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CLUSTER ANALYSIS OF SOCIAL AND ECONOMIC DEVELOPMENT OF CITIES

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Abstract

The social and economic development of cities is the main driver of progress. In the social sphere, the main indicators of the level of urban development are the state of education and health care, the availability of goods and services, indicators of demography and employment. Economic development depends on the growth rate of the economy, infrastructure, innovation potential, skill level of workers, productivity and wages. The state of the potential of the created and natural habitat of the population is of great importance, which affects the quality of life. Reducing waste production, reducing emissions, achieving energy efficiency are important features of modern politics, economics and municipal governance. Urban development indicators are calculated in the context of the main indicators and areas of municipal governance. Cluster analysis makes it possible to systematize urban districts by a set of social and economic indicators into homogeneous groups. The object of the cluster analysis was urban districts of the Volga Federal District of the Russian Federation. Clustering of urban districts was carried out according to indicators of social and economic development. For a more accurate clustering of urban districts, an agglomerative hierarchical algorithm was used. Homogeneous groups of cities were formed according to the most important indicators of labor productivity in employment. Based on the results of the cluster analysis, municipal solutions were proposed for the transition to a higher cluster.

1. Introduction

Urban development is based on citizen-centered approaches and municipal solutions to create added value and collective goods. The development of the urban economy is associated with an improvement in the business climate, the attractiveness of the city for startups, investors, businesses and new highly skilled workers. Also important is the innovative and sustainable growth of the municipal economy to increase competitiveness. Economic development is an important tool for actively seizing opportunities and creating conditions conducive to business and job growth. Social development of cities ensures high living standards for citizens. Facilitating livelihoods and optimizing the management of the living environment are challenges that need to be tackled together to maximize benefits for municipal government and citizens. The social dimension of urban development focuses on improving social and digital inclusion, health and care for the elderly, housing and safety. Infrastructure development of cities is aimed at rational planning of urban space, optimizing logistics flows, increasing the efficiency and quality of service in urban transport in order to expand the use and implementation of new mobile solutions, increase people's mobility through effective management and targeted investments in infrastructure. In the scientific literature, a system of integrated indicators of urban development is considered (Porfiryev & Bobylev, 2018), indicators of the sustainability of cities are ranked and weighted (Ameen & Mourshed, 2019), a typology of assessment indicators is determined (Lützkendorf & Balouktsi, 2017), methods for choosing indicators of urban development (Tran, 2016). Urban development indicators are closely related to policy and progress goals (Hansson et al., 2019), learning and adaptation (Pupphachai & Zuidema, 2017). Conceptual provisions for assessing urban development as the coordination of people and the environment are being developed (Ko & Chiu, 2020).

2. Problem Statement

The cities of the Russian Federation are not homogeneous in terms of social and economic growth rates. The systematization of cities with the allocation of their homogeneous groups makes it possible to rank cities according to the degree of their development and achievement of the goals of municipalities. The formulation of the problem of systematizing cities requires a cluster analysis. Cluster analysis of cities is carried out on a set of the most important social and economic indicators. The most important indicators should be the drivers of urban development. For the clustering of cities, the methods used should be determined. The selection of the most important social and economic indicators of labor productivity and fertility for clustering allows you to clarify and verify the results of the previous clustering.

3. Research Questions

The existing methodological provisions present numerous indicators of the development of individual urban spheres of life. These indicators, to varying degrees, affect the rate of their development. Determining important indicators of urban development is a research question. Among the most important, several indicators should be identified - drivers of social and economic development. City clustering is carried out using different methods. It is advisable to use methods of k-means and hierarchical

agglomerative clustering, which complement each other. Consideration should also be given to developing a summary indicator for ranking urban clusters. The graphical interpretation of cluster analysis matters.

4. Purpose of the Study

The activities of the municipal government include setting goals and developing strategies for the social and economic development of the city. This requires a preliminary analysis of numerous statistical indicators. The indicators are usually grouped according to the directions of urban development. The purpose of the article is to identify homogeneous groups of cities and their ranking according to a set of development indicators. This information is important for making management decisions. This goal is being realized on the basis of cluster analysis of cities in the federal district by a set of indicators. Cluster analysis can be performed by k-means and agglomerative hierarchical algorithms.

5. Research Methods

The research methodology is based on a comparative assessment of the development of cities in the Volga Federal District. Statistical methods were used in the selection of indicators of public municipal development. The selection of the four most important indicators has been made. Clustering of cities by a set of indicators was carried out using the k-means method in a computer program. A method for assessing the level of public municipal development of each cluster by the geometric mean is proposed. The conducted cluster analysis was supplemented with an agglomerative hierarchical algorithm. The analysis used indicators of labor productivity and fertility.

