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Macrosocial determinants and public health risks in Russia's regions*

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Abstract. The article presents the results of the comprehensive analysis of the macro-economic factors that determine the medical and demographic situation in Russia, using the methods of mathematical modeling. The authors have constructed regression models to determine the proportional contribution of macro-social determinants to a negative deviation of population health indicators. The authors have carried out the cluster analysis and highlighted six types of territories with similar socio-economic and demographic situation. They have also calculated additional cases of general and infant mortality determined by macro-economic factors for each type of territories. In addition, the authors have assessed health risks associated with the effect of social factors at the macro-level.

Key words: health, mortality, macro-social factors, medical and demographic situation, risk.

Introduction. The enhancement of health and life expectancy in the Russian Federation are called the key strategic priorities of both national and regional policy for a long term. The importance of addressing demographic issues and the relevance of stabilization and growth of Russia's population was highlighted repeatedly by the President in his Address to the Federal Assembly [7, 8]. The focus on the adoption of urgent measures in the field of demography and public health is declared in the Concept of long-term socio-economic development of the Russian Federation for the period up to 2020 [5]. The state program for development of health in the Russian Federation aims to increase life expectancy at birth up to 74.3 years in 2020 [1]. The solution of tasks set out in the strategic documents, and the achievement of the stated values of the indicators requires effective management decisions at all the levels of government concerning the health care of the population.

The population health management includes identification of factors that make the greatest contribution to its formation [2]. Among all the managed determinants of health, special importance is attached to those associated with the environment – both natural and social.

The impact of ecologically troublesome areas, expressed in the pollution of atmospheric air, drinking water and soil, on the health of the population as a whole and individual age-sex groups is proved [3, 4, 14, 17]. It is also possible to consider undeniable the effects of macrosocial and macroeconomic characteristics on public health [16, 18]. However, quantitative parameterization of the influence of environmental factors is the issue, which is much more complex and which can be solved only if considered in relation to specific territories and the actual situation. This fact is proved by the differences in assessing the contribution of socio-economic [6] and anthropogenic factors in the formation of health problems. For example, the contribution of environmental pollution in the population health varies, according to different researchers, in the range from 10 to 57% [13].

The purpose of the study is to establish the priority macroeconomic factors that create negative trends in the health of the population in Russia's regions, in order to solve the problems of management of the medico-demographic situation and ensure the sanitary and epidemiological welfare of the territory.

Materials and methods. Empirical base of the research is the materials provided by the Federal information fund of the data of the socio-hygienic monitoring, and the data of the Federal State Statistics Service for the period from 2009 to 2011 [10, 11].

Among all of the indicators included in the system of socio-hygienic monitoring (the list approved by the order of the Federal Service for Supervision of Consumer Rights Protection and Human Welfare, dated November 17, 2006, No. 367) we have selected several indicators that describe the macroeconomic determinants of health, according to the following criteria:

1) the integrity of the indicator, its ability to describe holistically any determinant (the level of socio-economic development, standard of living, living conditions of the population);

2) the availability of the data for the study period on all the subjects of the Russian Federation. The original list of indicators is presented in *table 1.*

We assessed the interrelationships between the indicators by conducting the correlation and factor analysis, which allowed us to arrange the macrosocial factors into groups of related indicators, each of which was characterized by a single indicator.

According to the results of the correlation analysis the following was revealed:

a) the indicators "Proportion of the total area of housing stock not equipped with running water", "Proportion of the total area of housing stock, not equipped with sewerage" and "Proportion of the total area of housing stock that is not equipped with central heating" are closely related (x4, x5, x7); the further analysis included the indicator "Proportion of the total area of housing stock, not equipped with sewerage" (x5);

b) the indicators "Share of persons with income below the subsistence level" and "Ratio of average per capita money income of the population to the subsistence level established on the territory" (x6 and x11) are dependent; we left the integral indicator

