COVID-19

Geography of the Passenger Turnover Dynamics at Airports in Europe and Russia's Regions in the First Year of the COVID-19 Pandemic¹

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Abstract—Due to restrictions on people's movement as a result of the COVID-19 pandemic, the air passenger traffic sharply decreased in 2020. A geographic study of this phenomenon is highly relevant. The article describes the features of the spread of the pandemic across Europe from a transport–geographical viewpoint; reveals differences in the negative passenger turnover dynamics at large and medium-sized airports in 49 European countries (including Russia) impacted by the COVID-19 pandemic during the first year. The changes were measured absolutely and relatively, which made it possible to identify the types of their dynamics: catastrophic, strong, medium, moderate, weak, and insignificant declines. Geographically, the spread of COVID-19 was extremely uneven: at first, the epidemic covered large countries of Europe (Northern Italy became the main center after Wuhan), then closely related neighboring and more distant countries were involved; last but not least, the Balkan countries and countries in post-Soviet Eastern Europe. The disease spread hierarchically. The first cases arrived by air, first from the main centers, whence coronavirus infection was then transmitted to other countries by new groups of air passengers. Then, the infection was transmitted by ground transport passengers within the zones of influence of the largest airports. The airports of European countries are characterized by a strong decline in passenger turnover (65–85%); Russian regions, by moderate (30–45%) and weak (15–30%) declines. The retrogression time lag (return to the values of the distant past) turned out to be the largest (27–40 years) for the largest European airports with a large share of international passengers and transit, relatively medium (16–26 years)—for medium-sized or large airports with a large share of domestic transportation, relatively short (9–16 years)—for the largest airports in Russia with a high proportion of international passengers, short (4–8 years)—for almost all other airports in Russia, very short (2–3 years)—for resort and tourist airports in Russia and some airports with an increased share of domestic passengers. Since different airports had different dynamics of passenger turnover, the ranks of their hierarchy in 2020 changed somewhat: before, the largest airports gave way to others, which bypassed the first ones due to a smaller level of recession and rapid recovery in the volume of domestic air traffic.

Keywords: COVID-19, spatial diffusion, hierarchical diffusion, air transport, airports, passenger turnover, Europe, Russia, retrogression time lag

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FORMULATION OF THE PROBLEM

The COVID-19 pandemic has completely changed the entire world and our understanding of its sustainability. It divided the current stage of world development into the pre-COVID and COVID eras. It was a very significant impact on the tertiary sector of the economy, especially tourism, the hotel business, and the entertainment industry, as well as on communications, including transport connectivity and people's mobility. First of all, people themselves suffered, and secondly, the economy.

It is still difficult to estimate the scale and nature of the impact of the COVID-19 pandemic on the territo-

rial structure of the economy as a whole, its individual industries, people's lives, the settlement pattern, and spatial structure of urban agglomerations, in particular, due to the lack of the necessary territorially fractional statistical data. From the viewpoint of a transport geographer, it is important to understand how strong the impact of the pandemic on transport was, i.e., how significant was the decline in the volume of traffic by each type of transport in different countries and macroregions of the world and in certain areas within countries, and how was this reflected in the territorial structure of transport. Unfortunately, such an analysis is not yet possible due to the extremely incomplete and fragmentary statistical information on the transport system in a territorial context.

Air transport in this respect yielded better results than did other modes of transport, since at most air-

¹ The article has been revised and substantially expanded (with situation in Russia's regions) by the author for publication in *Regional Research of Russia*.

ports, by fall 2021, accurate information on their passenger² and cargo turnover³ was published for the 2020 in its entirety versus 2019 (and for a number of airports even for every month of 2019 and 2020). This allowed the author to carry out this study.

The pandemic led to restrictions of people's movement both within and between countries, as a result of which the passenger traffic by air transport sharply decreased, the level of aviation mobility of people decreased⁴, and the degree of air connectivity between cities and countries decreased. All these changes had pronounced spatial differences.

Revealing the geographical features of the impact of the pandemic since its beginning has become an important topic of Russian economic and geographical research. By summer 2020, a series of general articles appeared on the impact of COVID-19 on the structure of the economy and society as a whole. A special section of the journal *Sotsial'no-Ekonomicheskaya Geografiya. Vestnik Assotsiatsii Rossiiskikh Geografov-Obshchestvovedov*, no. 1 (9), 2020 contains very short essay articles on this topic (Gerasimenko T. and Gerasimenko A.; Druzhinin; Zyryanov; Kagan-sky; Kolosov; Kuznetsova; Rodoman; Shuper and others), which have a preliminary evaluative character of this new phenomenon. The most interesting among them is a publication by V.L. Kagansky, in which he analyzes the possible spatial and functional consequences of the impact. A number of publications that appeared several months later analyzed the diffusion of the pandemic, the factors of its spread, and regional impact on the Russian economy (Zemtsov and Baburin, 2020a, 2020b; Zubarevich and Safronov, 2020).

In 2021, new articles on this topic were published in Russian geographical journals. In (Panin et al., 2021), a cartographic analysis of the spatial patterns of the spread of the COVID-19 pandemic in Russia is carried out; it states that the three initial centers of its distribution were the Moscow region, the oil and gas producing north of Western Siberia, and the North Caucasus. The main factors of the rapid spread of COVID-19, from the viewpoint of the authors, were not only trans-

port and logistics parameters, but also a high proportion of the creative class in the Moscow region; shift-work flows and overcrowding of shift settlements in the Yamal-Nenets Autonomous Okrug; and increased contacts and weak healthcare system in regions of the North Caucasus. Makhrova and Nefedova (2021) consider the possibilities of a transition from seasonal dacha mobility to real suburbanization and deurbanization in areas with different degrees of remoteness from Moscow under new conditions of quarantine restrictions.

Abroad, studies have also appeared on analysis of the geographical factors involved in the spread of COVID-19. A special issue of the Dutch journal *Tijdschrift voor economische en sociale geografie* no. 3, 2020, published a series of articles on the relevant topic (Geography ..., 2020). Kuebart and Stabler (2020) use a spatial diffusion model to study the spread of COVID-19 in Germany.

Chen et al. (2021) apply a gravity model to study the spatial diffusion of COVID-19, which spread from Wuhan to cities in Hubei province in China. The simulation results showed that the size of provincial cities and distance from them to Wuhan influenced the total number of confirmed cases of the disease and that Wuhan was the main source. Thus, the spread of the epidemic was hierarchical, while the immediate neighborhood of cities with each other did not much matter.

Sigler et al. (2021), using regression analysis, obtained the following conclusions: the values of human development indicators and total population predict well the spread of COVID-19 in countries with a large number of reported cases (per 1 mln inhabitants); larger household sizes, older populations and more intense human interactions predict the spread of COVID-19 in countries with low reported cases (per mln inhabitants). Population density and other characteristics of the population, such as total population, proportion of older persons and household size, are relevant explanatory indicators in the early weeks of the epidemic, but have a smaller impact on the rate of spread of COVID-19 over time. In contrast, the influence of interpersonal communication and out-of-store trade increases over time, indicating that higher human mobility may best explain the persistent spread of the disease.

In (Ascani et al., 2020), the spread of COVID-19 in Italy at the regional level (NUTS 3) is analyzed in terms of economic geography. The bright spatial unevenness of the spread of the disease indicates that the coronavirus infection hit the cores of the most economically developed regions of the country the hardest. The specialization of a particular region in a certain type of economic activity that is geographically concentrated turns out to be a means of transmission of the disease. This leads to the formation of center-periphery spreading of COVID-19, where the disease

² The airport passenger turnover is the total amount of passengers that passed (arrivals + departures) through it during a certain time period (month or year; most often it is calculated per year). The author considered the values for the entire year, not for individual months.

³ The airport cargo turnover is the total amount of cargo (in tons) that passed (arrived + sent) through it during a certain time period (month, year; more often per year).

⁴ The aviation mobility of the population is a conditional statistical indicator that is the quotient of dividing the number of passengers transported by air (measured by the passenger turnover of airports) in a certain area (region, country, city) by the size of its population. If the value of the indicator is large, this demonstrates that many passengers pass through airports, including foreign tourists and transit passengers. And the more there are, the higher the level of mobility of one inhabitant on average. If the value is small, then there are significantly fewer visitors, or there none at all.

can follow along the main axes of the regional economic landscape.

In (Ramires-Aldana et al., 2021), the spread of COVID-19 across Iran at the *ostan* (province) level from February 19 to March 18, 2020 is described by a series of cartograms of increase in the number of cases compiled by the authors. The highest morbidity rate was found in the urban agglomeration of Tehran. Urban provinces with older populations and higher average temperatures had significantly more COVID-19 cases. The higher the population's level of literacy (including health), the fewer their number.

Florida and Mellander (2021) investigate the geographic drivers of COVID-19 in Sweden. These include population density, household size, existence of air transport, income, race and ethnicity, age, political affiliation, temperature and climate, isolation, and physical distance from each other. This study examined the impact of some of these factors on geographic differences in the number of COVID-19 cases and deaths, both by municipalities and provinces (*län*). It turned out that the geographical variations in COVID-19 are largely associated with variables such as population density, population size, socioeconomic characteristics of localities, and household size. The geographic variability of COVID-19 across Sweden has been found to be large, but highly random.

