by the government, and similarities in the COVID spreading timeline have been taken into account. Our examples for SMCs, the region of Agder in southern Norway and the greater Innsbruck area in western Austria, are comparable in the aspects described above, as well as in terms of geographic restrictions (settlements concentrated along a main route), population size, and the limitation of PT services to mainly busses (and trams in the case of Innsbruck). To measure the pandemic impact on PT against the urban form, we also selected the Norwegian capital city of Oslo and the Austrian capital city of Vienna as examples of European metropolises. Both metropolises have a well-developed public transport network and a high share of public transport in the modal split. All four cases represent typical settlements for their specific European geographies. This makes the related findings of the present study easily transferable to similar urban settlements.

Furthermore, we used the ridership data collected from the PT providers in the four cases considered, combined with public data on the pandemic development (number of cases per day, measures taken to limit contagion) to analyze the effect of the pandemic on PT in the case studies. We also identified the limitations of the existing data in understanding the exact correlations between the cause and effects.

In this section we introduce the study areas in more detail and give insights on the data collection and analysis.

Areas of study

In areas where SMCs are the predominant urban form, commuting is a daily necessity as the distribution of the job market is spread out in the territory (Aldrich et al., 1997). The coastal area of Agder county in the south of Norway, with the regional capital in Kristiansand, and the mountain area of Tyrol in western Austria, with the regional capital in Innsbruck, are excellent examples for this. The two regions are similar in their geography in the sense of a densified urban network along a transit corridor, with diverse towns and cities that offer various points of attraction throughout the region. The two regions have unique public transport providers: Agder Kollektivtrafikk AS (AKT) in Agder, which provides bus-based services; and Innsbrucker Verkehrsbetriebe und Stubaitalbahn GmbH (IVB) in the greater Innsbruck area in Tyrol, which provides bus and urban rail-based services for the Innsbruck agglomeration.

In addition to the SMCs networks mentioned, we analyzed the metropolitan areas of Vienna and Oslo to identify similarities and differences between the two spatial types considered (networks of SMCs and towns and metropolises). Taking different regions into account allowed us to compare the effects of COVID-19 related measures (both general and PT-related), which were not always taken at the same time and to the same extent. Oslo and Vienna also benefit from the services of unique PT providers, namely Wiener Linien GmbH (WL) in Vienna and Ruter in Oslo. Table 1 presents a synthetic overview of the four cases studied and their most important characteristics regarding population and PT provision.

Data collection and analysis

The study uses two types of data: quantitative (number of COVID-19 cases in Austria[1] and Norway[2], patronage data for each of the four cases) and qualitative (pandemic control measures taken in Austria and Norway). The patronage data covers the period between January 2019 to February 2021 and were supplied by AKT, IVB, Ruter and Wiener Linien (WL) – the local public transport authorities in Agder, Innsbruck, Oslo and Vienna. The following quantitative data sets were used for the PT ridership analysis:

- Daily passenger data for the whole network in Agder and Oslo.
- Aggregated monthly ticketing income data for Agder.
- Aggregated monthly passenger data for the whole network in Innsbruck based on ticketing and on-site counts.
- Aggregated weekly and monthly passenger decrease data for 2020 and 2021 compared to 2019 in the whole network in Vienna.

We identified a lack of understanding of the direct effect on PT of the measures taken by authorities and PT providers to limit the virus spread. To be able to analyze the chronology of the measures taken in Norway and Austria in relation to the PT ridership variation in the four studied cases, a national measures timeline and two timelines focusing on measures taken by PT providers in Norway (AKT and Ruter) and Austria (IVB and WL) were compiled. For the national measures timeline, the primary sources for the data were the European database for pandemic measures (ECML Covid, 2020) and the Norwegian government website (Regjeringen, 2021). As these databases are not complete, we used university press releases and news articles as secondary sources of information. The other two timelines were compiled with information provided by AKT, IVB, Ruter, and WL, as well as data collected from various official and news publication sources.

Once the chronology of the events was established, we observed the immediate effect of the measures presented in the timelines on the PT ridership in each case and compared variations in ridership resulting from similar measures at similar points in time. Special attention was given to identifying visible differences in the effect of the same measure applied in each of the two countries by comparing the ridership variation in the two different urban forms observed. As the approach of the present study is mainly descriptive, no statistical analyses were applied on the collected data.

Findings

This section contains the findings of our research: the timeline of the pandemic and measures taken for its containment in Austria and Norway; the measures affecting public transport in the four case studies taken either nationally or at local level by local governments or PT authorities; and the variation in ridership of PT based on data given by the four PT providers in Vienna, Oslo, Agder, and Innsbruck. All data presented cover the period between February 2020 and February 2021.

Course of the COVID-19 pandemic and general measures taken in Austria and Norway

The COVID-19 pandemic shows three different waves both in Austria and Norway (Fig. 1), with a stagnation period between the first two waves in both countries. The first wave hit both countries almost simultaneously between March and April 2020. The Norwegian second wave had two peaks, one in November and one in January, with a

[1] Data source: https://covid19-dashboard.ages.at/dashboard.html?l=en.

[2] Data source: Norhealth statistics bank, Norwegian Institute of Public Health, http://www.norgeshelsa.no.

Table 1
Overview of case studies and their characteristics.

Country	Urban area	Population	City category	Surface	Modal split PT	PT network
Austria	Vienna	1.9 million (city of Vienna) 2,873,995 (Vienna metropolitan area).	Metropolis	415 km^2	38%[1]	Metro, suburban trains, trams, buses, bicycle rental, scooter rental, airport, train, inland port (Danube)
	Greater Innsbruck area (Tyrol region)	132,110 (city of Innsbruck) 300,000 (greater Innsbruck)	Small cities and towns	104.9 km^2 (greater Innsbruck)	16%[2]	Trams, buses, bicycle rental, scooter rental, train, airport
Norway	Oslo	674,000 (city of Oslo) 1 million (Oslo metropolitan area)	Metropolis	426 km^2	24%[3]	Metro, suburban trains, trams, buses, bicycle rental, scooter rental, airport, train, ferry port
	Agder region	112,588 (Kristiansand, capital of the Agder region) 300,000 (Agder region)	Small cities and towns	16,434 km^2	approx. 5%[4]	Buses, scooter rental (Kristiansand only), train, airport

[1]Data sourced from Wiener Linien (2020d).
[2]Data from last major travel survey in 2011 (Köll & Bader).
[3]Data from the documentation submitted by the Oslo Municipality for the European Green Capital contest (European Green Capital Award).
[4]Data from last major travel survey in 2013/2014 (Haugsbø et al., 2015a, 2015b).

plateau in between, during which the daily number of new cases remained high, while the Austrian second wave of infections peaked in November 2020. The third wave in Austria and Norway is ongoing at the time of writing this paper and does not yet have a well-defined epidemiological peak. A synthetic overview of the national pandemic containment measures timeline is given in Fig. 1, together with the contagion chronology for the four case studies, while the detailed overview of national measures implemented in the two countries is provided in comparison in Appendix A.