Table 1. Indicators of the macroeconomic factors for the regions of the Russian Federation

x1	Subsistence level established in the territory, rubles
x2	Total area of residential premises, on average by 1 resident, m2
x3	Gross regional product (gross value added) per capita, rubles
x4	Proportion of the total area of housing stock not equipped with running water, %
x5	Proportion of the total area of housing stock, not equipped with sewerage, %
x6	Share of persons with income below the subsistence level, %
x7	Proportion of the total area of housing stock that is not equipped with central heating, %
x8	Average per capita money income of the population, rubles
x9	Average monthly nominal accrued wages of employees of organizations, rubles
x10	Cost of the minimum set of food products, rubles
x11	Ratio of average per capita money income of the population to the subsistence level established on the territory
x12	Proportion of old and dilapidated housing in the total area of housing stock, %

"Ratio of average per capita money income of the population to the subsistence level established on the territory" (x11) for the subsequent analysis;

c) the indicators "Subsistence level established in the territory", "Average per capita money income of the population", "Ratio of average per capita money income of the population to the subsistence level established on the territory" and "Cost of the minimum set of food products" (x1, x8, x10 and x11) are dependent; this group of indicators is described by the integral indicator "Ratio of average per capita money income of the population to the subsistence level established on the territory" (x11);

d) the indicators "Total area of residential premises, on average by 1 resident" (x2), "Gross regional product per capita (x3) and "Proportion of old and dilapidated housing in the total area of housing stock" (x12) not are closely related. All the indicators are included in the analysis.

The health status of the population is described by the following demographic and health indicators: mortality (y1), standardized mortality rate (y2), infant mortality (y3), overall morbidity rate for all classes of diseases (y4), primary morbidity rate for all classes of diseases (y5), life expectancy of the population (y6).

The correlation analysis allowed us to find strong feedback between standardized mortality rate of the population and life expectancy (the value of the Pearson correlation coefficient amounted to (–) 0.98 if $p<0.05$), and total and primary morbidity of the population (the value of the Pearson correlation coefficient is 0.9 if $p<0.05$). We have also found out weak feedback between the overall and infant mortality (the value of the Pearson correlation coefficient is (–) 0.40 if $p<0.05$).

The results of correlation analysis allowed us to select two demographic and health indicators to be included in the cluster analysis: the standardized mortality rate (cases per 100 thousand population) (y2) and primary morbidity rate (cases per 1 thousand population) (y5).

The general algorithm of analytical data processing is a sequence of two stages. During the first stage the linkages between macrosocial factors and population's health status indicators were simulated and the contribution of individual factors was determined. During the second stage the spatial classification and typing of the territories were carried out and the major classes (clusters) and their characteristics were defined.

The relationships between the macroeconomic indicators (x2, x3, x5, x11, x12) and medico-demographic responses (y1 – y6), which were selected on the basis of the results of the correlation analysis, were determined using the regression analysis. The multiple linear regression model describing the dependence of changes of the medico-demographic indicators on the set of macrosocial factors is as follows:

$$y = \alpha_0 + \sum_{i=1}^{n} \alpha_i f_i(x_i), \qquad (1)$$

where x_i is the control factors (macrosocial indicators);

y is the response (medico-demographic indicators), which depends on the control factors;

α_i is the model parameters.

The macrosocial factors that are included in the model were tested for multicollinearity. A determination coefficient R^2 (the proportion of the explained variance), which indicates how well the model describes the dependence between the variables, was determined for each regression model. The models with the highest determination coefficients were selected out of all the models.

The obtained regression models served as the basis, on which we determined the proportional contribution of the set of macrosocial factors to the negative deviation of the indicator of the health of the population. It is necessary to use the minimum levels of factors to determine the contribution of the factors to the variance of the health indicators. The minimum level of the factor $(\hat{x}_i)$ was the best value of the indicator among the areas under consideration (RF subjects).

We calculated the additional cases of morbidity (mortality), defined as the difference between the morbidity (mortality) set in accordance with the regression models for the current value of the macroeconomic factors and the minimum, adjusted for the determination coefficient of the model:

$$\Delta y = \left[y(x_i) - y(\hat{x}_i) \right] \cdot R^2 , \qquad (2)$$

where

Δy is additional cases of morbidity (mortality);

R^2 – is the determination coefficient.

The set of medico-demographic indicators and macrosocial factors obtained in the course of the analysis served as the basis for the clustering of the regions using a probabilistic approach (method of K-means). Having performed the cluster analysis, we arranged the subjects of the Russian Federation into six groups with similar values of the considered factors. The median, minimum and maximum values were calculated for each cluster.