At the very beginning of 2021, the first, most general articles on the impact of the pandemic on air transport worldwide during 2020 appeared in a special press dedicated to air transport problems (Air Passenger ..., 2021; Dunn, 2021, 2020; Worst Year ..., 2021), but they lack analysis of the spatial differentiation of this process. There are still very few publications on the geographical analysis of the dynamics of air passenger traffic in the context of the COVID-19 pandemic, since there is still no corresponding territorially fractional statistical information for 2020 in the context of countries and their individual parts. For this reason, this issue has hardly been studied. Suau-Sanchez et al. (2020) assesses the medium- and long-term impact of the pandemic on air transport based on interviews with airline executives. However, this article is not so much geographic as sociological in nature.

This article partially fills the existing gap in the geographical analysis of this phenomenon. The objectives of the article are to identify the process of the spread of the COVID-19 pandemic across Europe and Russian regions from a transport–geographic viewpoint, as well as territorial differences in the dynamics of passenger turnover at airports in European countries and Russian regions in the first year of COVID 2020 versus pre-COVID 2019. It is important to study and understand what these differences are from place to place, where this decline was stronger and weaker, and why in some places the decline was very large, while in others it was medium and small. Geographic concepts

(including the theory of spatial diffusion of innovations) make it possible to identify such differences.

MATERIALS AND METHODS

To analyze the dynamics of air traffic, statistical data on passenger turnover for almost 300 large and medium-sized airports in Europe and Russian regions for 2019 and 2020 were used, which were collected from a large number of sources: annual reports of individual airports, groups of airports, national aviation agencies, and departments of individual countries. The first reports (including monthly) for 2020 were published in January 2021, but most appeared on the Internet only in May–July 2021.⁵ Thus, information from different sources was combined and systematized.

Airport passenger turnover proved best indicator of spatial activity and passivity of people during COVID-19: if an airport was closed, it meant complete lockdown in a given city and the surrounding area; if the number of passengers was insignificant compared to the pre-COVID year, then this indicated a partial lockdown; the smaller the decrease in passenger traffic through the airport during the year, the weaker were the restrictions on movement. Based on the dynamics of passenger turnover at most airports, one can judge not only its nature, but also geographic differences.

The values of the total passenger turnover of all airports of each European country for 2019 (the last pre-COVID) and 2020 are compared. The changes are measured absolutely (growth/decline) and relatively, as: (1) the ratio of growth/decline to value in 2019, %; (2) the ratio of values in 2019 to 2020, times. In addition, the time lag of the depth of retrogression was calculated (how many years ago the passenger turnover in a COVID year was “set aside”).

To break down changes in airport passenger turnover into types, the author used his own methodology developed earlier for quantitative assessment of the degradation of passenger air connectivity at Russian airports in 1990–2006 (Tarkhov, 2015, p. 124), where the types of growth and decline in air passenger traffic were empirically identified. The quantitative parameters of the types are presented in Table 1 (gradations for the third indicator of dynamics are added).

The author has calculated the indicators of the passenger turnover dynamics at airports in almost all European countries, including Russia, for which complete statistical data were found.

⁵ Until now, information on the majority of airports in France, Portugal, Romania, and Moldova has not been published.

Table 1. Types of airport passenger turnover dynamics in context of radical socioeconomic crises

Type of dynamics	Variations in relative change, %	Change, 2019/2020, times
Weak growth	+15.0 + 29.9	0.81–0.70
Insignificant growth	+3.0 + 14.9	0.95–0.82
Stagnation (zero growth)	–2.9 + 2.9	0.96–1.02
Insignificant decline	–3.0–14.9	1.03–1.16
Weak decline	–15.0 –29.9	1.17–1.42
Moderate decline	–30.0 to –44.9	1.43–1.80
Average decline	–45.0 –64.9	1.81–2.85
Strong decline	–65.0 to –84.9	2.86–6.6
Catastrophic decline	–85.0 to –99.9	6.7–29.0
Disappearance of phenomenon (closure)	–100	...

Compiled empirically by author. The second column shows the percentage to the base level of the beginning of growth (decline); the third shows the quotient from division of the base (pre-COVID, i.e., 2019) value to the current value (2020).

RESULTS

Spatial Distribution of COVID-19 in Europe: Transport–Geographic Analysis

Analysis of electronic information sources (including media publications) revealed the centers of the first cases of COVID-19⁶ and made it possible to trace how coronavirus infection spread across Europe. The SARS-CoV-2 coronavirus was introduced in Europe in the last ten days of January 2020 due to the availability of direct flights between Wuhan (China) and several major European airports (Table 2). Regular passenger flights from Wuhan airport at the end of 2019 flew to Paris (Charles de Gaulle airport), London (Heathrow), Rome (Fiumicino), Istanbul, Moscow (Sheremetyevo), and St. Petersburg; there were also some charter flights to other European airports; there were cargo flights to Luxembourg.

The first case of COVID-19 in Europe was reported on January 24, 2020, in Bordeaux (France). Then, cases were recorded on January 27 in Germany, on January 28 in Finland, on January 30 in Italy, and on January 31 in the UK, Spain, and Sweden, when Chinese tourists rushed to spend the Chinese New Year holidays in European tourist centers, ski resorts, and shopping centers in France and Italy to take advantage of post-New Year sales. On January 31, the first cases were recorded in Tyumen and Chita (Russia), where residents from China arrived from Wuhan. On February 2, the first case arrived in Belgium on a flight from Wuhan. Thus, from January 24 to February 2, coronavirus infection entered European coun-

tries with air passengers from Wuhan (either Chinese tourists or Europeans returning from China).

The main peak of infections occurred first in Italy, since this is the European country most visited by Chinese tourists.⁷

The first two cases recorded in Italy were two Chinese tourists in Rome on January 30, who arrived on January 23 from Wuhan at Milan (Malpensa) airport, then flew to Verona airport and traveled by land to Rome via Parma. However, a massive COVID-19 outbreak occurred almost three weeks later, on February 21–22, and the number of infections skyrocketed. The main centers of the epidemic were the Lombardy and Veneto regions. Airports in Northern Italy became the main centers of transmission and cross-spreading of infection, since they had direct flights with many other air hubs not only in Europe, but also in Russia, Africa, and America. At the largest airports in Lombardy, the infection was picked up by tourists returning to their homeland at the end of February from the alpine ski resorts of Northern Italy, becoming coronavirus vectors to other countries (see Table 2). Since the end of February, northern Italy has become the main source of diffusion of infection. From February 25 to March 13, it spread from Milan airports (Malpensa and Linate) and Bergamo to 28 European countries, i.e., the overwhelming majority.

The second spreading center since the end of February was Innsbruck Airport, where COVID-19 very quickly entered from neighboring Lombardy. Tourists on holiday in the ski resorts of Tyrol flew to all corners of Europe. Via Austria's airports, the infection first entered Norway and Denmark.

⁶ The main sources of information on the first cases of the disease and number of cases of COVID-19 by individual countries: <https://github.com/CSSEGISandData/COVID-19> (COVID-19 statistics by countries of the world of J. Hopkins University); <https://stopcoronavirus.rf> (Coronavirus COVID-19: official information); https://en.wikipedia.org/wiki/Category:COVID-19_pandemic_by_country.

⁷ In 2018, 3201 thous. Chinese arrived in Italy, 2109 thous. in France, 1583 thous. in Germany, 1210 thous. in Switzerland (2015), 973 thous. in Austria, 860 thous. in Great Britain, 649 thous. in Spain, 619 thous. in the Czech Republic (14 480 thous. to the European Union as a whole (statista.com/statistics)).

Table 2. Geographic features of spread of SARS-CoV-2 in European countries (listed in chronological order when first cases were recorded)

