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ANALYSIS OF DEMOGRAPHIC SYSTEMS AND PROCESSES BASED ON THEIR MODELING

Scientific specialty 2.3.1. System analysis, information management and processing, statistics

DISSERTATION
for the degree
of Candidate of Technical Sciences
Translation from Russian

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Saint-Petersburg
2024

CONTENTS

Introduction

Demography is a field of knowledge devoted to the study of the population. Specialists in this field, known as demographers, seek to understand how the number of people is changing by analyzing key processes: birth rate, marriage, migration and aging, including death. These processes affect the size of the population, as well as how people organize their lives on the planet, form nations and societies, and develop their culture [1].

Demographers collect information mainly through State censuses, as well as birth and death registers. However, the accuracy of this data may vary depending on the quality of official reports. In addition to this, demographers also use indirect data to study small groups of people. These samples are analyzed using statistical models, which allows us to draw conclusions about the entire population.

Research in the field of demography is conducted at universities, research institutes, as well as in statistical agencies and international organizations.

Among them, we can mention demographic institutes that are part of the CICRED network (International Committee for the Coordination of Demographic Research), as well as scientists working within the framework of the International Association of Population Sciences [1,2].

The Agency of Statistics under the President of the Republic of Uzbekistan and its research institute, which is aimed at supporting family research.

Important initiatives include the creation of a scientific and educational laboratory "Family Demography" and the development of a national portal network "Demography" in Uzbekistan [2,88].

Modern Uzbekistan has a significant demographic potential. As of December 2024, the permanent population of the country was 37 million 535 thousand 938 people, of which 18 million 858 thousand 056 are men and 18 million 595 thousand 305 are women. In terms of demographic potential, Uzbekistan occupies one of the leading places among the CIS countries [1,87].

Forecasting of the population size and demographic structure was performed in three scenarios of future changes: "medium", "high" and "low". The "medium" scenario reflects the most likely path of development of the demographic situation.

The "high" and " low "scenarios indicate the boundaries of the possible future course of events, taking into account the instability of the outcomes described in the" medium " scenario. These boundaries are set as the limits that demographics are most likely not to exceed during the analyzed time period or at the current time [2, 90].

In the republic, the birth rate is increasingly controlled at the family level. The State implements a policy aimed at strengthening family ties, improving the health of mothers and children, focusing on the concept of "reasonable birth rate", which brings tangible results.

Relevance of the research topic.

Demographic processes include several important aspects that are important for both science and practical policy. Such phenomena as the birth rate, mortality, marriage and population aging strongly affect the socio-economic development of countries and regions. In the context of globalization and changing lifestyles, understanding these processes becomes particularly relevant for predicting future trends and developing effective management strategies [2, 55].

Modern modeling methods allow us to analyze complex demographic systems in more detail, taking into account various factors and their interaction. The use of mathematical and statistical models opens up opportunities for identifying patterns that may be overlooked by traditional methods of analysis [1, 60].

Changes in demographics are closely linked to issues of sustainable development, social policy, and resource planning. It is important for governments and organizations to be aware of how demographic changes can affect areas such as health, education, pension systems, and the labor market [3,56].

Research in the field of modeling demographic processes contributes to the development of the theoretical foundations of this science and helps to improve existing models, adapting them to new challenges and realities [3,57].

The analysis and study of demographic systems using modeling methods is a relevant and significant area that deepens the understanding of demographic changes and their consequences for society [2,5,61,88].

Goals and objectives of the dissertation work.

The main goal and objective of this dissertation is a comprehensive study of demographic systems and processes using mathematical modeling. To achieve this goal, the following is proposed:

Analysis of demographic processes, creation and testing of approaches to ensure stable growth in our country. To do this, it is necessary to comprehensively analyze demographic changes, develop national content, and develop software and an applied model of demographic processes [1,3,88].

An important goal is to formulate proposals for optimizing the demographic strategy aimed at sustainable development and improving the quality of life, based on the results of modeling, to develop a platform for forecasting and methodological approaches that can be used by state institutions and research centers for long-term analysis of the demographic situation [2, 58].

To successfully complete these tasks, it is necessary to deepen theoretical knowledge about demographic processes and develop practical tools for their research and management. The **tasks set include**:

1. Creation of a national demographic portal for free access to information.
2. Comparative analysis of international experience in creating such portals.
3. Development of a demographic passport for regions (districts and cities) of Uzbekistan [55].
4. Create an interactive demographic map for different regions of the country.
5. Development of a digital librarythat includes research results and multimedia materials, as well as scientific and statistical infographics [88].
6. Conducting scientific and applied research to form the theoretical basis of the electronic demography (E-demography) system in Uzbekistan [88].
7. CoBuilding a system for informing about the population and living standards for a wide audience.

8. Development of a single platform for monitoring data updates and publishing open information, which contributes to updating data.

Scientific novelty

Today, the demographic situation in Uzbekistan shows relative stability and a number of positive trends that are of long-term importance. The country is experiencing an increase in the population with moderate reproduction, which is associated with the impact of a system of transformations in economic and social relations, as well as changes in the reproductive behavior of citizens [57-59].

In the process of independent development, the birth rate significantly decreased, which also contributed to an improvement in the age structure of the population and a decrease in mortality, especially in socially important indicators. Population development in different regions of the republic generally corresponds to the general direction of the country, but there are certain territorial differences, including different population sizes in different regions [54-56].

This study presents a comprehensive analysis of demographic systems and processes using modern modeling methods. Scientific novelty consists in the following aspects:

1. In this study, classical demographic models were integrated with the latest approaches, such as agent-based modeling and system simulations. This makes it possible to more accurately account for complex interactions between different demographic factors [60].
2. A detailed analysis of factors influencing population changes, such as marriage, birth rate and mortality, is carried out. Modeling these processes helps to identify possible scenarios for changing the demographic situation in different regions [2,5].
3. Methods of big data analysis are used to process and interpret demographic information. This opens up new horizons for understanding trends and patterns in demographic processes [3].