National-level situation in Austria and Norway

In the case of Austria, the virus spread quickly in the touristic ski regions bordering Italy. Once the situation began to worsen in the beginning of March (see Fig. 1), the Austrian authorities took rapid steps to try and establish control over the spread of the virus. The epidemiologic peak of the first wave of the pandemic was reached in Week 13.

In Norway, the first case of COVID-19 was registered on February 21 and made public five days later (Life in Norway, 2020). The situation deteriorated rapidly, triggering a quick response from the side of the Norwegian government. The minor peak of the first wave of infections was caused mainly by Norwegians who travelled for the winter holidays to Tyrol and Italy, where they predominantly contracted the virus in ski resorts (Dagsavisen, 2020). By the time the borders were closed, and the containment measures imposed, the virus had propagated to a large number of individuals. This created a sharp increase in cases that generated the epidemiologic peak of the first wave of the pandemic, which was reached in Week 13, similar to Austria.

Both countries had “hard lockdowns” imposed nationally during the first pandemic wave (six-week lockdown in Norway and five-week lockdown in Austria). Fig. 1, complemented by Table A1 in the Appendix, shows a strong similarity between the calendar of events for the first wave in both countries.

The measures taken in Austria and Norway during the “contagion stagnation period” of the pandemic between the first and second waves are presented in Table A2 in the Appendix. The period and contagion level corresponds very well for both countries, with relaxation measures being implemented throughout the end of the spring and the entire summer period (Weeks 16 to 29). The main difference in containment measures between the two countries are: limitations in free international movement of EEA countries, with Norway having a more restrictive set of measures applied; and the requirement for wearing mouth-nose protection in enclosed public spaces, which was active almost continuously in Austria, while Norway never introduced this requirement at national level.

The second wave of the pandemic starts almost simultaneously in both countries (see Table A3 in the Appendix for details), with increasing numbers of infections registered starting August. Restrictive measures are imposed gradually, reaching another national lockdown order in late October in Norway and beginning of November in Austria. For both countries, the second lockdown has lighter measures and a longer duration than the first. In the case of Norway, the second lockdown has not yet been lifted at the moment of writing this paper. In Austria, the lockdown was partially lifted for a short period of time December 2020. A third lockdown was imposed just before the Christmas holidays, and kept in place until mid-February 2021.

Regional level contagion situation in Vienna, Tyrol, Agder, and Oslo

In Austria, the chronology of the pandemic (daily new cases registered) is similar between the national level and the situation in Vienna and Tyrol. As the region of Innsbruck is part of Tyrol, pandemic data are only available at the county level. The lowermost graph in Fig. 1 shows a comparison between the number of daily cases and cumulative cases per 100,000 inhabitants in Austria, Vienna, and Tyrol. For both the first and second waves, Tyrol seems to have a larger overall number of cases per 100,000 inhabitants than Vienna or the national average. Between the two waves, Vienna dominated the number of daily cases.

The Norwegian situation is somewhat different from the Austrian one, especially beginning with the second wave of the pandemic. Overall, the number of cases per 100,000 inhabitants is close to three times smaller in Norway than in Austria at the highest peak observed in the data available (see Fig. 1). The daily number of new cases per 100,000 inhabitants is clearly higher in Oslo than the national average or than the number of cases in Agder (see uppermost chart in Fig. 1). The situation in Agder was better than the national average for most of the period under discussion, with the rate of contagion rising slightly in February 2021. This positive situation in Agder is mainly due to the lower population density, limited international flights (all direct international flights from Kristiansand Airport were suspended starting in October 2021 and remain suspended at the moment of writing this paper).

Measures affecting public transport taken in Vienna, Oslo, Innsbruck, and Agder

The comparative timeline presented in Subsection 3.1 and detailed in the Appendix showed that the general restriction measures were similar and relatively synchronized between Austria and Norway until February 2021. This subsection presents the PT-related measures implemented to reduce the propagation of the virus in the four case

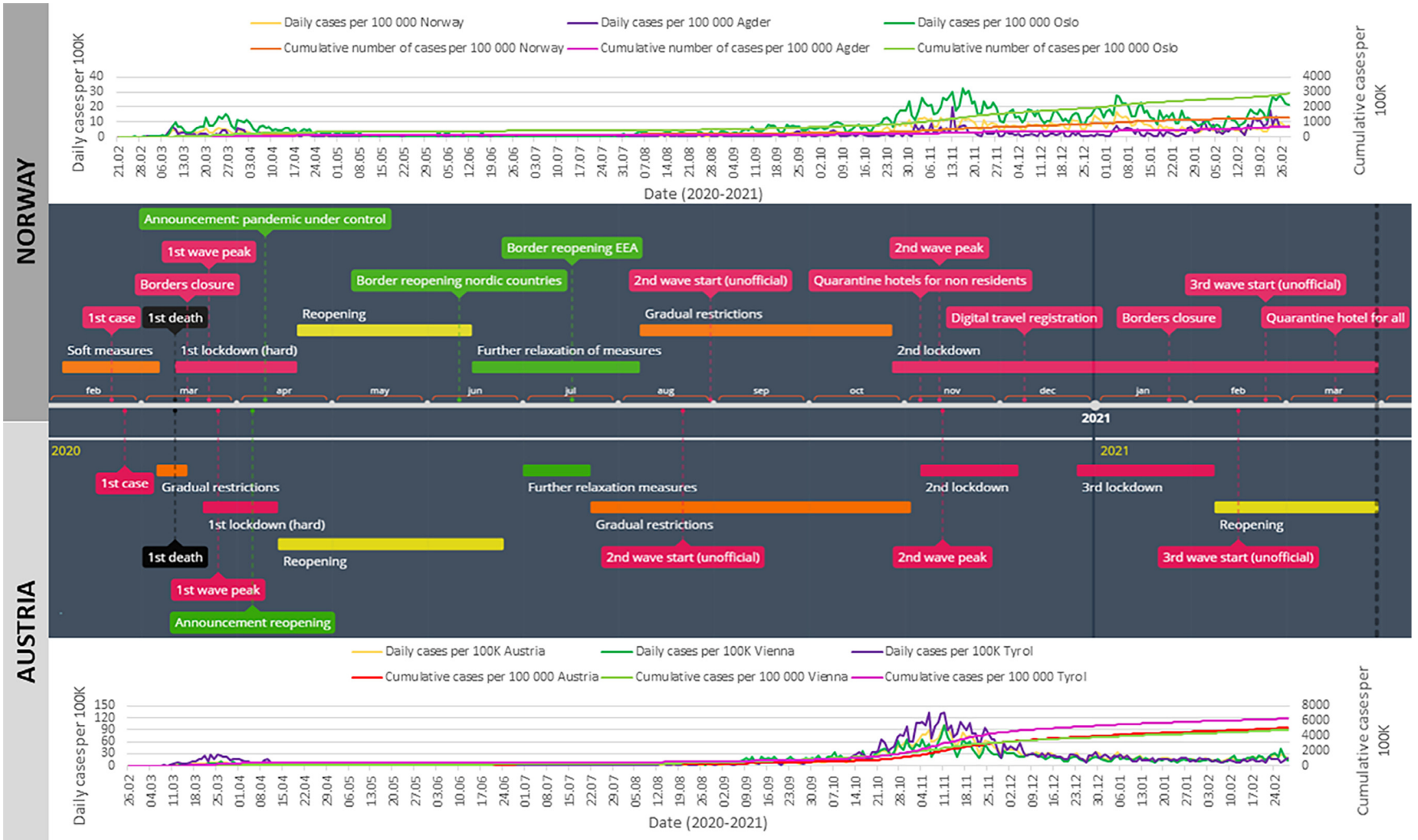

Fig. 1. Parallel timeline of contagion development (February 2020-February 2021) for the four case studies (Oslo and Agder on uppermost graph, Vienna and Tyrol on lowermost graph) and major national events in the pandemic for Norway and Austria (timeline in the figure center).