Country	Date first case was recorded	Where it was brought from	Type of transport	First locales covered by epidemic	Most affected areas
France	January 24, 2020	Wuhan (China)	Air transport	Bordeaux	Ile-de-France, Auvergne-Rhône-Alpes, Hauts-de-France, Provence-Alpes-Côte d'Azur
Germany	January 27, 2020	Wuhan (China)	Air transport	Starnberg (near Munich)	North Rhine-Westphalia, Bavaria, Baden-Württemberg, Lower Saxony
Finland	January 28, 2020	Wuhan (China)	Air transport	Ivalo (Lapland)	Helsinki, Uusimaa
Italy	January 30, 2020	Wuhan (China)	Air transport	Rome	Lombardy, Piedmont, Emilia-Romagna, Veneto
United Kingdom	January 31, 2020	Wuhan (China)	Air transport	York, Brighton (February 6, 2020)	London, Kent, Boston, South Wales, Sheffield, Leeds
Spain	January 31, 2020	Lombardy (Italy)	Air transport	Gomera, Tenerife (Canary Islands)	Madrid, Catalonia, Andalusia, Valencian community
Sweden	January 31, 2020	Wuhan (China)	Air transport	Jonköping	Södermanland, Örebro, Jämtland, Stockholm
Russia	January 31, 2020, February 27, 2020	Wuhan (China; January 31); Italy (February 2)	Air transport	Tyumen, Chita (January 2020); Moscow (27.02)	Moscow, St. Petersburg; Moscow, Nizhny Novgorod, Sverdlovsk, Voronezh oblasts
Belgium	February 4, 2020	Wuhan (China)	Air transport	Brussels	Hainaut, Antwerp, Brussels, Liege, East and West Flanders
Austria	February 25, 2020	Lombardy (Italy)	Road transport	Tyrol (Innsbruck)	Vienna, Upper and Lower Austria, Styria, Tyrol
Switzerland	February 25, 2020	Milan (Italy)	Road transport	Lugano	Zurich, Vaud, Bern, Geneva, Aarau
Croatia	February 25, 2020	Italy	Road transport	Zagreb	Zagreb, Split–Dalmatia, Primorje–Gorski Kotar
Norway	February 26, 2020	Austria, Wuhan (China)	Air transport	Tromsø	Viken, Oslo, Westland
Romania	February 26, 2020	Italy	Air transport	Prigoria (Gorj)	Bucharest, Cluj, Timis, Ilfov, Braşov, Iasi, Constanta
Greece	February 26, 2020	Northern Italy	Air transport	Thessaloniki	Attica, Central Macedonia
North Macedonia	February 26, 2020	Italy	Air transport	Skopje	Skopje, Kumanovo
Netherlands	February 27, 2020	Italy	Air transport	Tilburg (Loon op Sand)	Southern Holland, North Brabant, Northern Holland, Gelderland
Denmark	February 27, 2020	Lombardy (Italy), Tyrol (Austria)	Air transport	Roskilde, Copenhagen	Copenhagen, East and South Jutland
Iceland	February 27, 2020	Italy (Andalo)	Air transport	Reykjavik	Reykjavik
Estonia	February 27, 2020	Iran (via Riga)	Air transport	Tallinn	Tallinn, Harjumaa, Saaremaa, Ida-Viru
Belarus	February 28, 2020	Iran (via Baku airport)	Air transport	Minsk	Minsk, Vitebsk Oblast
Lithuania	February 28, 2020	Verona (Italy)	Air transport	Kaunas, Siauliai	...
Monaco	February 28, 2020	Lombardy (Italy)	road transport	Monaco	Monaco
San Marino	February 28, 2020	Italy	Road transport	San Marino	San Marino

Table 2. (Contd.)

Country	Date first case was recorded	Where it was brought from	Type of transport	First locales covered by epidemic	Most affected areas
Luxembourg	February 29, 2020	Italy (via Charleroi Airport)	Air transport	Luxembourg	Luxembourg
Ireland	February 29, 2020	Northern Italy	Air transport	Dublin	Donegal, Lowth
Czech Republic	March 1, 2020	Italy (Milan, Udine, Auronzo di Cadore)	Air transport, railway	Prague, Decin	Prague, Frydek-Mistek, Brno, Karvina
Portugal	March 2, 2020	Lombardy (Italy)	Air transport	Porto	Lisbon, Porto
Andorra	March 2, 2020	Milan (Italy)	Road transport	Andorra la Vella	Andorra
Latvia	March 2, 2020	Milan (Italy)	Air transport	Riga	Riga, Kuldiga, Daugavpils
Liechtenstein	March 3, 2020	Switzerland	road transport	Vaduz	Liechtenstein
Ukraine	March 3, 2020	Italy	Air transport and road transport	Chernivtsi	Kiev, Odessa, Kharkov, Lvov, Kiev, Dnepropetrovsk regions
Gibraltar	March 4, 2020	Northern Italy (via Malaga Airport)	Air transport	Gibraltar	Gibraltar
Faroe Islands	March 4, 2020	Paris, Northern Italy	Air transport	Torshavn	Streimoy Island
Poland	March 4, 2020	Germany	Bus	Zielona Gora	Warsaw, Krakow, Poznan
Hungary	March 4, 2020	Iran	Air transport	Budapest	Budapest, Borsod, Gyor-Sopron, Hajdu-Bihar, Bacz-Kiskun
Slovenia	March 4, 2020	Italy	Road transport	Ljubljana	Ljubljana
Bosnia and Herzegovina	March 5, 2020	Italy	...	Banja Luka (March 5, 2020), Zenica (March 9, 2020)	Republika Srpska, Sarajevo, Tuzla
Serbia	March 6, 2020	Budapest (Hungary)	Road transport	Subotica	Belgrade agglomeration, Nisava, Yablanitsa
Slovakia	March 6, 2020	Venice (Italy)	Air transport	Kostoliste	Presov, Zilina, Trencin, Kosice, Trnava
Malta	March 7, 2020	Italy	Air transport	Valetta	Malta
Moldova	March 7, 2020	Milan (Italy)	Air transport, road transport	Chisinau	Chisinau, Gagauzia
Bulgaria	March 8, 2020	...	...	Pleven, Gabrovo	Sofia, Burgas, Varna
Albania	March 8, 2020	Florence (Italy)	Air transport	Tirana	Tirana, Fieri, Durres, Vlora
Turkey	March 11, 2020	Europe	Air transport	...	Trabzon, Rize, Hordu, Giresun, Samsun
Kosovo	March 13, 2020	Italy	...	Vitina	Pristina
Montenegro	March 17, 2020	Barcelona (Spain), New York (USA)	Air transport	Podgorica, Ulcinj	Podgorica, Niksic
Pridnestro-vian Moldavian Republic	March 21, 2020	...	Road transport	Bendery, Ribnita	Tiraspol, Bendery
Luhansk People's Republic	March 29, 2020	...	Bus	Slavyanoserbsky district	...

Compiled by author based on various sources in foreign languages, including media materials. The following information resources were used: <https://github.com/CSSEGISandData/COVID-19> (COVID-19 statistics for the countries of the world of the University of J. Hopkins), <https://stopcoronavirus.rf> (Coronavirus COVID-19: official information), https://en.wikipedia.org/wiki/Category:COVID-19_pandemic_by_country. Information on the number of cases by August 1, 2021 from: <https://index.minfin.com.ua/reference/coronavirus/geography/europe/>

Another source of infection was Iran (coronavirus infection was first brought to this country by a businessman from Qom, who visited Wuhan: the first fatal case was recorded on February 19, 2020), from where COVID-19 together with air passengers (most often Iranian students returning to study in European universities) penetrated four countries of Eastern Europe (Belarus, Latvia, Estonia, and Hungary).

The infected arrived in Montenegro by air from New York and Barcelona.

By road transport, the coronavirus penetrated from Switzerland to Liechtenstein, from Germany to Poland, from Hungary to Serbia, from Italy through the Romanian airport, and then by vehicle to Moldova.

The COVID-19 epidemic quickly turned into a pandemic, affecting all countries without exception. At the end of January, these were large countries (France, Germany, Great Britain, Italy, Spain). In February – early March, due to the rapid spread, medium-sized and then small countries were also added. The last to receive the coronavirus were the states of Eastern and Southeastern Europe (Moldova, Bulgaria, Albania, Kosovo, and Montenegro, March 17), as well as unrecognized post-Soviet republics (Pridnestrovian Moldavian Republic, March 21; Luhansk People's Republic, March 29).⁸

On August 4, 2021, the total cumulative number of all coronavirus cases during 2020 and the first seven months of 2021 in Europe was 52 068 704.⁹ The number of cases in the first 7 months of 2021 in all European countries as a whole was 2.2 times higher than all of 2020.

The coronavirus came to 8 countries from Wuhan, to 28 countries from northern Italy, 4 from Iran, 2 from Austria, and the rest from others. As Table 2 demonstrates, it reached some countries at the same time from several. In 39 out of 49 countries, the first cases arrived by air transport, which became the main vector of the epidemic. In 24 out of 49 countries, the infection first appeared in their capitals, then from there it began to spread by other modes of transport within them; in 25 countries, the coronavirus was first recorded in noncapital cities.

The objectives of the article did not include analysis of in-country differentiation of the number of cases, but from Table 2, it is obvious that the regions and cities within countries most affected by the pandemic differ greatly by type: in some places, these are the largest cities and their agglomerations, while in others, completely different areas and centers, and still

in others, remote outskirts. Nevertheless, even the most superficial comparison of countries in this table shows that the pandemic hit major cities the hardest.

Spatial Distribution of the COVID-19 in Russian Regions

Table 3 shows the geographical origins of the first cases of the disease in Russia. On the first day (January 31), the carriers of the disease were Chinese citizens who had come to Russia; these were isolated cases. A month later, Italy became the main source of infection, from where 32 cases arrived by plane (31 were Russians vacationing in ski resorts in Northern Italy or traveling in Italy). This "Italian inflow" took place from February 27 to March 12. On March 13, the first infected Russian tourists arrived from France and Austria; on March 14–15, this was augmented by those who had returned from Spain and Switzerland.

The first peak of the epidemic was on March 2–8 (coronavirus infection was recorded in nine Russian regions); the second peak, on March 16–19 (it already covered 39 regions, including 26 new ones). Then, the epidemic began to expand rapidly in all geographic directions. The first and second peaks were concentrated in European Russia (ER), subsequent peaks everywhere, including the regions of Asian Russia (AR). By March 10, 2020, cases were recorded in nine regions (including 7 ER and 2 AR); March 20, in 40 (including 30 ER and 10 AR); March 25, in 55 (including 44 ER and 11 AR); March 30, in 71 (including 54 ER and 17 AR); April 5, 79 (including 58 ER and 21 AR); April 17, 85 (including 61 in ER and 24 in AR). Thus, the geographical lag of the spread of the epidemic throughout Russia was 51 days (February 27 – April 17¹⁰).

