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COVID-19 PANDEMIC CRISIS

The COVID-19 Pandemic in the Regions of Greater Siberia: Regional Types of Spatial Interaction

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Abstract—The object of the study was the spread of the COVID-19 pandemic in Siberia in 2020–2021. The authors examined this process with a case study of 15 federal subjects. The aim of the study is to explain the mechanism and result (in excess mortality) of penetration of the coronavirus into Siberia, based on the characteristic features of the space of Siberian regions. The novelty of the approach is the use of the most reliable monthly excess mortality statistics for characterizing the demographic impact of the pandemic, involvement of regional normative legal acts with antivirus focus, and application of the theory of spatial diffusion of innovations to describe pandemic waves in the regions of Greater Siberia. The main results of the work are as follows. First, the authors identified five types of Siberian regions in terms of integral demographic damage from the pandemic in 2020–2021: Yamalo-Nenets and Khanty-Mansi autonomous okrugs had the highest excess mortality; Omsk, Novosibirsk, Tyumen oblasts, moderately high mortality; Tomsk oblast and Altai and Krasnoyarsk krais, with relatively high mortality; Irkutsk oblast, the Altai Republic, Kemerovo oblast, the republics of Khakassia and Buryatia, and Zabaykalsky krai, excess mortality below the national average; the Tyva Republic, extremely low excess mortality for the entire pandemic. Second, the authors identified four types of regional spatial systems of Siberia according to the degree of vulnerability to coronavirus diffusion: the most vulnerable open polycentric system; highly vulnerable open centralized system; medium-vulnerable closed centralized system; the least vulnerable closed polycentric system. Third, the authors found that in the first type, the most important for the spread of the pandemic, was relocation spatial diffusion (and its particular characteristic case of rotational migrations); in the second type, relocation diffusion ("airplane") and horizontal diffusion (in the contour of the local labor market); in the third and fourth types, horizontal spatial diffusion. The common factors of industry specialization, population density, and transport infrastructure in the conditions of Siberia had little effect on the level of coronavirus incidence. Much more important was the communication (contact-intensive) context of these factors, which determined the potential for infection and the pandemic spreading rate in the space of Siberian regions.

Keywords: COVID-19 pandemic, regions of Greater Siberia, relocation, horizontal, hierarchical spatial diffusion of the virus, permeability of the regional space, types of regional spatial systems

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INTRODUCTION

Numerous studies on the COVID-19 pandemic in Russian regions and major cities in recent years by geographers and economists, as a rule, are concentrated around two spatial levels. At the national level, studies compare the demographic, economic, and fiscal impacts of the pandemic on a national scale (Kravchenko and Ivanova, 2021; Obshchestvo ..., 2020; Zemtsov and Baburin, 2020a; Zubarevich, 2021). At the level of federal subjects and municipalities, the internal features and differences in the contraction of coronavirus infection and multidimensional consequences of a two-year pandemic for the regional economy and social sphere are being analyzed (Akhmetov, 2020; Bessonova, 2021; Galkin, 2021).

Thus, with the relative development of issues in relation to the macro- and microlevels, the mesolevel of large traditional regional "blocks," macro-regions, is skipped; e.g., Siberia, the Urals, the Far East (a rare exception is (Kryukov and Seliverstov, 2022). Meanwhile, the mesolevel is exceptionally interesting, because it can overcome the limitations of research into the spatial phenomena of the pandemic, both at the macro- and microlevels (to see the forest for the trees): on the one hand, it provides a panorama, which is impossible when looking at an individual region,

and on the other, it retains the details of local specifics, which many federal experts miss.

At the mesolevel, Greater Siberia is certainly interesting for research. The region, considered within traditional physical and geographical boundaries, includes the Yamalo-Nenets (YaNAO) and Khanty-Mansi (KhMAO) autonomous okrugs and southern Tyumen oblast (traditionally they were Western Siberia, but now they belong to the Ural Federal District), the Republic of Buryatia, and Zabaykalsky krai (traditionally they belong to Eastern Siberia but are now included in the Far Eastern Federal District). Greater Siberia simultaneously possesses the features of extreme geographic zoning of economic and social processes (which almost 40 years ago inspired A.G. Granberg and his students to create the monographic "canvas" *Economy of Siberia in the Context of Latitudinal Zones* (1985)), extreme ultracontinentality (economic and geographical relegation inland, away from coastal trade intersections and maritime freight traffic (Bezrukov, 2006)), colossal internal interregional contrasts, and hence diversity (in territory, the polar regions of Krasnoyarsk krai and the Republic of Khakassia differ almost 40-fold; in population density, the extreme Kemerovo oblast and YaNAO differ by 39 times; in population, Krasnoyarsk krai and the Altai Republic differ by 13 times; in the share of rural population, the difference between the poles is tenfold, 7–70%; in the share of pensioners, the difference between the Tyva Republic and Altai krai is 2.5-fold).

A natural question arises: how did these stark features of ultrazoning, ultracontinentality (relative autonomy), and interregional contrasts of the Siberian space affect the penetration and spread of coronavirus during the 2020–2021 pandemic? This became the main research topic of this study, the aim of which is to explain the mechanism and result (in excess mortality) of penetration of coronavirus into Siberia, based on the characteristic features of the space of Siberian regions.

This aim required (1) integral and dynamic (monthly) diagnostics of the course of the pandemic in Siberian regions using the most reliable indicator of excess mortality in Russian conditions; (2) linking the integral demographic losses from the pandemic with the type (characteristic features) of space of Siberian regions; (3) assessing the permeability of the space of each Siberian region for the coronavirus and, based on it, determining the dominant type of spatial diffusion and identifying the relationship between it and the key anti-COVID measures taken by the regional authorities.

The object of the study was the spread of the pandemic in Siberia in 2020–2021, considered from a case study of 15 federal subjects.[1] The desire to ensure a comprehensive study entailed the use of various information sources: indicators of state regional statistics, regional regulatory legal acts from the ConsultantPlus legal database, Internet sites of Siberian regions on the topic of the pandemic, etc.

[1] Yamalo-Nenets and Khanty-Mansi autonomous okrugs; Tyumen (south), Omsk, Novosibirsk, Tomsk, Kemerovo, and Irkutsk oblasts; Altai, Krasnoyarsk, and Zabaykalsky krais; republics of Altai, Khakassia, Tyva, and Buryatia.

MATERIALS AND METHODS

Studies of the geographical aspects of the spread of the coronavirus pandemic and its consequences, to which our study is devoted, are not completely new. For example, S.P. Zemtsov and V.L. Baburin (2020a), with econometric analysis on the material of the early phase of the spread of coronavirus in Russian regions (spring 2020), proved that this process, with some reservations, can be described using the innovation diffusion model. They found that the main factors accelerating diffusion include high population density in cities, proximity to the largest urban agglomerations, an increased share of the most active and frequently traveling citizens in the population, intense ties within the community, other countries, and regions (Zemtsov and Baburin, 2020b).

A series of articles by N.V. Zubarevich demonstrated that the most affected by the lockdown were urbanized regions with a high concentration of service facilities and increased employment in this area. Among the industrially oriented regions, the most significant economic decline was experienced by regions specializing in the extraction of oil and natural gas (due to lower global demand) and regions with a developed automotive industry (due to lower domestic demand) (Zubarevich, 2021; Zubarevich and Safronov, 2020).

