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URBOECOLOGICAL ZONING OF THE KRASNOYARSK CITY

Abstract. *As an urban area, Krasnoyarsk is a multi-component system with environmental, social, economic and architectural planning problems like other industrial centres. Analyzing the principles of ecological zoning of the urban environment, the authors took into account several aspects, the main of which was to consider a city as a system of social and functional settlement. The paper highlights the main critical factors of development and proposes easures to improve the quality and comfort of the living environment in the city on t he basis of the regression model of panel data with deterministic effects.*
Keywords*: urbanized area, zoning, regression model.*

Introduction

Krasnoyarsk is the administrative city of the Krasnoyarsk Territory and one of the largest industrial centers of the Siberian Federal District. If earlier the growth of industry in cities gave additional effect to development, now more often its negative moments come to the fore: city transport collapse, water supply and other ecological problems. The attractiveness of an area is related to its comfort, therefore along with balanced development of the territory, the interests of its residents should become paramount. Recently in cities the development vector has shifted from the economic to the social direction. The transition to a "green economy" implies reducing an ecological burden, supporting economic growth, which requires thinking over the strategies of cities planning and forecasting, adjusting its target functions and limitations, taking into account recent wishes of the population. In the literature there are many approaches to assessing the degree of urbanisation of city areas (Vershinin, 2002, Sheveleva, 2015, Khusnutdinova, 2015).

Krasnoyarsk is a multi-component system with environmental, social, economic and architectural planning problems similar to industrial centres. In accordance with the concept of sustainable development of urban areas town planning should be aimed at creating an optimal environment.

There is no doubt that the largest cities are the biggest threats to the environment in terms of ecological safety. When developing a city, it is necessary to take into account the problem of preserving landscapes, as well as the existing anthropogenic load on residential, recreational and industrial zones. The main pressure points of urban ecosystems throughout the period of their existence were pollution, high population density, high crime rate, high morbidity, a greater degree of risk in case of natural disasters. The development of society, unfortunately, did not help to solve these problems, and some of them were even aggravated.

For a modern citizen, the comfort of living today is connected not only with the high economic potential of the territory, but also its environmental performance and the quality of architectural and planning design. In modern conditions of urban management and planning, it is necessary to solve a multidimensional multicriteria problem with a complex system of restrictions (a multivariate paths and various types of risks), which primarily should take into account the interests of the population.

Methodology

The following social, economic and environmental indicators were chosen to evaluate the territory and to construct a regression model of panel data with deterministic effects:

- economic indicators - industrial output, investments in fixed assets, fixed capital, financial outcomes of enterprises, gross revenue, transport and infrastructure development;
- social-demographic indicators - migration, level of services and trade development, quality of education, health indicators;
- environmental indicators - atmospheric air pollution rate, discharge and withdrawal of water, the rate of waste, recreation areas, disturbed landscapes.

When analyzing the principles of ecological zoning of the urban environment, we took into account several aspects, the main of which was the consideration of a city as a system of social and functional settlement. Cluster analysis was carried out on these indicators. For calculation of air pollution rate from mobile sources the standard GOST R 56162-2014 technology was used. Data processing was carried out by the statistic analysis programs "Statistics Version 10" and "STATA".

Measurement and analysis

69 factors were used to create the model: 12 ecological ones, characterizing the impact on the environment; 25 social ones (education, healthcare); 11 economic ones (investments, loaded output); 21 infrastructure ones (architectural and planning). All figures were taken for the period from 2007 to 2016. Correlation analysis identified the collinear and non-significant indicators, which reduced the total number of data significantly. For Krasnoyarsk city, as well as for other cities of the region, (link) analysis of end-to-end regression and the one with deterministic and random effects showed ~~a~~ stable correlation of the permanent population on the indicators that determine the quality of life. Thus, the end-to-end regression throughout the entire ~~time~~ period without taking into account the panel data structure, which was made using a simple least squares method, determines the "local budget costs" through the indicators: "total living area", "population", "sports facilities", "education", "healthcare", "ecology factors", "year". The results of equation coefficient and their value are shown in Table 1 and 2. Thus, we can say that the regression model of the city confirmed social orientation focus in its development.