Due to its transport remoteness, as well as complete or partial overland isolation, the last regions where the disease arrived were the Tyva Republic, the Nenets and Chukotka autonomous okrugs, and the Altai Republic (April 10–17, 2020). These are predominantly more backward socioeconomic regions with a deep-peripheral transport–geographic location.

The first infected people arrived in Russia by air from China and Italy. In March, the main carriers were Russian tourists returning from cities and ski centers in Northern Italy. Then they from Moscow and St. Petersburg, where they originally arrived, moved by plane and train to the regions, spreading the infection, first of all, to all the largest cities of the country (Nizhny Novgorod, Yekaterinburg, Novosibirsk, Krasnodar, Rostov-on-Don, Samara, Kazan, etc.). At the same time, the disease was transmitted by ground transport passengers in the gravitational zones of the airports of these major cities. Infected people later moved mostly by land transport, but to remote and

⁸ Quite possibly, in a number of Eastern and Southeastern European countries, information on recording of the first cases were not immediately reported in the media, but it is impossible to verify this.

⁹ <https://index.minfin.com.ua/reference/coronavirus/geography/europe/>

¹⁰ The first two cases on January 31 are not included here, since they did not lead to a massive outbreak.

Table 3. Geographical features of spread of SARS-CoV-2 in Russian regions in first days of 2020 epidemic (listed in chronological order the first cases were recorded)

Date first case was recorded	Where was it brought from	Type of transport	Areas affected by epidemic; people
January 31, 2020	China	Air transport	Tyumen (1 Chinese citizen)
January 31, 2020	China	Air transport	Chita (Zabaykalsky Krai, 1 Chinese citizen)
February 27, 2020	Northern Italy, ski resort	Air transport	Moscow (1 Russian)
March 2, 2020	Italy	Air transport	Moscow Oblast (1 Russian)
March 5, 2020	Italy	Air transport	St. Petersburg (Italian student studying in St. Petersburg; arrived February 29, 2020)
March 6, 2020	Italy	Air transport	5 people in Moscow + 1 person in Nizhny Novgorod (all Russians)
March 8, 2020	Italy	Air transport	1 person in Kaliningrad, 1 person in Belgorod, 1 person in Moscow Oblast
March 12, 2020	Italy	Air transport	4 persons in Moscow, 1 in Kaliningrad, 1 in Krasnodar Krai
March 13, 2020	Italy	Air transport	3 persons in Lipetsk who arrived via Moscow
March 13, 2020	Italy, France, Austria	Air transport	11 Russians: 5 in Moscow, 1 in Moscow Oblast, 3 in St. Petersburg, 1 in Leningrad Oblast
March 14, 2020	Italy, France	Air transport	14 Russians: 9 in Moscow, 1 in Moscow Oblast, 1 in St. Petersburg, 2 in Kemerovo Oblast, 1 in Kaliningrad Oblast
March 15, 2020	Italy, France, Spain, Switzerland	Air transport	4 Russians: 3 in Moscow Oblast; 1 in Tyumen Oblast

Source: https://en.wikipedia.org/wiki/Template:COVID-19_pandemic_data/Russia_medical_cases (304 links to media reports and newsletters of Rospotrebnadzor).

inaccessible regions, exclusively by air (north of Krasnoyarsk Krai, the Sakha Republic, Magadan Oblast, Kamchatka Krai, Chukotka, Nenets and Yamalo-Nenets autonomous okrugs).

Impact of Coronacrisis on Passenger Air Transport

The COVID-19 pandemic led to a sharp decrease in the air passenger traffic, since the borders of many countries were closed and strict controls on the movement of people were introduced, which significantly reduced the need for air travel and people's air mobility. Many companies stopped flying their planes or went bankrupt. Some airports were closed (e.g., Paris Orly did not operate from the beginning of April to the end of June 2020), and in the largest, some terminals were closed and the remaining flights are concentrated in one to two terminals. In October 2020, 193 regional out of 740 European airports were close to bankruptcy due to a sharp decline in passenger traffic.

The peak of the pandemic in April–May 2020 led to an almost complete cessation of flights, when passenger traffic was reduced to a minimum (Fig. 1). Most scheduled international flights were discontinued, and several countries have even banned domestic air travel in an attempt to contain the spread of COVID-19. This crisis has hit especially hard on international air transportation. It had a much smaller impact on domestic passenger traffic.

Decline in Passenger traffic at Individual European Airports

Airports in Europe were hit hardest in the world by the COVID-19 pandemic, with their largest decline in passenger turnover. It decreased particularly sharply at airports with values of more than 1 mln people in 2020 (Table 4).¹¹

The strongest decline of passenger turnover occurred at the largest airports of London–Gatwick, Munich, Barcelona, Frankfurt am Main, and London–Heathrow. A *strong decline* was typical not only of the largest, but also for some airports serving regional traffic (Graz, Nottingham, Leeds, Cardiff, Southampton) and local centers (Exeter, Newquay, Paderborn). In addition, these were small airports in large air hubs where the main airport "suppressed" them (for example, Girona near Barcelona; London City and London Southend near other London airports, Glasgow–Prestwick near Glasgow airport); a significant number of flights from small airports in this hub were discontinued, while flights to the same cities were operated

¹¹ Airports that had more than 1 mln passengers in 2019, but in 2020 moved to the small group (less than 1 mln passengers), as well as airports with a passenger turnover of more than 400000 people per year (in 2019) are excluded from this table, but conclusions about them are presented in the text. For a number of countries (most of the airports in France, many in Portugal and Romania, one in Moldova), statistical information for 2020 has not yet been published.

Fig. 1. Density of civil aircrafts in space of Europe: (a) April 18, 2019, 11:40 (number of aircrafts in sky, 3100); (b) April 16, 2020, 11:40 (number of aircrafts in sky, 380).

Author A.D. Suzansky, May 25, 2020.

from the main airport (for example, Reus near Barcelona).

The decline in passenger turnover was *medium* or *moderate* at small airports and in areas where types of land transport are either poorly developed or absent altogether, or airports are very remote from the main area of development with a relatively high population density. Airports located on remote islands or very far from economically developed territories have not lost as many passengers (e.g., Voar in the Faroe Islands, Bornholm, airports on Sicily and Sardinia in Italy, etc.).

A number of tourist airports passed through the COVID crisis relatively unscathed (Gran Canaria, Tenerife Norte, Lanzarote, Fuerteventura—all in the Canary Islands), others, conversely, suffered greatly (Tivat in Montenegro, Dubrovnik and Pula in Croatia, Girona—Costa Brava in Spain).

Let us briefly characterize the peculiarities of the decline in passenger turnover at airports for only a few countries.

Germany. A catastrophic decline in passenger turnover occurred at Paderborn Airport (87%); very strong at the airports of Leipzig—Halle (80%), Münster, Weeze and Nuremberg (78%), Cologne—Bonn, Munich and Hanover (77% each), Dresden and Berlin Tegel (76% each). The smallest decline was observed at the airports of Memmingen (specializing in servicing low-cost airlines near Munich; 60%) and Dortmund (55%). At the same time, the low-cost Hahn (71%) and Weeze (78%) airports lost more passengers than Memmingen.

United Kingdom. Despite a significant share of international passengers, the country's largest airport,

London—Heathrow, lost only 73% of passengers. There were significantly fewer passengers in Southampton (83%), London City (83%), Leeds (81%), Nottingham (81%). Aberdeen Airport was least affected by the pandemic (passenger traffic decreased by only 66%). Catastrophic declines occurred in Cardiff (87%), Glasgow—Prestwick (86%) and Exeter (85%).

Spain. The maximum (catastrophic) decline was typical of the airports of Reus (96%) and Girona (91%), and strong for Jerez de la Frontera (81%), Murcia (80%), Almeria (80%), Palma de Mallorca (79%) and Barcelona (76%). The smallest decline (moderate) was observed at the airports of Gran Canaria (61%), Melilla (55%), Tenerife Norte (52%), La Palma (51%).

In *Italy* the passenger turnover of airports has decreased by 63–80%, and for the exclusively tourist-oriented Rimini (which serves the seaside resorts of Riviera de la Sole) and Treviso (Venice low-cost airport), by more than 80%. A strong decline occurred at the airports of Rome—Fiumicino (77%), Florence (77%), Venice (76%), Pisa (76%), and Milan—Malpensa (76%), i.e., the main ones serving tourists. However, at the airports farthest from the economically developed north, in the west of Sicily and Sardinia (Trapani, Palermo, Alghero), it decreased much less (55–61%), and at the airport on the small island of Lampedusa, quite insignificantly (36%). The decline has affected airports with a narrow tourist specialization, and it was much less for airports with the common functions of serving the surrounding territories.

