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GEOINFORMATION ANALYSIS RUSSIAN HEALTH SYSTEMS: MODELING, VISUALIZATION, ANALYSIS

Annotation

In the Russian Federation, noticeable differences remain between its constituent entities in the possibilities of obtaining quality medical care for citizens living on their territory. The main tasks of developing the health care system of the country and its regions lie in the plane of demographic trends and the priority solution of the problem of mortality. The state of regional health systems is a determining factor for mortality rates, and mortality is an indicator of the level of development of regional and municipal health systems. In this regard, the creation of an algorithm (method) for assessing the effectiveness of health care systems, provided for in the documents of strategic and territorial planning at all levels, is an urgent scientific problem and is the purpose of the study. The construction of the algorithm was carried out on the basis of multivariate analysis and the method of geoinformation mapping. The authors established criteria for assessing the current state of the health care system of the constituent entities of the Russian Federation and municipalities in the context of the impact on the target socio-economic indicators and mortality rates that correspond to the national goals of the Russian Federation, the targets of the National Healthcare Project and the National Demography Project. A comprehensive analysis of demographic and socio-economic factors made it possible to determine the features of the spatial organization and structure of the healthcare system at the municipal level and the level of constituent entities of the Russian Federation, to develop options for typology of constituent entities of the Russian Federation based on a comprehensive integral indicator that takes into account the influence of medical and non-medical factors. The authors proposed a system of cartographic indicators for evaluating the effectiveness of the spatial organization of the healthcare system at different territorial levels: subjects of the Russian Federation, municipalities and settlements. A series of original cartographic materials has been prepared for each of the levels and assessment indicators.

Keywords: geoinformation methods, multivariate analysis, spatial organization of the healthcare system, strategic planning, territorial planning, typology

Introduction

Assessment of the current state of the health care system in the context of the spatial organization of this system, its impact on the demographic and socio-economic development of the country and regions is a topical area of research. This relevance becomes much more acute when evaluating the effectiveness of the spatial organization of the healthcare system, including in the framework of strategic and territorial planning.

An analysis of the experience of foreign and domestic research shows that the issues of analyzing the spatial organization of the system of healthcare institutions, evaluating the effectiveness of this system, especially at the regional and municipal levels, are extremely complex and often debatable. In particular, at present there is no unified systematic approach to determining and evaluating the effectiveness and sustainability of Russian healthcare.

The problem of assessing the performance of the health care system at the level of the constituent entities of the Russian Federation and the municipalities within them is exacerbated by significant differences between the regional health care systems of the country due to territorial (geographical), transport, financial, personnel, organizational and other differences.

In Russia, a three-level model of the organization of medical care has developed, according to which medical organizations are classified into 3 levels:

1. primary health care;
2. multidisciplinary (more than five profiles) and specialized medical care at the intermunicipal level;
3. high-tech medical care for the population at the regional and federal levels.

At the same time, the greatest difficulties and nuances arise during the implementation of the primary link, including at the stage of strategic goal-setting and territorial planning in the future. All these problems determined the object and subject of the work, its purpose and objectives, subsequent directions and results.

Goal of the work:

Creation of an algorithm (method) for assessing the effectiveness, shortage and validity of the construction and reconstruction of healthcare facilities provided for in the documents of strategic and territorial planning of the constituent entities and municipalities of the Russian Federation based on the assessment of the impact on target socio-economic indicators and mortality rates of the population of the constituent entities of the Russian Federation and municipal formations.

Key tasks:

- Development of criteria for assessing the current state of the health care system of constituent entities and municipalities of the Russian Federation in the context of the impact on target socio-economic indicators and mortality rates.
- Development of criteria for evaluating the feasibility (potential effectiveness) of the implementation of healthcare development projects provided for in the strategic and territorial planning documents of the constituent entities and municipalities of the Russian Federation.
- Creation of an algorithm for determining the effectiveness and priority of the implementation of healthcare development projects in the constituent entities and municipalities of the Russian Federation;
- Definition of target indicators of socio-economic development and demographic indicators used as indicators of the developed algorithm.
- Development of the structure of the geodatabase - a list of quantitative indicators (factorial signs), their composition and structure, sources and mechanisms for obtaining, the frequency of updating, the territorial level (regional / municipal), the corresponding socio-economic and / or demographic indicator (effective sign) used in the algorithm.
- Development of a system of cartographic indicators of the algorithm.

Methods _

A variety of quantitative and qualitative materials were used as sources of information: theoretical and methodological developments in the field of analysis of the spatial organization of the health care system, data from Rosstat (including materials from the All-Russian population censuses), materials from the Federal State Information System for Territorial Planning (FSIS TP), data from industry statistics in the field of health care at various territorial levels (Russian Federation, constituent entities of the Russian Federation, municipalities), regulatory legal acts regulating aspects of the development of the health care sector, demography, urban planning.

The complex of works was carried out using a wide range of methods: multidimensional comparative analysis, factorial and structural analysis, expert assessments, statistical methods of modeling and identifying relationships, thematic geoinformation mapping.

The results obtained in the course of the work are of a research and exploratory nature, and require further in-depth study in order to confirm the validity of the conclusions and hypotheses. Subsequent studies in the field of spatial organization of regional and municipal health care systems, assessment of their effectiveness and sustainability (including in the context of territorial planning) will improve the proposed methodological apparatus in terms of expanding the coverage of factors affecting the development of the industry.

Five regions of the Russian Federation were taken as pilot subjects of the Russian Federation within the framework of the study: Belgorod, Kaluga, Murmansk, Sakhalin, Chelyabinsk. For these areas, the analysis was carried out at the level of municipalities and individual settlements. Studies and calculations adopted for 85 constituent entities of the Russian Federation, excluding new constituent entities of the Russian Federation included in the country

in 2022, due to the lack of complete, representative and comparable data on these constituent entities.