Results and their discussion. The regression analysis of the dependence of medico-demographic indicators on macrosocial factors indicates the presence of a relationship between the standardized mortality rate, standard of living and living conditions in the territory.

This relationship is described by the following equation:

$$y_2 = 13{,}89268 - 0{,}77648x_3 - 0{,}08877x_4 , \quad (3)$$

where

y_2 is the standardized total mortality rate;

x_3 is the ratio of average per capita money income of the population to the subsistence level established on the territory;

x_4 is the proportion of old and dilapidated housing in the total area of housing stock.

The determination coefficient is 0.12, the multiple determination coefficient is 0.347.

This connection indicates that if the proportion of dilapidated housing in the total area of housing stock increases and the indicators of per capita income approach the subsistence level, the standardized mortality rate of the population in the territory tends to increase.

Besides, we found a link between infant mortality and the indicator of comfortable housing; the link is described by the following equation:

$$y_3 = 6{,}38942 + 0{,}27501x_4\,, \qquad (4)$$

where y_3 is infant mortality;

x_4 is the proportion of old and dilapidated housing in the total area of housing stock.

The determination coefficient is 0.18, the multiple determination coefficient is 0.296.

We selected six types of territories according to the results of the cluster analysis of the RF regions using the set of macroeconomic and medico-demographic indicators.

The first type comprises the regions with extremely intense medico-demographic and social situation in the context of high level of economic development. This group consists of the territories that are rich in natural resources and, consequently, a significant share of extractive industries in their economy: the Magadan Oblast, the Sakhalin Oblast, the Republic of Sakha (Yakutia) and Chukotka Autonomous Okrug. This was the reason for the high level of GRP per capita – 646.14 thousand rubles, high ratio of income to consumer basket – 2.99. However, the proportion of old and dilapidated housing in these areas is 10.2% on average. The mortality rate is high – 15.3 cases per one thousand people, and the incidence rate is the highest among all the groups (984.6 cases per one thousand people).

The number of additional deaths (standardized indicator) caused by the influence of macrosocial factors in this cluster ranges from 0.21 cases per one thousand population (Chukotka Autonomous Okrug) to 0.36 cases per one thousand population (the Republic of Sakha (Yakutia)), which can be classified as a median level of risk[1].

The number of additional cases of infant deaths associated with the influence of macrosocial factors on the territories of the cluster varies from 0.33 cases per one thousand newborns (Chukotka Autonomous Okrug) to 0.66 cases per one thousand newborns (the Republic of Sakha (Yakutia)). The risk can also be classified as median. This level of risk requires dynamic control and in-depth study of the sources and consequences for deciding on the measures of risk management.

The first group could include Nenets Autonomous Okrug, which in general has the same structure of socio-economic and medico-demographic indicators like all the territories of the first cluster. However, according to two indicators – GRP per

[1] The risk of damage to the health of the population was characterized on the basis of the following criteria: a) the risk equal to or lower than 1×10^{-6}, which corresponds to one additional case of illness or death per 1 million exposed persons is perceived by people as negligibly small, not different from normal, everyday risks (De minimis level). Such a risk does not require any additional measures for its reduction, the level of risk is subject to periodic monitoring; b) the risk of more than 1×10^{-6}, but less than 1×10^{-4} corresponds to the maximum permissible risk, i.e. the upper limit of acceptable risk. This level is subject to continuous monitoring. In some cases of such levels of risk additional measures for their reduction can be carried out; c) the risk more than 1×10^{-4}, but less than 1×10^{-3} is not acceptable to the population in general. The occurrence of such risk requires the development and implementation of planned recreational activities. The planning of measures to reduce risks in this case should be based on the results of a more in-depth evaluation of the various aspects of the existing problems and establishment of the degree of their priority in relation to other hygienic, environmental, social and economic problems in the given territory; d) the risk throughout life equal to or more than 1×10^{-3} is not acceptable neither for the public nor for professional groups. This range is denoted as De manifestis Risk and when it is reached, it is necessary to give recommendations for the persons who make desicions on urgent measures to reduce the risk.

capita and the level of primary morbidity of the population – this region differs from the others, because its values of these indicators are significantly higher. For instance, GRP per capita in the okrug is 3254.6 thousand rubles (5 times exceeding the average for the cluster), and the incidence is 1757.3 cases per one thousand population (exceeding the average for the cluster by 1.78 times).