6. Findings

The cities of the federal district differ in a number of indicators of social municipal development. The following list of cities has been formed: Ufa (1), Yoshkar-Ola (2), Saransk (3), Kazan (4), Izhevsk (5), Cheboksary (6), Perm (7), Kirov (8), Nizhny Novgorod (9), Orenburg (10), Penza (11), Samara (12), Saratov (13), Ulyanovsk (14). The work used an expert method for selecting the most important social and economic indicators of the development of cities in the federal district. The degree of importance was established by the influence of the indicator on the dynamics of urban development. As a result, four indicators of social and economic development were selected. Indicators "produced goods, works and services", "average payroll number of employees" are calculated. The data are presented in Table 1.

Table 1. Social and economic indicators of cities

Cities	Goods, works and services produced, billion rubles	Average payroll number of employees, thousand people	Labor productivity, million rubles/person	Average monthly salary, thousand rubles	Total area of living quarters, m²/person	The number of births per 1000 people of the population, people
1	1327	31.33	4.24	42.3	26.0	12.8
2	84	66.6	1.26	31.1	28.1	11.7
3	123	93.4	1.32	28.2	26.1	9.9

4	693	338.4	2.05	41.0	27.8	15.2
5	300	182.0	1.65	35.0	23.2	12.4
6	152	126.6	1.20	30.5	25.7	12.6
7	954	276.9	3.45	41.3	25.9	12.5
8	146	136.3	1.07	32.7	26.7	11.8
9	894	413.6	2.16	42.5	27.3	11.6
10	292	165.6	1.76	36.5	27.2	11.9
11	181	131.9	1.37	31.1	31.6	9.6
12	626	354.1	1.77	39.3	30.9	11.7
13	363	230.5	1.57	32.5	31.8	10.3
14	303	166.1	1.82	32.6	28.6	10.9

Source: author.

The clustering of the number of cities (N) was performed by the k-means method in a computer program for 5 clusters, the number of which (n) was determined by the formula:

$$n = 1 + 1.44 \ln N = 1 + 1.44 \ln 14 = 4.8.$$

The clustering results of urban districts are presented in Table 2.

Table 2. Clustering of urban districts by the k-means method

Cities	Vector	Cluster number	Cluster centroid
1	4.24, 42.3, 26.0, 12.8	2	3.28, 42.0, 26.4, 12.3
2	1.26, 31.1, 28.1, 11.7	4	1.47, 31.1, 29.24, 10.48
3	1.32, 28.2, 26.1, 9.9	4	1.47, 31.1, 29.24, 10.48
4	2.05, 41.0, 27.8, 15.2	1	2.05. 41.0, 27.8, 15.2
5	1.65, 35.0, 23.2, 12.4	3	1.42, 33.68, 25.7, 12.17
6	1.2, 30.5, 25.7, 12.6	3	1.42, 33.68, 25.7, 12.17
7	3.45, 41.3, 25.9, 12.5	2	3.28, 42.0, 26.4, 12.3
8	1.07, 32.7, 26.7, 11.8	3	1.42, 33.68, 25.7, 12.17
9	2.16, 42.5, 27.3, 11.6	2	3.28, 42.0, 26.4, 12.3
10	1.76, 36.5, 27.2, 11.9	3	1.42, 33.68, 25.7, 12.17
11	1.37, 31.1, 31.6, 9.6	4	1.47, 31.1, 29.24, 10.48
12	1.77, 39.3, 30.9, 11.7	5	1.77, 39.3, 30.9, 11.7
13	1.57, 32.5, 31.8, 10.3	4	1.47, 31.1, 29.24, 10.48
14	1.82, 32.6, 28.6, 10.9	4	1.47, 31.1, 29.24, 10.48

Source: author.

The degree of public municipal development of each cluster was determined by the geometric mean of the normalized values (from 0 to 1) of the corresponding centroids. The calculation is carried out in Table 3.

Table 3. The degree of public municipal development of each cluster

Cluster numbers	Cluster centroid	Normalized values	Geometric mean
1	2.05. 41.0, 27.8, 15.2	0.63, 0.98, 0.9, 1.0	0.863
2	3.28, 42.0, 26.4, 12.3	1.0, 1.0, 0.85, 0.81	0.911
3	1.42, 33.68, 25.7, 12.17	0.43, 0.8, 0.83, 0.8	0.691
4	1.47, 31.1, 29.24, 10.48	0.45, 0.74, 0.95, 0.69	0.684
5	1.77, 39.3, 30.9, 11.7	0.54, 0.94, 1.0, 0.77	0.791

Source: author.