For all the airports of *France*, complete information on the dynamics of their passenger turnover is not

Table 4. Decrease in passenger turnover at European airports (excluding Russia) in 2020 due to COVID-19 pandemic (more than 1 mln passengers), thous. people (listed in descending order of passenger traffic in 2020)

Airport	Country	2019	2020	Relative change, %	Absolute reduction in passenger turnover, 2019/2020, times
Istanbul	Turkey	68 651	23 409	−65.90	2.93
Paris—Charles de Gaulle	France	76 150	22 257	−70.77	3.42
London—Heathrow	United Kingdom	80 890	22 111	−72.66	3.66
Amsterdam	Netherlands	71 707	20 884	−70.87	3.43
Frankfurt am Main	Germany	70 561	18 771	−73.40	3.76
Madrid	Spain	61 735	17 112	−72.28	3.61
Barcelona	Spain	52 688	12 739	−75.82	4.13
Munich	Germany	47 960	11 120	−76.81	4.31
Paris—Orly	France	31 853	10 797	−66.10	2.95
London—Gatwick	United Kingdom	46 576	10 173	−78.16	4.58
Rome—Fiumicino	Italy	43 533	9 831	−77.42	4.43
Lisbon	Portugal	31 173	9 268	−70.27	3.36
Berlin (Tegel + Schönefeld)	Germany	35 645	9 098	−74.48	3.92
<i>including Berlin—Tegel</i>	Germany	24 228	5 868	−75.78	4.13
<i>including Berlin—Brandenburg (until October 31, 2020, Schönefeld)</i>	Germany	11 417	3 224	−71.77	3.54
Oslo—Gardermoen	Norway	28 593	9 022	−68.45	3.17
Zurich	Switzerland	31 508	8 341	−73.53	3.78
Athens	Greece	25 574	8 078	−68.41	3.17
Vienna	Austria	31 662	7 814	−75.32	4.05
London—Stansted	United Kingdom	28 124	7 540	−73.19	3.73
Copenhagen	Denmark	30 256	7 525	−75.13	4.02
Dublin	Ireland	32 908	7 267	−77.92	4.53
Milan—Malpensa	Italy	28 846	7 242	−74.90	3.98
Manchester	United Kingdom	29 397	7 035	−76.07	4.18
Brussels—Zaventem	Belgium	26 360	6 743	−74.42	3.91
Dusseldorf	Germany	25 508	6 570	−74.24	3.88
Stockholm—Arlanda	Sweden	25 643	6 536	−74.51	3.92
Palma de Mallorca	Spain	29 721	6 108	−79.45	4.87
Geneva	Switzerland	17 927	5 601	−68.76	3.20
London—Luton	United Kingdom	18 216	5 551	−69.53	3.28
Warsaw—Chopin	Poland	18 824	5 476	−70.91	3.44
Malaga—Costa del Sol	Spain	19 859	5 162	−74.00	3.85
Kiev—Boryspil	Ukraine	15 260	5 158	−66.20	2.96
Gran Canaria	Spain	13 261	5 134	−61.28	2.58
Helsinki	Finland	21 861	5 053	−76.89	4.33
Nice	France	14 485	4 580	−68.38	3.16
Hamburg	Germany	17 309	4 557	−73.67	3.80
Bucharest—Otopeni, Coanda	Romania	14 825	4 457	−69.94	3.33
Porto	Portugal	13 105	4 436	−66.15	2.95
Budapest	Hungary	16 173	3 859	−76.14	4.19
Bergamo—Orio al Serio	Italy	13 857	3 833	−72.34	3.62

Table 4. (Contd.)

Airport	Country	2019	2020	Relative change, %	Absolute reduction in passenger turnover, 2019/2020, times
Alicante	Spain	15048	3739	−75.15	4.02
Prague	Czech	17805	3666	−79.41	4.86
Catania	Italy	10223	3654	−64.25	2.80
Lyon—St. Exupery	France	11 740	3542	−69.83	3.31
Edinburgh	United Kingdom	14737	3475	−76.42	4.24
Tenerife Sur	Spain	11 169	3392	−69.63	3.29
Marseilles	France	10 152	3359	−66.91	3.02
Stuttgart	Germany	12733	3214	−74.76	3.96
Toulouse	France	9597	3125	−67.44	3.07
Cologne—Bonn	Germany	12369	3077	−76.86	4.02
Sofia	Bulgaria	7107	2938	−58.66	2.42
Brussels—Midi—Charleroi	Belgium	8221	2558	−68.89	3.21
Birmingham	United Kingdom	12651	2870	−77.32	4.41
Venice	Italy	11 562	2800	−75.78	4.13
Tenerife Norte	Spain	5840	2796	−52.12	2.09
Naples	Italy	10860	2780	−74.40	3.91
Bergen	Norway	6506	2711	−58.33	2.40
Palermo	Italy	7018	2702	−61.51	2.60
EuroAirport (Mulhouse—Basel—Freiburg)	France	9090	2599	−71.41	3.50
Krakow	Poland	8411	2593	−69.17	3.24
Lanzarote	Spain	7293	2538	−65.19	2.87
Bologna	Italy	9406	2506	−73.35	3.75
Valencia	Spain	8540	2487	−70.87	3.43
Heraklion	Greece	7934	2378	−70.02	3.34
Nantes	France	7227	2328	−67.79	3.10
Thessaloniki	Greece	6897	2317	−66.40	2.98
Seville	Spain	7544	2316	−69.31	3.26
Milan—Linate	Italy	6571	2274	−65.39	2.89
Bordeaux	France	7703	2253	−70.75	3.42
Faro	Portugal	9009	2208	−75.49	4.08
Bristol	United Kingdom	8964	2195	−75.52	4.08
Fuerteventura	Spain	5635	2144	−61.95	2.63
Eindhoven	Netherlands	6781	2113	−68.84	3.21
Ibiza	Spain	8156	2110	−74.12	3.86
Riga	Latvia	7798	2011	−74.21	3.88
Glasgow	United Kingdom	8847	1946	−78.00	4.54
Minsk	Belarus	5102	1939	−61.99	2.63
Belgrade	Serbia	6159	1904	−69.08	3.23
Trondheim	Norway	4382	103	−58.86	2.43
Cagliari	Italy	4748	1768	−62.76	2.69
Malta	Malta	7310	1748	−76.09	4.18
Belfast	United Kingdom	6279	1747	−72.17	3.59
Gdansk	Poland	5375	1711	−68.16	3.14

Table 4. (Contd.)

Airport	Country	2019	2020	Relative change, %	Absolute reduction in passenger turnover, 2019/2020, times
Bari	Italy	5546	1703	−69.29	3.26
Bilbao	Spain	5906	1690	−71.38	3.49
Stavanger	Norway	4310	1675	−61.14	2.57
Rome—Ciampino	Italy	5879	1621	−72.43	3.63
Gothenburg	Sweden	6671	1577	−76.36	4.23
Rhodes	Greece	5543	1551	−72.01	3.57
Hanover	Germany	6325	1452	−77.04	4.35
Luxembourg	Luxembourg	4416	1446	−67.25	3.05
Katowice	Poland	4844	1446	−70.15	3.35
Turin	Italy	3952	1407	−64.39	2.81
Keflavik	Iceland	7248	1374	−81.04	5.27
Liverpool	United Kingdom	5046	1338	−73.48	3.77
Pisa	Italy	5388	1315	−75.59	4.10
Vilnius	Lithuania	5005	1312	−73.78	3.81
Tirana	Albania	3338	1311	−60.74	2.55
Tromsø	Norway	2371	1270	−46.41	1.87
Paris—Beauvais	France	3982	1258	−68.41	3.16
Dortmund	Germany	2720	1221	−55.12	2.23
Pristina	Kosovo	2374	1102	−53.57	2.15
Menorca	Spain	3495	1077	−69.19	3.24
Newcastle	United Kingdom	5204	1064	−79.55	4.89
Verona	Italy	3638	1041	−71.40	3.50
Olbia	Italy	2979	1024	−65.62	2.91
Brindisi	Italy	2698	1017	−62.32	2.65
Wroclaw	Poland	3549	1007	−71.62	3.52
Aberdeen	United Kingdom	2913	994	−65.87	2.93

Source: <http://www.airportsbase.com/index.php?Page=World&ID=1;>
https://www.parisaeroport.fr/docs/default-source/groupe-fichiers/finance/relation-investisseurs/trafic/2020/a%C3%A9roports-de-paris-sa-traffic-du-mois-de-d%C3%A9cembre-2020.pdf?sfvrsn=9673d3bd_2;
[https://www.fraport.com/en/investors/traffic-figures.html;](https://www.fraport.com/en/investors/traffic-figures.html)
[https://www.pasazer.com/statystyki-lotnisk/pl;](https://www.pasazer.com/statystyki-lotnisk/pl)
[https://www.swedavia.se/globalassets/statistik/fpl_202012tot.pdf;](https://www.swedavia.se/globalassets/statistik/fpl_202012tot.pdf)
[https://www.wsssl.aena.es/csee/Satellite?pagename=Estadisticas/Home;](https://www.wsssl.aena.es/csee/Satellite?pagename=Estadisticas/Home)
<https://www.schiphol.nl/en/schiphol-group/page/transport-and-traffic-statistics/>, etc.

yet available. The available data for the ten largest of them reveal that the rate of decline varies from 67 to 71% (the latter figure was noted at the airports of Marseille, Paris—Beauvais, Paris—Charles de Gaulle, EuroAirport, and Bordeaux).

In *Greece*, airports with largest share of international tourists in their passenger turnover were hardest hit by the pandemic (Chania and Zakynthos, 76%; Santorini and Cephalonia, 75%; Mykonos, 73%; Rhodes, 72%). Skiathos Airport had the maximum decline (80%; Northern Sporades islands). Athens and Thessaloniki, the country's largest airports, lost

66–68% of their passenger traffic. Some airports in the small islands of the Aegean archipelago, far removed from mainland Greece (Mytilene, Naxos, Milos, Lemnos, Chios), also lost fewer passengers than other large tourist airports in this country.