Table 1

The results of equation coefficient of multiple regression

Multiple Regression Results

Dependent: Local budget costs Multiple R = ,99939606 F = 236,3291
R?= ,99879249 df = 7,2
No. of cases: 10 adjusted R?= ,99456621 p = ,004220
Standard error of estimate:284834,82995
Intercept: 30391210672, Std.Error: 316027E4 t(2) = 9,6167 p = ,0106

Year b*=-12, environmental factors, b*=1,14 population b*=11,6
sports facilities b*=-,96 total living area b*=2,50 education b*=2,23
healthcare b*=1,26

(significant b* are highlighted in red)

Regression Summary for Dependent Variable: local budget costs, executed, thousand rubles
R= ,99939606 R?= ,99879249 Adjusted R?= ,99456621
F(7,2)=236,33 p<,00422 Std.Error of estimate: 2848E2

Since the year of the study is one of the significant indicators in the model, all indicators were analyzed by year. To determine the stability of the city development, the following indicators were analyzed:

- Economic indicators: the shipped output of various industres, investment, revenue, trade turnover.

- Social indicators: health, education, morbidity, availability of doctors, the number of students, the number of pensioners.
- Infrastructure indicators: street lighting, highways, dilapidated and emergency housing, construction output, social, cultural and leisure facilities.
- Ecological indicators: amount of air pollutants, water intake, discharge of polluted waters, waste volume, parks, squares, protected areas.

Table 2

The significance of the regression coefficients

	b*	Std.Err. of b*	b	Std.Err. of b	t(2)	p-value
Intercept			3,039121E+10	3,160266E+09	9,61666	0,010641
Population	11,5777	1,133620	8,865486E+02	8,680555E+01	10,21304	0,009451
Year	-12,2128	1,267386	-1,558665E+07	1,617502E+06	-9,63624	0,010598
Ecology	1,1410	0,140606	4,136901E+04	5,098046E+03	8,11468	0,014849
Healthcare	1,2622	0,087824	4,619748E+00	3,214407E-01	14,37201	0,004806
Sports facilities	-0,9643	0,183156	-2,610057E+04	4,957672E+03	-5,26468	0,034237
Education	2,2323	0,198407	1,912945E+00	1,700255E-01	11,25093	0,007808
Total living area	2,5012	0,403579	4,312049E+03	6,957542E+02	6,19766	0,025060

In the calculations, all indicators are inverted into specific ones (per person, per km. of the territory). The obtained figures were compared with the average ones, taking into account their specific weight.

$$К = \sum_{1}^{21} \frac{P_{Kr}}{P_{Rus.}}$$

If the urban impact indicators (air pollution, waste generation, discharge of polluted waters, the number of diseases per 1,000 people, the area of dilapidated and emergency housing) exceeded the average figures for Russia, they were taken into account in the overall development index with a "minus". The sustainable positive dynamics of Krasnoyarsk city development was revealed (Fig. 1).

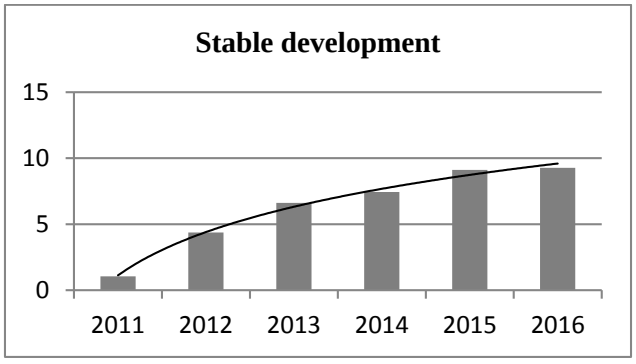

Figure 1. Dynamics of the index of development of Krasnoyarsk with logarithmic trend

For evaluating temporal dynamics of changes in factors related to different spheres, average figures were calculated for each of them and for all factors the values above the average were considered to be positive and those below to be negative, except for ecological factors which have negative effect on the environment and the population of the city(Fig.2).

The outcomes of the research characterize the city as a whole, but Krasnoyarsk is divided into seven administrative districts which differ in many aspects. The greatest problem of the city in recent decades is air pollution, which leads to an increase in days with adverse weather conditions. Temperature stratification, reduction of wind mixing due to high-rise buildings is a

common problem of urban areas. Research of employees of the Institute of Thermophysics of Russian Academy of Science, Delft University and Novosibirsk University proved that severe environmental conditions (accumulation of harmful impurities in the atmosphere of Krasnoyarsk) are due to the influence of the Krasnoyarsk hydroelectric power station (resulting in non-freezing river and a significant temperature difference). At the same time, the time interval of adverse weather conditions (so called "Black sky mode") takes from 50% to 67% of the total time (Hanjalić, Hrebtov, 2016,2017).