The criterion assessment of the current state of the healthcare system of the subjects of the Russian Federation is determined, first of all, by the need to achieve the national goal of the development of the Russian Federation until 2030 - the preservation of the population, the health and well-being of people (Decree of the President of the Russian Federation dated July 21, 2020 No. 474), as well as targets (system of goals and target indicators) of the National Project "Healthcare" and the National Project "Demography".

Within the framework of the National Healthcare Project, 9 such indicators (indicators) are planned, grouped according to the directions of changes into 2 blocks (National projects ..., 2019):

- Goals targets aimed at reducing;
- Objectives targets aimed at growth.

The characteristics of each block of target indicators are presented in Table 1.

Table 1. Goals and targets of the National project "Healthcare"

	No.	Name of indicator	Unit rev.	Value by 2024
decline	1.	Mortality of the population of working age	cases per 100 thousand population	up to 350
	2.	Mortality from diseases of the circulatory system		up to 450
	3.	neoplasms, including malignant		up to 185
	4.	infant mortality	cases per 1 thousand born children	up to 4.5
	5.	Elimination of personnel shortage in medical organizations providing primary health care, including:		
	5.1	Staffing of medical positions in units providing medical care on an outpatient basis	%	95
	5.2	Staffing of positions of paramedical personnel in units providing medical care on an outpatient basis		95
	5.3	Number of specialists involved in the system of continuous education of medical workers, including using distance learning technologies	thousand people	1880
	6.1	Ensuring coverage of all citizens with preventive medical examinations at least once a year	%	70
	6.2	Increasing the coverage of children aged 15-17 years with preventive medical examinations in order to maintain their reproductive health		80
Height	7.	Ensuring optimal accessibility for the population (including residents of settlements located in remote areas) of medical organizations providing primary health care, including:		
	7.1	The number of settlements with a population of over 100 to 200 thousand people, located outside the reach of a medical organization or its structural unit, providing primary health care	Unit	0
	8.	Optimization of the work of medical organizations providing primary health care, reducing the waiting time in line when citizens apply to these medical organizations, simplifying the procedure for making an appointment with a doctor, including:		
	8.1	The share of medical organizations participating in the creation and replication of a "new model of a medical organization providing primary health care" (out of the total number of medical organizations providing this type of care)	%	72.3
	9.	An increase in the volume of exports of medical services by at least four times compared to 2017	million US dollars per year	1000

The goals and targets of the National Project “Demography” (National Project “Demography”, 2019) are also of critical importance for the development of the healthcare system and are aimed at achieving the following quantitative and qualitative results by 2024:

- Increased healthy life expectancy to 67 years.
- Increasing the total fertility rate to 1.7 per woman.
- Increasing the proportion of citizens leading a healthy lifestyle.
- Increasing by 2030 to 55% the share of citizens systematically engaged in physical culture and sports.

The main part of the tasks of developing the health care system of the country and its regions lies in the plane of demographic development and the priority solution of the problem of mortality. Obviously, the level of development of regional health systems is largely a determining factor for mortality rates, and mortality is an indicator of the level of development of regional and municipal health systems.

Despite the relevance and seriousness of the problem of mortality for the Russian Federation, its depth and severity in different regions differ significantly, as well as the factors that determine this severity. The demographic landscape of the country is extremely contrasting and depends on a complex of factors related to the characteristics of the general level of socio-economic development of the region, individual sectors of the economy (primarily health care), the quality of life and quality of the population, the development of infrastructure, the state and quality of the environment.

Actually, mortality is one of the indicators of the level of development of the healthcare system in the region. It is obvious that the identification and analysis of the degree of quantitative and qualitative influence of various factors, both on overall mortality rates and on mortality by disease classes, not only provides an understanding of cause-and-effect relationships, but also serves as the basis for developing practical recommendations and proposals for a qualitatively positive change in mortality rates in Russia and its regions.

The relevance of the problem of mortality, its various manifestations in the regions and municipalities of the country served as the main criterion for the level of development of territorial health systems, determined the choice of factors that determine trends and the current situation in mortality in the subjects of the Russian Federation (with the maximum degree of detail of spatial analysis at the level of municipalities and individual populations). points for pilot subjects).

The choice of methodological tools for conducting a comprehensive analysis of the factors that determine the spatial organization and structure of the healthcare system and mortality rates at the municipal level and the level of constituent entities of the Russian Federation is due to the requirements of the terms of reference, as well as the need to obtain representative data for formulating and evaluating the reliability of working hypotheses.

Based on this, the factors are divided into two groups:

- factors determining mortality rates at the level of subjects and municipalities, as an indicator of the state of the spatial structure of the healthcare system;
- factors that determine the spatial organization and structure of the health care system at the level of subjects and municipalities.

To conduct an analysis at the level of constituent entities and municipalities, the statistical data of Rosstat for 2019 were used as sources of information:

1) Data on the number of deaths by the following parameters:

– final clinical and pathoanatomical diagnoses (based on the reference books of the International Classification of Diseases of the 10th revision (ICD-10) - regional section, municipal section (for five pilot subjects);

– the level of education;

– circumstances of death (at home / in an ambulance / in a hospital) regional profile, municipal profile (for five pilot subjects);

– sex and age structure;
– died from acute conditions.

2) Data on factors influencing mortality rates, including:
– consumption of alcohol and tobacco products;
– degree of involvement in sports and physical activity;
– natural (environmental) indicators;
– presence / absence of medical organizations of the state health care system and the municipal system;
– the presence / absence of medical personnel, the level of medical examination;
– transport accessibility of medical organizations of the state healthcare system;
– Population;
– sex and age structure of the population.

3) Data on the number of cases in the following sections:
– clinical diagnosis of patients by type of disease - regional cross-section;
– sex and age structure of patients .