In this article, excess mortality is the baseline, central to all subsequent findings, indicator for measuring the impact of the COVID-19 pandemic. The authors calculated excess mortality on a monthly basis as the current relative excess over the pre-COVID 2015–2019 averages. Many foreign and Russian researchers note that in the context of unequal opportunities to detect morbidity and in the presence of different methods for recording COVID mortality at the level of countries and regions (which is completely true for Russia), the excess mortality rate was the most reliable (Ghafari et al., 2022; Kostina and Kostin, 2021; Kotov et al., 2022; Ramirez et al., 2022; Rodriguez-Poze and Burlina, 2021; Wang et al., 2022). Individually, it is worth explaining why we preferred the indicator of excess mortality to a similar one, but calculated per capita. The main goal of our study was to identify the spatial factors of the spread of the pandemic. Excess mortality per capita in Russian conditions largely depends not on the properties of space, but on the age structure, being directly dependent on the share of the population older than working age (Kotov et al., 2022). The "simple" indicator of excess mortality more accurately reflects the increase in the burden on

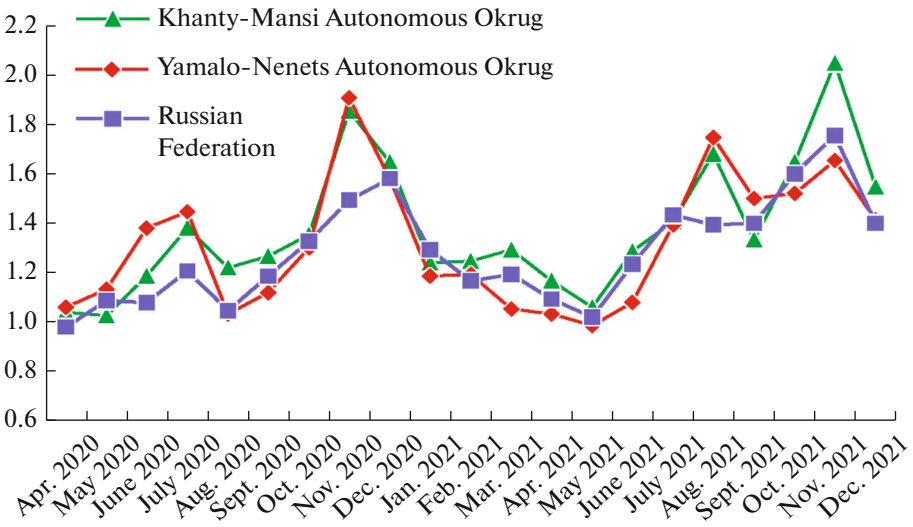

Fig. 1. Monthly dynamics of excess mortality from COVID-19 in Yamalo-Nenets and Khanty-Mansi autonomous okrugs.

a region's health care system relative to the regular pre-pandemic level.

The novelty of our approach is as follows: first, focus on the mesolevel of the Siberian space; second, the effort to give the traditional indicators of state statistics a new interpretation from the viewpoint of the characteristics of the regional space, how it "lets through" negative innovations in the form of coronavirus; third, special attention to regional normative legal acts with an anti-COVID direction to combat the pandemic, based on the local characteristics of the space, economy, and society.

MAIN RESULTS

Five types of Siberian Regions Distinguished Based on Monthly Excess Mortality from the COVID-19 Pandemic

The first wave of COVID-19 in Russia spanned from April to August 2020. The pandemic arrived belatedly in Siberian regions compared to European Russia, in June, and its peak occurred in July. Most Siberian regions were not affected by the first wave or were only slightly affected. In six regions (the republics of Khakassia, Buryatia, and Altai; Altai and Zabaykalsky krais; Kemerovo oblast), in none of the months of the first wave did excess mortality (relative to the mean for the five years prior to the pandemic) exceed the threshold value of 1.14; i.e., it did not go beyond the standard range of fluctuations in monthly mortality from year to year in long time series. The Tyva Republic, Krasnoyarsk krai, and Irkutsk and Tomsk oblasts passed the first wave with minimal damage: on average, excess mortality did not exceed 6%; the wave lasted one month (July) and had a low peak. Omsk, Tyumen, and Novosibirsk oblasts were more affected: excess mortality in the first wave ranged from 11 to 17%, with a high peak in Tyumen and Omsk oblasts, and a more gradual wave in Novosibirsk oblast. The most affected were the KhMAO and YaNAO, where the excess mortality in the first wave was 20 and 32%, respectively. In the KhMAO, the wave lasted the longest, three months from June to August; in the YaNAO there was a record peak excess mortality, 45% in July (Fig. 1). The second and third waves of the pandemic were significantly higher than the first, but the differentiation of the Siberian regions in terms of these is less pronounced.

Taking into account the nature of the course of the pandemic from April 2020 to December 2021, five types of regions can be distinguished in Siberia (Fig. 2):

(1) KhMAO and YaNAO: high first wave and high excess mortality (well above the national average) for the entire pandemic. The Siberian paradox in the spread of the pandemic was that compact regions with a high population density were not at all leaders in terms of demographic damage from coronavirus infection, in comparative terms, extractive regions with a vast area and dispersed settlement pattern suffered the most from it.

(2) Omsk, Novosibirsk, and Tyumen oblasts: a moderately high first wave and high excess mortality for the entire pandemic.

(3) Tomsk oblast, Altai krai, and Krasnoyarsk krai: low first wave (or lack thereof) and high excess mortality throughout the pandemic.

(4) Irkutsk oblast, Altai Republic, Kemerovo oblast, Republic of Khakassia, Republic of Buryatia, and Zabaykalsky krai: low first wave (or lack of it) and excess mortality for the entire pandemic slightly below the Russian average;

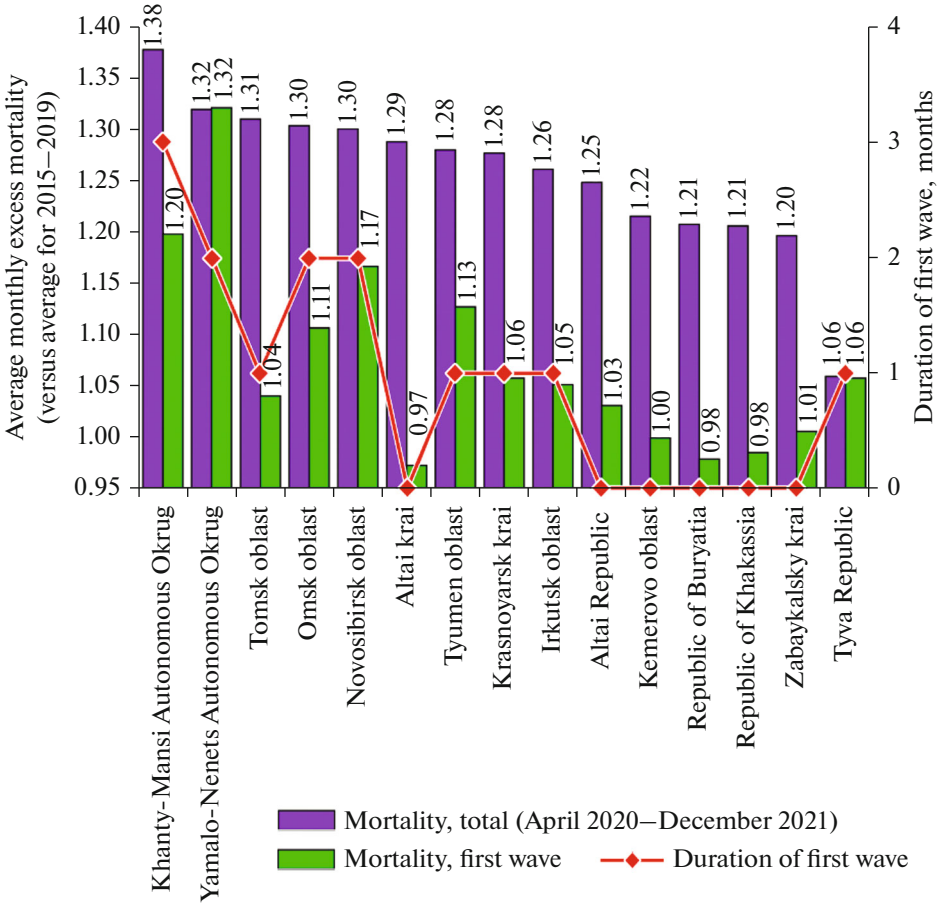

Fig. 2. Excess mortality in Siberian regions for April 2020–December 2021 and in first wave of COVID-19 pandemic (April–August 2020).

