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Original article

STATISTICAL DEPENDENCIES OF INDICATORS OF PHYSICAL WELL-BEING OF THE POPULATION OF A BIOSPHERE-COMPATIBLE CITY

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Background. *In the near future, one should ensure a radical increase in the comfort of the urban environment and its quality index and reduce the number of cities with unfavorable living environments. The deterioration of the ecological situation in many cities poses the task of developing new principles of urban life that regulate the biosphere compatibility of cities and the development of human capital.*

Purpose. *The research aimed to identify the statistical regularities of the population's livelihoods in residential areas of Russian cities, depending on the functional and spatial organization of these areas.*

Materials and Methods. *The theoretical basis of the research is the paradigm of the livelihoods of bio spherically compatible cities and settlements that develop humans and its following principles: (1) assessment of physical well-being and progress in human development in the city, (2) satisfaction of rational human needs with city functions, (3) implementation of social standards in public relations.*

The practical methods used to solve the scientific problem were the methods of correlation and regression analysis, used to identify statistical dependencies in various municipal entities, mainly in large cities in Russia with high population density.

Results. *Statistical data on the level of the population's livelihood environment and the results of providing social infrastructure objects in the process of implementing public urban functions in 17 residential micro-districts in 15 cities were analyzed. Based on the obtained data, a type of regression model was chosen, and its parameters were numerically evaluated.*

Conclusion. *The identified statistical regularities can serve as a characteristic of the physical well-being of the population and be the subject of further scientific discussion of the multifactorial processes of livelihoods in a biospherically compatible city to achieve indicators of its comfort and safety.*

Keywords: *living environment; biosphere-compatible city; comfort; safety; correlation and regression analysis; statistical dependencies*

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Научная статья

СТАТИСТИЧЕСКИЕ ЗАВИСИМОСТИ ПОКАЗАТЕЛЕЙ ФИЗИЧЕСКОГО БЛАГОПОЛУЧИЯ НАСЕЛЕНИЯ БИОСФЕРНО-СОВМЕСТИМОГО ГОРОДА

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Обоснование. *В обозримом будущем следует обеспечить радикальное повышение комфортности городской среды и индекса ее качества, сократить количество городов с неблагополучной средой проживания. Ухудшение экологической обстановки во многих городах ставит задачу разработки новых принципов городской жизни, регулирующих биосферную совместимость городов и развитие человеческого капитала.*

Целью *исследования явились статистические закономерности жизнедеятельности населения жилых районов городов России, выявленные в зависимости от функционально-пространственной организации этих районов.*

Материалы и методы. *Теоретической основой исследования является парадигма жизнедеятельности биосферно-совместимых городов и поселения, развивающих человека и ее следующие принципы: (1) оценки физического благополучия и прогресса в развитии человека в городе, (2) удовлетворения рациональных потребностей человека функциями города и (3) внедрения социальных стандартов в общественные отношения.*

Практическими методами для решения поставленной научной задачи являются методы корреляционного и регрессионного анализа, используемые для выявления статистических зависимостей в различных муниципальных образованиях, преимущественно крупных городах России с высокой плотностью населения.

Результаты. *Были проанализированы статистические данные об уровне среды жизнедеятельности населения и результатах обеспечения объектами социальной инфраструктуры в процессе реализации общественных городских функций в 17 жилых микрорайонах 15 городов. На основе полученных данных был выбран тип регрессионной модели и проведена численная оценка ее параметров.*

Заключение. *Выявленные статистические закономерности могут служить характеристикой физического благополучия населения и явятся предметом дальнейшего научного обсуждения многофакторных процессов жизнедеятельности биосферно-совместимого города для достижения показателей его комфортности и безопасности.*

Ключевые слова: *среда жизнедеятельности; биосферно-совместимый город; комфорт; безопасность; корреляционно-регрессионный анализ; статистические зависимости*

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Introduction

One of the most important tasks of urban planning science is the task of creating a comfortable and safe environment for city life. Solving this problem requires building new models and identifying patterns in the functioning of urban elements of planning structures [1]. The quality of the urban environment (comfort and safety) includes residential areas and their infrastructure [2]. Residential areas are objects of urban development activities that determine the ability of the urban environment to meet the vital needs of the population, taking into account socio-economic and demographic prospects and human development [10].