Table 2
Pandemic containment and relaxation measures taken in the PT sector (Vienna and Innsbruck, March 2020–February 2021). Color code: red – restrictive measure; green – relaxation measure.

Week	Event details for Vienna (WL)	Event details for Innsbruck (IVB)	Code
W11	10.03 Deep cleaning of all stations, vehicles and contact surfaces (Die Presse, 2020). 11.03 Doors opened automatically (Kurier, 2020a). 12.03 Front doors of buses and high-floor trams closed, driver's seat secured (ORF, 2020b).	12.03 Announcement of emergency measures starting 13 March. * 13.03 Front entrance of buses closed. Ticket sales on buses discontinued. *	AT.V.pt1 AT.V.pt2 AT.V.pt3 AT.I.pt1 AT.I.pt2
W12	16.03 No leisure trips by PT (Vienna Online, 2020).		AT.pt1
	17.03 Vienna short-term parking zones abolished (Kurier, 2020c).	16.03 Free parking until further notice. * 17.03 Restrictions on regional and city bus services: timetable changed to Sunday for all lines; lines TS and 6 temporarily suspended. Customer center only available by phone or email. * 20.03 City bikes temporarily suspended. *	AT.V.pt4 AT.I.pt3 AT.I.pt4 AT.I.pt5
W14	03.04 All lines converted to Saturday timetables (ORF, 2020a)		AT.V.pt5
W15	06.04 All PT employees equipped with reusable fabric mouth-nose protection (ORF, 2020b).	10.04 Announcement of new timetable and mouth-nose protection. *	AT.V.pt6 AT.I.pt6
	07.04 Federal regulations on traffic restrictions. *		AT.pt2
W16	14.04 Compulsory mouth-nose protection for passengers (Wiener Linien, 2020b). 15.04 Leisure trips by PT allowed again (Vienna Online, 2020a).	14.04 All lines switched to Saturday timetables during weekdays. Nightlines on limited operation. Mouth-nose protection compulsory. City bike back in operation. *	AT.V.pt7 AT.V.pt8 AT.I.pt7
W18	27.04 Short-term parking zones again subject to charge in Vienna (Vienna Online, 2020b).	27.04 IVB customer center reopens. * 02.05 Short-term parking zones subject to charge. *	AT.V.pt9 AT.I.pt8 AT.I.pt9
	01.05 Repeal of federal regulations on traffic restrictions. *		AT.pt3
W19	05.05 Student ticket validity extended until the end of September (instead of end of June) (Wiener Linien, 2020c)	04.05 All lines on vacation schedule. Line 6 runs again. On Saturdays, lines A-C-F-K-M 20 min. frequency. Line H still suspended. **	AT.V.pt10 AT.I.pt10
W20	11.05 Normal operation hours for the metro (Wiener Linien, 2020d).		AT.V.pt11
W21	18.05 Normal operation for all transport modes (Wiener Linien, 2020d).	18.05 All lines on normal timetable on weekdays. Exception: 2-5-6-R vacation schedule. **	AT.V.pt12 AT.I.pt.11
W23	01.06 Night lines start to operate (Wiener Linien, 2020b), but exclusively with buses instead of metro (Wiener Linien, 2020a).		AT.V.pt13
W40	02.10 Mouth-nose protection obligatory in all WL buildings, all vehicles and underground platforms (Wiener Linien, 2020c).		AT.V.pt14
W43	25.10 Austrian medical certificate necessary for exemption to wear mouth-nose protection (Wiener Linien, 2020c).		AT.V.pt15
W44		30.10 Intensified measures: front bus door blocked; mandatory wearing of a mouth-nose protection at all stops. *	AT.I.pt12
W4	FFP2 masks compulsory inside PT vehicles and stations for all passengers aged 14 and above (ECML Covid, 2020).		AT.pt4

*Innsbruck informiert (2020), **IVB internal info.

See above-mentioned references for further information.

Table 3
Pandemic containment and relaxation measures taken in the PT sector (Oslo and Agder, March 2020–February 2021). Color code: red – restrictive measure; green – relaxation measure.

Week	Event details for Oslo (Ruter)	Event details for Agder (AKT)	Code
W11	12.03 Deep cleaning, automatic door opening, no tickets sold onboard, front door closed, protection of drivers. ** 13.03 Ticket control stopped until March 26 (*Norway Today*, 2020)		NO.O.pt1 NO.O.pt2
W12	19.03 No direct customer contact. *	17.03 Closing of customer centers. Front door of buses closed for boarding. Front rows of seats blocked off. Cash payment on board stopped. Enhanced cleaning of buses. Maximum capacity 50% (one passenger per two seats). Drivers decide when a bus is full. **	NO.O.pt3 NO.A.pt1
W13	23.03 Reduced travel offer. * 25.03 Advice to use PT only when necessary. *	23.03 All school routes cancelled. **	NO.O.pt4 NO.O.pt5 NO.A.pt2
W14		30.03 Summer schedule introduced in the Kristiansand area. **	NO.A.pt3
W16		16.04 Gradual opening of customer centers. Plexiglass mounted at all customer centers. **	NO.A.pt4
W17	21.04 Increased capacity for school transport. *	22.04 Ticket inspecting machines installed at the middle door in Kristiansand area. **	NO.O.pt6 NO.A.pt5
W18	27.04 Reintroduction of ticket checks. * 30.04. Introduction of maximum occupancy and marked seating. *	27.04 Schools open (first to fourth grades). School routes run on normal route plan (distance restrictions apply, buses at 50% capacity). AKT customer centers resume ordinary opening hours (distance restrictions apply). **	NO.O.pt7 NO.O.pt8 NO.A.pt6
W20		11.05- Physical marking of seats in star formation. Vocal announcement for respecting distance restrictions. Capacity indicator tool for time and route. **	NO.A.pt7
W24		08.06 Reintroduction of full capacity in school buses. **	NO.A.pt8
W27		01.07 Front door opens for buses. No cash payment. **	NO.A.pt9
W28	09.07. Passengers allowed to sit next to each other. *		NO.O.pt9
W29		13.07 Local routes run at full capacity (front door boarding, first row of seats behind driver still blocked). Inter-city routes still maximum 50% capacity. ** 15.07 Passengers permitted to sit shoulder-to-shoulder in the direction of travel. Line 170 Evje-Hovden at 50%. **	NO.A.pt10 NO.A.pt11
W33	14.08 Recommendation to wear face masks inside PT vehicles during rush hours. *		NO.O.pt10
W43	14.10 Checks for application of mask regulation. *	16.10 Updated list of bus departures with reported infection. On AKT website. **	NO.O.pt11 NO.A.pt12
W47	19.11 Measures to insure school transport. *	16.11 Predicted occupancy level in AKT trip planner app to help passengers avoid agglomeration. **	NO.O.pt12 NO.A.pt13
W01	08.01. Recommendation to avoid public transport for weekend trips and leisure activities (*Norway Today*, 2021a)		NO.O.pt13
W03	23.01 Ticket control and onboard ticket sales stopped. *		NO.O.pt14
W05	05.02. Several bus routes canceled due to infection among bus drivers (*Norway Today*, 2021b).	02.02 Masks required for everyone over the age of 12 where distance of 2m or more cannot be ensured. **	NO.O.pt15 NO.A.pt14

** Ruter internal info. ** AKT internal info.*

See above-mentioned references for further information.

studies. Table 2 presents the measures taken in the two Austrian cases, while Table 3 shows the measures taken in the Norwegian cases.