Most airports of *Norway* are characterized by a relatively insignificant reduction in their passenger turnover (by 35–60%, moderate and medium declines), but for two serving Oslo, there was a much greater decline (68–69%, strong). In the southern, most developed part of the country, the passenger turnover of airports decreased by 61–70%. The farther north

from Oslo an airport is located, the lower the decline in its passenger turnover (maximum by only 25–28%). This is because, in the central and northern parts of the country, air transport remains the only means of fast communication, although there is a network of good roads and most cities have seaports, but the distances to the south of the country are significant. An exception is the main airport of Svalbard (decline of 63%).

In *Finland*, the decline in passenger turnover is higher in the airports of the largest cities in the south (62–83%), while in the north it is much lower (38–60%), as in the northern airports of Norway. The largest reduction in passenger traffic is characteristic of southern Finnish airports that are simultaneously important rail and road junctions in this most populated part of the country. Helsinki Airport declined 77%; Turku, 75%; and northern Rovaniemi, only 59%.

For *Swedish* airports, the drop was mostly 67–80%, and the only exceptions were the northern airports of Kiruna (59%) and Luleå (64%) (medium decline). The largest (strong) decline was typical for the three airports of Stockholm: Bromma (80%), Skavsta (76%), and Arlanda (75%).

In *Iceland*, passenger turnover decreased very strongly (81%) only at the main international airport of Keflavik, while at local airports (Reykjavik, Akureyri), this was not as significant.

Poland. Most of all, the decrease in passenger traffic fell on the airports of Szczecin (83%), Poznan (72%), Wrocław (72%), low-cost Warsaw–Modlin (72%) and Warsaw–Chopin (71%).

In *Ukraine*, the decline was not as significant (with the exception of both airports of Kiev): four out of six airports had a moderate and weak decline, which was not observed in the rest of Europe.

Decline in Passenger Turnover at Individual Airports in Russia

Unlike European airports, Russian airports had a *moderate* annual decline, i.e., not as significant. It amounted to 91.3 mln passengers (a decrease from 220.89 mln to 129.56 mln), i.e., 41.3%. Compared to other European countries, Russian airports were in the best position in terms of reduction in passenger turnover (Table 5), since in the former, the decline ranged from 83% (Slovenia) to 60% (Albania).

On average, the decline in passenger turnover at individual Russian airports was 30–48%, or 1.4–1.9 times; at European airports, 2.5–4 times. However, due to a significant decrease in the number of international passengers, the Moscow air hub experienced a larger decline (52%). In 2020, 11 994 thous. passengers of international airlines used the services of its three airports (75.8% less than in 2019); on domestic

airlines, the volume of passenger traffic decreased by 29.9%, 36.527 thous. people.

Due to a sharp decrease in the number of international passengers, the maximum reduction in passenger turnover was noted at the airports of Sheremetyevo (60.4%), Vladivostok (58.0%), and Vnukovo (46.7%). A significant drop in passenger turnover (more than 40%) occurred at other large airports (Pulkovo, Yekaterinburg, and Irkutsk), as well as at large airports in the south of the Far East (Vladivostok, Khabarovsk, and Yuzhno-Sakhalinsk).

The passenger turnover of airports in a number of large cities located within the main core of the developed territory of European Russia, with convenient rail links, as well as being in the shadow of larger neighboring airports, significantly decreased: Nizhny Novgorod (48.4%), Voronezh (48.1%), Belgorod (46.0%), Nizhnekamsk (45.2%), and Samara (44.1%). The same thing happened in the south of Western Siberia, where Novosibirsk airport dominates, in the land gravitational zone of which are small airports: Tomsk (53.5%), Barnaul (43.9%), and Kemerovo (42.1%). A significant decline was noted in a number of small airports in the shadow of larger ones: Saransk (55.0%) and Kogalym (48.8%).

Conversely, at main tourist airports (Sochi, Simferopol, and Kaliningrad), where Russians rushed in July–August 2020 instead of the former foreign centers of sea health tourism in the pre-COVID era, conversely, the passenger turnover decreased insignificantly (by only 4–10%). And at the airports of Gelendzhik (+29.7%) and Anapa (+10.5%), it even increased versus 2019 (and in the summer months, at Kaliningrad airport). Growth also occurred in Gorno-Altaysk (+45.0%) and Kursk (+47.4%) due to completion of their reconstruction.

A slight decline (12–29%) was noted in cities far removed from the main area of the continuous developed territory of the country (Petropavlovsk-Kamchatsky, Norilsk, Magadan with no railway passenger traffic, and where air transport remains the only means of communication with Moscow and the rest of the country's major airports; Murmansk, Novy Urengoy, Noyabrsk, Abakan, Blagoveshchensk, and Chita have rail links, but are significantly removed from the main strip of economic development), as well as airports in the regional centers of the North Caucasus (Makhachkala, Vladikavkaz, and Stavropol¹²). A slight decline is also typical of cities that with inconvenient transport–geographical position on the railway network (at a dead end or a connecting branch) within the core of the developed territory of European Russia; therefore, the local airports have not lost a very large number of passengers (Cheboksary, Ulyanovsk, and Izhevsk). Kaluga airport, located in the shadow of the

¹²There are no data on Grozny Airport for 2020.

Table 5. Decline in annual passenger turnover of Russian airports due to COVID-19 pandemic, passengers (listed in descending order of passenger turnover; airports with passenger turnover in 2019 less than 400000 people are not included, but those for which passenger turnover in 2020 exceeded this value are included)

Air hub and airport	2019	2020	Relative change, %	Absolute reduction in passenger turnover, 2019/2020, times
Moscow air hub (without Zhukovsky), including	101 692 403	48 521 070	−52.29	2.10
<i>Sheremetyevo</i>	49 438 545	19 566 402	−60.42	2.53
<i>Domodedovo</i>	28 252 337	16 389 427	−41.99	1.72
<i>Vnukovo</i>	24 001 521	12 565 241	−47.65	1.91
St. Petersburg	19 581 262	10 944 421	−44.11	1.79
Sochi—Adler	6 760 567	6 505 301	−3.78	1.04
Simferopol	5 140 000	4 630 000	−9.92	1.11
Novosibirsk	6 571 396	4 531 157	−31.05	1.45
Yekaterinburg	6 232 318	3 489 286	−44.01	1.79
Krasnodar	4 642 791	3 084 079	−33.57	1.50
Ufa	3 556 533	2 368 689	−33.40	1.42
Kazan	3 470 742	2 171 603	−37.43	1.60
Kaliningrad	2 370 157	2 117 931	−10.64	1.12
Rostov-on-Don—Platov	3 060 000	2 086 000	−31.83	1.47
Anapa	1 641 376	1 813 128	+9.47	0.90
Mineralnye Vody	2 526 419	1 797 989	−28.83	1.40
Samara	2 999 252	1 675 034	−44.15	1.79
Krasnoyarsk—Emelyanovo	2 481 914	1 656 190	−33.27	1.50
Makhachkala	1 500 690	1 399 489	−6.74	1.07
Tyumen—Roshchino	2 039 007	1 374 620	−32.58	1.48
Irkutsk	2 433 794	1 344 484	−44.76	1.81
Surgut	1 866 416	1 297 578	−30.48	1.44
Vladivostok	3 079 344	1 292 560	−58.02	2.38
Khabarovsk	2 185 051	1 270 203	−41.87	1.72
Chelyabinsk	1 713 532	1 154 750	−32.61	1.48
Perm	1 647 005	1 118 143	−32.11	1.47
Omsk	1 348 505	933 587	−30.77	1.44
Zhukovsky (Moscow)	1 324 260	...	...	...
Murmansk	1 029 661	899 835	−12.61	1.14
Volgograd	1 214 216	781 071	−35.67	1.55
Novy Urengoy	973 705	698 876	−28.22	1.39
Yuzhno-Sakhalinsk	1 209 161	697 357	−42.33	1.73
Arkhangelsk—Talagi	922 539	643 511	−30.25	1.43
Yakutsk	949 746	582 731	−38.64	1.63
Nizhny Novgorod	1 114 056	574 305	−48.45	1.94
Petropavlovsk-Kamchatsky	757 698	554 057	−26.88	1.37
Saratov—Tsentrallyy (closed August 20, 2019)	327 968	—	—	—
Saratov—Gagarin (opened August 20, 2019)	257 582	534 502	+51.81	0.48
Saratov as a whole	585 550	534 502	−8.72	1.10
Orenburg	783 647	524 134	−33.12	1.50
Astrakhan	672 456	521 618	−22.43	1.29
Vladikavkaz	565 581	487 144	−13.87	1.16

Table 5. (Contd.)