In urban planning, the comfort of the spatial environment is an objective state and subjective perception. It corresponds to the system of needs, values, ethical norms and cultural traditions that have developed at a given time, in a given place, in a given society, which form an idea of what elements and properties of the spatial environment are necessary for a decent human existence [11].

Academician V. A. Ilyichev identified a comfortable and safe environment for city life that meets modern challenges. Under his leadership, he formulated the definition within a new scientific direction and a new paradigm of life (biosphere-compatible city) at the Russian Academy of Architecture and Construction Sciences (RAACS). Biosphere compatibility of a city is a state of symbiosis between a city and the surrounding biosphere. The city and its inhabitants are developing positively, and the biosphere can develop naturally in this region [7]. By a comfortable urban environment, we mean the living conditions under which the harmonious development of a person (physical, material, and spiritual) is achieved in unity with the natural environment of the city, taking into account the public interests of all categories of the urban population. The complex feature of objective and subjective living conditions of the population determines the level of favorability and comfort of the habitat.

For the first time, a methodology for establishing causal relationships between the population of the region and the levels of many factors determining the conditions of human development in a biosphere-compatible city was proposed in the "Methodology for predicting indicators of biosphere compatibility of urbanized territories" [8]. The proposed simulation procedure allows us to assess the demographic situation as the primary indicator of the city development, depending on environmental factors.

In the scientific study "Technologies for providing an environmentally safe and accessible environment of a biosphere-compatible city for people with limited mobility," E. V. Bruma developed a mathematical model for analyzing the habitat of people with limited mobility as the least socially protected group of the population today [9]. The researcher found correlations between the number of people with disabilities in various morbidity categories and many ecological and socio-economic factors. Therefore, it was possible to assess the dynamics and build short-term forecasts of the development of the number of low-mobility groups in the population [3]. In the same scientific work, considering environmental factors, a model of the dynamics of the age structure of the population of an urbanized territory was constructed, and a forecast of the growth of the disabled population was made. Research in the field of development of population dynamics models has established that the current environmental situation in the urban environment significantly reduces the quality of human resources, leading to depopulation. This factor may be accompanied by aging and disability of the population and an increase in the number of temporarily disabled people belonging to low-mobility groups [4]. In [5], mathematical modeling of the dynamics and mutual influence of population size and environmental factors was developed and considered. Nevertheless, the results of the research obtained so far require the identification of patterns of formation of comfortable living conditions, first of all, in the residential environment of the city. It satisfies not only the material needs of the population but also cultural and spiritual, for example, cognition, self-knowledge, and creativity.

In connection with the aspects mentioned above, the research aims to establish patterns of comfortable living conditions of the urban population, depending on the functional location of residential areas.

Materials and methods

The theoretical basis of this research is the paradigm and principles of the life of biosphere-compatible cities and settlements that develop a person [14].

The correlation and regression analysis methods served as practical tools for establishing statistical patterns of life of the population depending on the functional location of residential areas of the city and providing conditions for human development.

The research hypothesis was the following thesis – the infrastructure of residential areas that implements the functions of a biosphere-compatible city is an indicator of its comfortable and safe habitat and the physical well-being of the population living in these areas.

The choice of factors influencing the studied indicators of a comfortable and safe environment for a biosphere-compatible city is made based on a meaningful analysis of environmental, socio-economic, and demographic conditions and processes using statistical data and regulatory requirements of urban planning design of residential areas. However, for all its apparent simplicity, the definition of such indicators in residential areas of modern cities contains several problems that prevent an adequate assessment of indicators.