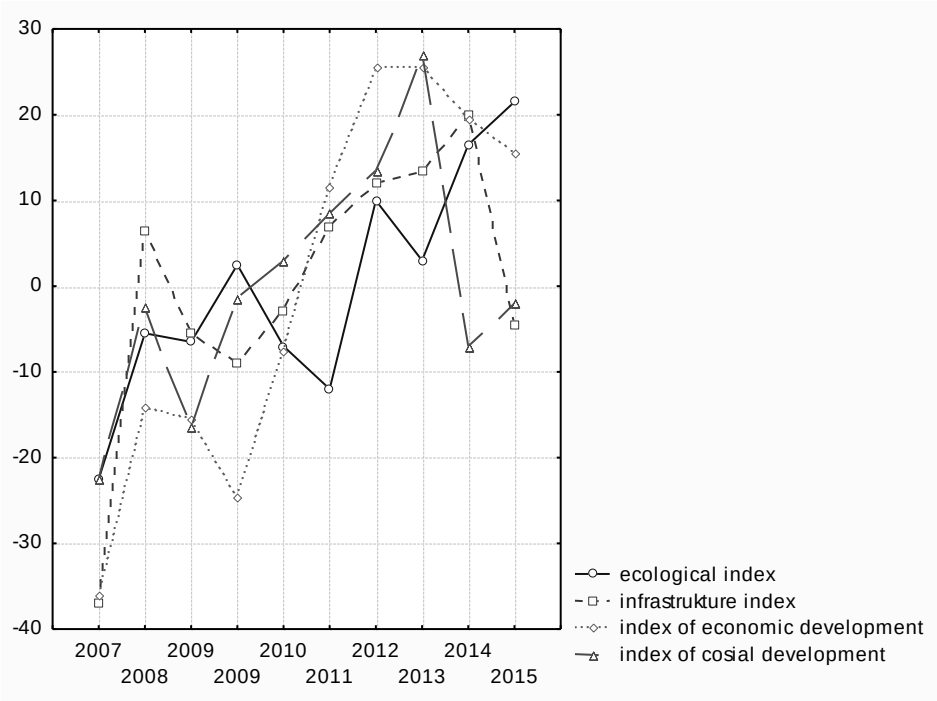

Figure 2. The dynamics of the indicators

The air pollutants in the atmosphere of the city consists of two almost comparable components: air pollution from stationary and mobile sources. Flow traffic at main highways of the city was analyzed during the week in the morning, afternoon and evening to calculate the volume of air pollution from mobile sources. The air pollution was calculated according to state standard GOST R 56162-2014 and visualized on the city map. It can be seen that Zentralniy and Zneleznodorozhniy districts of Krasnoyarsk are the most polluted areas. (Fig.3).

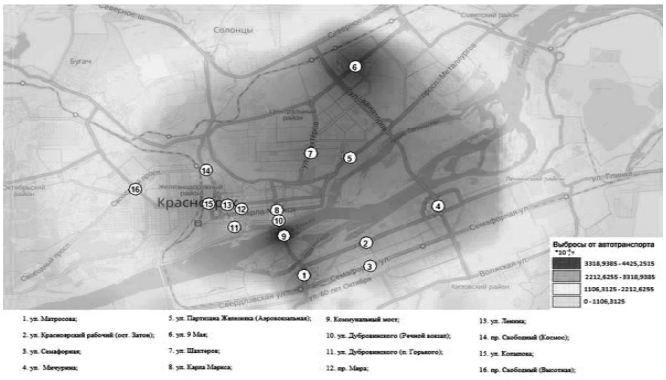

Figure 3. Air pollution from mobile sources

A cluster analysis was carried out to assess the development of the city in a long-term series of observations taking into account an urban zoning. Due to the fact that the indicators differ significantly, the data were normalized (Fig.4). Clustering by the "Euclidean distances" method

allowed to allocate three stable clusters for the whole observation period, the significance of the outcomes is visualized in the table.

Table 3

The significance of the cluster analysis outcomes

	F	signif.,p
Area, sq. km.	5,88529	0,046498
Population, thous.	70,33025	0,000765
Green area/total area	6,84311	0,017158
Industrial area/total area	5,43750	0,047324
Waste, t/person	70,33019	0,000765
Pollution, t / km2	70,33031	0,000765
Recreation zone/total area	70,33038	0,000765

In the first cluster there is the Sovietsky District, one of the largest, rapidly developing, with high economic potential. The second cluster includes 2 districts – Sverdlovsky and Oktyabrsky, as they have the largest ecological capacity in their development. In the third cluster there are Railway, Kirovsky, Leninsky and Central Districts, because they are similar on the economic and ecological indicators.