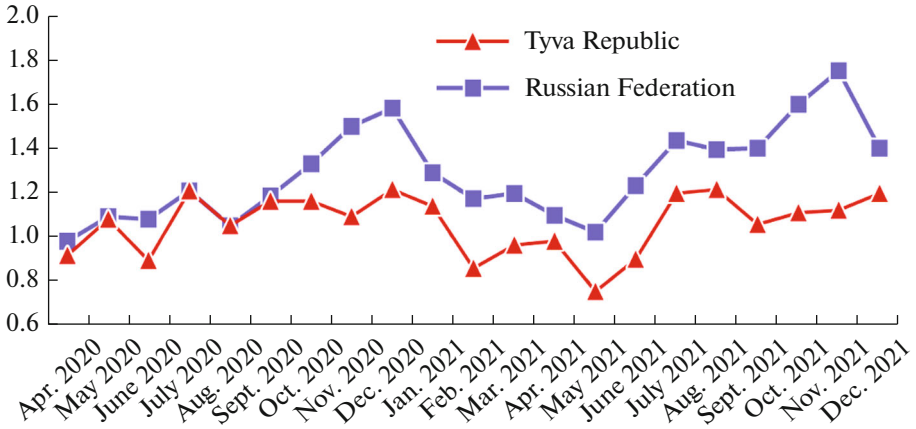

Fig. 3. Monthly dynamics of excess mortality from COVID-19 in the Tyva Republic.

(5) The Tyva Republic: low first wave and a record low excess mortality for the entire pandemic among all regions of Russia—6% (Fig. 3).

Clearly, it is impossible to explain the diversity of situations in the resulting indicator of the demographic damage from the pandemic in Siberian regions by any one reason or factor. Various factors were at work in different waves of the pandemic. It can only be reliably stated that the previously described essential properties of the Siberian space—zoning, ultracontinentality (which leads to autonomy of many social processes), and contrast—also manifested

Table 1. Statistical indicators used to characterize regional spatial systems of Siberia

Region	Arrivals in 2020 within region, %	Departures in 2020 within region, %	Share of capital in population of the region as of January 1, 2020, %
KhMAO	29.1	34.2	6.1
YaNAO	22.4	27.2	9.4
Tomsk oblast	47.8	41.8	55.4
Omsk oblast	55.0	43.9	59.9
Novosibirsk oblast	40.9	42.0	58.1
Altai krai	56.3	54.3	27.3
Tyumen oblast (south)	58.3	58.7	52.5
Krasnoyarsk krai	56.5	57.4	38.2
Irkutsk oblast	56.1	49.1	26.1
Altai Republic	60.3	62.2	29.3
Kemerovo oblast	53.7	50.6	20.9
Republic of Khakassia	47.5	47.3	35.0
Republic of Buryatia	65.0	62.8	44.5
Zabaykalsky krai	60.9	52.3	33.2
Tyva Republic	51.7	48.8	36.5

Regions are listed in descending order of excess mortality during 2020–2021 coronavirus pandemic.
Compiled by the authors.

themselves in the COVID pandemic. In the Arctic and northern Siberian regions, infection occurred through different mechanisms compared to the regions located in the zone of the Trans-Siberian Railway. In the regions of Eastern Siberia, the pandemic, as a rule, came later than in the regions of Western Siberia (therefore, these parts of Siberia are clearly diagnosed by the height of the first wave, i.e., by indicators of COVID-dependent excess mortality in the spring–summer of 2020). It is impossible to establish an unambiguous relationship between the degree of industrial specialization and the demographic damage from the pandemic (this is the difference from the all-Russian situation): in the ranks of excess mortality, the industrial Irkutsk oblast and the agrarian Altai Republic, the industrial Zabaykalsky krai and the agrarian Tyva Republic are adjacent, only for three regions with the maximum excess mortality (KhMAO, YaNAO and Tomsk oblast), one can unequivocally state a combination of high specialization in the extractive industry and extreme indicators of excess mortality.

Obviously, for a clearer understanding of the mechanisms of the spread of coronavirus in the Siberian regions, we need a better knowledge of the very nature of each regional space.

Four Types of Regional Spaces in Siberia Are a Significant Factor in the Spread of the Pandemic and Measures to Combat It

The systematic approach popular in Soviet times gives us an economical tool for simple (compact) differentiation of Siberian regional space. It is known that systems differ in the properties of openness/closedness and concentration/corpuscularity (dispersion, polycentricity) (Bogdanov, 1989; Gumilev, 1990). Integrally there are four types of Siberian regional spatial systems: open fused (centralized), open decentralized, closed fused (centralized), closed corpuscular (dispersed). The question arises how to find indicators for each axis: open–closed, concentrated–dispersed. These indicators are found in the official statistical reporting.

The degree of openness/closedness is a good indicator of the share of migrants who arrived in and departed the region in their total flow (also taking into account Russian migration from other regions and international migration from other countries). It is conditionally possible to consider an open region in which the arithmetic average of the share of arrivals and departures within it is less than 50%; closed, a region where the share of arrivals and departures per year (or as an average over several years) is more than 50%.

The degree of concentration of the regional space can be evidenced by the share of the population of the regional capital in its entire population (Table 1), because we are interested not in the physical, but in the social area of the region, i.e., the part of its territory landscaped by communities of people. According to their behavior, and not abstractly physically, it is necessary to measure the degree of concentration and openness of regional spatial (in fact, sociospatial) systems. We consider 50% a conditional boundary of

centralized (central–peripheral) and decentralized (polycentric) systems: a capital city that concentrates more than 50% of the population of a region forms a centralized system of regional space, and if less, then decentralized (polycentric, when the capital explicitly does not dominate but is one of the leading cities along with others).

Let us characterize four regional spatial systems based on the already obtained rating of Siberian regions in terms of excess mortality for 2020–2021: from the most to the least vulnerable to penetration of the virus according to the peculiarities of the internal structure of the regional space.

1. The most vulnerable open corpuscular (dispersed) regional spatial system: YaNAO and KhMAO. This type of regional space (regions with specialization in the extractive sector) is characterized by a polycentric infection mechanism with a large number of isolated disease outbreaks, usually as a result of relocation-related (aviation) spatial diffusion of the virus from outside the region to shift camps, single-industry towns, new construction sites, etc. Unsurprisingly, there was an early first peak in the incidence of coronavirus infection and the highest relative excess mortality rates among Siberian regions.

For a polycentric region, an additional sign of the vastness of the area is necessary, because, e.g., in the compact Republic of Khakassia, the three largest cities—Abakan, Chernogorsk, and Sayanogorsk—are de facto combined into one, the Abakan urban agglomeration, which means that this region is not a corpuscular, but, on the contrary, a centralized spatial system. The Republic of Khakassia presents the researcher with another surprise: the indicators of intraregional migration are at the boundary between openness and closedness. After examining all 15 Siberian regions, it became obvious to us that the republic is essentially more similar to Tyumen oblast, i.e., to a closed centralized regional space, not open centralized, as we first thought.

2. Highly vulnerable open centralized regional spatial system: Novosibirsk, Omsk, and Tomsk oblasts. This type of regions with a developed manufacturing is characterized by a center-peripheral mechanism of infection from a large metropolitan city, which, due to its status as a transport hub of interregional significance, itself received the induction of the virus through external relocation (air) or horizontal (railway and road) networks, to the periphery or by hierarchical spatial diffusion to centers of lower order.[2] All these regions are characterized by a high level of excess mortality: industrial enterprises of a continuous cycle (e.g., oil refineries or mining), which are the basis for the local economy, could not impose strict restrictions (hard lockdown), and constant personal contact between workers of large production teams remained here throughout the pandemic, increased mortality was noted during its peak periods.