In the process of analyzing urban planning activities and assessing the compliance of project documentation of residential neighborhoods with regulatory requirements, as well as statistical reporting data of cities of the Central Federal District, we have identified indicators of the vital activity of the population, which can be attributed to the group of indicators of the physical well-being of the population. The research utilized survey data from 17 residential areas in 15 different cities of Russia (Orel, Kursk, Belgorod, Ryazan, Tver, Bryansk, Lipetsk, Moscow, Kaluga, Tyumen, Yoshkar-Ola, Kirov, Voronezh, Yelets, Tula) with a population of two thousand or more up to 50 thousand people.

At the initial stage of building statistical dependencies, we refine the list of indicators that, in principle, can be included in the model. Their number can be significant. However, the model should not include more than one-third of the available data to obtain reliable estimates. Paired and multiple correlation coefficients are used to determine the most significant factors. The list of dependent (explicable) factors of the habitat of microdistricts includes indicators of the physical well-being of the population, identified according to the Federal State Statistics Service: Y_1 *"Number of births in the last year" and* Y_2 *"Number of deaths in the last year."*

As independent (explanatory) factors, 50 indicators ($X_1 - X_{50}$), were taken, characterizing various components of the feasibility of city functions Φ_i, provided that the significance of all city functions is the same. However, their feasibility in residential areas is different. In particular, as the analysis of the feasibility of city functions has shown, seven factors ($X_1 - X_7$) relate to the living conditions of the population and 22 factors ($X_8 - X_{29}$) – to the life support systems of residential areas and reflect the feasibility of the city function *"Life support"*; five factors ($X_{30} - X_{34}$) relate to the function *"Entertainment and rest"*; three factors ($X_{35} - X_{37}$) – to the control system, i.e., functions *"Power"*; four factors ($X_{38} - X_{41}$) – to the educational function – *"Knowledge";* one factor (X_{42}) – to the function of the city "*Creativity*"; three factors ($X_{43} - X_{45}$) – to harmonize relations with the environment, etc. functions of the city "*Connection with nature*." In addition, we considered the factors of environmental safety of residential areas due to emissions from mobile and stationary sources of air pollution and the management of municipal solid waste (MSW) ($X_{46} - X_{49}$). The factor of the so-called "mechanism of demographic reproduction" is the indicator *"Size of the population"* (X_{50}) [16].

The numerical values of the indicated explained $Y_1 - Y_2$ and explanatory $X_1 - X_{50}$ factors were selected for each of the 17 microdistricts. Consequently, the number of data sets is $n=17$.

The relationship between the dependent variable Y_i $(i=1–2)$ and the independent variables X_j $(j=1\text{-}50$ is assumed to be linear as a function

$$Y_i = t_i\,(x_1, x_2, \ldots x_{50}).$$

According to the recommendations, to be included in the model for each Y_i, it is necessary to choose $m=5$ $(m \le \frac{n}{3} = \frac{17}{3} \approx 5$ of the most significant factors from X_j.

Essentially, it is necessary to construct and estimate the parameters of functions of the form

$$Y_i = a_{0i} + a_{i1}\,x_{i1} + a_{i2}\,x_{i2} + \ldots + a_{i5}\,x_{i5},\ (i = 1 \div 2),$$

where a_{0i}, a_{ij} ($j=1\div5$)) are constants to be determined;

x_{ik} are the five most significant explanatory factors for a given Y_i, obtained by analyzing the values of the pair correlation coefficients r_{YiXk}, *(k = 1÷ 50).*

The dependence shows the average value of the Y_i. The variable will be if the X_{ij} variables take specific values.

Analysis of the pair correlation coefficients. We calculated the coefficients of pair and multiple correlations at this stage: six of them (r_{YiX1}, r_{YiX2}, ... r_{YiX50}) = 300 coefficients of the form r_{YiXk} (*i=1-2 и k=1-50*) and a set of coefficients of form r_{X1X2}, …, r_{X49X50}. Furthermore, while assessing the significance of the factors, their comparative assessment is made. Some of the factors are screened out by analyzing the coefficients of pair correlation r_{YiXk} and r_{YmXn}.

Results

The values of the pair correlation coefficients are in the range from -1 to +1. Their positive value indicates a direct connection (with the calculation of one variable, the other also increases). A negative value indicates the opposite (with the growth of one variable, the other decreases). The closer the coefficient is to 1, the closer the relationship. The relationship is considered strong enough if the correlation coefficient gives an objective assessment of the tightness of the relationship only with a linear dependence of the variables.

