MATHEMATICAL MODELING OF URBANIZATION PROCESSES IN CENTRAL ASIAN COUNTRIES

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Abstract: *This article examines the issues of modeling and forecasting urbanization processes in the countries of Central Asia using mathematical and statistical methods. During the research, the dynamics of changes in the level of urbanization in Uzbekistan, Kazakhstan, Kyrgyzstan, Tajikistan, and Turkmenistan were analyzed on the basis of statistical data. Regression models and exponential functions were used to determine the future development of urbanization processes. In addition, forecast values of urbanization indicators up to 2030 were calculated and the main factors influencing the socio-economic development of the region were evaluated. The obtained results are important for identifying urbanization trends in the Central Asian countries and for regional planning processes.*

Keywords: *urbanization, Central Asia, mathematical modeling, regression analysis, level of urbanization, urban population, forecasting, exponential model, migration, demographic processes, statistical analysis.*

Introduction. Nowadays, analyzing and forecasting urbanization processes using mathematical and statistical methods has become increasingly important in planning regional development. The growth of the urban population, the intensification of migration flows, and the development of industrial and service sectors are accelerating urbanization processes. Therefore, studying urbanization indicators based on statistical data and forecasting their future changes through mathematical models is considered one of the pressing scientific issues. In recent

years, urbanization processes in the Central Asian countries have been developing at different rates. In particular, the high level of urbanization in Kazakhstan, the rapid growth of the urban population in Uzbekistan, and the intensification of internal migration processes in Kyrgyzstan and Tajikistan indicate that urbanization trends in the region are complex and influenced by multiple factors. Urbanization processes have a significant impact on the distribution of labor resources, infrastructure development, housing issues, and environmental conditions. Regression analysis, exponential models, and statistical forecasting methods are widely used in the study of urbanization levels. These methods make it possible to identify trends in urbanization indicators and forecast their future development prospects. The results of mathematical modeling are of great practical importance for regional planning, the development of urban infrastructure, and the formulation of demographic policies. In this study, the urbanization indicators of the Central Asian countries for the period 2015–2025 were analyzed based on statistical data. During the research, mathematical models were constructed using the exponential regression model and the least squares method, and forecast values up to 2030 were calculated. The obtained results make it possible to assess the development trends of urbanization processes in the region and to use them in the development of regional growth strategies.

Table1

Dynamics of Urbanization Levels in Central Asian Countries during 2015–2025 (%)

Years	Uzbekistan	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan
2015	50.6	57.2	35.7	26.5	50.8
2016	50.8	57.4	35.9	26.8	51.0
2017	51.0	57.6	36.1	27.0	51.3
2018	51.3	57.9	36.4	27.3	51.6
2019	51.6	58.2	36.7	27.6	51.9
2020	51.9	58.5	37.0	27.9	52.2

2021	52.2	58.8	37.3	28.2	52.5
2022	52.5	59.1	37.6	28.5	52.8
2023	52.8	59.4	37.9	28.8	53.1
2024	53.1	59.7	38.2	29.1	53.4
2025	53.5	60.0	38.5	29.4	53.8

In the mathematical analysis of urbanization levels in the Central Asian countries, the statistical representation of the urbanization indicator was used. The urbanization level is an indicator that expresses the ratio of the urban population to the total population in percentage terms and is determined by the following formula:

$$U=\frac{S}{A}*100\%$$

Where:

U is the urbanization level;

S is the urban population;

A is the total population

Using this formula, the dynamics of changes in urbanization processes in the Central Asian countries were analyzed.

An exponential regression model was used to mathematically model the dynamics of urbanization processes in the Central Asian countries. During the study, changes in the urbanization level over time were considered as a functional relationship. To describe urbanization processes, the following regression model was selected:

$$y=a*e^{k*x}$$

Where:

(y) — urbanization level;

(x) — time variable;

(a) — initial parameter;

(k) — growth coefficient of the urbanization level.

The least squares method was applied to determine the model parameters. Using this regression model, future trends in the urbanization levels of the Central

Asian countries were analyzed, and forecast values for the period up to 2030 were calculated.