3. Medium-vulnerable closed centralized regional spatial system: Tyumen oblast and the Republic of Khakassia. This type of agroindustrial regions is characterized by a central–peripheral "road-based" infection mechanism within the region (from the capital city to the countryside) and horizontal spatial diffusion along the contour of the labor market of the capital city and its suburbs (through public transport, roads, and railways). The role of outside "aircraft" relocation diffusion of the virus is reduced compared to the regions of the first and second types.

In this group of regions, the authorities introduced strict additional restrictions, because here, due to the relative compactness of these regions and their initial greater closedness to the outside world, it was easier to impose and control restrictions. In October 2021, the Republic of Khakassia introduced Russia's most severe lockdown, including a curfew from 22:00 to 06:00 and stopping public transport. Tyumen oblast was characterized by periodic outbreaks of coronavirus infection (in the Ioanno-Vvedensky Convent, Vinzilinsky Psychoneurological Boarding School, the Medical City oncological center, Tyumensky drug rehabilitation center, the Snezhinka Center of Restorative Medicine, etc.), which by its nature (dozens of cases, "forcefully" being compact) was similar to local COVID outbreaks in Novgorod oblast (only there it happened later) or to mass cases of COVID in Swedish nursing homes in 2020.

4. The least vulnerable closed corpuscular regional spatial system: Altai Republic, Zabaykalsky krai, Krasnoyarsk krai, Republic of Buryatia, Altai krai, Irkutsk oblast, Kemerovo oblast, and the Tyva Republic (multifocal type of internal spatial diffusion). This type of agroindustrial regions is characterized by an internal infection mechanism from many centers. With the exception of Altai and Krasnoyarsk krais, in all regions of this group, minimum excess mortality levels were recorded. A single sharp surge in excess mortality in summer 2021 in some regions was apparently associated with a significant recreational inflow of Russians from other regions to Lake Baikal and Altai.

From the viewpoint of demographic damage from the pandemic, regions of this type had the most favorable structure of the regional space: insufficiently powerful regional subcenters were not able to drive the wave of the pandemic further into the space, and it seemed to die out as it moved. Of great importance for the spread of the virus was the degree of corpuscularity here; i.e., the average distance between the largest cities: all else being equal, the larger it is, the weaker the spatial diffusion, because there was no interference of

[2] In order to determine which type of internal spatial diffusion dominated further, already within the region—center–periphery (from the capital city to its peripheral rural suburbs) or classical hierarchical spatial diffusion (from the capital city to lower-order cities–centers), studies are needed on the course of the pandemic in the municipalities of these regions.

Table 2. Assessing severity of additional restrictions imposed by regional authorities in 2020 during COVID-19 pandemic

Region	Degree of severity of additional restrictions ("traffic light")	Remote work format (yes/no)	Extended self-isolation of visitors (yes/no)	Quarantine of regional level in certain territories (yes/no)	Restrictions on intraregional transportation/flights of passengers (yes/no)	Penalty for violation of restrictions (yes/no)
Altai krai	Green	0	0	0	0	0
Irkutsk oblast	Green	0	0	0	0	0
Kemerovo oblast	Green	1 (at least 30%)	0	0	0	0
Novosibirsk oblast	Green	0	0	0	0	0
Omsk oblast	Green	0	0	0	0	0
Tomsk oblast	Green	0	0	0	0	0
KhMAO	Green	0	0	0	0	0
Krasnoyarsk krai	Yellow	0	0	1	0	0
Tyva Republic	Yellow	0	0	1	0	0
Tyumen oblast	Yellow	0	0	0	0	1
Republic of Khakassia	Yellow	1 (at least 30%)	0	0	0	0
YaNAO	Yellow	0	1	0	0	0
Altai Republic	Red	0	1	1	0	1
Republic of Buryatia	Red	1 (at least 30%)	0	0	0	1
Zabaykalsky krai	Red	1 (at least 70%)	0	0	1	0

Compiled by the authors based on ConsultantPlus legal database.

oncoming waves from two neighboring cities. The authorities here frequently introduced a complete temporary quarantine in certain hotspot areas, which interrupted communication social networks.

The authorities of most regions of this group (except for Altai krai and Irkutsk and Kemerovo oblasts) introduced strict additional restrictions on spatial mobility. The severity of restrictions can be assessed according to the "traffic light" principle: red, severe; yellow, medium; green, soft, basically repeating federal ones (Table 2).

The generalization of the COVID regulatory legal framework of all Russian regions for 2020, associated with the first waves of the pandemic made it possible to identify five areas of additional restrictions on the spatial movement of people:

(1) transition to a remote work format (yes/no) and in what specific variant in terms of mass character (share of workers, category of workers, etc.);

(2) extended (i.e., stricter) self-isolation of visitors against all-Russian norms (yes/no);

(3) introduction of quarantine at the regional level (not just by mayors of cities and heads of municipal districts) for individual municipalities/territories (yes/no). Quarantine did not always indicate real outbreaks of infection; frequently, it was about the ease of closing and separating space, which was used by the authorities, man-made turning the space of flows into a space of places, especially frequently in regions of the fourth type of spatial system;

(4) restrictions on intraregional transportation of passengers and baggage at airports and/or checkpoints (yes/no);

(5) fines for violating the spatial movement regime (yes/no).

Later, all Russian regions, including Siberian ones, were evaluated in binary logic (yes/no) by the presence of these five additional restrictions. The result was an assessment of the degree of severity of additional restrictions in Siberian regions (see Table 2).

There is consistency between the type of regional spatial system and the presence of additional legal restrictions on the spatial mobility of people in the region. For example, among open spatial systems, only the YaNAO introduced additional restrictions due to the particular difficulties in controlling them in such regions. In open regional systems—KhMAO, and Tomsk, Omsk, and Novosibirsk oblasts—the authorities limited themselves to the federal list and did not introduce additional restrictions. Perhaps, for this reason as well, these regions are among the top five in terms of excess mortality.

Introduced in closed regional spatial systems, frequent additional restrictions on spatial mobility everywhere, except for Krasnoyarsk krai (due to the special case of the Norilsk industrial region), worked to reduce the level of excess mortality. The type of closed

corpuscular system contributed to the establishment of local restrictions on spatial mobility, on the one hand, because in such regions it is easier to control them compared to open regions, and on the other hand, due to the authorities' anxiety that polycentricity, i.e., the geographical dispersal of urban centers in the regional space, will complicate the control of the spread of the pandemic and create an unbearable burden for district and city hospitals. The result of the combined action of these two factors was a lower level of excess mortality than in other types of regions. Paradoxically, in closed spatial systems (corpuscular and centralized), the authorities more frequently imposed additional restrictions, and this may explain the resulting better excess mortality values in these regions versus open regions, in which the authorities did not impose additional restrictions on spatial mobility.

Thus, we observe the rollout of the following logical chain: the type of regional spatial system determines the degree of possible control over the spatial mobility of people by the regional authorities, and hence the willingness to introduce restrictions additional to federal ones, and the strength of additional restrictions, in turn, affects the rank of a region among other types in terms of excess mortality.