4. Forecast scenarios have been developed that take into account a variety of social, economic, and environmental factors. This makes it possible to more accurately predict changes in the structure of the population and its needs.
5. The results of this study can be useful for developing effective strategies for population management and social planning, which is especially important in the context of globalization and rapid changes in the demographic situation [1,3,87].

Thus, this study makes a significant contribution to the development of the theory and practice of demographic analysis, offering new tools for understanding and predicting demographic processes.

Theoretical significance of the work

Theoretical approaches to the analysis of demographic processes are of serious scientific importance and can be effectively used to study the demographic problems faced by Uzbek society in our time.

The theoretical significance of this work is confirmed by participation in a number of research projects:

- Grant RusMir_2022: My Innovative Russia, contract number: 2606Gr / II-461-22, Russian World Foundation: 399,348 rubles, 1/06/22 → 30/12/22
- Grant RusMir_2022: My Innovative Russia, contract number: 2640Gr / II-155-23 Russian World Foundation: 399,002 rub., 3/07/23 → 30/11/23/22

Practical significance of the work. As a result of the conducted research, we can highlight the practical value of the work. It consists in the possibility of applying the results obtained to create regional regulations that regulate the social, technological and organizational aspects of managing demographic processes.

In addition, the materials of the dissertation can be useful in developing targeted programs at the regional level related to demographic policy.

The conclusions and main provisions of the study are designed to help improve the management of demographic processes in the relevant region.

Testing the work. The main results of the dissertation work were presented and discussed at the following conferences:

- III International Scientific and Practical Conference dedicated to the 90th anniversary of Bryansk State University of Engineering and Technology, "Digital region: experience, competencies, projects", November 26-27, 2020, Bryansk, Russia, pp. 593-596, Demographic prism of Social development, 3 p. [54]
- IV All-Russian Scientific and practical conference with international participation "Modern trends in the development of fundamental and applied sciences", January 25, 2021, Bryansk, Russia, pp. 54-67, Demographic situation in the country, its impact on the economy, 7 p. [55]
- Problems of automated learning technologies, Samara University International Scientific and Technical conference "Advanced Information Technologies" PIT-2021, May 24-27, 2021 Samara, Russia, Demographic prism of social development, pp. 3-5. [60]
- Problems of automated learning technologies, Samara University International Scientific and Technical conference "Advanced Information Technologies" PIT-2021, May 24-27, 2021 Samara, Russia, Demographic situation in the country, its impact on the economy, pp. 5-11. [61]
- International Journal of Humanities and Natural Sciences, articles in journal No. 12-4 2023г, ISSN 2500-1000, Russia, Model of active interaction between internet providers in the context of a multi-agent environment, pp. 124-129, DOI: 10.24412 / 2500-1000-2023-12-4-124-128. [58]
- International Journal "Scientific Aspect", No. 12-2023 volume 32, issue 12/23-19-056, ISSN 2226-5694, Russia, Dynamic model of competitive interaction of firms with taxation in the market, pp. 4072-4080. [59]
- Journal "Perspektivy Nauki", Issue #2 (173) 2024, ISSN 2077-6810, Russia, Birth rate and population growth from the matrix population model, pp. 29-32. [56]
- Journal "Perspektivy Nauki", Issue #3 (174) 2024, ISSN 2077-6810, Russia, Reproductive value from the model matrix, pp. 18-21. [57]
- Computer programs and Databases in the Federal State Budgetary Institution FIPS (Rospatent) "Software package for analyzing demographic data based on the state electronic register", No. RU2024666023 dated 09.07.2024 [4, P2]

Personal contribution. All the achievements presented in the dissertation work were obtained by the author independently.

Publications. The main results of the study are reflected in 8 publications. Of these, 2 articles were published in journals recommended by the Higher Attestation Commission, and 6-in conference proceedings. There is also a certificate of state registration of computer software and an ACT on the implementation of scientific and practical results of scientific research.

Brief description of the dissertation structure

The dissertation includes an introduction, three chapters, and a conclusion. The total volume of the work is 148 pages, including 32 illustrations and 22 tables. The list of references includes 95 sources.

The dissertation is divided into three chapters, each of which examines different aspects of demography in Uzbekistan. The first chapter, entitled "Methodology of demographic research and sources of data on the population of the Republic of Uzbekistan", analyzes the key methods and approaches used to study demographic processes.

The second chapter, entitled "Analysis of the prospects for demographic development of the Republic of Uzbekistan", examines important aspects and trends affecting the demographic situation. It focuses on the dynamics of birth rate, mortality, marriage and migration, as well as analyzes changes in the age structure of the population.

The third chapter "Development of a model for studying demographic processes in the Republic of Uzbekistan". This chapter focuses on developing and justifying models that will help you study and predict demographic changes in your country. It focuses on key demographic indicators, such as the birth rate, mortality rate, marriage rate and age structure of the population, as well as their impact on the socio-economic development of Uzbekistan.

In addition, the limitations of the model and possible directions for future research are considered. It is emphasized that the created model can become the basis for a deeper understanding of demographic processes and their impact on the sustainable development of the Republic of Uzbekistan.

In conclusion, the results of the study are summarized and the main conclusions are formulated.

Main scientific results

1. As part of this research, a demographic passport was developed for various regions, including districts and cities, of the Republic of Uzbekistan. The methodology focuses on improving the efficiency of demographic processes and covers such important aspects as birth rate, marriage, mortality rate and other factors that affect the development of society in demographic terms. As a result of the study, an algorithm and approach for analyzing demographic processes were developed [57,58,88].
2. PDeveloped software for implementing the created applied model of demographic processes. The reliability of the obtained scientific results and conclusions was confirmed by testing algorithms and programs, as well as their practical use in the laboratory "Family Demography" [4,56,88,91].
3. A "Software package for analyzing demographic data based on the state electronic register" was created at the current software and hardware complex in the Family Demography laboratory. This complex makes it possible to conduct research in Uzbekistan and emphasizes the importance of the topic under consideration [4,57,88,91].

The reliability of the results obtained was confirmed through their presentation at scientific conferences.