The debut of the pandemic brought the adoption of similar measures to all four cases almost simultaneously: enhanced cleaning and disinfection, automated door opening, protection of bus drivers through the blocking of the front doors and rows of seats behind the driver's cabin, and the cessation of onboard ticket sales. The start of the first lockdowns (March 12 in Norway and March 16 in Austria) marked a noticeable change in approach between the Norwegian and Austrian cases. In Austria, no leisure travel was permitted by PT (AT.pt1), the frequency of departures was reduced (AT.V.pt5 and AT.I.pt4), and parking within city limits was made free of charge (AT.V.pt4, AT.I.pt.3). In Norway, by contrast, the PT schedule was kept almost at regular levels throughout the first lockdown and the rest of the pandemic, and the use of PT was only discouraged via recommendations (Table A1), but never restricted. Only school and express busses were discontinued in Agder, while in the Kristiansand area the PT provision was reduced to a summer schedule between the end of March and the end of April (NO.A.pt3). The parking charge was kept constant within city limits in the Norwegian cases throughout the pandemic.

One of the main differences between the Austrian and Norwegian approaches was the introduction of compulsory use of mouth-nose protection (face masks) and physical distancing between passengers. In Austria, the use of mouth-nose protection of no specific kind was made compulsory inside all vehicles and at the PT stations in mid-April (AT.I.pt6, AT.V.pt7), but physical distancing was not enforced. On January 25, 2021, a national regulation made FFP2 masks compulsory inside PT vehicles and stations for all passengers aged 14 and above (AT.pt4). For the Norwegian cases, the use of mouth-nose protection inside PT vehicles was introduced as a recommendation first in Oslo, starting in July 2020 (NO.O.pt10) in the situations where physical distancing was not possible, and then in Agder six months later (NO.A.pt14), as a requirement for when the minimum distance of 2 m between passengers could not be ensured. On the other hand, in both Norwegian cases physical distancing was enforced, starting on March 16 in Agder (NO.A.pt1), first by the driver and then by blocking seats with visual signaling on May 11 (NO.A.pt7) and starting May 2 in Oslo (NO.O.pt4).

After the first wave, Innsbruck and Vienna reverted to their normal operation schedule, with full capacity, on the same date: May 18 (AT.V.pt.12, AT.I.pt.11). Agder reinstated school bus routes on the 27th of April (NO.A.pt.5), thus resuming normal schedule for its busses, but with reduced capacity. The return to regular capacity and schedule for the Norwegian cases happened only in July (NO.O.pt9, NO.A.pt10).

Throughout the summer and during the second pandemic wave, restrictive measures were maintained for PT in Austria (no front-door boarding for buses, mouth-nose protection required in PT stations). In the case of Agder and Oslo, the only changes brought by the second pandemic wave were the requirement to use mouth-nose protection inside PT vehicles when physical distancing could not be ensured and the live occupancy information in the PT transport apps to help passengers select a less crowded vehicle for their trip. In addition, on January 8, 2021, the population of Oslo was advised to avoid the use of PT for leisure trips due to the rising number of COVID-19 cases (NO.O.pt13).

Effect of pandemic on public transport ridership in Vienna, Oslo, Innsbruck and Agder

This section presents the PT ridership variation during the pandemic period studied (February 2020–February 2021) for the four cases. The presented data were provided by the PT companies in Vienna (WL), Oslo (Ruter), Innsbruck (IVB), and Agder (AKT). Due to the different level of detail in the available data, the monthly patronage figures are presented first, for all four cases, followed by the weekly figures presented for Vienna, Oslo, and Agder only, where the passenger count is done via automatic passenger counting (APC). Weekly data was not available for the case of Innsbruck, where on-site counts are used for estimating patronage.

Impact of pandemic containment and relaxation measures on monthly PT patronage

When analyzing the patronage data for the four PT providers, the general trends are similar for all cases up until November 2020 (Fig. 2). For January and February 2020, the patronage is comparable to the same months in 2019. With the first lockdown in March 2020, the numbers start to drop to an all-time-low in April 2020. The Austrian PT providers were the strongest hit in April, with patronage loss of approximately 80 percent. Oslo and Agder had a similar timeline in passenger loss in March and April, with passenger losses of up to 70 percent.

The recovery trend in all four PT networks started in May and continued until July. This corresponds to the period when there were few new COVID-19 cases in both countries and restrictions were relaxed. Innsbruck stood out as having a different behavior for the summer months (July and August), with figures in July registering a loss of more than 50 percent compared to the similar period of 2019.

In both countries, the second pandemic wave started in August 2020. The immediate response to this was a slight passenger drop in September in the two metropolises, but the drop was not so strong in the case of Innsbruck and Agder. Innsbruck registered a notable patronage increase in September compared to the summer months. The second and third lockdown periods in Austria (see Fig. 1) had a visible impact on PT ridership in Vienna in November 2020 and January 2021. The data provided by IVB showed a different behavior for the Innsbruck region, where December presented the second lowest patronage for this case, with patronage losses close to 70 percent com-

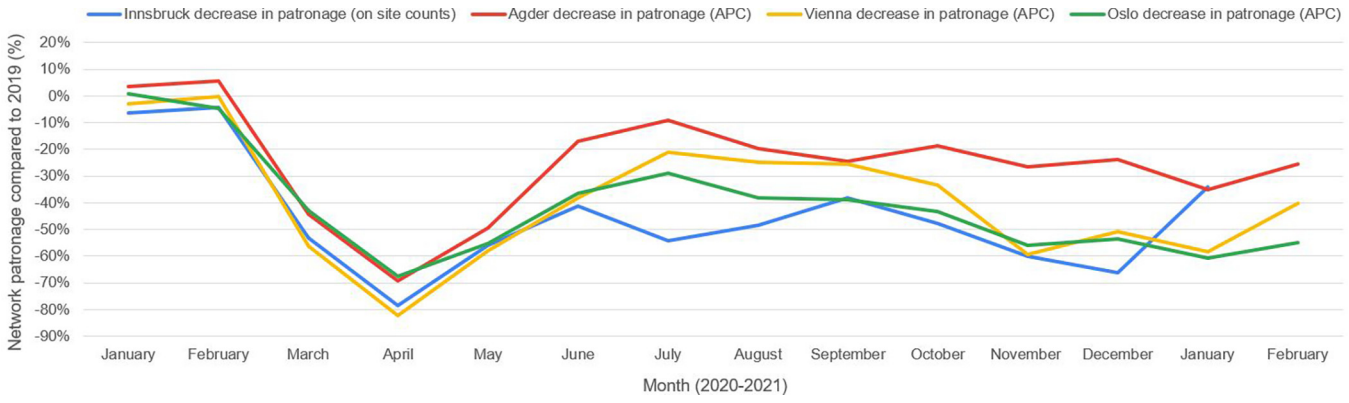

Fig. 2. Monthly public transport patronage variation in Vienna, Oslo, Innsbruck, and Agder based on APC and on-site counts (2020 and 2021 compared to 2019).