Let us consider the case of the Republic of Buryatia, where strict additional restrictions on spatial mobility resulted in the best (in addition to the indicators for the Tyva Republic and Zabaykalsky krai) of excess mortality for the entire 2020–2021 pandemic. In 2020 and 2021 the authorities of the republic announced a lockdown several times to slow the spatial diffusion of the pandemic. After every eighth resident of Shuluty in Tunkinsky district became infected with COVID (49 out of 390 people), authorities dug several 1-m ditches to counter vehicular mobility.[3]

The authorities of the Tyva Republic chose another, more modern, way to combat the pandemic[4] in a case similar to the village of Yrban in Todzhinsky district (*kozhuun*). A guest from Krasnoyarsk krai, who arrived in the village on March 21, 2020, was infected with COVID. Based on the results of an epidemiological investigation, 556 persons were contact-traced, from whom samples were taken for laboratory tests. In addition to the previously adopted restrictive measures, by order of the head of the Tyva Republic, from April 8, 2020, a quarantine was introduced in all of Todzhinsky district.[5] In Yrban, a completely new cell tower was erected to convert hitherto face-to-face communication within the village and between the village and the outside world into a remote format.[6]

The Tyva Republic, due to its geographical isolation even from neighboring regions, poor industrial development of the territory (there are no large-scale continuous-cycle production facilities), low population mobility, and due to several hard lockdowns, had the best excess mortality situation in Siberia.

The Type of Permeability of the Regional Space Predetermined the Type of Dominant Spatial Diffusion of COVID, which Led to Specific Anti-COVID Measures of the Part of Regional Authorities

Earlier, the aggregate characteristics of the existing spatial systems of Siberian regions were considered with respect to the demographic damage that each of them suffered during the 2020–2021 COVID pandemic. There is a need to supplement them with ideas about the permeability of the space of the Siberian regions, their flow, transit or enclave. This will make it possible to understand what type of spatial diffusion is dominant in each regional case: relocation, usually associated with air travel; hierarchical, tied to passenger interregional and intraregional transportation by road and rail between centers of different levels, the center and the periphery; horizontal, along the contour of the local labor market, tied to public transport, electric trains, and private vehicles. The dominant type of spatial diffusion of COVID in the Siberian regions will help to understand the logic of the anti-COVID measures (primarily restrictions on mobility) taken by the regional authorities.

To assess the type of permeability of the regional space, it was decided to combine standard statistical indicators of the transport infrastructure (provision of a region with roads, railways, local households with private cars) and a list of areas with limited delivery times for goods (Pilyasov et al., 2021),[7] i.e., without a year-round land transport network (based on air transportation, seasonally operating river and maritime networks). We emphasize that we did not look for a direct relationship between COVID-19 incidence and excess mortality and regional transport accessibility; this would be too simplistic. Conversely, for Siberian

[3] The Buryat village became the most infected on the planet and was fenced off with trenches. https://www.vesti.ru/article/2428312.

[4] An obvious explanation for the differences in the reaction of the authorities of the republics of Buryatia and Tyva to the same situation with a localized outbreak of coronavirus in a separate village is the radically different proportion of households with broadband access to the information and telecommunications Internet network: in Tyva, according to Russian Federal Service for State Statistics (Rosstat), there were 91.8%, and this is the maximum figure among the Siberian regions, and in Buryatia it is significantly less: 77.6%. See: Regions of Russia: Socioeconomic Indicators. 2021. Moscow: Rosstat, 2022).

[5] Decree of the Government of the Tyva Republic no. 147-r of April 10, 2020, On the Approval of the Set of Restrictive and Other Measures to Prevent the Spread of New Coronavirus Infection (COVID-19) in the Tyva Republic."

[6] Tyva: In the quarantine Yrban, a cell tower was erected for residents. https://news.myseldon.com/ru/news/index/227537987.

[7] See also: List of regions of the Far North and areas equated to them with limited delivery times for goods (products). Decree of the Russian Federation Government no. 402 of May 23, 2000, with changes and additions of September 27, 2001; March 31, 2009; and December 6, 2016.

regions, the incidence of COVID-19 per 1000 people in 2020 was inversely related to development of the transport infrastructure in a region (density of railways, −0.60; density of roads, −0.59). We only wanted to identify the main type of spatial diffusion of COVID in the space of a particular Siberian region. The analyzed indicators are presented in Tables 3 and 4.

In the northernmost Siberian regions—YaNAO and KhMAO—due to their being cut off from most national transport routes and the absolute predominance of areas with limited delivery times for goods, the main factor in the spread of the pandemic was relocation (aircraft) spatial diffusion. In both cases, rotating-shift labor migration played a huge role in infection (the YaNAO has the unofficial status of the most "rotational" region of Russia: there are about 100000 people working on a rotational basis). Shift camps felt the impact of the pandemic already in the first months of 2020. The infection mechanism could be not only external—via an arriving infected shift worker—but also internal, with rapid transmission of infection due to the compact living space in a shift camp and the weakened immune system of shift workers, with their diurnal rhythms interrupted by long-distance travel.

Analysis of the entire set of "rotational" legislation in force in the Siberian regions during the pandemic revealed three variants of measures introduced by regional authorities to combat this particular type of viral relocation diffusion (Table 5).

Shift camps and shift workers posed a particular threat of mass infection of local residents in dispersed systems of the regional space with a road network (larger than in centralized systems) due to the possibility of chain transmission of the virus, first by relocation diffusion and then horizontally, from several centers at once. Under these conditions, the authorities of both Tyumen's autonomous okrugs took special measures to ensure the spatial separation of shift workers and local residents.

In the YaNAO, entry restrictions were introduced: first, in summer 2020, for those arriving in Novy Urengoy as the main rotational base of entry in the autonomous okrug, and in summer 2021, for all those entering (the requirement is a negative PCR test, no earlier than 72 h prior to arrival, or a certificate of a full course of vaccination with a QR code). In the local labor markets of the main cities of the autonomous okrugs, there was horizontal spatial diffusion during commuting between home and work on public transport, in taxis, and private vehicles.

Thus, in the case of YaNAO and KhMAO, we see a zonal and production-dependent type of COVID spread in rarefied spaces, when the initial role was played by aircraft diffusion, which was then picked up and spread further through the input multimodal base cities, through shift camps, already based on a short, sometimes seasonally operating, local transport network (roads, river and maritime routes, winter roads) according to the horizontal diffusion mechanism.

The next group of three regions with an open centralized regional spatial system is internally heterogeneous in terms of the permeability of its contour. The most transited region is Novosibirsk oblast, which has the best positions in the density of roads, railways, and number of personal vehicles. At the same time, Novosibirsk is the largest Siberian air hub. This means that all three types of spatial diffusion took place here in the spread of the virus: relocation, horizontal, and hierarchical. Despite this situation, extremely vulnerable from the viewpoint of spatial permeability, here the regional authorities did not impose strong restrictions of their own on spatial mobility (primarily interregional, which would be natural for the largest transit Siberian center) here.

The transit potential of Omsk oblast, as can be judged by all indicators of the transport infrastructure, is weaker than the potential of the Novosibirsk oblast. Here, intermunicipal transportation was relatively more important in the spread of the virus, i.e., horizontal (as well as hierarchical) spatial diffusion. The role of aircraft diffusion in the contamination of the regional space was comparatively lower than in Novosibirsk oblast.

Tomsk oblast stands apart in this group, which, in the degree of permeability of the regional space, is closer to the northern regions. There is a significant proportion of areas with limited delivery times, a meager density of roads and railways, while shifts are widespread in the mining industries of the north of the region. Therefore, the initial role in spatial infection here was played by aircraft diffusion, which was then picked up by horizontal diffusion of the virus in the contour of the local labor market. It is no coincidence that the authorities imposed restrictions on movement precisely in labor markets.[8]

Internal analysis of each region of this group proved very methodologically important: it confirmed that the commonality of the regional spatial system does not exclude significant differences in the properties of permeability of the regional space, which affect both the type of dominant spatial diffusion and the key anti-COVID measures by the regional authorities aimed at restricting movement of people within the regional contour. That is, the initial breakdown of Siberian regions by types of spatial system must necessarily be supplemented with an internal analysis of the permeability of this regional spatial system, which will provide an understanding of the specific mechanisms

[8] "... When going to a place (from the place) for carrying out activities, it is necessary to have a certificate (of a state or municipal employee, military man, judge, lawyer, notary, editorial certificate) or a certificate of the established form posted on the website rabota.tomsk.rf." See: Coronavirus (COVID-19) background information. Restrictions on movement and access control in the Russia's federal subjects" (as of 08.12.2020). ConsultantPlus legal database.