In addition, the following sources of information were used in the study:

• Data on the volume of consumption of food products, alcohol and tobacco products (Federal Tax Service of the Russian Federation and Rosstat);

• Data on the share of citizens systematically engaged in physical culture and sports (Ministry of Sports of Russia);

• Data on quantitative and qualitative indicators of medical organizations of the state healthcare system and the municipal system, quantitative indicators of medical personnel, the level of medical examination (Ministry of Health of Russia);

• Data on natural (environmental) factors (Rospotrebnadzor);

• Information on citizens' appeals to state bodies and local governments (data from social media and open sources of information).

Rossreestr data (public cadastral map) was used as geodata .

The specified data are grouped, based on the objectives and logic of the study, into 2 thematic blocks:

1) Effective values of mortality;

2) Indicator values of factors.

In each block, statistical indicators were grouped in accordance with the scale (territorial coverage) at 3 hierarchical levels:

- the Russian Federation - to identify and analyze trends in the development of the general situation according to the parameters of the study;

- subjects of the Russian Federation (including 5 pilot subjects) - to identify macro-regional features, trends and disproportions in the development of the studied phenomena;

- Municipal formations of pilot subjects of the Russian Federation - to identify intra-regional features, trends and disproportions in the development of the studied phenomena, statistical testing of hypotheses and assumptions.

Mortality rates are taken in accordance with the final clinical and pathological diagnoses based on the International Statistical Classification of Diseases and Related Health Problems ICD-10 (according to the territorial coverage given above).

For mortality rates, as the main indicator of the state of the regional health care system, of paramount importance are statistical indicators and data characterizing medical factors that affect mortality by main classes and individual causes of death: the availability of medical personnel and the level of development of the material and technical base (provision of medical organizations) .

The quantitative characteristics of the provision of medical organizations are:

- Availability of beds;
- Number of ambulance stations (departments);

- Number of ambulances.

Statistical indicators of the factor “Provision of medical personnel”:

- Availability of doctors;
- Staffing of medical positions in units providing medical care on an outpatient basis;
- APU capacity, visits per shift.

Second block factors reflects environmental factors - the state of the ecological environment and the quality of life of the population. In total, there are 13 statistical indicators in the block:

- Consumer basket;
- sugar consumption;
- tobacco consumption;
- alcohol consumption;
- The volume of housing construction;
- GRP in basic prices;
- Unemployment rate (ILO);
- Average index of urban environment quality;
- Number of equipped public spaces;

Statistical indicators of the factor " Ecology " :

- Air pollution from vehicles;
- Air pollution from railway transport;
- The number of unauthorized dumps.

The third block contains indicators of infrastructure factors that reflect the transport accessibility of medical organizations and medical care for residents of individual settlements.

Statistical indicators of the factor “Transport accessibility of medical organizations”:

- The share of the population living outside the transport accessibility zones of medical institutions;
- The share of the population living within the transport accessibility zones of medical institutions;
- The share of settlements located outside the transport accessibility zones;
- The share of settlements located within the transport accessibility zones of medical organizations.

The fourth block is the actual demographic factors, one way or another related to the sex and age structure of the population and the demographic characteristics of the territory:

- Coverage of citizens older than working age with preventive examinations, including clinical examination (RD);
- Proportion of population older than working age;
- total fertility rate;
- The level of morbidity of the population;
- Life expectancy.

This group of indicator factors is the result of generalization and selection at the preliminary stage of the study. In total, 28 statistical indicators and indicators were selected, which showed the most significant results for further analysis and have the maximum impact on mortality rates in the Russian Federation and the pilot regions of the Russian Federation.

The source of information about the causes of death is the records in the medical death certificates compiled by the doctor (The number of deaths ..., 2019).

To refine regional differences, we used a breakdown of total mortality and mortality by causes of death in the context of “urban-rural”, since the relationship between individual classes (causes) of death and the values of indicators can vary greatly depending on the type of territory (urban or rural areas). Differences in mortality rates in urban and rural areas, including pilot regions, served as the basis for formulating the working hypotheses of the study.

For example, the availability of ambulances in the region plays a decisive role in saving a person from death from external causes in rural areas.

The main tools for analysis during the study were chosen: correlation-regression analysis and the method of integral-scoring.

Correlation analysis was used in the study as a quantitative method for determining the closeness and direction of the relationship between sample variables (factors and values of mortality). Regression analysis is a quantitative method for determining the type of mathematical function in a causal relationship between the specified variables.

To identify the indicators of each of the groups, a list of indicators is preliminarily compiled and the Pearson pair linear correlation coefficient is calculated between the indicators of each factor and the mortality of the population by main classes and individual causes of death. At the same time, the indicator values of the factors act as factor signs, and the mortality rates act as effective ones. The value of the pair linear correlation coefficient varies from -1 to +1.

The estimation of the value of the coefficient was carried out in two aspects:

- the sign of the correlation coefficient (+/-) shows the direction of the connection - a direct connection with a positive value of the coefficient and, accordingly, an inverse one - with a negative one;
- the strength (measure of tightness) of the connection was determined according to the Chaddock scale (Table 2).

Table 2. Chaddock's scale for assessing the degree (measure) of the closeness of the relationship between factor and resultant features in the correlation-regression analysis

The value of the correlation coefficient	The degree of tightness (strength) of the connection
Less than 0.1	Negligible
0.1 - 0.3	Weak
0.3 - 0.5	Moderate
0.5 - 0.7	Noticeable
0.7 - 0.9	High
More than 0.9	Decisive

To assess the degree of variational certainty in the linear relationship of variables, the coefficient of determination (the square of the correlation coefficient) was calculated, which shows the proportion of variation in mortality values due to changes in the values of factors. This coefficient allows to determine and establish the significance of the indicator (factor) in changes in mortality rates and serves, among other things, as a selection criterion for the most significant factor characteristics.

The statistical significance of the paired linear correlation coefficient is tested on the basis of a t-distribution with a given level of probability significance. The calculated value of t is compared with the tabular value, and in the case of its larger value, the relationship between the phenomena is recognized as statistically significant.