pared to the previous year. This may be explained by the strong limitation imposed on winter tourism (Tyrol and Innsbruck are popular European destinations for winter sports), combined with the light lockdowns in place in Austria at the time. On the other hand, the patronage for Innsbruck in January showed a strong spike, which is hard to explain given that Austria was still in lockdown at the time.

For February 2021, no data was available from IVB. For the remaining three cases, a recovery trend can be observed for that month, which also corresponds with the start of the third wave of the pandemic.

The data in Fig. 2 show that the first wave of the pandemic had the strongest impact on the PT network in all four cases, with the two Norwegian urban areas registering the least patronage loss. Full recovery of the PT patronage did not take place in any of the cases. At the same time, the effects of the second and beginning of the third wave, marked by light lockdown versions where schools could remain open, seem to be weaker on the PT network in all four cases, despite the contagion rate per 100,000 inhabitants being much higher than in the first wave (see Fig. 1). In Norway, where extreme restrictions on international travels were imposed starting in January 2021, and where PT usage was strongly discouraged by authorities in Oslo and Agder due to high regional contagion rates (see Fig. 1), January 2021 marked the month with the second lowest patronage figures in the data available.

With regard to ticketing, in May 2020 the COVID-19 pandemic was already expected to caused yearly ticket losses in "a double-digit million range" in Vienna (Vienna Online, 2020a). Data for other types of tickets were not available for analysis for Vienna, Innsbruck, and Oslo.

In Agder, ticketing data such as ticket usage, which reflects the actual passenger numbers, was almost impossible to collect in March and April, due to the middle door boarding procedure (ticket scanning machines were located at the front door of the vehicles). Therefore, data were only collected through APC. Large discrepancies between the number of tickets sold and the number of passengers were reported by AKT, pointing in the direction of riders travelling without tickets. The ticketing income data provided by AKT Fig. 3 confirms the patronage trend. The monthly income for April 2020 was reduced by 83.2 percent compared to April 2019 in Agder. We can observe that up until August, the ticketing income reduction is significantly larger than the patronage reduction. The difference was in double digits in April-July, which corresponds with the time when the front doors of the buses were closed. It is necessary to note that in Norway school children benefit from free public transport. Therefore, the income data presented in Fig. 3 only reflects the losses for the rest of the patronage, namely the paying customers.

Impact of pandemic containment and relaxation measures on weekly PT patronage

Fig. 4 presents the weekly variation in patronage for 2020 compared to 2019 in the entire network for Agder and Vienna, and for 2020 compared to an average of regular business years for Oslo. The period presented spans between Week 6 of 2020 and Week 9 of 2021. This type of data was not available in the case of Innsbruck. An analysis of weekly data is seen as important from the perspective of correlating the timeline of restrictions and relaxation measures imposed in a country or region (see Appendix) with the effect of the measures taken on the PT patronage level.

Up to Week 8 in all three cases considered, the situation presented "business as usual" in terms of patronage levels. In Vienna, the situation showed signs of patronage reduction (11.56 percent less passengers than in the same week of 2019) as early as Week 9 (February

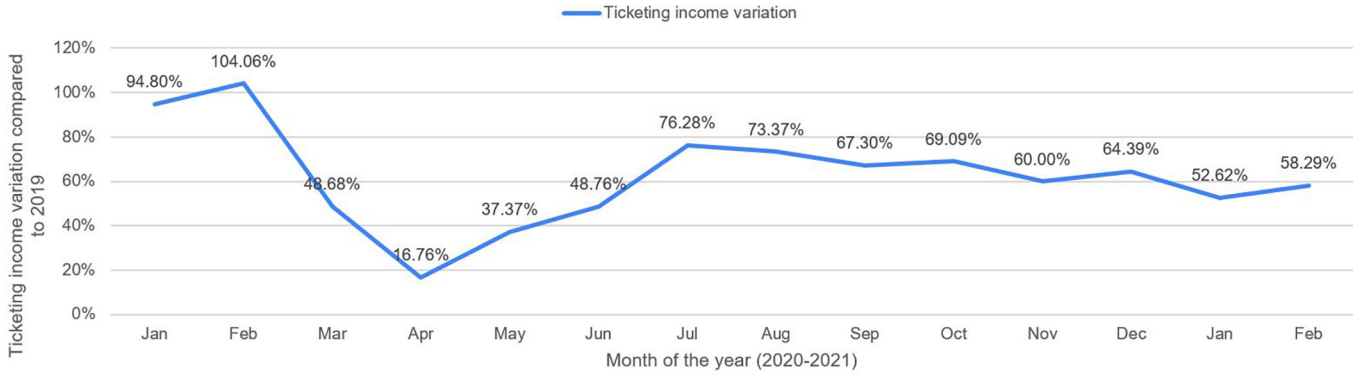

Fig. 3. Ticketing income variation for AKT (values from January 2020 to February 2021 compared to 2019 values).

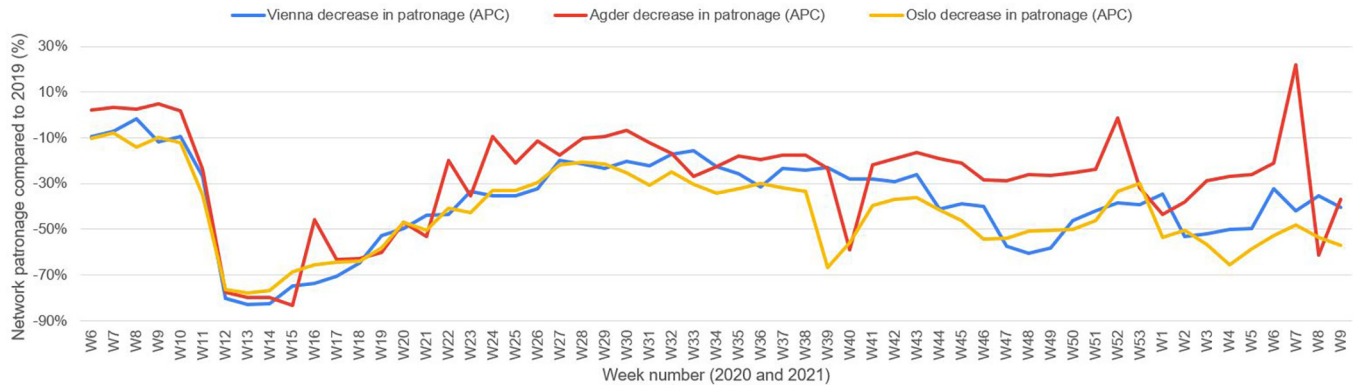

Fig. 4. Weekly public transport patronage variation in Vienna, Oslo, and Agder based on APC (2020 compared to 2019).