Table 3. Spatial permeability type, viral spatial diffusion type, anti-COVID measures by authorities

Region	Number of districts with limited delivery times/total number of municipal districts	Cities–transport hubs (COVID input bases)	Spatial diffusion type of COVID	Anti-COVID measures by regional authorities
1. Open disperse system of regional space				
YaNAO	7/7	Novy Urengoy, Noyabrsk	*Relocation*, limited horizontal	Shift regulations, entry restrictions
KhMAO	6/9	Khanty-Mansiysk, Surgut, Nefteyugansk, Nizhnevartovsk, Pyt-Yakh and eight other air hub cities and railway hubs	*Relocation*, horizontal	Shift regulations
2. Open centralized system of regional space				
Novosibirsk oblast	0/30	Novosibirsk	*Relocation, hierarchical, horizontal*	Regulations on interregional transportation
Omsk oblast	0/32	Omsk	*Horizontal, hierarchical*, relocation	?
Tomsk oblast	10/16, including cities of Kedrovy and Strezhevoy	Tomsk	*Relocation, horizontal*	Shift regulations, regulations for horizontal movements in labor market
3. Closed centralized system of regional space				
Tyumen oblast(south)	3/20	Tyumen	*Horizontal, hierarchical*, relocation	Shift regulations
Republic of Khakassia	0/8	Abakan, Chernogorsk, Sayanogorsk	*Horizontal*, hierarchical	Regulation of horizontal movements in labor market
4. Closed dispersed system of regional space				
Altai krai	0/59	Barnaul, Biysk, Rubtsovsk, Novoaltaysk, Zarinsk, Kamen-on-Ob, Slavgorod, etc.	*Horizontal*, hierarchical	?
Kemerovo oblast	0/5	Kemerovo, Novokuznetsk, Prokopyevsk, Mezhdurechensk, Leninsk-Kuznetsky, Kiselevsk, Yurga, Belovo, Anghero-Sudzhensk, etc.	*Horizontal*, hierarchical	Remote regime
Krasnoyarsk krai	8/44, including cities of Igarka, Norilsk	Krasnoyarsk, Achinsk, Kansk, Zheleznogorsk, Minusinsk, Zelenogorsk, Lesosibirsk, Nazarovo, Sosnovoborsk, Sharypovo, Divnogorsk, etc.	*Relocation, horizontal*, hierarchical	Quarantine (Minusinsk, Minusinsky district)
Irkutsk oblast	4 + 6/32 (four entirely, six individual settlements)	Irkutsk, Bratsk, Angarsk, Ust-Ilimsk, Usolye-Sibirskoe, Ust-Kut, Cheremkhovo, Shelekhovo, Tulun, Sayansk, Nizhneudinsk, Taishet, etc.	*Horizontal*, relocation	Shift regulations
Zabaykalsky krai	5/31 (five districts separate settlements)	Chita, Krasnokamensk, Borzya, Petrovsk-Zabaykalsky, Nerchinsk, Mogocha, Shilka, Boley, Khilok, etc.	*Horizontal*, relocation	Remote regime, shift regulations
Republic of Buryatia	5/21	Ulan-Ude, Severobaikalsk, Gusinoozersk, Kyakhta, etc.	*Horizontal*, hierarchical	Remote regime

Table 3. (Contd.)

Region	Number of districts with limited delivery times/total number of municipal districts	Cities–transport hubs (COVID input bases)	Spatial diffusion type of COVID	Anti-COVID measures by regional authorities
Altai Republic	2 + 5/10 (two entirely, five separate |settlements)	Gorno-Altaysk	*Horizontal*, hierarchical	Quarantine (Kosh-Agachsky and other districts), self-isolation of all those arriving in the region
Tyva Republic	2 + 13/17 (two entirely, 13 separate settlements)	Kyzyl	*Horizontal*, hierarchical	Quarantine, shift regulations

Italics indicate dominant spatial diffusion.
Compiled by authors from Rosstat data.

Table 4. Density of roads and railways

Region	Density of railways at the end of 2020, km of tracks per 10000 km^2 of territory	Density of public hard surface roads at the end of 2020, km of tracks per 1000 km^2 of territory	Number of owned passenger cars per 1000 people at the end of 2020
YaNAO	6	4	320.3
KhMAO	20	12	367.7
Novosibirsk oblast	85	116	326.5
Omsk oblast	52	100	263.2
Tomsk oblast	11	25	304.3
Tyumen oblast (south)	55	90	326.6
Republic of Khakassia	108	93	419.8
Altai krai	93	210	334.6
Kemerovo oblast	175	182	316.4
Krasnoyarsk krai	9	12	301.7
Irkutsk oblast	32	32	261.6
Zabaykalsky krai	56	34	285.6
Republic of Buryatia	35	27	263.6
Altai Republic	0	50	206.4
Tyva Republic	0	21	164.1

Compiled by the authors from Rosstat data.

of virus diffusion and the direction of anti-COVID government measures.

Two regions from the group of the closed centralized spatial system, Tyumen oblast and the Republic of Khakassia, were also characterized by different permeability of the regional space and different infection mechanisms. Tyumen oblast, with its capital Tyumen, a major transport hub, as well as shift camps in the northern oil fields, received a starting impulse to become infected through aircraft diffusion of the virus, which then turned into horizontal diffusion due to the high density of roads and the high level of local households with their own cars. On the other hand, the main infection mechanism in the Republic of Khakassia was horizontal diffusion of the virus in the contours of local labor markets—public and private transport.

The largest group of eight Siberian regions with a closed dispersed spatial system is characterized by extreme heterogeneity in the permeability of its space for COVID. The most obvious division is into a subgroup of regions included in the national road net-

Table 5. Anti-COVID regulation of rotational shift work in Siberian regions

Region	Availability of regulatory legal act on rotational shift work	Act passed by
YaNAO	1	Chief state sanitary doctor for the YaNAO
KhMAO	1	Governor of KhMAO. Creation of quarantine facilities for outpatient treatment (observation) based on possibility of accommodating at least 5% of shift workers, with possibility of increasing up to 10% or more taking into account current epidemiological situation. Placement of sites in camps is allowed
Tyumen oblast	1	Chief state sanitary doctor for Tyumen oblast. Heads of oil and gas enterprises, heads of contractors and subcontractors. Observation of workers before start of shift for period of at least 14 days, division of all workers involved in work in one cluster into teams depending on work performed in order to minimize contact
Irkutsk oblast	1	Chief state sanitary doctor for Irkutsk oblast. Prohibition on entry and exit by vehicles to and from territory of camp. Exclusion of access of workers living in shift camps to settlements
Tyva Republic	1	Chief State Sanitary Doctor for Tyva Republic
Altai krai	2	Limiting exit of employees from territory of organization
Zabaykalsky krai	2	–
Krasnoyarsk krai	2	–
Republic of Buryatia	2	14-day isolation of arriving shift workers
Tomsk oblast	2	–
Kemerovo oblast	3	At least 80% of shift workers must be vaccinated
Novosibirsk oblast	3	–
Republic of Khakassia	No mention	–
Omsk oblast	No mention	–
Altai Republic	No mention	–

Note. 1, special NLA on shift work; 2, mention of regulation in general regional anti-COVID legal acts in first waves of pandemic; 3, mention in connection with vaccination in last waves of pandemic.