To ensure comparability and calculation of the integral estimate of mortality at the regional level, all collected indicators are normalized and reduced to a single system of units.

Using the method of principal components, their number is reduced to the most significant variables. The choice of this method of information aggregation (integral assessment) is due to the possibility of identifying the maximum dispersion in the correlation matrix, which allows reducing the number of indicators without losing information about the variability of the properties of territorial units.

The next step was to calculate the values of the selected factors influencing mortality for each subject. The further logic of reasoning and the calculation algorithm are described below in a series of sequential actions without detailing the mathematical details of the calculations.

At the first stage, a multidimensional typology algorithm was applied, which includes the normalization of the system of initial indicators by variances.

Each subject of Russia (the total number n in 85 regions - operational territorial units - OTU) is characterized by a fixed set of initial indicators.

Normalized indicators are presented in the form of a matrix for calculating Euclidean distances (calculated using the Pythagorean theorem) connecting each pair of territories included in the calculation and reflecting their differences.

This approach makes it possible to correctly reflect the differences between territorial units for statistically independent indicators. When dependent indicators are used in the calculation, Euclidean distances are distorted. To eliminate this effect, the initial normalized indicators were preliminarily “weighted”, for example, by component loads identified using the principal component method.

This made it possible to bring the original normalized indicators to independent values. By excluding components covering a small percentage of the variance, data were generalized, which made it possible to exclude secondary or even random variations in the system of initial indicator indicators.

In a number of cases, an “objective numerical method for leveling and normalizing nonlinear pairwise monotonic correlations” was applied, which makes it possible to bring normalized initial indicators to a normal distribution and increase the reliability of calculations.

Thus, having chosen one of the measures of similarity of territorial units, the general population was divided into homogeneous groups - types. These groups are formed under the condition that intragroup differences are minimal, expressed as the sum of Euclidean distances (connections) between all pairs of units included in the groups.

At the second stage (when three groups are formed), the algorithm for distributing the remaining territorial units among the three cores is applied, by analogy with the previous stage. For each grouping option, the sum of intra-group differences is calculated and the option that gives the smallest amount is taken as the final one, and the territorial unit that served as the core is fixed as the final third core.

The procedure continues similarly for the formation of four, five, six, and so on. homogeneous groups. Moreover, at each step, a new core is determined and a new grouping is formed.

It is convenient to analyze the results obtained by the arithmetic mean values of each indicator, relative to all territorial units included in one or another type. In some cases, it is advisable to find extreme values in each group for all initial indicators. These characteristics can be used for the semantic characterization of types. The described typology algorithm divides territorial units into groups, provided they are homogeneous.

The calculation of the weight of each factor was made after calculating the integral assessment for each group of factors (for each statistical indicator from each group of factors) based on the final score (IB) of the region - “Integral assessment of mortality factors at the regional level”.

The weight of the factor is calculated as a percentage and reflects the impact (degree of nesting, participation of the factor) on the mortality rate in the region.

To calculate the indicators in the infrastructure block (transport accessibility), the methodology for calculating transport accessibility was used. The task of calculating transport accessibility was solved using the GIS (QGIS) module v.isochrones (GIS - Lab, 2022) by constructing isochrones - lines of equal time spent (20 minutes) to overcome space relative to given points (medical institutions).

It should be noted that the time interval for the availability of medical institutions is determined by the order of the Ministry of Health of Russia dated February 27, 2016 No. 132n for the development of acute diseases that require the arrival of an ambulance within 20 minutes.

The isochrones are constructed taking into account the following parameters: the average speed of movement along a single road, which was determined taking into account the coverage of the road network (asphalt, unpaved, earthen), and the number of traffic lanes. OpenStreetMap vector data was used for this task .

Categories of roads and the accepted average speed on them (Basic assessment ..., 2023):

- trunk - the most important and largest roads, for example, for our territory, Moscow highway. Accepted speed - 90 km / h;
- primary - major highways, next level after trunk. Accepted speed - 90 km / h;
- secondary - relatively large roads, the next level after primary. Accepted speed - 60 km / h;
- tertiary - ordinary roads between small settlements. Accepted speed - 60 km / h;
- living_street - residential areas where pedestrians have a clear advantage in the right to move. Accepted speed - 15 km / h;
- residential - roads in residential areas. The accepted speed is about 40 km/h;
- service - service entrances, entrances, etc. Accepted speed - 30 km / h;
- road - road of unknown type. Accepted speed - 60 km / h;
- track - unpaved roads, usually for agricultural machinery. Accepted speed - 30 km / h;
- raceway - roads for motor sports. Accepted speed - 90 km / h;
- tertiary_link – sections connecting a tertiary with other tertiaries or roads of other types. Accepted speed - 40 km / h;
- secondary_link – sections connecting secondary with other secondary or roads of other types. Accepted speed - 40 km / h;
- primary_link - sections connecting primary with other primary or roads of other types. Accepted speed - 40 km / h;
- trunk_link – sections connecting a trunk to other trunks or roads of other types. Accepted speed - 40 km / h;
- unclassified – roads without a tag. The accepted speed is 40 km/h.

Next, the congestion of roads leading to settlements of arrival according to GOST R 52398-2005 was calculated and the excess of vehicles on certain sections of roads during peak hours (from 07:00 to 10:00 and from 17:00 to 20:00) was calculated taking into account their throughput capabilities. These sections were taken into account when calculating the average speed of vehicles on specific roads. This approach makes it possible to adjust the average speed of the ambulance along the entire length of the road.

The result of the application of the chosen methodology was: the calculation table “The weight of factors affecting the mortality of the population in the Russian Federation, 2019”, a series of maps reflecting the territorial characteristics of mortality, a general integral assessment of the development of the healthcare system of the constituent entities of the Russian Federation.

Actually, this approach made it possible to divide the subjects of the Russian Federation into typological groups according to the nature and characteristics of the spatial organization of the healthcare system.