The high morbidity rate of the population may be explained by factors such as uncomfortable climatic conditions; low population density; lack of roads; severe weather conditions in winter for ambulance aircraft flights; remote, small villages with population in long-term isolation; nomadic way of life; the presence of endemic foci of some parasitic diseases and disposition to spread due to the mentality of the indigenous and small-numbered peoples of the North; favorable conditions for distribution of some socially significant diseases, reduced physiological reserves of a human organism, leading to various diseases [9, 15].

The second type comprises the regions with acute medico-demographic problems, which are formed on the background of the average level of socio-economic development of the territories.

The regions of this type are characterized by mortality level of 12.8 cases per one thousand population (the values range from 11.2 cases per one thousand population in the Astrakhan Oblast to 14.3 cases per one thousand population in Kamchatka Krai), and the incidence rate is at the level of 871.6 cases per one thousand population (the values range from 673.8 cases per one thousand population in the Pskov Oblast to 1098.5 cases in the Republic of Karelia). With an average GRP per capita in the regions (190.5 thousand rubles), the actual standard of living is quite low: the ratio of average per capita income to the subsistence level established in the territory is 2.53. In addition, there is the high proportion of emergency and dilapidated housing – 4.59%.

This cluster is the largest – it includes 33 subjects of the Russian Federation. The basis of the cluster is formed by the regions of Central Russia (the Vladimir Oblast, the Vologda Oblast, the Ivanovo Oblast, the Kirov Oblast, the Kostroma Oblast, the Novgorod Oblast, the Pskov Oblast, the Smolensk Oblast, the Tver Oblast, the Ulyanovsk Oblast, the Yaroslavl Oblast) and the Volga region (the Astrakhan Oblast), the Republics of Mari El and Chuvashia. The cluster also includes some regions of the Urals (Perm Krai, the Republic of Udmurtia, the Komi Republic, the Kurgan Oblast, the Orenburg Oblast), Siberia (Altai Krai, Zabaykalsky Krai, the Kemerovo Oblast, Krasnoyarsk Krai, the Republic of Altai, the Republic of Buryatia, the Khakassia Republic, the Tomsk Oblast, the Irkutsk Oblast), the Far East (Kamchatka Krai, Primorsky Krai and Khabarovsk Krai) and the North-West of Russia (the Arkhangelsk Oblast, the Republic of Karelia).

Note that the quality of life is low in most of the identified regions. For instance, according to LLC "Rating Agency "RIA Rating", which has made the ranking of Russia's regions by quality of life based on 64 indicators in 2012, only three regions of the second cluster were among the top thirty regions (the Yaroslavl Oblast ranked 13th, the

Tomsk Oblast – 24th, and Perm Krai – 29th). Most of the territories were in the fourth and fifth tens [12].

The number of additional deaths (standardized indicator) associated with the influence of macrosocial factors in this cluster varies from 0.2 cases per one thousand population (the Kemerovo Oblast) to 0.31 cases per one thousand population (the Republic of Mari El), which can be classified as the medium level of risk.

The number of additional cases of infant death associated with the action of macrosocial factors on the territories of the cluster varies from 0.05 cases per one thousand newborns (the Ulyanovsk Oblast) to 0.46 cases per one thousand newborns (the Republic of Komi). The risk should be categorized as low in some territories (the Ulyanovsk Oblast, the Chuvash Republic, the Smolensk Oblast, Altai Krai). In the other territories the risk can be considered median.

The third type consists of the regions with moderate prosperity, without acute medico-demographic or socio-economic problems.

This group differs from the regions of the second type by slightly lower mortality rates (11.52 cases per one thousand) and significantly lower incidence rate (785.8 cases per one thousand). The ratio of income to the subsistence level is above average – 3.13; the share of dilapidated housing is low – 2.05%, GRP per capita is medium – 191.2 thousand rubles.

The group of regions of the second type includes 22 subjects of the Russian Federation. Moreover, we have not detected any specifics associated with the geographical location of the territories.