Air hub and airport	2019	2020	Relative change, %	Absolute reduction in passenger turnover, 2019/2020, times
Grozny	484000	...	...	...
Gelendzhik	338786	482151	+29.73	0.70
Nizhnevartovsk	749520	460400	−38.57	1.63
Voronezh	856969	444846	−48.09	1.93
Blagoveshchensk	552802	436768	−20.99	1.27
Norilsk	514501	431479	−16.14	1.19
Nizhnekamsk	782501	428804	−45.20	1.82
Syktyvkar	549748	370482	−32.61	1.48
Chita	455350	346292	−23.95	1.31
Magadan	425652	342005	−19.65	1.24
Ulan-Ude	478448	340997	−28.73	1.40
Tomsk	732754	340463	−53.54	2.15
Stavropol	411895	337991	−17.94	1.22
Kemerovo	512916	297160	−42.06	1.73
Barnaul	519743	291413	−43.93	1.78
Khanty-Mansiysk	406445	253682	−37.58	1.60
Belgorod	468672	252953	−46.03	1.85

Source: <https://favt.gov.ru/deyatelnost-ajeroporty-i-ajerodromy-osnovnie-proizvodstvennie-pokazateli-aeroportov-obyom-perevoz/>—statistics of passenger turnover at Russian airports for 2019–2020. Statistical information on the airports of Simferopol, Rostov-on-Don, Saratov, Zhukovsky, Grozny, Ulan-Ude, for which there are no data on the website of the Federal Air Transport Agency (FAVT), is taken from media publications and from airport websites.

Moscow air hub, where the route network was not closed in spring 2020, has the same type of dynamics.

The minimum decline was noted at the airports of Sochi (3.8%), Makhachkala (6.7%), Saratov (8.7%), Simferopol (9.9%), and Kaliningrad (10.6%).

What are the differences in the passenger turnover dynamics at airports in individual Russian macroregions? Airports of the *Moscow Air Hub (MAH)*, as mentioned above, lost more passengers from the pandemic than others. The group of sea resort airports of *Southern Russia* were least affected by the negative consequences. Despite the pandemic, passenger traffic at two airports (Gelendzhik and Anapa) increased. At the two largest sea resort airports in Southern Russia (Sochi and Simferopol), the decline was insignificant, while at Mineralnye Vody, it was weak. The passenger turnover of Kaliningrad Airport, which serves the resorts of the Baltic seaside, also experienced an insignificant decline.

Reduced passenger traffic at airports of the *Far North* was minimal: an insignificant decline for Murmansk airport (13%); weak for Norilsk (16%), Magadan (20%), and Novy Urengoy (28%); moderate for the airports of Arkhangelsk (30%), Syktyvkar (33%), and Yakutsk (39%). The decline at *Siberian* airports was slightly higher: only in two of them

(Chita, Ulan-Ude) was it weak (24–29%); in 9, moderate; and in two, medium (45% (Irkutsk) and 53% (Tomsk)). Here, a *moderate* decline dominated (from 30% to 44%: Surgut, Novosibirsk, Omsk, Tyumen, Krasnoyarsk, Khanty-Mansiysk, Nizhnevartovsk, Kemerovo, and Barnaul).

Airports of the *Far East* fell into two groups: weak (Blagoveshchensk, 21%, and Petropavlovsk-Kamchatsky, 27%) and moderate (Yuzhno-Sakhalinsk, 42%; Khabarovsk, 42%; Vladivostok, 58%) declines.

Airports of *European Russia* (without Moscow, sea resorts, and northern airports) had three types of decline: 3 insignificant (Makhachkala, 7%; Saratov, 9%; Vladikavkaz, 14%); 2 weak (Stavropol, 18%; Astrakhan, 22%); 11 moderate (from 30 to 45%: Rostov-on-Don, Perm, Chelyabinsk, Ufa, Orenburg, Krasnodar, Volgograd, Kazan, Samara, Yekaterinburg, and St. Petersburg), 4 medium (Nizhnekamsk, 45%; Belgorod, 46%; Nizhny Novgorod, 48%; and Voronezh, 48%). A moderate decline dominated at the airports of European Russia.

In general, among the airports in Russia with a passenger turnover of more than 400 000 people, moderate (27 airports) and weak (10) declines prevailed, but there were also airports with insignificant (7) and medium (8) declines. In contrast to European air-

Table 6. Time lag of depth of retrodegression of passenger turnover at a number of airports in Europe and Russia due to COVID-19 pandemic (passenger turnover, thous. people)

Airport	2019	2020	Passenger turnover close to 2020 or minimum value (year)	Retro-lag (number of years)
London—Heathrow	80 884	22 110	31 676 (1986)	>40
Frankfurt am Main	70 561	18 771	17 664 (1980)	40
Hamburg	17 309	4 557	4 559 (1980)	40
Zurich	31 508	8 341	7 628 (1980) 9 104 (1985)	>35
Paris—Roissy—Charles de Gaulle	76 150	22 257	28 355 (1995)	30
Munich	47 960	11 120	10 485 (1989) 11 424 (1990)	30
Amsterdam—Schiphol	71 707	20 885	19 145 (1992) 21 274 (1993)	27
Vienna	31 662	7 814	5 929 (1990) 9 322 (1996)	27
Luxembourg	4 416	1 446	1 268 (1995) 1 669 (2000)	24
Barcelona	52 688	12 739	11 728 (1995) 13 435 (1996)	24
Bristol	8 697	2 193	2 142 (2000) 2 694 (2001)	19
Tallinn	3 268	864	716 (2003) 997 (2004)	16
Moscow—Sheremetyevo	49 439	19 566	19 123 (2010) 22 351 (2011)	10
St. Petersburg	19 581	10 944	9 611 (2011) 11 155 (2012)	8
Novosibirsk	6 571	4 531	4 097 (2016) 5 007 (2017)	3
Kaliningrad	2 370	2 118	2 149 (2018)	2
Sochi	6 772	6 520	6 343 (2018)	2

Sources: various, including materials of author.

ports, Russian airports had no strong or catastrophic declines in passenger turnover.

Another indicator of the decline is the *time lag of the depth of retrodegression* (setback (lag) in time)—the number of years that have passed since the moment when the traffic in the past was approximately equal to the value in the COVID crisis year of 2020. Unfortunately, not all airports have annual data on their passenger turnover for the last 25–40 years, which would make it possible to determine what year that was. Nevertheless, the author managed to find such information for a number of European and Russian airports. The retro-lag is indicated in the last column of Table 6 (only a few examples were left in it).

This retrodegression time lag turned out to be the largest (27–40 years) for the major European airports

with a large share of international passengers and transit (London—Heathrow, Frankfurt am Main, Hamburg, Paris—Charles de Gaulle, Munich, Amsterdam, Brussels, Zurich, Vienna, Geneva); relatively medium (16–26 years), for medium-sized or large airports with a large share of domestic traffic; relatively short (9–16 years), for the major airports in Russia with a high share of international passengers; short (4–8 years), for almost all other airports in Russia; very short (2–3 years), for resort and tourist airports in Russia and some airports with an increased share of domestic passengers.

It is not possible to determine the time lag (retrodegression) at all airports; therefore, the possibilities of using this indicator for geographical comparisons are very limited.

DISCUSSION

Torsten Hägerstrand (1967) identified three forms of innovation diffusion within his theory of innovation diffusion (Smirnyagin and Tarkhov, 2013):

(1) hierarchical—the distribution occurs hierarchically through a network of centers and nodes: from the main center, the innovation enters the centers of the second order, from the latter, to centers of the third order, etc., by all ranks of the hierarchy of centers and settlements;

(2) wave (contact)—propagation is frontal in the form of a spatial wave, continually encompassing the entire territory, from one (region) to neighboring territories (regions);

(3) mixed—certain types of innovations spread simultaneously in a hierarchical and wave way.

Using this theory, geographers in the 2000s studied the spatial distribution of influenza and epizootic epidemics (Cliff et al., 2004; Haggett, 2000; Lawson, 2006; Souris, 2019). The geographical features of the spread of these forms of diseases are as follows. Contact (wave) diffusion of infection is characterized by an outbreak in one region (area) and spread to neighboring regions and districts, so that the disease has the highest intensity at the place of origin. Conversely, hierarchical spread is characterized by the onset of disease in a certain place and its jumping to more distant areas and points associated with the initial place of origin via hierarchical connections. Disease diffusion can also be mixed, when wave and hierarchical spreading is observed simultaneously. Whereas in the preaviation era, epidemics spread in linearly-hierarchical manner via land and water transport, in the modern era predominated by long- and medium-range air transport, they diffuse in a pointwise hierarchical manner.

From the viewpoint of the theory of diffusion of innovations, at the early stages, COVID-19 spread exclusively in a hierarchical manner through an extensive air communication system: major and large cities and large urban agglomerations receiving direct flights from Chinese, then Italian air hubs, were the first to suffer. From these, at later stages, infection began to penetrate together with passenger-vectors already through land transport to medium and small cities in the zone of influence of major and large cities; it ended up in the countryside last. Later stages of distribution were characterized by a mixed form of diffusion in which the hierarchical form predominated.

As a result of such a hierarchical spread of the pandemic, primarily large European countries with the largest airports were affected; in the second order, medium-sized countries in the shadow of the zone of influence of the latter; and to a lesser extent, peripheral countries with a more disadvantageous transport and geographic position.

In Europe, airports with a strong decline dominated (65–85%): 172 out of 231. Another 42 airports

had moderate declines. Norway stands out, with 10 of 12 airports experiencing a moderate decline. In Italy and Spain, seven airports in each also experienced an average decline. There were almost no cases of weak and insignificant decline in Europe, except for Zaporozhye Airport (weak).