The factors that determine the spatial organization and structure of the healthcare system at the level of subjects and municipalities are expressed in a system of quantitative indicators that characterize the general features of the spatial organization of the territory.

Among such factors, first of all, the factors of the established stable systems of settlement are distinguished:

1) the level of urbanization - the share of the urban population;

2) the distribution of the urban population in cities of different population classes (small - up to 50 thousand people, medium - 50-100 thousand, large - 100-250 thousand, large - 250-500 thousand, largest - 500-1000 thousand ., “ millionaires ” - over 1 million people);

3) coefficient of urbanization of the territory - the share of the population living in the city - the administrative center of the subject and the share of the urban population living in the administrative center of the subject;

4) features and nature of rural settlement - the distribution of the population in rural settlements of different population (super-small, small, medium, large, large) and the ratio between the number of such settlements and the size (shares) of the population living in them, which makes it possible to determine the type and nature of the rural settlement of the region - large-populated, medium-populated, small-populated, continuous, dispersed, focal, etc.

5) the density of settlements - the number per 1000 square meters. km of territory (total, separately for urban and rural settlements);

6) the average distance between settlements and the maximum remoteness of the administrative center of the subject (distance to the most remote settlement of the regional settlement system).

These factors make it possible to take into account the specific features of the spatial organization of the territory, which are inevitably projected onto the spatial organization of the health care system of the subject.

Results and discussion

Typology of subjects and municipalities in terms of mortality and spatial organization and structure of the health care system

To assess the impact of the spatial organization and structure of the healthcare system (medical factors) on the trends and state of mortality in the regions of Russia, statistical indicators were selected, grouped into two blocks: “Presence of medical organizations” and “Sufficiency of medical personnel”.

As part of the first area “Availability of medical organizations”, 3 indicators were used for analysis:

- Provision of the population with beds in hospitals (per 10 thousand people of the permanent population of the region);
- Number of ambulance stations (departments) (units);
- Number of ambulances (units per 1000 population).

As part of the “Provision of medical personnel” direction, there are 3 indicators:

- Provision with doctors (per 10 thousand population);
- Staffing of medical positions in units providing medical care on an outpatient basis;
- The capacity of outpatient clinics (visits to APU per shift per 10 thousand population).

These statistical indicators for correlation-regression analysis act as the values of a factor trait to identify the statistical significance of their impact on mortality rates.

Mortality rates (per 1000 population, ‰) are the overall mortality rate and mortality rates by cause (according to the final clinical and pathoanatomical diagnoses based on the 10th revision of the International Classification of Diseases (ICD-10) handbooks) act as effective indicators.

Mortality rates, both general and for individual classes of causes of death, are grouped separately for urban and rural areas, including for each of the pilot regions.

For the main classes of causes of death (in accordance with ICD-10), the following mortality rates for 2019 were used:

– Respiratory diseases;
– Diseases of the digestive system;
– Diseases of the circulatory system;
– External reasons;
– All types of transport accidents;
– Neoplasms;
– Malignant neoplasms;
– Infectious and parasitic diseases;
– Cardiac ischemia;
– Suicide;
– Murders;
– Cases of alcohol poisoning;
– Cerebrovascular diseases.

Establishment of the assessment of the influence of factor signs in the blocks "Presence of medical organizations" and "Provision of medical personnel" was carried out according to the method of correlation and regression analysis.

In order to identify the characteristic features and causes of the relationship of phenomena at the preliminary stage of the analysis, the following working (preliminary) hypotheses were formulated:

- medical factors in general have a significant impact on the state of mortality in all regions of the Russian Federation, including in the pilot regions;
- the degree of influence of each of the directions of medical factors "Presence of medical organizations" and "Provision of medical personnel" is approximately the same and significant;
- the degree of influence of medical factors is inversely proportional to the statistical nature - the higher the value of the indicators "Presence of medical organizations" in the pilot regions and the value of the indicators "Sufficiency of medical personnel", the lower the mortality rate;
- the indicator of the factors “Presence of medical organizations” and the degree of medical staffing of the population of the pilot regions is the higher, the higher the overall level of socio-economic development of the territory;
- the greatest differentiation in the significance of the influence of medical factors can be traced in the direction "city - village", i.e. the significance of the influence of medical factors in rural areas of the pilot regions is higher than in cities (especially large ones);
- geographically, the growing role of the influence of medical factors on overall mortality rates can be traced in the pilot regions in the direction “ center – periphery ” ;
- the influence of medical factors in the pilot regions on mortality for certain classes of diseases is not of a significantly pronounced statistical nature and manifests itself exclusively at the level of general values;
- between the pilot regions, differences in the statistical impact of medical factors on mortality rates are primarily due to the level of general socio-economic development of the territory.

Visualization and analysis of results

As a result of statistical correlation-regression analysis, the following results were obtained, grouped according to working hypotheses. In the pilot subjects of the Russian Federation, a feedback was noted between factor and resultant signs: Belgorod region ($r = -0.61$), Kaluga region ($r = -0.35$), Chelyabinsk region ($r = -0.18$).

In the Murmansk region ($r = 0.10$) and the Sakhalin region ($r = 0.01$), a direct relationship was noted between mortality rates and the presence of medical organizations. The quantitative value of the coefficient is significant only for the regions of the Central Federal District - Kaluga and Belgorod.

The reasons for this uneven distribution are probabilistically related not only to quantitative parameters (presence of medical organizations), but also to the effectiveness of their work in the regions.

It should be noted that the presence of medical organizations has a positive effect on reducing mortality in pilot subjects with a higher level of socio-economic development, located within the main zone of settlement and the concentration of economic functions. The opposite situation develops in the peripheral pilot subjects.