24–March 1), when the first COVID-19 case was registered in Austria. Week 10 (March 2–8) maintained a reduction of 9.32 percent in patronage for Vienna. For Weeks 9 and 10, in both Oslo and Agder, there is no noticeable deviation from the 2019 patronage values.

Week 11 (March 9–15) presented an accentuated drop in patronage for all three networks. Norway entered its first lockdown on the evening of 12 March and Austria introduced several national restrictions and announcing the upcoming lockdown in the same week. The passenger reduction continued practically synchronized in all three cases between Weeks 12–14, as the national lockdown was in place in both countries.

In the Viennese and Oslo networks, the recovery trend commenced in Week 15 (April 6–12). In Vienna, this coincided with a public announcement about the easing of restrictions starting April 14 (Week 16). Agder registered its lowest patronage in Week 15, when the Norwegian Health Minister announces the outbreak is "under control" and had a sudden spike in Week 16. The opening of daycare centers, kindergartens, and schools also generated a particularly strong impact (Week 17 in Austria and Week 21 in Norway), as it allowed parents to go back to work. Throughout the 57 weeks of data considered, we can observe several sudden variations appearing in consecutive weeks for the patronage figures. Such variations are mainly caused by school or bank holidays for which the week numbers do not correspond between 2019 and 2020.

The recovery trend is very similar for all three cases between Weeks 16 and 38 (April-September), with noticeable patronage increases when the first lockdown was lifted (Week 18 for Vienna and 19 for Norway), when borders to neighboring countries that had the contagion situation under control were open (Week 25 in both Austria and Norway), and when an extensive relaxation of restrictive measure came into force at national level (Week 27 in Austria and 29 in Norway). A small decrease in patronage was registered in Norway starting August, when the number of new daily infections began rising again and gradual restrictions were imposed (e.g., ban on alcohol serving after midnight starting Week 32). Vienna also registered a slow decrease in patronage for the same period.

The Norwegian cases started showing strong patronage reductions beginning with week 39, but Vienna's patronage remained constant in comparison. Week 43 (October 19–25) marked a sudden drop in patronage for all cases. This was related to the announcement of imminent lockdowns in both countries (Week 44 in Norway and 45 in Austria).

For all three cases, the month of December 2020 brought a clear increase in ridership. In Vienna, that corresponded with the post-lockdown relaxation measures put in place in the weeks before Christmas. For the Norwegian cases, the patronage increase period was shorter, closely corresponding with the winter holidays that had a limited set of lockdown relaxation measures. Even though a lockdown was in place in Austria starting December 24, ridership remained high in Vienna until the first week of 2021, which is longer than in the case of Agder and Oslo. Both metropolises showed a strong decrease in ridership throughout January 2021, with signs of recovery starting February. In Agder, the recovery started already in the third week of the year, with an advance of several weeks to the larger cities.

In Norway, the recovery trend was slightly different between Oslo and Agder. Agder registered a more rapid recovery up until Week 30 and a slight decline afterwards, with noticeable losses in the periods before and after Christmas holidays. The main difference in trends between Oslo and Agder was a higher patronage loss in Oslo starting Week 22. This difference was clearly connected to the higher contagion rate registered in Oslo compared to Agder throughout the pandemic.

A strong alignment can be noticed between the calendar of events in Austria and Norway and in the impact these events had on the patronage of PT in Vienna and Agder. It can also be noted that the PT patronage decrease in Agder recovered more quickly than the PT patronage in the two metropolises considered and maintained smaller overall losses throughout the course of the pandemic after the first lockdown ended.

Conclusions and further research

The COVID-19 pandemic and the related containment measures introduced by governments worldwide had strong impacts on PT ridership (Jenelius & Cebecauer, 2020; Orro et al., 2020). To understand the mobility behavior of the citizens and plan for future crises from a PT provider and policy perspective, it is essential to gain insight into the developments that took place (Wang, 2014). To examine the effects of the pandemic on the PT system, patronage data provided by two Austrian and two Norwegian PT companies for the period between February 2020 and February 2021 were compared with the 2019 (case of Agder, Vienna and Innsbruck) and average for regular business years (case of Oslo) data for the same period and location. Measures set by the government and PT providers were taken into account in the comparison.

Conclusion points

The European Economic Area (EEA) has only nine cities with a population of over three million inhabitants (Statista, 2021). This means that the majority of the cities in the EEA are urban areas with population sizes comparable to the four cases studied in the present research. Many metropolises in Europe, such as Budapest, Bucharest, Stockholm or Copenhagen are very similar to the cases selected here. In this respect, the findings of the present study are comparable to the situation in other European urban settings, and should be applicable to them as well.

Comparing the data for Vienna (Austria), Innsbruck (Austria), Oslo (Norway), and Agder (Norway) for the whole period considered (February 2020 – February 2021), we found that the negative impact on PT patronage was extremely strong during the first pandemic wave (between 67 and 82 percent loss of patronage), despite the low number of infection cases per 100,000 inhabitants. This points to the conclusion that the length and variation in severity of the pandemic itself were decisive in regards to the PT ridership variations, with the beginning of the pandemic registering stronger impacts due to the "fresh fear" effect (Wang, 2014).

The consequent pandemic wave presented a reduced rate of loss in PT ridership, possibly due to the population becoming used to the situation. At the same time, the measures taken by authorities and PT providers were less severe (no hard lockdown, schools still open etc.) and more delayed in the second and third wave of the pandemic. A parallel analysis of the pandemic timelines for the four cases presented in the Findings section shows a clear reflection of regional contagion level in the ridership variation. The relation between the number of new cases registered and the losses in PT patronage presents itself as directly proportional. This aspect is more clearly visible starting with the second wave of the pandemic, when the containment measures imposed to the population are relatively constant.

When comparing the ridership recovery in the period immediately after the first wave lockdown (April and May 2020), the SMCs present a faster recovery trend than Vienna and Oslo in a national comparison. The PT in Agder was clearly the least affected overall, while the case of Innsbruck, which is the only case where APC data was not available, presents an atypical behavior. The stronger effect in the cases of the two metropolises, which show close similarities in the patronage losses registered throughout the studied period, is probably caused by fear of contagion in large cities, aspect mentioned in the state-of-the-art section. In SMCs, on the other hand, reduced population densities and fewer COVID-19 cases worked in favor of patronage recovery for PT. In addition, subway lines with underground stations are not available

in the SMCs, but rather open-air bus and tram stations, which could be perceived as a lower risk.

The detail level of the data did not permit an in-depth comparative analysis of the impact of each measure taken for pandemic control in the four cases. Nevertheless, the weekly level data for Vienna, Oslo and Agder showed that public statements from national authorities can generate a rapid impact on the movement of people. The opening of daycare centers, kindergartens, and schools generated a particularly strong, as it allowed parents to go back to work. The opening and closing of borders were also received as a positive or negative signal by the population in relation to the status of the pandemic, reflecting in the PT ridership. Therefore, we can conclude that policy makers should evaluate the potential impact of upcoming measures and strategically choose the release date for announcing the implementation of such measures.