Is included in the model those factors that are most strongly associated with the dependent variable. In addition, one of the conditions of the regression model is the assumption of the linear independence of the explanatory variables X_{ij}. The close relationship between two independent factors is called collinearity. The phenomenon of collinearity in the initial data is considered established if the pair correlation coefficients between two variables are more than 0.7. In this case, it is necessary to eliminate collinearity since there will be a cumulative impact on each other. Thus, it will be impossible to assess the impact of each factor separately. The stronger the multicollinearity, the less reliable the estimate resulting from the model. One of the strongly related factors is excluded from the model, and the next most important factor is included.

To identify the fact of collinearity, the matrix of the pair correlation coefficients between the explanatory factors r_{Xx} is analyzed. As a result of the calculations of all coefficients of pair correlation, selection of the most significant explanatory factors for each Y_i, considering the strong relationships between the explanatory and explicable factors, and excluding collinearity, statistical dependence of the physical well-being of the population of a biosphere-compatible city were obtained in the form of multiple linear regression equations for the factors Y_1 *"Number of births in the last year"* and Y_2 *"Number of deaths in the last year."*

$$Y_1 = a_{01} + a_{11}x_{50} + a_{21}x_{48} + a_{31}x_{24} + a_{41}x_{34} + a_{51}x_3, \quad (1)$$
$$Y_2 = a_{02} + a_{12}x_{50} + a_{22}x_{48} + a_{32}x_{30} + a_{42}x_{14} + a_{52}x_{12}. \quad (2)$$

Based on the results of the correlation analysis, it was found that the studied indicator Y_1, *"Number of births in the last year,"* is influenced by many explanatory factors of human life in residential areas, in particular:

- Population size, thousand people (x_{50});
- Emissions of pollutants into the air from mobile sources, thousand tons (x_{48});
- Engineering protection of the territory and the level of environmental safety (level of protection of premises from the accumulation of radon) (x_{24});
- The area of the territories of the zones of mass short-term rest, m (x_{34});
- Coefficient of building density (x_3).

As the analysis of equation (1) has shown, the most significant impact on the number of births is associated with emissions from mobile sources - vehicles (x_{48}). Automobiles, as a means of transportation, are most widespread in residential areas, which affects the state of the atmospheric air. The amount of emissions directly determines the degree of impact on the population's health and its reproductive capacity. Environmental factors include ionizing radiation of natural and artificial nature - factor (x_{24}).

With the help of the regression model was constructed (2), it was found that the studied indicator Y_2, *"The number of deaths in the last year,"* is influenced by the following explanatory factors:

- Population number, thousand people (x_{50});
- Emissions of pollutants into the air from mobile sources, thousand tons (x_{48});
- Provision of facilities for institutions, organizations, and service enterprises (cafes, restaurants, bars) (x_{30});
- Housing affordability index (market value of housing, rubles / m^2) (x_{14});
- Availability of infrastructure facilities of primary / daily services (medical organizations) (x_{12}).

Discussion

The question of dynamics and cause-effect relationships of fertility remains controversial due to its multifactorial nature. Experts often cite urbanization and the quality of life associated with it among the factors that reduce the birth rate. Numerous studies of demographers have shown that the birth rate among urban dwellers is about one and a half times lower than in rural areas [16]. At the same time, experts draw attention to the dynamics of the urban lifestyle associated with stress and rest (factors (x_{34}) and (x_{30})), which leads to a decrease in the birth rate and stimulates mortality. In addition, scientists, long before the emergence of statistics and demography, established an inverse relationship between income and fertility. In 1776, A. Smith noted the inverse relationship between the number of children born and the social status of mothers [12]. In France in the 20th century, statistician Jacques Bertillon studied differential fertility (systematic differences in fertility rates between social groups). In 1980, he published the results of a statistical study of differences in the birth rates of residents of four European capitals (Vienna, Berlin, Paris, London), showing an inverse correlation between the material standard of living and the birth rate [18].