Provisions to be defended

This study makes an important contribution to the analysis of demographic processes in the Republic of Uzbekistan, thanks to several key achievements:

1. Creating a Demographic passport for regions: A new methodology has been developed for creating a Demographic passport covering districts and cities of Uzbekistan. This passport includes key indicators such as the birth rate, mortality

rates, marriage rates, and other significant factors affecting demographic development [4,56,88,91].

2. Increase the effectiveness of demographic process analysis: Algorithms and techniques have been developed for in-depth analysis of the current demographic situation. These approaches make it possible to predict changes in the demographic structure, identify the needs of society and develop state measures for the sustainable development of the nation [4,57,91].

3. Software implementation of demographic process models: A practical model of demographic processes was developed, which was implemented in the form of software. The software package for analyzing demographic data was created and tested in the Family Demography laboratory, which confirms its practical applicability and effectiveness [4,56,88].

4. Testing and practical implementation: The reliability of scientific conclusions and results is confirmed by testing the developed algorithms and software. These algorithms and methods have been successfully tested and implemented in real practice [4,88].

5. Implementation at the state level: The software package for analyzing demographic data was created on the basis of the state electronic register. This highlights the importance of demographic data for socio-economic planning and management in Uzbekistan [4,91].

Chapter 1. Methodology of demographic research and sources of data on the population of the Republic of Uzbekistan

Demographic statistics is one of the areas of socio-economic statistics that collects, processes, analyzes and presents data describing the size, composition, location and movement of the population of countries, territories or individual population groups using statistical methods.

Section IV of the Decree of the President of the Republic of Uzbekistan No. PF-87 dated March 7, 2022 "On measures to further accelerate the work onsystematic support for the family and women" - Strengthening the family institution, 4.3 Direction-Stimulating demographic development and improving the level of family welfare, item 91-Conducting scientific research on strengthening the family institution, in order to: to attract young people to it, create a scientific and educational laboratory " Family Demography "and in Uzbekistan, the task is to crea tea national portal network “Demography".

At the same time, the implementation of the tasks stipulated by the resolution of the Cabinet of Ministers of the Republic of Uzbekistan No. 888 dated 21.10.2019 "On additional measures for the development of national content in the global information network of the Internet" and the policy, in order to increase and strengthen the role of demography in the socio-economic aspect, the need to create a network of "National Demographic Portal" and conduct research in Uzbekistan indicates relevance of the topic of this project.

Demographic information about the population should meet the following criteria: be specific, detailed, complete, reliable, and systematic.

The main sources of population data in demographics are:

- population censuses;
- current accounting of demographic events.
- population lists and registers.
- sample and special demographic studies [1,3,8,16,60,60].

A population census is a scientifically organized process of collecting and processing demographic and socio-economic data on the entire population of a given country or territory at a certain point in time according to a single methodology [2,3,8,16,55,55]. The population census provides socio-demographic and economic characteristics of the population that are necessary for forecasting and managing the development of society.

The main principles of conducting a population census include the following:

- generality – information is collected about all residents of the territory where the census is conducted.
- instantaneous – information about the population refers to the established critical moment of the census (the critical moment of the 2024 census is 00 hours 00 minutes on December 01, while those who died after this time are rewritten as alive, and those born after the critical moment are not registered by census takers).
- self-determination – information about the interviewee is entered in the census form only from his words, the census taker does not require documents confirming the status of the person being rewritten (diploma of education, passport, marriage certificate, etc.);
- name list – information is collected personally about each citizen and recorded in the census form.
- confidentiality – keeping secret information about the citizens being re-registered, and the results of the census are provided in a generalized form.
- consistency – the presence of a single census program, common indicators and a single processing method; in addition, continuity with the program of the previous census is necessary to be able to compare / compare the results and identify dynamics, trends, and patterns.
- centralization –the organization and management of the population census are carried out by a single center; in Uzbekistan, these functions are assigned to the Population Census Department and the Demographic Statistics Agency under the President of the Republic of Uzbekistan [2,54,54].

The population census program is a list of questions addressed to the population. Census programs are compiled according to a certain methodology, which includes the sum of rules and requirements similar to those used in conducting a specific sociological study [5,16,61,16,61].

The main document of the population census program is the census form. The census form is a form for recording the answers to the questions asked [5,16]. When conducting a census, two main methods can be used: the survey method and the self-calculation method. [16, 85]

A. Quetelet first introduced the concept of population categories that are takenыinto account during census. The following population categories are distinguished [16,85,85]:

- permanent population – a set of people living in a given locality, regardless of where they are located during the census. This category includes people who consider a locality to be their main place of residence. [3,4,5]. A part of the permanent population that is absent at the time of the census is considered temporarily absent; [25,67,67].
- available population –a group of people who are at he moment of conducting the census in a given locality. A non-permanent part of the per capita population is considered to be temporarily resident;
- assigned (legal) population – a set of people who are permanently / temporarily registered in a given locality, regardless of their physical location [5,16,85].

There is a relationship between the numbers of the current population and the permanent population:

$$\mathrm{MON} = \mathrm{NN} + \mathrm{VO} - \mathrm{VP} \quad (1.1)$$

where

MON – permanent population.

NN – the current population.

VO – temporarily absent.

VP – temporary residents [5,16,85].

In accordance with the Law of the Republic of Uzbekistan " On Population Census" Adopted by the Legislative Chamber on November 21, 2019 and approved by the Senate on February 28, 2020, the following population censuses are subject to [1,2,5,92]:

- citizens of the Republic of Uzbekistan, foreign citizens and stateless persons residing on the territory of the Republic of Uzbekistan as of the date of the population census [1,2,5,92];
- citizens of the Republic of Uzbekistan permanently residing in the Republic of Uzbekistan, but located outside the Republic of Uzbekistan as of the date of the population census [1,2,5,92].

1.1 Demographic indicators and population of the Republic of Uzbekistan

The population size in the country is a significant demographic parameter for the Republic of Uzbekistan. As of December 1, 2024, the total number of inhabitants is 37 million 515 thousand 152 people.

