MATHEMATICAL MODELING AND FORECASTING OF POPULATION AND LABOR RESOURCES IN THE REGION (CASE STUDY OF CHUST DISTRICT)

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Abstract: *This article examines the demographic growth and industrial development of Chust district in Namangan region using mathematical modeling and forecasting methods. Statistical data on permanent population and industrial production for 2015–2025 were analyzed using exponential regression models and the least squares method. The study evaluates the dynamics of population growth and industrial production and determines their growth coefficients. Based on the constructed mathematical models, forecasts for the period 2026–2031 were developed. The results indicate a steady increase in both population size and industrial production volume in the district over the forecast period. The research highlights the importance of mathematical and statistical methods in analyzing socio-economic processes and forecasting regional development indicators. The obtained results may be useful for regional economic planning, labor resource management, and socio-economic policy development.*

Keywords: *Chust district, mathematical modeling, population growth, industrial production, forecasting, regression analysis, least squares method, socio-economic development.*

The study of patterns inherent in mass random events (processes) using mathematical-statistical methods requires the collection of statistical data, their

classification into groups, the development of methods for analysis, and drawing appropriate conclusions based on them. Solving many problems put forward by science and technology through economic-statistical methods serves as an important factor in constructing optimal production models for multi-sector economic systems. Modern economic theory, regardless of the level at which it is studied, is difficult to imagine without mathematical models and their methods. In planning the development of national economic processes, determining initial benchmarks with the help of scientifically grounded forecasts is of great importance. As a result of forecasting, the possible future state of the national economy is determined, and the outcomes of decisions made today are approximately evaluated. Forecasting defines the possible future development paths and outcomes of events and processes, and provides an assessment of the indicators characterizing these processes over a certain long-term perspective. Probability theory plays an important role in accounting for the uncertainty of population growth. Using such models, the future population size and its changes can be estimated probabilistically. In this article, we consider issues of mathematical modeling using the example of Chust district in Namangan region. Chust district is an administrative-territorial unit located in Namangan region, established on September 29, 1926. Geographically, Chust district is situated in the northeastern part of Namangan region, approximately 40 km from the regional center. The district borders Kyrgyzstan to the north (54.2 km), Pop district to the west (71.7 km), Kosonsoy district to the northeast (12.0 km), To‘raqo‘rg‘on district to the east (26.0 km), and Mingbuloq district to the southeast (6.6 km). The total area of Chust district is 937.0 square kilometers, and the total border length is 170.5 km. The administrative center is the city of Chust. The population mainly consists of Uzbeks, as well as Tajiks, Russians, Tatars, and representatives of other nationalities. As of January 1, 2023, the population of the district is 279.7 thousand people, which accounts for 9.3% of the total population of Namangan region (3,066.1 thousand people). Of these, 195.4 thousand people live in urban areas and 90.4 thousand in rural areas. The population density is 304.7 people per square kilometer. Chust

district includes 1 city, 11 urban-type settlements, 24 settlements, 72 citizens' assemblies, 47.3 thousand households, and 70.7 thousand families. There are 70 enterprises and organizations operating in the district, including 13 joint ventures, 17 large organizations, and 1,697 small enterprises and firms. Among the population, 98,407 are minors, and 26,645 are aged 60 and above. The changes in population and industrial production in Chust district of Namangan region, and how they have developed at different stages of socio-economic progress, are among the key factors determining the present and future development of our country. Therefore, studying population growth and industrial production together with mathematical modeling and forecasting has significant scientific and practical importance. Through statistical analysis of population growth, it is possible to study indicators such as age, gender, migration, birth rate, and mortality. Using mathematical modeling, it is possible to model and forecast future demographic conditions based on these indicators. For this purpose, various statistical methods and probabilistic models are used. Taking into account the growth rates. Taking into account the growth rates of population and industrial production in Chust district, mathematical modeling and forecasting are among the important issues. Today, in demographic statistics, there are several mathematical models used to determine current and future forecasts of population and industrial production. These include parabolic models, exponential (logarithmic-type) models, logistic models, and the least squares method, which are widely used in modeling population growth and industrial production. The permanent population of Chust city and industrial production data for the years 2015–2025 are presented in the following table (Table 1)

1-table

№	Years	Chust district population(thousand people)	Industrial production (billion UZS)
1	2015	242.0	105.4
2	2016	246.7	128.9

3	2017	251.0	186.9
4	2018	255.0	244.9
5	2019	259.7	334.4
6	2020	264.8	584.0
7	2021	269.3	801.1
8	2022	274.5	1483.6
9	2023	279.7	1920.9
10	2024	285.6	2256.4
11	2025	291.4	2656.9

Namangan region, Chust district population growth is analyzed using mathematical modeling based on graphical-statistical and least squares methods. In this case, population growth is considered as a function of time. The mathematical model for population growth can be expressed as follows:

$$y=a*e^{k(x-2015)}$$

Here, a and k are unknown parameters. In this formula, parameter k is called the natural growth coefficient of the population.

Replacing the parameters with their estimated values, the regression equation can be written as:

$$y(x)=a*e^{k(x-2015)} \quad (1)$$

The coefficients in this expression are determined using the least squares method.

In this case, the equation takes the following form:

$$y(x)=241.7*e^{0.01839(x-2015)}$$

Here, k=0.01839 represents the natural population growth coefficient. Using this formula, it is possible to forecast the population size for the required future years. As can be seen from the table, the population growth rate in Chust district has been increasing. In this regard, creating new jobs for the rural population of Chust district, increasing employment in agriculture and farming sectors, is one of the most important and pressing issues of the regional economy.

Without reallocating labor resources to other sectors, particularly the service sector, it becomes possible to forecast an increase in cultivated land per capita in agriculture, ensure direct economic interest from earned income, and improve labor productivity as well as production efficiency. In modeling the dynamics of industrial production in Chust district, the least squares method was also applied, and the following regression equation was obtained:

$$y(x)=94.72*e^{0.355(x-2015)}$$

Here, k=0.355 represents the growth coefficient of industrial production. Using this formula, it is possible to forecast the required number of labor resources for future years. The significance of the regression coefficients was confirmed at a 0.95 probability level using Fisher's statistical test. Based on the above mathematical models, it is possible to forecast the growth of the permanent population and industrial production processes in Chust district for the period 2026–2031.

2-table

Forecasts of Population Size and Industrial Production Volume in Chust District[2]

Years	2026	2027	2028	2029	2030	2031
Forecast indicators						
Population	295.89	301.38	306.98	312.67	318.48	324.39
Industrial production volume	4703.59	6706.29	9567.42	13645.12	19460.76	27755.06

As can be seen from the data in Table 2, during the forecast period, both the permanent population and the production volume in one of the industrial sectors are expected to increase.

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