In addition, the Sakhalin and Murmansk regions are characterized by a special spatial organization of the territory, the settlement system and, accordingly, the healthcare system, which influenced the values of the coefficients. These features for the two pilot subjects are manifested in the following:

1) the situation within the regions of the Far North and territories equated to them;

2) the focal nature of settlement and the predominance of small settlement forms in its structure;

3) the highest proportion of the urban population, which has developed due to special natural and climatic conditions;

4) a high proportion of population concentration in one city - the administrative center of the subject (in the Murmansk region - 40.5%, Sakhalin - 40.4%);

5) a large area and asymmetric position of the administrative center, which determines the high remoteness of the center from the peripheral-marginal territories.

Of the total number of statistical indicators in the structure of medical factors, one showed a significant impact on the overall values of mortality rates. It has been established that the staffing of medical positions in units providing medical care on an outpatient basis (an indicator of the shortage of medical personnel) has the maximum impact, compared with other statistical indicators of medical factors, on the overall mortality of the population (r = -0.63) .

For pilot subjects, the maximum values of the positive impact of the staffing of medical positions in units providing medical care on an outpatient basis on the reduction in mortality are also noted in the Belgorod, Kaluga and Chelyabinsk regions.

The values of the corresponding correlation coefficients obtained at the all-Russian level were taken as the normative values taken as the basis for comparison for the medical factors “Sufficiency of medical personnel” and “Presence of medical organizations”.

Thus, calculations of the correlation coefficient between the integral values of indicators of medical factors and general mortality rates (r = -0.27) indicate the presence of a relationship between the phenomena, but the statistical significance of this relationship is weak, approaching moderate. At the same time, only 2 of the pilot subjects - Belgorod and Kaluga regions - consistently showed an excess of the value over the all-Russian, and a relatively high degree of influence of medical factors on mortality rates.

The sign of the coefficient for these regions shows an inverse relationship - the more the region is provided with medical organizations and the lower the indicator of the shortage of medical personnel, the lower the overall mortality rates. This confirms the hypothesis of an inversely proportional relationship between the phenomena.

Comparison of the all-Russian indicator of the relationship between the level of socio-economic development and the factors “Presence of medical organizations” and “Sufficiency of medical personnel” and the similar value of the coefficients in the pilot regions shows full compliance of all pilot regions with the all-Russian trends.

Figure 1. Types of subjects of the Russian Federation according to the integral assessment of the provision (deficit) of medical organizations in 2019

In addition, it was found that this manifestation has a clear spatial reference at the country level and confirms a high degree of correlation - as a rule, the high level of socio-economic development of the subject directly determines the low indicator of the shortage of medical personnel and the high value of staffing of medical positions.

Figure 2. Types of constituent entities of the Russian Federation according to the integrated assessment of the provision of medical personnel in 2019

The analysis of the influence of the indicators “Presence of medical organizations” and “Sufficiency of medical personnel” in the pilot regions of the Russian Federation allows us to draw the following conclusions:

- The relatively weak influence of medical factors is explained not so much by the low value of the factor itself, but by the more significant influence of other (non-medical) factors. This confirms the coefficient of determination, showing that the variation in total mortality in the pilot regions of the Russian Federation by only 7.3% depends on medical factors.

- The results of the statistical analysis showed that the mortality rate is influenced not only by the “Presence of medical organizations” indicator, but also by the efficiency of their work. It is for this reason that there is a stable feedback in the relatively more developed pilot subjects of the main zone of settlement, in comparison with the peripheral pilot regions.

- Upon reaching the full staffing of medical organizations in the pilot region, a noticeable decrease in overall mortality can be expected - the possibility of reducing mortality by 39.7% depends on this factor.

- The degree of influence of medical factors is polarized in the direction “center – periphery”, both at the level of the country as a whole and at the level of individual regions (including pilot subjects) (which is clearly seen on the maps).

- This feature determines the need for the development and support of the material and technical provision of medical organizations and personnel medical support for the population in the peripheral regions of the country and regions.

- In the context of individual classes of mortality, a certain pattern of influence of medical factors can be traced. In particular, the staffing of physician positions in outpatient units in the pilot regions has the greatest impact on mortality rates from diseases of the circulatory system and neoplasms (the two main causes of death). This allows us to conclude that it is the full staffing of medical organizations that should be a priority for the development of regional health care systems, especially in rural areas.

When considering the block of medical factors, one can see that the structure of their influence is heterogeneous, and manifests itself differently in different regions. In the course of statistical analysis, it was also found that the reliability of the influence of statistical indicators of medical factors can be traced when working with relative mortality rates (both general and for individual classes of diseases). The identification of the relationship between the absolute values of mortality and indicators of medical indicators does not make sense and distorts the real picture of the statistical relationship.

The hypothesis about the significance of the influence of medical factors on overall mortality in the pilot regions of the Russian Federation was confirmed only for the following pilot regions: Belgorod, Kaluga and Chelyabinsk regions. Checking the reliability of the correlation coefficient between medical factors and mortality values shows that the correlation coefficients have high statistical significance only in the Belgorod and Kaluga regions. In the Chelyabinsk region, the influence of medical factors on the mortality rate is weak. And in the Murmansk and Sakhalin regions it has no statistical significance.

The hypothesis about the approximate equality of the degree of influence and significance of each of the indicators of medical factors “Presence of medical organizations” and “Sufficiency of medical personnel” was not confirmed due to often diametrically opposite results for each of the pilot subjects.

The hypothesis about the inversely proportional statistical nature of the degree of influence of medical factors was confirmed in 3 out of 5 pilot regions.

The hypothesis that the indicator of the factor “Presence of medical organizations” and the indicator of the shortage of medical personnel in the pilot regions is the higher, the higher the overall level of socio-economic development of the territory is fully confirmed.

There is a confirmation of the geographical increase in the role of the influence of medical factors on the indicators of total mortality in the “center-periphery” direction, not only at the level of pilot regions, but also throughout the country as a whole. Moreover, this trend is negative.