The group includes, first of all, the regions of Central Russia that are located to the south, west and north-west of Moscow: the Bryansk Oblast, the Belgorod Oblast, the Kaluga Oblast, the Kaliningrad Oblast, Krasnodar Krai, the Kursk Oblast, the Lipetsk Oblast, the Moscow Oblast, the Murmansk Oblast, the Orel Oblast, the Rostov Oblast, the Samara Oblast, the Tambov Oblast, the Tula Oblast, the Republic of North Ossetia – Alania. Second, this group includes the Volga and Ural regions: the Republic of Bashkortostan, the Republic of Tatarstan, the Nizhny Novgorod Oblast, the Sverdlovsk Oblast and the Chelyabinsk Oblast; third, the regions of Siberia: the Novosibirsk Oblast, the Omsk Oblast.

The quality of life is high in many of these regions compared to other regions of the Russian Federation. For example, the Moscow Oblast ranked 3rd, the Republic of Tatarstan – 4th, Krasnodar Krai – 5th, and the Belgorod Oblast – 6th in the ranking of regions by the quality of life of the population [12].

The number of additional deaths (standardized indicator) due to the influence of macrosocial factors in this cluster ranges from 0.1 cases per one thousand population (the Republic of Tatarstan) to 0.24 cases per one thousand population (the Tula Oblast). The level of risk is median.

The number of additional cases of infant death associated with the influence of macrosocial factors, on the territories of the cluster varies from 0.01 cases per one thousand newborns (the Kursk Oblast) to 0.27 cases per one thousand newborns (the Tula Oblast). The level of risk is low (maximum risk) in

most of the territories included in this cluster, except for the Tambov Pblast, the Tula Oblast, the Novosibirsk Oblast, the Kaluga Oblast, and the Republic of North Ossetia-Alania. These territories are characterized by the median level of risk.

The fourth type includes the territories of relative prosperity with the high level of socio-economic development and relatively favorable medico-demographic indicators for the Russian Federation. The regions included in this group as a result of the clustering have virtually the lowest mortality rate – 9.86 cases per one thousand population (the value varies from 7.4 in Moscow to 11 in the Tyumen Oblast). At the same time the primary morbidity rate seems to be quite high – 913 cases per one thousand population; the values range from 717 (Moscow) to 1193 (Yamalo-Nenets Autonomous Okrug). However, the high levels of primary morbidiy are not typical of most areas of the analyzed cluster. Yamalo-Nenets Autonomous Okrug makes the main contribution to the formation of the high values.

The territories of this group are characterized by the highest level of GRP per capita (926.310 thousand rubles, which is two times higher than the average value in the cluster that follows this one by the level of socio-economic development), and by the highest average ratio of per capita income to the consumer basket – 3.97. The share of rundown and dilapidated housing in the total housing stock is 4.64%.

This type includes the cities of federal importance: Moscow and Saint Petersburg, the Tyumen Oblast, and Khanty-Mansi and Yamalo-Nenets autonomous okrugs.

Note that these areas in general have a high level of quality of life. Almost all of them (except for Yamalo-Nenets Autonomous Okrug) are among the top eight regions ranked by the quality of life in 2012 [12].

The number of additional deaths (standardized indicator) conditioned by the influence of macrosocial factors in this cluster ranges from 0.01 cases per one thousand population (Moscow) to 0.21 cases per one thousand population (Khanty-Mansi Autonomous Okrug). The risk is within the boundaries of the maximum permissible for the cities of Moscow and Saint Petersburg; and the risk is assessed as median for the Tyumen Oblast, Khanty-Mansi and Yamalo-Nenets autonomous okrugs.

The number of additional cases of infant death associated with the action of macrosocial factors on the territories of the cluster varies from 0.01 cases per one thousand newborns (Moscow) to 0.47 cases per one thousand newborns (Yamalo-Nenets Autonomous Okrug). Again, the level of risk for the cities of federal importance can be classified as low, for other regions of this cluster – as average.

The fifth type consists of the regions with a relatively favorable medico-demographic situation, emerging against the background of a low level of socio-economic development.

Its main features are: low mortality rate (10.95 cases per one thousand) and low morbidity rate (627 cases per one thousand) of the population; the lowest average ratio of per capita incomes to the consumer basket – 2.36; practically the lowest level of GRP per capita – 128.8 thousand rubles (it is lower only in the Republics of Dagestan and Ingushetia); but at the same time the

proportion of rundown and dilapidated housing is low – 1.85%. This group is represented by the central and southern regions of Russia: the Ryazan Oblast, the Volgograd Oblast, the Voronezh Oblast, the Penza Oblast, the Saratov Oblast, the Republics of Adygea, Kalmykia, Kabardino-Balkaria, Karachay-Cherkessia, Mordovia, the Chechen Republic and Stavropol Krai.