Another point on the aspect of data was the large differences noted between the case of Innsbruck, where no APC was available, and the other three cases where patronage was tracked using APC. Given the unexpected variations in the data for Innsbruck compared to the other three cases, we can conclude that there might be reliability issues with classic data collection (on site counts). Moreover, this type of data does not give a good level of detail for the immediate impact of different measures. This makes it almost impossible for PT providers to quickly adapt their offer to new measures. We therefore recommend PT providers and local governments to invest in the introduction of APC systems in their PT networks.

The paying customers segment seems to be more strongly affected in Norway than the school transport, which is reflected in reduced ticketing income. More remote work and fear of contagion seem to be the main influence factors for this effect in Norway, according to the national survey of Vy (2020) and the report of Betanzo et al. (2020). For Vienna, the annual ticket holders remained loyal to PT, whereas single and multiple ticket sales dropped significantly (Vienna Online, 2020a).

Another conclusion is that, despite the differences in applied measures, such as the compulsory wearing of facial masks (mouth-nose covering was made compulsory very early in Austria for indoor spaces, while in Norway this measure was introduced half a year later in Oslo and almost one year later in Agder), or the capacity limitation (implemented in Norway during the first wave but not in Austria) and reduced PT provision (implemented in Austria during the first wave, but not so much in Norway), the patronage losses seem to be very similar, at least in the case of the two metropolises. We can thus conclude that the contagion situation and connected national measures such as lockdowns and social distancing restrictions have a larger impact on the travel behavior of individuals than regulations imposed by PT providers.

Limitations of the study and proposals for further research

The main limitation in our study was the availability of detailed data. In each of the four cases considered, the data collection was performed differently. AKT in Agder provided APC based data detailed to trip level for every bus in their network. Ruter in Oslo and WL in Vienna provided APC based aggregated data to the week level for the entire network. IVB in Innsbruck only had monthly level data estimated based on counts on-site and ticketing. Different expectations and needs among PT users can only be understood and met when sufficient data is available. Data on the percentage of home office, detailed passenger data, increased use in individual transport modes (bikes, scooters, cars, taxis, etc.) and especially active modes, high resolution in temporal aspect for the collected data, socio-demographic data on usage patterns for PT, help to set measures that suit the customers. Furthermore, data on mode choice shifts is essential to better understand the reasoning behind the shift and whether it is related to reliability factors or only contagion fear aspects.

Observing the difference in impact for the two different pandemic waves, and in light of the research of Wang (2014), we propose that more studies are made on the “fresh fear” and “lingering fear” effects on PT ridership in the context of the COVID-19 pandemic. This would help better understand human behavior in relation to different pandemic stages and support forecasting for potential new pandemic scenarios in the future.

We also observe a gap in research in terms of what concerns the effect of wearing mouth-nose covering or facial masks on the perception of safety from contagion in public transport, especially in a European context. Furthermore, we find that more research is necessary on the effect of a home office on modal split and the need and the usefulness of introducing data collection on percentage of home offices in the workforce for passenger mobility forecasting purposes.

CRediT authorship contribution statement

Sinziana Rasca: Conceptualization, Methodology, Data curation, Writing - original draft, Visualization, Investigation. **Karin Markvica:** Conceptualization, Methodology, Writing - original draft, Visualization, Investigation. **Bernd Peter Ivanschitz:** Conceptualization.

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Appendix. Chronological list of COVID-19 measures taken in Norway and Austria between February 2020 and March 2021

Color code for all tables in the Appendix: red- restrictive measure, green – relaxation measure, white – pandemic event.

Table A1
Chronological presentation of COVID-19 pandemic events and measures in Norway and Austria – first wave of infections (February to mid-April 2020).

Week	Events Norway	Events Austria
W7	13.02- Discourages travel to Hubei province and Zhejiang, China. *	
W8	17.02- Advice against not strictly necessary travel to mainland China. *	
	21.02- First case of COVID-19 (Tromsø resident) (FHI, 2020).	
W9	26.02- Discourages travel to areas with widespread infection rates. *	25.02- First two cases of COVID-19- both in the province of Tyrol. ***
	26.02- Public announcement first COVID-19 case (Life in Norway, 2020).	
	27.02- Public announcement: Norwegian authorities are closely monitoring the situation. *	
W10	02.03 Contact information required for air passengers and employees. *	06.03- Health checks at the border to Italy. ***
	07.03 Two weeks home quarantine for people returning from countries with high contagion risk. *	
W11	10.03 Workplace measure to limit contagion. **	10.03- Ban on events with large numbers of participants, restriction of travel, recommendation for "social distancing". Closure of universities until 16.03.2020. ***
	12.03 First COVID-19 death (FHI, 2020).	11.03- Closure of schools starting at 18.03.2020 and federal museums. ***12.03- First COVID-19 fatality Visiting ban in hospitals. ***
	12.03 National lockdown: closure of non-essential activities, such as supermarkets, hospitals, gas stations, effective from 18:00 on the same day. Use of PT and leisure travel strongly discouraged. PT runs as normal. No more than 5 people in a group unless from the same household. No visits in institutions with vulnerable groups. *	14.03- Adoption of the COVID-19 Act by the National Council. Ban on visiting nursing and elderly homes. ***
	13.03 Travel advice for the United States and France. * Stricter home isolation rules for suspected or confirmed COVID-19 cases. *	13.03- Announcement of restrictions starting 16 March.
	14.03 Advice against non-essential travel to all countries. New standards on quarantine after travelling outside the Nordic region. *	
	15.03 Travel ban to Norway extended to all non-residents. *	
W12	19.03 Ban on visiting cabins outside home municipalities. *	16.03- National lockdown: temporarily close all non-essential facilities. Employers requested to send staff into the home office where possible. Restriction of contact with people outside own household. ***
		17.03- Closure of pubs, cafés, bars and restaurants and playgrounds. ***
		18.03- Second COVID-19 law adopted. Closing down: sports facilities, health resorts and schools. Tyrol - all communities under quarantine. ***
		20.03- Broad COVID-19 law adopted. Extension of initial restrictions until further notice. ***
W13	24.03 Coronavirus measures to continue until April 13. *	25.03 Contact tracing through government endorsed app.**
	27.03- Peak of epidemiologic curve (wave 1) (***Fig. 1***).	26.03- Peak of the epidemiologic curve (wave 1): 1,050 new cases (***Fig. 1***).
W14	28.03- Comprehensive regulations on measures implemented. Temporary changes in health legislation. *	27.03- Distance learning until end of semester for nearly all university courses. ***
	03.04- Temporary exemptions for municipalities to facilitate quick necessary decisions. *	01.04- Mandatory wearing of mouth-nose protections in supermarkets. ***
W15	06.04- Norwegian Health Minister announces the outbreak is "under control". No relaxation measures.*	06.04- Announcement of the gradual opening after the Easter break. ***

*Regjeringen (2021), **ECML Covid (2020), ***Universität Wien (2020a).