In accordance with the legislative acts of the Republic of Uzbekistan, the working age population includes men from 16 to 60 years and women from 16 to 55 years [2,23] (children and adolescents under 16 years belong to the population younger than the working age, women over 55 years and men over 60 years are included in the population older than the working age).[1]

Uzbekistan has two regions with more than 4 million inhabitants.

Population density is determined by the ratio of the total permanent population in a given territory to the area of a given locality.

As of December 1декабрь, 2024, the population density in the country was 83.2 people per square kilometer. This is an increase of 1.7 people compared to the same period in 2023 (81.5 people per 1 sq. km as of December 1, 2023).

[1] Explanation: The methodology provided by the United Nations is used to calculate the working-age population.

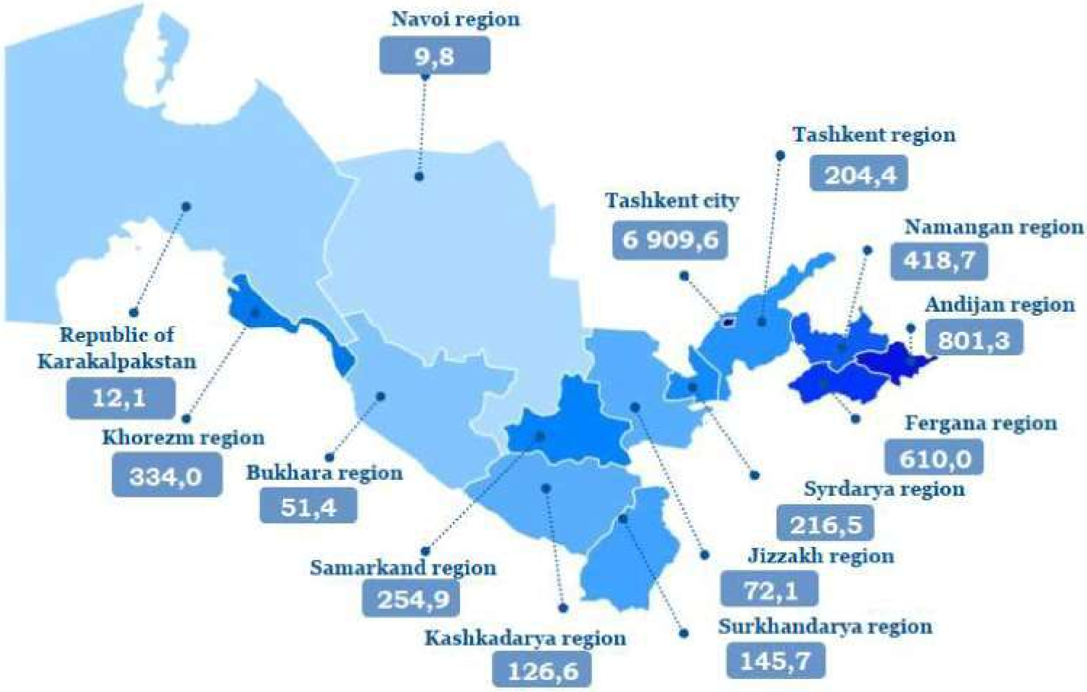

Figure 1.1. Population density in the Republic of Uzbekistan as of December 1, 2024, population per 1 sq. km, people

By region, the highest population density was 6,909. 6 in Tashkent, 801.3 in Andijan region, and 610.0 in Ferghana region. The lowest rates were recorded in the Navoi region - 9.8 and the Republic of Karakalpakstan - 12.1 people [4-5].

The share of permanent population is highest in Samarkand region - 11.4 %, Ferghana region-11.0 %, Kashkadarya region-9.7 %, Andijan region - 9.2%, Namangan region - 8.3 %.

The share of permanent population is the lowest in Syrdarya region-2.5 %, Navoi region-2.9 %, Jizzakh region-4.1 %, Khorezm region-5.4 %, the Republic of Karakalpakstan-5.4 %.

The largest permanent population in the regions is 4,275. 3 thousand people - in the Samarkand region, 4,123. 6 thousand people - in the Ferghana region, 3,618. 3 thousand people - in the Kashkadarya region, the smallest population is recorded in the Syrdarya region – 926.7 thousand people, Navoi region - 1,090. 0 thousand people and Jizzakh region - 1,530. 3 thousand. a person.

The absolute population size characterizes the people living in a given territory at a given timeни [2,3,5,92]. Information on the absolute population size is obtained насfrom population censuses or by calculation, using data on the number of births and deaths, as well as arrival sand departures. The difference between those born and those who died is called natural population growth, and the difference between those born and those who left is called migration growth (balance of migration) [2,3,5,92]. Natural growth and migration balance are components of population change over a period that allow us to derive the demographic balance equation:

$$P_t = P_0 + (B - M) + (M_t - M_0) \qquad (1.2)$$

where P_t denotes the population at time t; P_0 is the initial population size; B is the total number of births during the interval; M is deaths during the same period; M_t is immigration, i.e. the arrival of people; M_0 is emigration, or the departure of the population [5,65,85].

In the field of demographic research, based on data on population size, the following metrics are used [3,65,85]:

- Demographic growth:

$$EP = V\text{-}M \qquad (1.3)$$

- Migration growth:

$$MP = M_i - M_0 \; or \; MP = OP - EP \qquad (1.4)$$

where OP is the cumulative population growth.

- Natural growth rate:

$$\mathrm{K_{ep}} = \frac{\mathrm{EP}}{\tilde{\mathrm{R}}\mathrm{T}} * 1000‰\% \qquad (1.5)$$

where $\mathrm{K_{en}}$ means the coefficient of natural population growth; T is the duration of the time interval; P is the average population size during a given period [5,65,85].

- Migration growth rate:

$$K_{MP} = \frac{MP}{\tilde{R}T} * 1000‰\,\% \qquad (1.6)$$

In this context, K_{MP} refers to the coefficient that reflects migration growth.