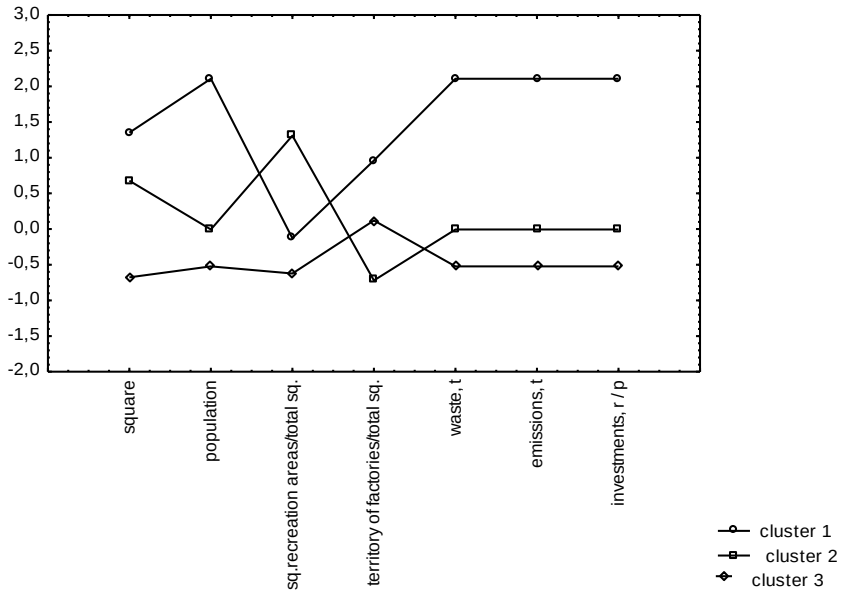

Figure 4. Splitting the districts into clusters

Analyzing the outcomes, all districts of the city can be compared by their suitability for comfortable living and further development.

The charts show that the Octyabrskiy and Sverdlovskiy districts are the most favorable for comfortable living. This is obvious due to major recreational areas located there: Natural Park "Roev Ruchey", nature reserve "Stolby" and Fun park "Bobroviy log" located in Sverdlovskiy district, and a birch forest area, Arboretum, Winter sport complexes "Sopka" and "Vetluzhanka" in Oktyabrskiy district. Unfreezing Yenisey river, high-rise buildings, district coal boilers, large industrial enterprises are considered as unfavorable conditions for all the parts of the city.

Lay of land is one of the main natural factors that determine the nature of landscape as a spatial factor. There is always a resource for improving ecological and hygienic factors of urban territories in its structure. The scheme of generalization of urban topography is primary while selecting appropriate structure of city landscape gardening, creating its "landscape-ecological frame" from point of view of hygienic and compositional-aesthetic terms. The lay of land determines the planning structure of ~~a~~

city, direction of its space, sanitary and hygienic condition of various urban areas, possibility of their self-cleaning. The Decision of the Krasnoyarsk city Council of deputies (The decision of the Krasnoyarsk city Council of deputies, 2016), provides the priority direction of city development to the North-West with the creation of a number of recreational and public zones. By 2033 it is planned to reduce industrial areas by 25% and increase the volume of housing by 25%, and to increase the green area by 80%. Free access to Yenisey on the right bank and on the left bank of the river should be provided. At the same time, it is planned to move industrial facilities from coastal areas and constructing leisure and sports complexes in their place.

Conclusion

Geographically, the administrative rating of urban areas showed their inhomogeneous development, which must be taken into account when carrying out modern architectural and planning activities aimed at the development of the city. Today city forests located mainly in Sverdlovskiy and Oktyabrskiy districts make 80% (app. 8139 hectares) of the green plantings of Krasnoyarsk. To improve the quality of urban areas it is necessary to allocate large areas for landscaping, to increase the number of city boulevards, squares and parks.

While carrying out architectural planning, especially high-rise construction, it is necessary to take into account the terrain of the city and the peculiarities of the air masses fluxes in the lower layers of the atmosphere, since the current volume of pollutants exceeds the natural potential of the environment and the level of ecological problem in the city is characterized as very high. The development of architectural planning should be based on the effective use of urban areas for both industries and housing, their functional zoning, a high level of comfort of living in urban areas. In connection with the increase of polluting atmospheric air by mobile sources it is necessary to revise traffic lines and improve the quality of roads, to consider a zone of intensive pollution when planning streets.

As town-planning decisions have high constructability and complexity, considering the offered model it is possible to carry out productive actions promoting environmental protection to improve an ecological component of living standards of citizens in the city of Krasnoyarsk.

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