A catastrophic decline (over 85%) was recorded at 12 European airports (out of 231), including 4 British (Cardiff, Exeter, Glasgow–Prestwick, and Newquay), 2 Spanish (Reus and Girona), and 2 Croatian (Pula, Dubrovnik), as well as the German Paderborn, Montenegro Tivat, and Italian Treviso. Reus (96%), Girona (91%), Pula (89%), Dubrovnik (89%), Paderborn (87%), and Cardiff (87%) had the maximum catastrophic decline.

Eighty-two percent of European airports experienced a severe to moderate decline in passenger turnover as a result of the pandemic. The largest decline in passenger traffic in 2020 occurred at airports in the UK, Spain, Germany and Italy; medium, in Norway; moderate, in Russia.

Of the 285 airports studied (including Russian) for which statistical information on their passenger turnover for 2019 and 2020 was available, 60.4% experienced a strong decline; 17.5%, a medium decline; and 10.5%, a moderate decline. A catastrophic decline was recorded at 12 airports (4.2%); weak, at 11 (3.9%); insignificant, at 7 (2.5%). Passenger traffic increased only at two airports (Anapa and Gelendzhik).

CONCLUSIONS

The COVID-19 pandemic has had a radical impact on air travel and nearly all airports never seen before in postwar Europe.¹³ The study of the spatial differentiation of its consequences on air passenger traffic became possible owing to the use of statistical information on passenger traffic at airports. This latter indicator proved a good quantitative indicator of local, regional, and intercountry differences in such consequences when studying the decline in passenger traffic.

The decline in passenger traffic at almost 300 European airports was extremely spatially uneven. It was strong at the largest airports with a large share of international air transport, medium at medium-sized airports with a minimum share of international traffic, and moderate at Russian airports (due to the rapid restoration of domestic air traffic). The decline and recovery in airport passenger turnover depended directly on the duration of lockdowns and the number of recurring COVID-19 outbreaks, the introduction of entry bans, or the lifting of travel restrictions to certain areas, hotbeds, and countries.

¹³Excluding the significant but not catastrophic decrease after the events of September 11, 2001.

From the COVID crisis, the largest international airports and airports with narrow sea resort and tourist specialization were affected the most; airports that have dominant domestic traffic (including traffic to domestic resorts) and are located in remote and inaccessible areas suffered less. In general, in the entire sampling of 285 airports, *strong and medium declines* in passenger turnover predominated.

The pandemic has to some extent distorted the territorial structure of air traffic, including the hierarchy of airports throughout Europe as a whole and intranational airport systems. Some of the formerly largest airports in terms of passenger turnover lost their place in the hierarchy in 2020 to other European airports, which bypassed them due to a lower level of decline and rapid recovery of domestic air traffic.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

- Air passenger market analysis: Passenger volumes did not improve in December (IATA report), 2020. <https://www.iata.org/en/iata-repository/publications/economic-reports/air-passenger-monthly-analysis-december-2020/>. Accessed February 2, 2021.
- Ascani, A., Faggian, A., and Montresor, S., The geography of COVID-19 and the structure of local economies: the case of Italy, *J. Reg. Sci.*, 2021, vol. 61, no. 2, pp. 407–441. <https://doi.org/>. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7753650/>. Accessed September 18, 2021. <https://doi.org/10.1111/jors.12510>
- Chen, Y., Li, Y., Feng, S., et al., Gravitational scaling analysis on spatial diffusion of COVID-19 in Hubei Province, China, *PLoS One*, 2021, vol. 16, no. 6, p. e0252889. <https://doi.org/10.1371/journal.pone.0252889>
- Cliff, A., Haggett, P., and Smallman-Raynor, M., *World Atlas of Epidemic Diseases*, London: Hodder Education, 2004.
- Druzhinin, A.G., Socio-geographical metamorphosis in reflection of the COVID-19 pandemic, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 129–131.
- Gerasimenko, T.I. and Gerasimenko, A.S., Some geographic aspects of the coronavirus pandemic, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 124–126.
- Dunn, G., Traffic data shows how pandemic upset traditional hub dominance in 2020. https://www.flightglobal.com/networks/traffic-data-shows-how-pandemic-upset-traditional-hub-dominance-in-2020/142153-article?fbclid=IwAR3WVmHGsoIXMkCBHqg8Kxy-wj7P1VZeILne_fpiKzBLUrANDbbuQneTvL50. Accessed February 2, 2021.
- Florida, R. and Mellander, Ch., The geography of COVID-19 in Sweden, Centre of Excellence for Science and Innovation Studies, 2020. <https://swopec.hhs.se/cesisp/abs/cesisp0487.htm>. Accessed September 18, 2021.
- Geography of the COVID-19 Pandemic, *Tijdschr. Econ. Soc. Geogr.*, 2020, vol. 111, no. 3, pp. 201–583.
- Haggett, P., *The Geographical Structure of Epidemics*, Oxford: Oxford Univ. Press, 2000.
- Hägerstrand, T., *Innovation Diffusion as a Spatial Process*, Chicago: Univ. of Chicago Press, 1967.
- Kagansky, V.L., Coronavirus pandemic. Anthroposphere testing, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 138–140.
- Kolosov, V.A., The new field of research in social geography: taking the time without haste, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 140–142.
- Kuebart, A. and Stabler, M., Infectious diseases as socio-spatial processes: the Covid-19 outbreak in Germany, *Tijdschr. Econ. Soc. Geogr.*, 2020, vol. 111, no. 3, pp. 482–496. <https://doi.org/10.1111/tesg.12429>
- Kuznetsova, O.V., Economic relations between the center and regions in the context of coronavirus, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 144–147.
- Lawson, A.B., *Statistical Methods in Spatial Epidemiology*, New York: Wiley, 2006.
- Makhrova, A.G. and Nefedova, T.G., Can Covid-19 pandemic stimulate suburbanization in Central Russia? *Vestn. Mosk. Univ., Ser. 5: Geogr.*, 2021, no. 4, pp. 104–115.
- Panin, A.N., Ryl'skii, I.A., and Tikunov, V.S., Spatial pattern of the distribution of the COVID-19 pandemic in Russia and the world: cartographic analysis, *Vestn. Mosk. Univ., Ser. 5: Geogr.*, 2021, no. 1, pp. 62–77.
- Ramírez-Aldana, R., Gomez-Verjan, J. C., and Yaxmehen Bello-Chavolla, O., Spatial analysis of COVID-19 spread in Iran: Insights into geographical and structural transmission determinants at a province level, *PLoS Negl. Trop. Dis.*, 2020, vol. 14, no. 11, p. e0008875. <https://doi.org/10.1371/journal.pntd.0008875>. <https://pubmed.ncbi.nlm.nih.gov/33206644/>. Accessed September 18, 2021.
- Rodoman, B.B., Territorial estates and coronavirus, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 150–152.
- Shuper, V.A., The idea of progress after the coronavirus pandemic, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 155–157.
- Sigler, T., Mahmuda, S., Kimpton, A., et al., The socio-spatial determinants of COVID-19 diffusion: the impact of globalization, settlement characteristics and population, *Globalization Health*, 2021, vol. 17, no. 56. <https://globalizationandhealth.biomedcentral.com/articles/10.1186/s12992-021-00707-2>. Accessed August 8, 2021.
- Smirnyagin, L.V. and Tarkhov, S.A., Diffusion of innovations, in *Sotsial'no-ekonomicheskaya geografiya: terminy i ponyatiya. Slovar'-spravochnik* (Socioeconomic Geography: Terms and Definitions. Dictionary-Hand-

- book), Gorkin, A.P., Ed., Smolensk: Oikumena, 2013, pp. 94–95.
- Souris, M., *Epidemiology and Geography: Principles, Methods and Tools of Spatial Analysis*, New York: Wiley, 2019.
<https://doi.org/10.1002/9781119528203>
- Suau-Sanchez, P., Voltes-Dortac, A., and Cugueró-Escofet, N., An early assessment of the impact of COVID-19 on air transport: Just another crisis or the end of aviation as we know it? *J. Transp. Geogr.*, 2020, vol. 86, art. ID 102749.
<https://doi.org/10.1016/j.jtrangeo.2020.102749>
- Tarkhov, S.A., *Izmenenie svyaznosti prostranstva Rossii (na primere aviapassazhirskogo soobshcheniya)* (Changes in the Connectivity of the Space of Russia by the Example of Air Passenger Traffic), Moscow, 2015.
- 2020 Worst year in history for air travel demand. <https://www.iata.org/en/pressroom/pr/2021-02-03-02/>. Cited February 2, 2021.
- Zemtsov, S.P. and Baburin, V.L., COVID-19: spatial dynamics and diffusion factors across Russian regions, *Reg. Res. Russ.*, 2020a, vol. 10, no. 10, pp. 273–290.
- Zemtsov, S.P. and Baburin, V.L., Coronavirus in Russia: scale and consequences, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020b, no. 1 (9), pp. 133–135.
- Zubarevich, N.V. and Safronov, S.G., Russian regions in the acute phase of the coronavirus crisis: differences from previous economic crises of the 2000s, *Reg. Res. Russ.*, 2020, vol. 10, no. 4, pp. 443–453.
- Zyryanov, A.I., Geographical features of the coronavirus distribution, *Vestn. Assots. Ross. Geogr.-Obshch.*, 2020, no. 1 (9), pp. 135–137.