The hypothesis that the influence of medical factors in the pilot regions on mortality for certain classes of diseases is insignificant and that it manifests itself exclusively at the level of general mortality values has been partially refuted. A significant influence can be traced in the influence of the presence of medical organizations on mortality rates from cardiovascular diseases and from neoplasms.

Between the pilot regions, the differences in the statistical impact of medical factors on mortality rates are due, first of all, to the level of the general socio-economic development of the territory. The higher the general level of socio-economic development of the region, the higher the values of the provision of the population with medical organizations and personnel, respectively, the lower the values of total mortality.

Correlation-regression analysis of momentary data (in our case for 2019) should be supplemented by regression analysis of time series (series of dynamics) of statistical indicators of medical factors and comparable series of dynamics of mortality rates, which will improve the results of statistical analysis.

Increasing the efficiency of emergency medical care is one of the key tasks in the development of the healthcare system in the Russian Federation. The main goal of the ambulance

service is to ensure the availability of first aid and transportation of the patient to the medical center. One of the indicators of the availability and quality of the provision of ambulance services is the time of the call, which in turn depends on the time the ambulance arrives at the place of the call. According to studies (Begicheva, 2016), patients in need of emergency life support also need to be taken to the hospital in the shortest possible time.

One of the target indicators of the State Program of the Russian Federation “Health Development” is a 20-minute transport accessibility of an ambulance. However, at the moment, the arrival time of only 80% of ambulance teams in the regions of the Russian Federation is less than 20 minutes. The fulfillment of the target indicator can be ensured, for example, by reducing the radius of the service area of the ambulance substation .

In some regions of the country, there are problems with the provision of a network of paved roads. In view of this, individual settlements remain cut off from quality medical services. This problem is partially solved by the air ambulance, however, this service is expensive and cannot be applied in all areas experiencing problems with the availability of medical services.

The factor of transport accessibility, due to the inequality of regions in terms of territory, the degree of its development, the level of development of the network of public roads, differently affects the level of mortality.

In the course of the study, “transport inaccessibility” was used as an indicator of transport accessibility, that is, the proportion of the population outside the ambulance “ arrival ” zone, namely, the number of settlements and the population outside the accessibility zones of medical institutions.

It should be noted that the assessment of transport accessibility within settlements is currently not subject to statistical evaluation and requires separate studies related primarily to the possibilities of the road network, its capacity, the state of the traffic situation in cities with different populations. and different functional types.

Figure 3. Types of subjects of the Russian Federation according to the integrated assessment of the transport accessibility of medical institutions in 2019

The following statistical indicators were used as indicators used to assess the impact of transport accessibility of medical care on mortality rates in the constituent entities of the Russian Federation:

– the proportion of the population living outside the transport accessibility zones of medical institutions (%);

– the proportion of the population living within the transport accessibility zones of medical institutions (%);

– share of settlements located outside transport accessibility zones (%);

– the share of settlements located within the transport accessibility zones of medical institutions (%).

The dependence of mortality rates on indicators of transport accessibility was assessed according to the methodology for calculating transport accessibility.

In order to identify the characteristic features and causes of the influence of the "Transport accessibility" indicator on the overall mortality rates and mortality by cause of death classes (ICD -10), preliminary working hypotheses were formulated:

- the higher the indicator of transport accessibility of medical organizations, the lower the overall mortality rates in pilot subjects;

- transport accessibility of medical organizations in the pilot subjects equally strongly affects mortality rates for the main classes of causes of death within the general trend of mortality (see the formulation of the first hypothesis);

- the indicator of transport accessibility has the maximum impact on mortality in regions with a large area and a sparse network of settlements.

Correlation analysis of the factor of transport inaccessibility with the general mortality of the population revealed a low dependence, 0.14. At the same time, the factor of transport accessibility has a significant impact on mortality in individual groups.

Based on the analysis of the impact of transport accessibility of medical institutions on mortality rates in the regions of the Russian Federation, it was found that this problem is most acute in regions with a large area, low density of the network of settlements and a low degree of general development of the territory.

The maximum value of the correlation coefficient between the factor sign of this group is in the Murmansk region (r = 0.69). The value of the coefficient indicates a significant degree of connection between the proportion of the population living outside the zones of 20-minute transport accessibility and indicators of general mortality. Moreover, the quantitative value of the coefficient approaches a strong degree of connection (0.7 or more).

A moderate relationship in the value of the correlation coefficients between the factorial and effective characteristics is noted in the pilot subjects: Sakhalin, Kaluga and Chelyabinsk regions (the values of the coefficients vary in the range of 0.30-0.31). Weak connection in the Belgorod region - r = 0.27.

Comparison of the obtained coefficients with similar values for Russia as a whole (obtained on the basis of an integral assessment) shows the following values: r = 0.07 - for the total mortality rate (negligible relationship); r = 0.18 - for mortality from diseases of the circulatory system.

Noticeable indicators of communication can be traced in three positions:

r = 0.58 - for mortality from external causes;

r = 0.62 for suicide mortality;

r = 0.69 for homicide mortality.

Similar indicators in the values of correlation coefficients were obtained on the basis of an integral assessment for pilot subjects and the corresponding values of mortality for the main classes of causes of death.

Thus, the factor of transport accessibility has a significant impact on mortality in all pilot subjects from external causes (r = 0.62), murders (r = 0.54), suicides (r = 0.44), transport accidents, accidental poisoning and others (r = 0.43).

Pilot regions with identified maximum problems of transport accessibility of medical organizations are characterized by difficult natural and climatic conditions and (or) a relatively large territory, which partly explains the underdevelopment of transport infrastructure.

It is noteworthy that the issues of regional administrative subordination of medical institutions sometimes significantly exacerbate the problem of their actual transport accessibility.

Conclusion

For a more thorough study of the above problems and the development of measures to address them within specific regions, detailed studies and analysis of the problems of transport accessibility at the level of municipalities and individual settlements, identification of specific problem areas, areas and zones are required. Such studies are possible within the framework of the development of territorial planning documents for municipalities and settlements.