Systematization of clusters in descending order of the degree of public municipal development of cities in the federal district:

- cluster 2 includes the most developed cities in terms of the aggregate indicators of Ufa, Nizhny Novgorod and Perm;

- 1 cluster includes the city of Kazan, which is slightly inferior in terms of development, due to lower labor productivity;

- cluster 5 forms the city of Samara, which is inferior in terms of labor productivity and fertility;

- 3 cluster consists of the cities of Izhevsk, Cheboksary, Kirov, Orenburg;

- cluster 4 is formed by the least socially and economically developed cities of Yoshkar-Ola, Saransk, Penza, Ulyanovsk, Saratov.

The work carried out clustering of the cities of the Volga Federal District according to the most important indicators of labor productivity and fertility. The agglomerative hierarchical algorithm and the principle of "nearest neighbor" were used. The initial data for clustering cities in terms of labor productivity and fertility are presented in Table 4.

Table 4. Initial data for city clustering

Cities	Labor productivity, million rubles / person	The number of births per 1000 people of the population, people
1	4.24	12.8
2	1.26	11.7
3	1.32	9.9
4	2.05	15.2
5	1.65	12.4
6	1.20	12.6
7	3.45	12.5
8	1.07	11.8
9	2.16	11.6
10	1.76	11.9
11	1.37	9.6
12	1.77	11.7
13	1.57	10.3
14	1.82	10.9

Source: author.

The clustering results are shown in the distance matrix in Table 5.

Table 5. Clustering of cities by the hierarchical algorithm

Cluster number	City numbers	1	2, 8, 9, 10, 12, 5, 6	3, 11,1 3, 14	4	7
1	1	0	2.401	3.077	3.249	0.845
2	2, 8, 9, 10, 12, 5, 6	2.401	0	0.778	2.735	1.573
3	3, 11, 13, 14	3.077	0.778	0	4.306	2.284
4	4	3.249	2.735	4.306	0	3.041
5	7	0.845	1.573	2.284	3.041	0

Source: author.

The results of the clustering of cities according to two important indicators:

- 1 cluster includes the most developed city of Ufa;

- clusters 2 and 3 consist of 11 cities, which differ insignificantly in terms of the considered indicators in the distance matrix and are characterized by low indicators;

- 4 cluster forms the city of Kazan, which is inferior to the cities of Ufa and Perm;

- cluster 5 consists of the city of Perm, whose indicators are second only to those of the city of Ufa.

Graphical interpretation of the agglomerative hierarchical cluster analysis of the cities of the Volga Federal District is shown in Figure 1.
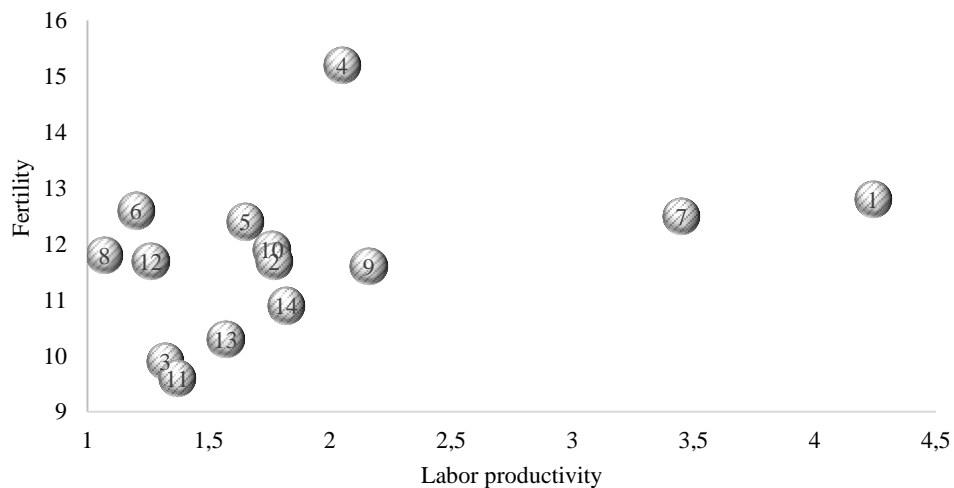

Figure 1. Interpretation of cluster analysis results

7.   Conclusion

The social and economic development of cities is the concern of the municipal government. At the heart of municipal management, statistical indicators of the vital activity of cities are used for decision-making. The aim of the study is to identify homogeneous groups of cities and their ranking according to a set of development indicators. For this, the k-means method was used in the cluster analysis of public

municipal development of cities in the federal district. This analysis was refined by an agglomerative hierarchical algorithm for labor productivity and fertility indicators. In ranking clusters according to the degree of social municipal development of cities, the geometric mean method was used. The results of cluster analysis, regardless of the method of its implementation, can be used in planning public municipal development of cities.

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