- Total growth rate:

$$K_{OP} = \frac{OP}{\tilde{R}T} * 1000‰ \quad (1.7)$$

where K_{OP} is an indicator of the overall increase.

- Growth rate for the period:

$$K_{growth} = \frac{P_t}{P_0} * 100‰ \quad (1.8)$$

- Growth rate for the period:

$$K_{increment} = \frac{P_t - P_0}{P_0} * 100‰ \quad (1.9)$$

- Average population:

$$\tilde{P} = \frac{P_i - P_0}{2} \quad (1.10)$$

Usually$t$, the value equivalent to one year is taken for the period t.

- Population density is defined as the number of people occupying a square kilometer of land:(^{km2})

$$MON = \frac{P}{Q} \quad (1.11)$$

The population density is 50 people per square kilometer [5,65,85].

1.2 Demographic structure by age and gender in the Republic of Uzbekistan.

The number of permanent residents as of December 1 was 37,536,020 thousand people, including 18,858. 2,2 thousand men, 18,595. 4 thousand women, 19,047.1595, thousand urban populations, and 18,308. 3 thousand rural populations.

The average age of a country's citizens is an approximate general description of the age composition of the population. Calculated as the arithmetic mean of the age of all residents in the general population. The median age is the age of the population divided into two equal groups, the first half of which is young and the second half is elderly [4,5,38,65,85].

The age structure of the population is the distribution of a country's citizens by age. For its construction, annual and five-year intervals are often used.

An age group is a group of people united by a common age and other characteristics [4,5,34,65,85]. Demographic groups include infants (under 5 years old), children (5-13 years old), young people (14-30 years old), middle-aged people (31-59 years old), and older people (60 years and older).

Age is equal to the period from birth to the current moment, measured as accurately as possible. For example, if you know the exact time of a person's birth, you can say that at some point their age is 31 years, 4 months, 13 days, 7 hours, 30 minutes, and 28 seconds [4,5,23,65,85].

In the Republic of Uzbekistan, as of December 1, 2024, when analyzing the composition of the permanent population by gender and age groups (under 65 years of age in the five - year age range, and at the age of 65 years and older – in aggregate), among men, children under five years of age accounted for the highest indicator-2 262.7 thousand people. Among men, the share of 60-64-year-olds was the smallest – 657.0 thousand people. Among women, the highest rate was registered for girls aged less than five years – 2,108. 1 thousand people, the lowest number of women was registered in the age group of 60-64-year-olds – 736.0 thousand people [4,5,23,65,85].

Life expectancy at birth is the average number of years that people should live at birth (age 0). At the same time, it is assumed that the mortality rate of the population of a certain age in the year for which this indicator is calculated will continue.

Population strukutra – distribution of the population of a country or region accordingto certain demographic characteristics. More oftenthan not, demographers use the following grounds foridentifying population groups:

- descriptive characteristics: gender, age, race,nationality;
- social characteristics: marital status,level ofeducation, country of origin, citizenship, native language;
- economic characteristics: employment, source of livelihood, profession;
- migrationcharacteristics: place of birth,length of residence in a given locality.

The main demographicstructures of the populationare gender and age.

Gender structure of the population – the distribution of the population by gender. It is influenced by the following factors [4,5,15,52,65,85]:

- the ratio of the number of boys and girls bornalive;
- mortality of men and women at different ages;
- gender differences in migration flows [4,5,15,52,65,85];

Demographics distinguish between primary, secondary, and tertiary sex ratios.

The primary sex ratio is the ratio of the number of malegametes (embryos) to the number of female gametes at fertilization.

The secondsex ratio is the numberof girls and boys bornalive (approximately 105-106 boys are born per 100girls).

The tertiary sex ratio is the proportion of men and women at reproductive age [8,24,52,65,85,92].

Age structure of the population – distribution of the population by age. For its construction чаще всего используются одного, one-year and five-year intervals are most often used. An age group is a group of people united by their commonage and othersigns [38,52,65,85,92].

Demographics include such groups as toddlers (0-2 years old), pre-school children(3-6 years old), peopleof working age (menaged 16-59 years and womenaged 16-54 years), women of reproductive age (15-49 years), conscripts (men aged 18-27 years) and others [3,52,65,85,92].

As a rule, the age structure of the population is considered simultaneously with the sexual structure.

In this case, it is called the age-sex (gender-age) structure of the population, it shows the distribution of the population of each gender by age.

The distribution of the population byage and gender canbe represented as an age-sex pyramid Figure (see Figure 1.2).

The main types of pyramids shown in Figure 1.2 are highlighted.

Analysis of age-sex pyramids allows you to:

- describe the current demographic situation.
- predict the demographic situation in the future.
- determine the impact of birth rate and mortality processes on the age composition of the population;

- compare the population structures of different territories.