Mortality is a demographic process that includes the entire set of deaths over a particular time. The mortality rate determines the frequency (intensity) of deaths in a population group during a certain period (usually a year).

The mortality rate depends on a combination of factors, among which there are two main groups: endogenous factors associated with the natural aging of the body, the characteristics of its physiology, genetics, psyche; exogenous factors, i.e., generated by the influence of the external environment – economic and social, and the ecological situation and the level of development of hygiene and health care, personal lifestyle. In countries with a low level of development, the role of an exogenous factor is abundant; therefore, there is a high level of infant and mortality. In countries with a higher level of development, the influence of endogenous factors prevails; therefore, the maximum mortality rate moves to older age groups [6].

The main reason for the low life expectancy of the population in the Russian Federation is the high mortality rate of citizens of working age. Among the total number of deaths, almost a third are citizens of working age. About 80 percent of them are men. Mortality from diseases of the cardiovascular system, accounting for 55 percent of mortality from all causes, in Russia is 3–4 times higher than in European countries. Among the causes of death at working age, a significant proportion (over 30 percent) are external causes – accidental poisoning, suicide, murder, traffic accidents, and other accidents [17].

The infant mortality rate calculated according to the system in force in the Russian Federation, despite its decrease from 18 per 1000 live births in 1992 to 10.2 in 2006, is about twice higher than in developed European countries, Canada and the USA (according to calculations following the recommendations of the World Health Organization) [15]. The population's mortality rate is based on indicators that wipe out multifaceted demographic processes: population density, demographic load, retirement and increased pressure on the working-age population, and more.

The forms of leisure that contribute to a healthy lifestyle (physical culture, sports, tourism, outdoor activities, and others) are underdeveloped. Even without delving into the intricacies of demography, it is clear that this thesis looks reasonable. We can say that the problems of the quality of life in modern residential areas are in direct connection with socio-demographics [13]. Thus, it indicates a direct relationship between life-supporting factors and the level of fertility and mortality. This fact cannot be ignored when predicting the indicators of the comfort of the living environment as a whole.

In addition to the identified factors, the mortality rate is also due to the high incidence of the population, alcoholism, drug addiction, and tobacco smoking. Often in residential areas, conditions have not been created that encourage people to take good care of their health and their children's health.

Conclusion

Based on the analysis of statistical material, the regularities of urban population factors were established depending on the functional location of residential areas in 15 cities of the Russian Federation. The revealed significance of the statistical indicators of the physical comfort of residential areas is due to the fact that they reflect the influence of numerous environmental conditions on vital indicators and characterize the level of satisfaction of physical, spiritual, and social needs of the urban population. As for the comfortable and safe residential areas of modern cities, the function of a biosphere-compatible city is a response to "human needs" through urban planning and design. In practical terms, the results of the study provide an opportunity to evaluate various planning and design solutions in order to compare methods of improving the structure of the city by one indicator – the degree human needs satisfaction.

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Vyacheslav A. Ilyichev: developer of the paradigm of a biosphere-compatible city and the fundamental principles of its transformation into a developing one for a person.

Natalia V. Bakaeva: developer of a methodology for establishing cause-and-effect relationships between the population of the region and the levels of factors that determine the conditions of human development in a biosphere-compatible city.

Vladimir A. Gordon: participating in the substantiation of the system of estimated indicators of the residential environment of microdistricts and conducting correlation and regression analysis.

Marina I. Afonina: conducting correlation and regression analysis and explaining the results obtained.

Aleksandra A. Kormina: formulated the research task and methods. Correlation and regression analysis and explanation of the obtained statistical dependencies of the well-being of the population of a biosphere-compatible city.

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Бакаева Н.В.: является разработчиком методики установления причинно-следственных связей между населением региона и уровнями ряда факторов, определяющих условия развития человека в биосферосовместимом городе.

Гордон В.А.: принимал участие в обосновании системы оценочных показателей жилой среды микрорайонов и проведении корреляционно-регрессионного анализа.

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