The Leningrad Oblast that has the highest GRP per capita (293.3 thousand) occupies the edge position among the regions of the second group. However, according to the other indicators, the region represents this group in general. For example, the Leningrad Oblast is characterized by a relatively low ratio of income of the population to the subsistence level (2.83). In the Voronezh Oblast and the Republic of Adygea, also included in this group, this indicator is 2.8 and 2.7 respectively. For comparison: in Saint Petersburg the value of the index is at the level of 4.34 (it exceeds the value for the Leningrad Oblast by 1.5 times).

The number of additional deaths (standardized indicator) conditioned by the influence of macrosocial factors in this cluster varies from 0.2 cases per one thousand population (the Voronezh Oblast) to 0.33 cases per one thousand population (the Republic of Kalmykia). In all the cases the risk is assessed as median.

The number of additional cases of infant death associated with the influence of macrosocial factors on the territories of the cluster varies from 0.02 cases per one thousand newborns (Stavropol Krai) to 0.12 cases per one thousand newborns (the Penza, Leningrad, Ryazan and Saratov oblasts). The level of risk is low on eight territories of this type and it is median on five territories of this type.

Finally, the sixth type is characterized by the extremely low level of socio-economic development, but at the same time – the most successful medico-demographic situation. Mortality here is at the level of 7.9 cases per one thousand, and morbidity rate is at the level of 885 cases per one thousand. While GRP per capita is only 75.3 thousand rubles, the ratio of incomes to the subsistence level is 2.9, and the share of rundown and dilapidated housing is 19.4%. This group comprises only two subjects of the Russian Federation – the Republic of Dagestan and the Republic of Ingushetia.

Additional deaths (standardized indicator) in the Republic of Dagestan constitute 0.31 cases per one thousand population (median level of risk), in the Republic of Ingushetia – 0.48 cases per one thousand population (median level of risk). Both regions are characterized by very high values of the indicator of additional infant deaths conditioned by macrosocial factors (0.9 cases per one thousand newborns).

Conclusions. The medico-demographic situation in Russia today depends largely on social determinants. The key social factor affecting mortality (standardized indicator) is the level of welfare of citizens, which is derived from the level of socio-economic development of the territory. That is why in Moscow, which is characterized by high incomes and the largest difference between average per capita incomes and established subsistence minimum, the number of additional deaths (standardized indicator)

determined by social factors is minimal. Infant mortality is determined largely by the conditions of living rather than by the standard of living. The indicator of the degree of comfort of the housing stock is the key one among all social factors affecting infant mortality in the territory.

The effective managerial decision-making in the field of public health implies the reliance on actual data on the state and dynamics of the demographic situation in the territory, as well as on the specific effects of macro-factors on morbidity and mortality. In addition, it requires adequate tools to study the optimal distribution of material and other resources of the society for various activities associated with the preservation and enhancement of the health of citizens.

The establishment of the leading factors influencing the demographic and health situation can serve as a starting point for choosing the priorities of both state and regional policies on management of population health. The development of strategies for socio-economic development of regions, and the formation of the target comprehensive programs can be based on the understanding which factors of risk in reducing the quality of human capital require immediate response, and in respect of which the countermeasures can be delayed for some time.

Russia's regions differ significantly by the level of public health, which indicates the heterogeneity of living conditions and quality of living environment (both natural and social). A comprehensive analysis of demographic and health indicators, socio-economic development levels and living conditions of the population in the Russian Federation subjects allowed us to identify the territories where the number of additional deaths (standardized indicator) and infant mortality that are determined by macrosocial factors is the greatest. First of all we are talking about the republics of Tyva, Ingushetia and Dagestan.

The policy focused on preserving and strengthening the health of citizens cannot be the same in all the regions. Understanding the importance of an integrated approach to the management of health, it is necessary to recognize the importance of a targeted impact on individual macro-factors of risk related to social environment, the minimization of which will help achieve optimal results when realizing the task of protecting the health of citizens.

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