See above-mentioned references for further information.

Table A2
Chronological presentation of COVID-19 pandemic events and measures in Norway and Austria – contagion stagnation period with relaxation measures (mid-April to mid-July 2020).

Week	Events Norway	Events Austria
W16		14.04- Gradual opening of shops. Mouth-nose protection extended to public transport and all shops. ***
W17	20.04- Kindergartens and daycare centers resume activities. Travel ban to summer cabins lifted. *	21.04- Announcement: Opening all shops from 1 May; end of national lockdown (gastronomy, schools) by 15 May. ***
W18	27.04- Gradual reopening of schools and specific university specializations. *	01.05- Opening of all shops (Kurier, 2020b).
W19	06.05 Visitors to hospitals allowed. ** 07.05- Public gatherings with up to 50 people. Home gatherings of up to 20 people. *	04.05 Nursing and elderly homes can recieve visits. Schools open for graduate classes. ***
W20	11.05- Schools open for all pupils. *	15.05- Restaurants, coffee shops and bars reopen with restrictions measures. ***
	15.05- Advice against foreign travels until 20 August. Borders remain closed until mid-July. Opening to Nordic countries from 15 June. *	
W21		18.05 Primary schools, AHS lower grades, new middle schools (NMS) and special schools reopen (medinlive, 2020).
W22	26.05- Inmates can receive visits again. *	30.05- Swimming pools open. Restrictions on minimum areas per customer lifted. ***
W23	02.06 Serving ban lifted for bars and other establishments that do not sell food with distancing rule of one meter. **	02.06- Universities open for employees and for some exams (TU Wien, 2020).
W24	08.06- Full capacity on school busses (50% occupancy before) (Furulunden Skole, 2020).	
W25	15.06- Universities, colleges and vocational schools resume activity. * Fitness centers, water parks and swimming pools reopened. Relief of entry restrictions for family members. Children and young people can deviate from distance rules at summer camp and similar activities. Events with up to 200 participants. Borders open to Denmark, Iceland, Finland and parts of Sweden. *	15.06- Mouth-nose protection only required in public transport, doctor offices, pharmacies, and hospitals. *** Borders open to 31 European countries. **
W26	24.06- Opens for cruises along the Norwegian coast. *	25.06- Renewed tightening of preventive measures. Mask compulsory in food retailing, supermarkets, banks and the post office (medinlive, 2020).
W27	01.07- Relief in entry restrictions for working immigrants and students with effect from 1st July. *	01.07- Extensive relaxation comes into force. ***
W29	15.07- Allow entry for EEA / Schengen with satisfactory infection situation (under 20 new cases per 100 000 in previous two weeks). *	

*Regjeringen (2021), **ECML Covid (2020), ***Universität Wien (2020).

See above-mentioned references for further information.

Table A3
Chronological presentation of COVID-19 pandemic events and measures in Norway and Austria – second wave of infections (mid-July to October 2020).

Week	Events Norway	Events Austria
W30		23.07- Reintroduction of compulsory masks at federal level. ***
W32	08.08- Events with a liquor license cannot serve alcohol after midnight. Overview of participants required. *	
W33	12.08- Norway extends global travel advice and makes changes for the Nordic region and Europe (applies until 1 October) Continued border control. *	
W34	18.08- Requirements for table service at events (including restaurants). *	17.08- Restrictions on travel to Croatia enter into force. ***
W35		28.08- Federal Chancellor announces that the Corona crisis will be over in summer 2021. ***
W36	31.08- Unofficial start of second wave (Fig. 1).	04.09- Corona traffic light comes into force. ***
W38	15.09- Simplified quarantine rules and structure of municipal preparedness. *	14.09- asks compulsory in retail, catering and all forms of customer contact. Events limited to 50 visitors indoor, and 100 outdoors (medinlive, 2020).
W39	21.09- Municipalities can ban private gatherings. *	21.09- Maximum 10 parcitipants at private parties and indoor events. Masks compulsory for guests in catering trade, consumption only possible while seated (medinlive, 2020).
	24.09 Global travel advice to be extended.until 15 January 2021. *	.
		25.09- Curfew at 22.00 for the three western states (medinlive, 2020).
W41	08.10- National facilitations are being replaced by local measures. *	
W43	21.10- More family members can come to Norway. *	19.10- Events participation limitations: private events-six people indoors and 12 outdoors (except funerals); professional events-1,500 visitors outdoors, 1,000 indoors. Mouth-nose protection mandatory (medinlive, 2020).
W44	28.10- New national restrictions: maximum 5 guests in addition to household members. Tightening of the quarantine rules for working immigrants. *	31.10- Lockdown announced starting 3 November 0:00 (enforcement initially until 30 November 2020) (RegiowikiAT, 2020).
	30.10- Entry restrictions extended until 1 June 2021. *	
W45	5.11 New national infection control measures. Stronger set of measures in regions with widespread infection (light lockdown). *	3.11 Start of second lockdown (distance learning, restaurants and bars can only provide take-away, non-essential commerce closed leisure travel not allowed; recommendation to keep social contacts to a minimum). **
	7.11 Stay in quarantine hotels compulsory for non-residents when entering Norway. Negative Covid-19 test required to enter Norway. *	
W49	2.12 Christmas holidays- 10 guests permitted for Christmas and New Year Eve. *	
W50	10.12 Introduction of a digital travel registration system. *	
W51	14.12 Quarantine hotel not compulsory for persons with access to another suitable quarantine location. *	
W52	21.12 Ban on direct flights from the United Kingdom. Registration requirement for all people entering Norway. *	26.12 Mandatory 10 days quarantine upon arrival. **
W53	29.12 Possibility to end quarantine on day 7 after a second negative COVID-19 test. *	
	31.12 Mandatory testing for travelers to Norway. *	
	2.01 Ban on flights from United Kingdom lifted. *	
W1	4.01 Strengthened national infection prevention measures for two weeks. *	
W2	12.01 Global travel advice extended until 1 March 2021. *	15.01 Online pre-travel-clearance compulsory before entering the country. **
W3	18.01 National level of measures for schools downgraded to yellow. Local sports and leisure activities for children and youth no longer discouraged. *	
	23.01 Stricter rules for testing and quarantine upon arrival to stop coronavirus mutation. *	

W4	27.01 Border closure for non-residents. * 30.01 Restrictions relaxation for children and young people and workplaces. *	25.01 FFP2 mandatory in most indoor public places for everyone aged 14 and above. **
W6		08.02 Strict stay at home order replaced by curfew between 20:00 and 6:00. Non-essential stores, museums and libraries reopen. ** Stricter border control to neighboring countries. FFP2 masks mandatory in all indoor public places for everyone aged 14 and above. **
W7	19.02 All non-residents to stay in quarantine hotels or pre-approved quarantine accommodation provided by the employer.* Indoor public gathering of maximum 10 people without allocated seats and maximum 100 people with allocated seats. **	
	19.02 Easing of the measures applicable to children, young people, and students. *	
W8	24.02 Simplified scheme for regional coronavirus measures from four to three levels. *	

*Regjeringen (2021), **ECML Covid (2020), ***Universität Wien (2020c).

See above-mentioned references for further information.

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