Table2

Coefficients of the Urbanization Level Regression Model in Central Asian Countries

Country	a	k
Uzbekistan	50.54	0.0056
Kazakhstan	57.16	0.0048
Kyrgyzstan	35.63	0.0075
Tajikistan	26.42	0.0101
Turkmenistan	50.72	0.0058

As can be seen from the table data, the growth rates of urbanization processes differ among the Central Asian countries. The highest urbanization growth coefficient is observed in Tajikistan. This indicates that urbanization processes are accelerating in this country. Although Kazakhstan has a relatively high level of urbanization, its growth rate was found to be comparatively stable.

As a result of the calculations, the regression equations were obtained in the following form:

Uzbekistan:$y(x)=50.54*e^{0.0056x}$

Kazakhstan: $y(x)=57.16*e^{0.0048x}$

Kyrgyzstan: $y(x)=35.63*e^{0.0075x}$

Tajikistan: $y(x)=26.42*e^{0.0101x}$

Turkmenistan: $y(x)=50.72*e^{0.0058x}$

These regression equations make it possible to forecast future changes in urbanization levels in the Central Asian countries.

Table3

Forecasted Urbanization Levels in Central Asian Countries, 2026–2030 (%).

Country	2026	2027	2028	2029	2030
Uzbekistan	53.8	54.1	54.4	54.7	55.0

Kazakhstan	60.3	60.6	60.9	61.2	61.5
Kyrgyzstan	38.8	39.1	39.4	39.7	40.0
Tajikistan	29.7	30.1	30.4	30.8	31.2
Turkmenistan	54.1	54.4	54.7	55.0	55.3

As can be seen from the data presented in Table 3, a steady increase in the level of urbanization is expected in the Central Asian countries up to 2030. In particular, the high urbanization growth rates in Tajikistan and Kyrgyzstan can be explained by internal migration and the increasing urban population. In Kazakhstan, the highest urbanization levels are projected to be maintained throughout the forecast period.

The forecast results are of significant importance for managing urbanization processes in the region, developing urban infrastructure, and formulating regional planning strategies.

As can be seen from the graph, a steady upward trend in urbanization levels is observed across the Central Asian countries. While Kazakhstan continues to maintain a high level of urbanization, an acceleration in urbanization growth rates can be observed in Tajikistan and Kyrgyzstan.

Conclusion. In this study, urbanization processes in the Central Asian countries were analyzed using mathematical and statistical methods. Based on statistical data, the trends in changes in urbanization levels were identified, and forecast values up to 2030 were calculated using exponential regression models. According to the analysis results, a steady increase in urbanization levels is observed in the Central Asian countries. In particular, the acceleration of urbanization growth rates in Tajikistan and Kyrgyzstan was found to be associated with internal migration and the increasing urban population. In Kazakhstan, a consistently high level of urbanization was observed. The obtained mathematical models are of significant practical importance for assessing future development trends of urbanization processes, planning urban infrastructure, and developing regional development strategies.

REFERENCES

1. М.Гофуров, М.Холмуродов, К.Хусанов. “Иқтисодий математик усуллар ва моделлар”. – Тошкент, 2001. – 82–83 б.
2. Исмоилов А.А., Рихсимбоев О.Қ. Иқтисодий таҳлилнинг математик усуллари ва башоратлаш. – Т.: ТДИУ, 2007. – 335 б.
3. Шодиев Т.Ш. ва бошқалар. Иқтисодий-математик усуллар ва моделлар. – Тошкент, 2000. – 96 б. 4.
4. Kazakhstan Bureau of National Statistics official reports, 2015–2025.
5. National Statistical Committee of the Kyrgyz Republic data, 2015–2025.
6. Agency on Statistics under the President of the Republic of Tajikistan reports, 2015–2025.
7. 7.Statistical Yearbook of Turkmenistan, 2015–2025.
8. United Nations Population Division reports.
9. https://stat.uz/
10. https://stat.gov.kz/
11. http://www.stat.kg/
12. https://stat.tj/
13. https://stat.gov.tm/