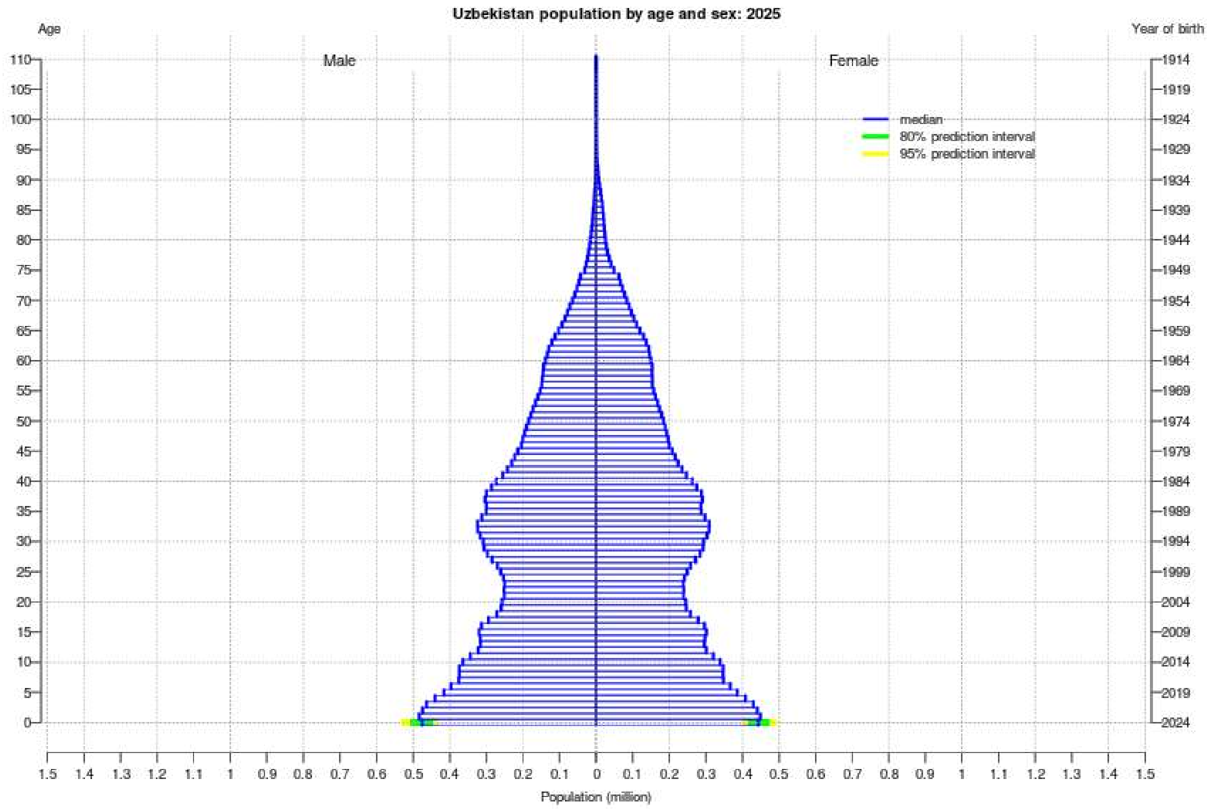

Figure 1.2. Demographic structure by age and gender of the population of Uzbekistan, December 2024 [3]

About 80% of the modern population of Uzbekistan is Uzbek, more than 10% are representatives of other peoples of Central Asia (4.5% are Tajiks, 2.5% are Kazakhs, 2% are Karakalpaks, 1% are Kyrgyz, as well as Turkmens and others.). Russian and other Slavic peoples remain one of the largest ethnic minorities (10%).

Uzbek families tend to have many children, especially in rural areas: the average size of an Uzbek family is 5-6 people. The family in Uzbekistan, in accordance with the centuries-old traditions and mentality of the Uzbek people, has been and remains one of the most important life priorities of modern society.

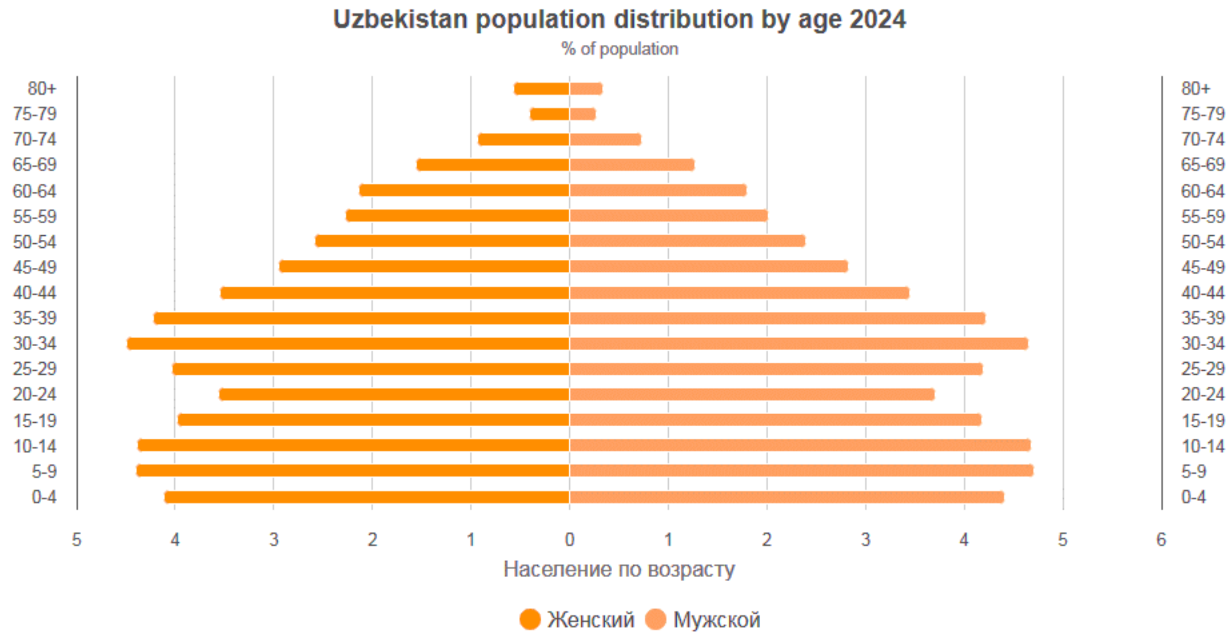

Figure 1.2. Classification of age-gender pyramids as of December 2024 [2]

When analyzing the size and composition of the population in demography , methodsof demographic analysis are used – the realgenerationmethod and the conditional generation method [5,52,65,85,92].

To understand the essence of these methods, you must first define a number of concepts. Generation – a set of individuals born in approximately the same period. Cohort – a set of individuals who simultaneously experienced a demographic event. Peers are people of approximatelyequal age. Bothnicknames are simultaneously living people.

The real generation method (longitudinal analysis) is a method of studying demographicprocesses, in which they are analyzedin cohorts [5,25,52,65,85,92]. This method is used when it is necessary to calculate the dynamics ofany demographicprocess over the lifeof a single generation. This methodalso makes it possible to determine the calendar of demographic events –the distribution of events over the life periods of a cohort. Thedisadvantages of this method include the following.