Compiled by the authors based on ConsultantPlus legal database.

works (Altai krai and Kemerovo oblast), and a subgroup of regions in which there are areas with limited delivery times, i.e., without a year-round surface transport network (the other six).

Let us consider the first subgroup. Altai krai is the champion among Siberian regions in the number of municipal districts. At the same time, the capital city of Barnaul shares its patronage functions in relation to the regional space with other large centers: the region has a polycentric urban structure. Therefore, not hierarchical, but horizontal diffusion of the virus along the contours of local labor markets during movement on public transport; personal transport was the main reason for the spread of the pandemic. The role of relocation diffusion was hardly manifested (there were no restrictions on entry on the part of the authorities).

A similar situation existed in Kuzbass (Kemerovo oblast), where industrial switching "home–work" on the circuits of local labor markets also played an important role in the spread of the virus. It is no coincidence that the regional authorities in the package of anti-COVID measures demanded transfer to a remote regime wherever possible.

Radical differences between Altai krai and Kemerovo oblast in industry specialization, level of urbanization, and values of local communities did not affect the properties of spatial permeability for COVID, but they were reflected in significant differences in the demographic impact of the pandemic: it was significant in Altai krai and moderate in Kemerovo oblast (with a comparable share of people older than working age, respectively, 27.1 and 25.4%). Therefore, using this pair of regions as an example, we can conclude that close levels of permeability of the regional space by one type of dominant spatial diffusion and a regional spatial system do not in any way entail "automatically" similar results in excess mortality rates. A huge role is played by nonspatial factors: social values, stereotypes of the behavior of local communities, due to the production structure and levels of urbanization and lifestyles.

All other regions of this type of spatial system include areas with limited delivery times, i.e., characterized by limitations in their spatial permeability. Krasnoyarsk krai is distinguished by extreme internal heterogeneity due to the meridional elongation of its territory: from roadless Arctic Taimyr to northern roadless Evenkia (Evenkiysky district of Krasnoyarsk krai) and the southern, most populated part, adjacent to the Trans-Siberian Railway. Naturally, the type of dominant diffusion of the virus in each part of the region was different. In the Arctic Norilsk industrial region, through relocation diffusion from the outside, the virus further spread through horizontal diffusion channels in the local labor market. In northern Evenkia, aircraft diffusion was also the main factor in the initial spread of the pandemic. In the south, a huge role in the spread of the virus was played by horizontal diffusion in the local labor markets of large cities–transport hubs and hierarchical diffusion along local roads (bus passenger traffic and movement in personal vehicles).

The regional authorities could not cope with such intraregional contrasts, limiting themselves to emergency responses to the most "fire-alarm" situations (e.g., the introduction of a regional quarantine in Minusinsk and Minusinsky district), and therefore the municipal authorities of specific cities and municipal areas acted instead.

In Irkutsk oblast, as well as in Krasnoyarsk krai, due to the significant polycentricity of the urban settlement pattern, each city–transport hub became a center of infection for the local labor market. Therefore, horizontal diffusion dominated. Airplane diffusion, unlike Krasnoyarsk krai, due to the smaller size and less elongated regional space, did not play a significant role in the spread of the virus. In both regions, there are shift camps, which in some cases became local centers of infection.

Zabaykalsky krai in all indicators (see Table. 3) is characterized by better spatial permeability than Krasnoyarsk krai and Irkutsk oblast. However, the demographic damage from COVID here was significantly less than in these two regions, which can be explained by much more stringent anti-COVID measures by the regional authorities. In combatting horizontal diffusion in local labor markets, employers were required to establish a "total" remote regime (at least 70% of office workers were to be transferred to it), and restrictions were imposed on the movement of workers across the territory of the Zabaykalsky krai.[9] For workers in continuous rotational production, additional restrictions were imposed on contacts with local residents.

The Republic of Buryatia, as well as Zabaykalsky krai and Irkutsk oblast, in terms of spatial permeability, was clearly divided into the northern part, which includes areas with limited delivery times, i.e., without a year-round land transport network, and the southern part adjacent to the Trans-Siberian Railway, which is relatively well equipped in terms of transport. In all three cases, this can be conditionally called a division into the southern space of flows with horizontal diffusion of the virus in local labor markets, which in all three cases was facilitated by the polycentricity of the regional urban settlement pattern, and the northern space of isolated localities in which separate centers of infection periodically occurred.

It is unsurprising that in Zabaykalsky krai, Irkutsk oblast, and the Republic of Buryatia, the regional authorities combatted horizontal diffusion by transferring workers to a remote regime. Quarantine in isolated northern areas was usually not declared. However, in the republics of Altai and Tyva, due to the radically different spatial permeability (here, not individual, but the absolute majority of districts are located outside the year-round transport network; there are no railways, and the personal households with their own cars are far fewer), regional authorities frequently struggled with interregional and intraregional horizontal diffusion, the introduction of quarantines in certain municipal districts, and establishment of a self-isolation regime for migrants.

For example, in the Altai Republic, due to a local outbreak of the disease, from June 10, 2020, entry and exit from the municipality of Kosh-Agachsky district was prohibited by land transport (with the exception of citizens with registration at the place of residence within the borders of the municipality); from June 23, 2020, residents of this area were ordered to comply with the self-isolation regime and not leave their place of residence.[10] From April 21, 2020, citizens who arrived in the Altai Republic by all means of transport from other federal subjects (except for transit passengers) had to comply with the self-isolation regime. Regional quarantines in individual, transport-isolated municipal districts to combat local centers of infection was very frequently introduced by the authorities of the Tyva Republic.

We see that the regional authorities of Siberian regions with the worst infrastructure for land transport in the north and south introduced different anti-COVID restrictions. In the north, in open spatial systems (i.e., in the space of flows), the fight against diffusion of COVID passed through regulation of the rotational shift work. In the south, in closed spatial systems (i.e., in the space of localities), this was com-

[9] It was necessary to carry a document proving a citizen's identity, a document confirming place of residence, or an official ID (if necessary). See background information Coronavirus (COVID-19). Restrictions on movement and access control in federal subjects" (as of December 8, 2020). ConsultantPlus legal database.

[10] See Coronavirus (COVID-19) background information. Restrictions on movement and access control in Federal Subjects " (as of December 8, 2020). ConsultantPlus legal database.

batted mainly with large-scale quarantine measures in certain municipal areas.

DISCUSSION AND CONCLUSIONS

The COVID pandemic in Siberian regions has revealed numerous paradoxes. The polycentric structure of the urban settlement system in the case of an open system exacerbated the demographic damage, and in the case of a closed system, conversely, it weakened it (here, a plurality of mid-level infection centers that were spatially separated was better than a high-level one, because there was no wave interference between them). Population density and transport infrastructure, which were considered classic factors in the spatial spread of the pandemic, catalysts for its spatial diffusion, in Siberian conditions, on the contrary, were insignificant or even yielded a negative correlation.

The paradoxical course of the COVID pandemic in Siberian regions has revealed the need to form a communication theory of the regional economy and regional development, based on a new division into contact-intensive economic activity that requires face-to-face interaction, and noncontact economic activity (digital, virtual) easily transferable to a remote format. It turned out that the spread of the pandemic in the regional space cannot be explained in terms of the usual dichotomies urban–rural, industrial–post-industrial activity, industrial–agrarian, etc.

The usual factors that are always taken into account when analyzing regional phenomena—industry specialization, population density, transport infrastructure, etc.—obviously had little effect on the spread of the virus and demographic damage from it. Much more important is the communication, contact-intensive context of these factors. It indeed has already had a real impact on the course of the pandemic. A variety of phenomena of regional life from different areas (a camp at a field, a religious ceremony, a cultural festival, a nursing home, a ski resort,) being sites of intensive communication and temporary localized concentration of people, could quickly become new centers of infection. This means that a new theory of regional development is needed, capable of linking together all these phenomena from completely different spheres of economic and social life in regional communities, considered individually for the time being. And this is all the more important because this theory will simultaneously become a theory of diffusion of innovations in the regional space, because all the studied features of the spread of the COVID (type of spatial system, permeability of the regional space, shift phenomenon, etc.) as a negative spatial innovation will obviously be at work in the case of positive innovations.