In the course of the correlation-regression analysis, the working hypotheses identified at the preliminary stage of the study showed different confirmations.

For example, it is worth noting that the larger the proportion of the population living outside the 20-minute transport accessibility zone of medical organizations, the higher the mortality rate.

The hypothesis that the transport accessibility of medical organizations in the pilot regions has an equally strong effect on mortality rates for the main classes of causes of death within the overall trend of mortality has not been confirmed.

The transport accessibility indicator indeed has the maximum impact on mortality values in regions with a large area and a sparse network of settlements.

The general calculation matrix obtained as a result of a comprehensive analysis of factors, the state of mortality and the spatial organization of the healthcare system in the pilot regions made it possible to apply an integral indicator and conduct a typology of the subjects of the Russian Federation according to a general integral assessment of the spatial organization of the healthcare system and mortality rates (Fig. 4).

Figure 4. Typology of subjects of the Russian Federation according to the general integral assessment of the spatial organization of the health care system and mortality rates

The typology is based on a multivariate analysis, which simultaneously takes into account the combined impact on the spatial organization of healthcare systems and mortality of a complex of medical and non-medical factors.

According to this indicator, all subjects are divided into 5 typological groups, information about which is presented in the table.

Table 3. Typology of subjects of the Russian Federation according to the general integral assessment of the spatial organization of the health care system and mortality rates

group number	Type name	List of subjects of the Russian Federation
I	Prosperous regions	Moscow, Kabardino-Balkarian Republic, Kursk region, Republic of Dagestan, Republic of North Ossetia-Alania, St. Petersburg, **Belgorod region,** Bryansk region, Sevastopol, Kaliningrad region, Karachay-Cherkess Republic, Lipetsk region, Moscow region, Orel region, Republic of Adygea, Republic of Ingushetia, Chechen Republic, Chuvash Republic - Chuvashia
II	Relatively prosperous regions	Voronezh Region, Kirov Region, Penza Region, Republic of Bashkortostan, Republic of Crimea, Rostov Region, Sakhalin Region, Stavropol **Territory,** Tula Region, Chelyabinsk Region, **Vladimir** Region, Ivanovo Region, Krasnodar Territory, Nizhny Novgorod Region, Republic of Mari El, Republic of Mordovia, Ryazan Region region, Samara region, Smolensk region, Tambov region, Udmurt Republic, Yaroslavl region
III	Relatively disadvantaged regions	Amur Region, Irkutsk Region, Murmansk **Region,** Novgorod Region, Omsk Region, Primorsky Territory, Republic of Altai, Republic of Kalmykia, Republic of Komi, Republic of Tyva, Tomsk Region, Tyumen Region, Chukotka Autonomous District, Yamalo-Henets Autonomous District, Altai Territory, Astrakhan Region, Volgograd region, **Kaluga region,** Kamchatka region, Kemerovo region - Kuzbass, Kostroma region, Krasnoyarsk Territory, Magadan Region, Novosibirsk Region, Orenburg Region, Perm Territory, Republic of Tatarstan, Saratov Region, Sverdlovsk Region, Tver Region, Ulyanovsk Region, Khabarovsk Territory, Khanty-Mansi Autonomous Okrug
IV	Troubled regions	Vologda Region, Jewish Autonomous Region, Kurgan Region, Leningrad Region, Republic of Buryatia, Republic of Karelia, Republic of Sakha (Yakutia), Republic of Khakassia
V	Problem regions	Arkhangelsk region, Trans-Baikal Territory, Nenets Autonomous Okrug, Pskov region

Prosperous and relatively prosperous regions with a high and sufficient level of spatial organization of regional health care systems and relatively low mortality rates are located within the main settlement zone of the European part of the country, they are distinguished by a small and compact territory. The problem area includes the republics of the Siberian and Far Eastern federal districts and the economically depressed territories of the European part.

Bibliography

1. Decree of the President of the Russian Federation of July 21, 2020 No. 474 “On the National Development Goals of the Russian Federation for the period up to 2030”. [Electronic resource]: URL: http://www.kremlin.ru/acts/bank/45726 (Date of access: 03/01/2023).

2. National projects: targets and main results. - M., 2019. - 56 p.

3. National project "Demography". [Electronic resource]: URL: http://government.ru/info/35559/ (Date of access: 01.12.2022).

4.ICD-10/ICD-10. International Statistical Classification of Diseases and Related Health Problems. Tenth revision. Volume 1 (Part 1). Special lists for the statistical development of mortality and morbidity data. [Electronic resource]: URL: https://mkb-10.com/ (Date of access: 01/26/2023).

5. The number of deaths by main classes and individual causes of death per year // EMISS. [Electronic resource]: URL: https://fedstat.ru/indicator/31620 (Date of access: 01/26/2023).

6. GIS Lab. [Electronic resource]: URL: https://gis-lab.info/qa/isochrone-map-grass-qgis.html (Date of access: 01/16/2023).

7. Order of the Ministry of Health of Russia dated February 27, 2016 No. 132n “On the Requirements for the Placement of Medical Organizations of the State Health System and the Municipal Health System Based on the Needs of the Population”. [Electronic resource]: URL: https://docs.cntd.ru/document/420341376 (Date of access: 03/01/2023).

8. Basic assessment of transport accessibility using GRASS GIS and QGIS // GIS- Lab. [Electronic resource]: URL: https://gis-lab.info/qa/isochrone-map-grass-qgis.html (Date of access: 01/16/2023).

9. GOST R 52398-2005 “National standard of the Russian Federation. Road classification. Basic parameters and requirements”. [Electronic resource]: URL: https://docs.cntd.ru/document/1200042582 (Date of access: 03/01/2023).

10. Begicheva S.V. Model of the optimal placement of stations and branches of emergency medical care // Bulletin of the Eurasian Science. 2016. No. 6 (37)