First, to apply it, you need to have information about births, deaths, marriages,divorces, etc. over a long period of time.

Secondly, itcan be used to obtain complete data only after the cohort hasleft the demographicstate under study.

For example, to obtaininformation on fertility, it is necessary that women in the cohort under consideration reach the age of 45-50 years [8,52,65,85,92].

The method of conditional generation (cross-sectional analysis) revealsthe features of demographicprocesses through conditional generation, attributing to it the characteristics of real generations. That is, in this method, population groups of different ages are conventionally considered as belonging to the same generation.

Then data on the population structure and demographic events of realgenerations can be "dissected" fromtop to bottom. As a result, age-specific characteristics of a demographic event (forexample, mortality) of a hypothetical (conditional) generation are obtained, i.e. we are talking about the fact that the intensity of demographic processes in a given population of people at eachage is the same as atpresent.

To apply the conditional generation method, you need data for 1-2 years. One of the disadvantages of the method is the distortion of the state of demographicprocesses with sharpchanges in their nature [8,52,65,85,92].

1.3 Demographic potential and fertility maintenancein the Republic of Uzbekistan

Indemographic research, the term "birth rate" refers to the number of births over a given time period. Fertility or fecundity is defined as the biological potential of an individual or couple to produce offspring, denoting the ability to conceive and bear a child. Fecundity represents the unfulfilled aspect of offspring generation, while fertility concretizes this aspect through the actual number of births, representing the realized potential in the context of population changes.

During the period from January to December 2024, 693.9 thousand newborns were registered, among which 360.0 thousand were boys, and the number of newborn girls reached 333.9 thousand. At the same time, 343.4 thousand births were recorded in urbanized areas, while in the agricultural zone this figure was 350.5 thousand [18,26,46,].

Live birth is characterized by the appearance of a baby that shows signs of life, such as active breathing, a working heart, a pulsing anatomical umbilical cord remnant, or spontaneous muscle contractions, regardless of whether the placenta is separated or not. Criteria for determining whether infants can survive include a maternal gestation period of at least 22 weeks, a statistical body height of 25 cm or more, and a minimum body weight of 500 grams or more.

In the course of studying demographic statistics for the period from January to December 2024, the following distribution of the birth rate was revealed: single - child births accounted for 97.7 %, two - child births-2.2 %, and multiple births (three or more children) - 0.1 % [61,74,88].

According to the provisions of the Family Code of Uzbekistan, the place of birth of a child is determined based on the permanent address of the mother or father, which affects the calculation of the total number of residents of this area.

The reproductive capacity is activated in girls aged 12-13 years and in boys aged 14-15 years. This physiological process deepens much earlier than the level of social maturity is reached, which requires postponing reproduction until such important events as the end of school, the formation of a professional career, the achievement of financial independence, etc. In general, during the period of reproductive life, a woman is able to give birth to 10-12 children.

Fertility is measured by the period of reproductive activity, which is the time when a woman can conceive and give birth to a child. In demographic studies, the reproductive age is set from 15 to 49 years for the analysis of fertility indicators.

Concepts that oppose fertility include sterility and infertility. Sterility refers to the inability to ovulate or conceive. This condition can be either irreversible, for example, in late age periods due to menopausal changes, or reversible, including during pregnancy and after childbirth, or as a result of the use of contraceptives. During the period of fertility, the causes of sterility can be gynecological pathologies, or performed operations on the reproductive organs. Infertility is characterized as the inability for adults of both sexes to produce offspring. A couple is considered to have experienced infertility if fertilization does not occur during three years of life in an active sexual relationship without using contraception.

- no conception occurs.
- the outcome of pregnancy is stillbirth.
- gestation ends with spontaneous termination.

Currently, in countries with a high level of economic development, the problem of infertility affects 10-15% of married couples [5, 91].

1.3.1 Reproductive trends in Uzbekistan

Reproductive behavior is a system of actions and relationships related to the birth or refusal to give birth to children of any order in or out of marriage.

Reproductive behavior as a system has the following components. The need for a certain number of children. The need for children is individual, hence there may be contradictions between spouses who need a different number of children. Throughout life, the individual strives to fulfill the need for children, while improving living conditions is not a factor that encourages the birth of more children. In demography, it is customary to distinguish three types of reproductive behavior: large children – the need for 5 or more children; medium children – the need for 3-4 children; small children – the need for 1-2 children [5,8,17,52,65,85,92].

If we consider the age of fathers of infants born in January-December 2024 in Uzbekistan, then 10.8 % of persons were under the age of 25, 82.4 % were aged 25-39 years and 6.8 % were aged 40 years and older. At the same time, 39.5% of newborns were under 25 years of age, 59.3% were 25-39 years of age, and 1.2% of infants were 40 years of age or older.

The highest birth rate was recorded in Samarkand region - 12.0 %, Ferghana region-11.2 %, Kashkadarya region-10.8 %, Andijan region - 9.3% and Surkhandarya region - 9.1 %.

The birth rate is relatively low in Syrdarya region-2.4 %, Navoi region-2.8 %, Jizzakh region-4.2 %, the Republic of Karakalpakstan-4.5 % and Khorezm region-4.8 %.

The highest birth rate by region is 29.0 ppm in Surkhandarya region, 27.8 ppm in Kashkadarya region, 26.7 ppm in Namangan region, the lowest indicator in the Republic of Karakalpakstan - 20.6 ppm, Bukhara region-22.1 ppm, Khorezm region-22.3 ppm [5,52,65,74,85,92].

The need for children is the result of the assimilation of reproductive norms.

Reproductive norms – principles and patterns of behavior associated with the birth of a certain number of children and adopted in different social groups. Reproductive norms of having many children are now being replaced by norms of having few children.

A reproductive attitude is a behavior regulator, which means that an individual is ready for a certain result of reproductive behavior. The reproductive system consists of three components:

- cognitive (cognitive);
- affective (emotional) behavior.
- behavioral (incentive) behavior.