The measures taken by the authorities of Siberian regions revealed different, parallel classifications–dichotomies of regional organizations and types of economic activity: continuous production, organizations that carry out urgent production and service work (e.g., repair, loading and unloading), etc.; backbone organizations of regional importance that have a significant impact on employment and social stability, and others that are smaller in size and comparative importance; the types of economic activity most affected by the COVID pandemic and relatively neutral to it. Since they rarely completely coincided with each other in regions, in order to determine the viability of regional economies, it is necessary to understand their relationship in specific regions and cities of Russia.

In some Siberian regions, the authorities chose to support backbone enterprises (e.g., in the Altai Republic[11]), while in others, support was provided according to the codes of economic activity established by the federal government, and in others, according to regional codes of economic activity and industries, in some cases, according to the territorial principle: all types of activities within the city district (e.g., in Zabaykalsky krai—Chita and Chitinsky district); in three cases, specific sectors and types of economic activity were not explicitly defined (Novosibirsk oblast, republics of Khakassia and Tyva).

The generosity of support for COVID-affected economic activities and entrepreneurs depended on the capacity of specific regional budgets. It was the most generous in the YaNAO (e.g., financial assistance to citizens who ceased their activities as individual entrepreneurs) and KhMAO (increase in the investment tax deduction for certain types of entrepreneurial activity), and more modest in the republics of Altai and Tyva.

The pandemic has clarified the traditional division of regions into centers and peripheries. The centers and central regions included municipalities (cities and districts), in which it was technically possible to transfer many processes to a remote format (e.g., distance education). In peripheral cities and districts, this was difficult to achieve (full-time education was maintained).

To determine the infection mechanism, it was no longer enough to talk simply about the spatial mobility of people; it became necessary to qualitatively clarify this phenomenon: from the viewpoint of regularity/frequency (daily, weekly, monthly, annual), goals (recreational, labor, travel-related, etc.), spatial confinement (transit, discrete, i.e., with stops; continuous, i.e., without stops, etc.), and orientation (central–peripheral, intermunicipal, etc.).

In the context of the pandemic in many Siberian regions, the previous institutional differentiation of enterprises by type of ownership has ceased to operate:

[11]The list of backbone organizations was approved by Decree of the Government of the Altai Republic no. 178-r of March 31, 2020.

measures by the regional authorities have been directed at organizations located in the territory, regardless of the form of ownership, organizational and legal framework, and individual entrepreneurs in the region. The future will show whether this force majeure erasure of boundaries between economic cells of different forms of ownership and different sizes will be fixed or the former ones restored. (A similar issue also arises in connection with elimination of competition requirements in many public procurement procedures—the transition to procurement from a single supplier due to force majeure circumstances.)

Obviously, the significance of spatial analysis of the spread of the pandemic in Siberian regions goes beyond medicine or demography and is already related to phenomena of the geography of innovations, diffusion of innovations, and "infection" with new knowledge. It is paradoxical that what in one case acts as a positive barrier to the spread of infection, in another case is a negative factor for innovation to rapidly take root.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

Akhmetov, V.Ya., Problems and prospects of the rural economy of the Republic of Bashkortostan in the context of the coronavirus pandemic, *Ekon. Biz.: Teor. Prakt.*, 2020, no. 6, pp. 26–29.

Bessonova, L.P., Risks of quality of life associated with the coronavirus pandemic, the case of Voronezh oblast, *Vestn. Akad. Znanii*, 2021, vol. 4, no. 45, pp. 35–43.

Bezrukov, L.A., Continental–oceanic dichotomy in international and regional development, *Doctoral (Geogr.) Dissertation*, Irkutsk, 2006.

Bogdanov, A.A., *Tektologiya: Vseobshchaya organizatsionnaya nauka* (Tectology: General Organizational Science), 2 vols., Moscow: Ekonomika, 1989.

Ekonomika Sibiri v razreze shirotnykh zon (Economy of Siberia in the Context of Latitudinal Zones), Granberg, A.G., Ed., Novosibirsk: Nauka, 1985.

Galkin, K.A., Social exclusion of older people in rural areas during the COVID-19 pandemic in the Republic of Karelia, *Vestn. Inst. Sotsiol.*, 2021, no. 4, pp. 193–210.

Ghafari, M., Watson, O.J., Karlinsky, A., Ferretti L., and Katzourakis, A., A framework for reconstructing SARS-CoV-2 transmission dynamics using excess mortality data, *Nat. Commun.*, 2022, vol. 13, p. 3015.

Gumilev, L.N., *Etnogenez i biosfera Zemli* (Ethnogenesis and Biosphere of the Earth), Leningrad: Gidrometeoizdat, 1990.

Kostina, E.A. and Kostin, A.V., How smart city technologies help to cope with the pandemic, *Reg.: Ekon. Sotsiol.*, 2021, vol. 112, no. 4, pp. 160–182.

Kotov, E.A., Goncharov, R.V., Kulchitsky, Yu.V., Molodtsova, V.A., and Nikitin, B.V., Spatial modelling of key regional-level factors of COVID-19 mortality in Russia, *Geogr., Environ., Sustainability*, 2022, vol. 15, no. 2, pp. 71–83.

Kravchenko, N.A. and Ivanova, A.I., Spread of the COVID-19 in Russia: Regional peculiarities, *Reg. Res. Russ.*, 2021, vol. 11, no. 4, pp. 428–434.

Kryukov, V.A. and Seliverstov, V.E., Coronavirus pandemic: Siberian dimension, *Nauchn. Tr. Vol'nogo Ekon. O-va Ross.*, 2022, no. 2, pp. 32–53.

Obshchestvo i pandemiya: opyt i uroki bor'by s COVID-19 v Rossii (Society and Pandemic: Experience and Lessons of Combating COVID-19 in Russia), Mau, V.A., Ed., Moscow: Anal. Tsentr Pravit. Ross. Fed., 2020.

Pilyasov, A.N., Zamyatina, N.Yu., and Kotov, E.A., Spread of the COVID-19 pandemic in the regions of Russia in 2020: Models and reality, *Ekon. Reg.*, 2021, vol. 17, no. 4, pp. 1080–1096.

Ramirez, M.D., Veneri, P., and Lembcke, A.C., Where did it hit harder? Understanding the geography of excess mortality during the COVID-19 pandemic, *J. Reg. Sci.*, 2022, vol. 62, no. 3, pp. 889–908.

Rodriguez-Pose, A. and Burlina, C., Institutions and the uneven geography of the first wave of the COVID-19 pandemic, *J. Reg. Sci.*, 2021, vol. 61, no. 4, pp. 728–752.

Wang, H., et al., Estimating excess mortality due to the COVID-19 pandemic: A systematic analysis of COVID-19-related mortality, 2020–21, *Lancet*, 2022, vol. 399, no. 10334, pp. 1513–1536.

Zemtsov, S.P. and Baburin, V.L., Coronavirus in the regions of Russia: Features and consequences of the spread, *Gos. Sluzhba*, 2020a, vol. 22, no. 2, pp. 48–55.

Zemtsov, S. and Baburin, V., COVID-19: Spatial dynamics and diffusion factors across Russian regions, *Reg. Res. Russ.*, 2020b, vol. 3, no. 10, pp. 273–290.

Zubarevich, N.V., Influence of the pandemic on the socioeconomic development and budgets of the regions, *Vopr. Teor. Ekon.*, 2021, vol. 10, no. 1, pp. 48–60.

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. https://doi.org/10.1134/S2079970520040115