In demography, as a rule, indicators of the cognitive component are studied, namely:

- desired number of children – the number of children that an individual would prefer to have in their family [5,8,52,65,85,92];
- expected number of children – the number of children that an individual plan to have in his family, taking into account a specific life situation and personal preferences.
- ideal number of children – an individual's idea of the ideal number of children in a family without taking into account a specific life situation and personal preferences [5,8,52,65,85,92].

Reproductive motivation reveals the qualitative side of the need for children and encourages the individual to achieve goals through the birth of a certain number of children. There are three groups of motives. Economic motives are related to improving wealth, economic status, benefits, and so on. Social motives are associated with the strengthening of social status, authority and prestige, as well as with the continuity of the family. Psychological motives can be divided into three subgroups.

The first subgroup includes motives in which parents act as subjects: the need to take care of the child, the desire to direct its development, and so on. The second subgroup consists of motives in which parents become objects: the need for filial / filial love, the desire to fill life with meaning, etc. The third subgroup combines all other psychological motives: the desire to avoid loneliness, preserve and strengthen marriage, etc.

The features of reproductive motivation include the following.

First, it is individual and represents a hierarchy of motives.

Second, reproductive motivation changes over the course of life.

Modeling of reproductive behavior is related to the reproductive situation, which consists of the characteristics of reproductive practices (the presence of pregnancies, abortions, etc.), family lifestyle, and the general situation in the country (region, territory).

1.4 Birth rate analysis in the demographic process: Demographic trends in Uzbekistan

To measure the birth rate of a population, a system of indicators is used in demography.

When studying the dynamics of the population's birth rate, the general birth rate coefficient is most often used, which is calculated using the formula as the ratio of the absolute number of births to the average population for a year and is measured inppm (%) [5,52,65,85,9252,65,85,92].

$$n = \frac{N}{\tilde{P}T} \cdot 1000‰ \qquad (1.12)$$

where N is the number of births for the period T; $\tilde{P}$ is the average population; and T is the length of the period (in years).

If the total birth rate is less than 16%, the birth rate is considered low, from 16 to 24% – average, and from 24 to 40% – high.

The value of the total fertility rate depends on the age and sex structure of the population and shows an approximate idea of the birth rate. A more accurate picture дает специальный is provided by the special fertility rate, which is the ratio of the number of births to the number of women of reproductive age [8,52,65,85,92]:

$$F = \frac{N}{WT} \cdot 1000‰ \quad (1.13)$$

where N is the number of births for the period $T;$ W is the number of women of reproductive age (15-49 years); T is the length of the period (in years) [8,52,65,85,9252,65,85,92].

In addition to the above coefficients, demographics calculate the marriage and extra-marital birth rates The marriage birth rate is the ratio of the number of married births to the number of married women of reproductive age:

$$F_m = \frac{N_m}{W_m T} \cdot 1000‰ \quad (1.14)$$

where N_m is the number of married births for the period T; $W_m$is the number of married women (15-49 years); T is the length of the period (in years).

The out-of-wedlock birth rate is the ratio of the number of births out of wedlock to the number of unmarried women of reproductive age:

$$F_n = \frac{N_n}{W_n T} \cdot 1000‰ \quad (1.15)$$

where $N_{Nn\ is\ the\ number}$ of births out of wedlock for the period T; W_nWn is the number of unmarried women (16-49 years); T is the length of the period (in years). [8,52,65,85,9252,65,85,92].

Along with the birth rates mentioned above, в демографии исчисляется the total birth rate is calculated in demography, which shows how many children one woman gives birth to on average during the reproductive period. In2024 г. в Узбекистане, the total birth rate in Uzbekistan was 2.1%.

According to forecasts for 2024, this figure will reach 2.1% in Uzbekistan [5,52,65,85,9252,65,85,92].

1.5 Main results and conclusions of the first Chapter

The methodology of demographic research in the Republic of Uzbekistan is characterized by a comprehensive and multi-pronged approach. This means that this area combines both quantitative and qualitative methods of analysis. One of the key aspects is the use of an extensive database of statistical data, which is formed on the basis of various sources. These sources include opinion polls, as well as analysis of administrative and registration documents, which allows you to get a more complete picture of the population.

The main sources of data on the demographic situation in the country include population censuses conducted every ten years. These censuses are crucial events, as they provide up-to-date information on the size, composition, and distribution of the population. In addition, current statistical observations carried out by the Statistics Agency under the President of the Republic of Uzbekistan play an important role in monitoring demographic trends. These observations are made regularly and help you track changes in real time.

Special attention is paid to migration processes, as well as aspects such as marriage, birth rate and mortality. These factors contribute to a better understanding of population dynamics and structure. For example, the analysis of migration flows reveals trends in internal and external migration, which has a significant impact on the economic and social situation in the country. The study of birth and death rates helps to assess the level of public health and quality of life, which is important for planning social programs.

At the same time, it is important to note that the methodology of demographic research in Uzbekistan actively applies international standards and methods. This ensures comparability of data at both the regional and global levels. The use of international standards can not only improve the quality of research, but also provide access to comparative analysis with other countries, which can be especially useful for developing public policy.

Thus, the methodology of demographic research in Uzbekistan is multi-level and multifunctional. It allows us to adequately reflect the current demographic situation in the country and use the data obtained to develop an effective state policy in the field of social and economic development. This, in turn, contributes to more targeted resource management and improving the quality of life of the population.

Chapter 2. Analysis of prospects of demographic development of the Republic of Uzbekistan

The second most important demographic process after birth is mortality.

In demographic science, mortality is considered as a process of generational extinction, one of the two main sub processes of population reproduction. How a mass process consists of many individual deaths occurring at different ages, and in its totality determines the order of extinction of a real or genetic generation.

Mortality was the first object of demographic science. Scientists of J. R. R. Tolkien Graunt, E. Halley, F. Bacon, D. Bernoulli, M. V. Lomonosov, Bunyakovsky, Ptukha, A. Ya. Boyarsky [42,23,20,18] and others investigated the causes and probabilities of mortality. The first demographic tables were mortality tables.

If we talk about the death of a person, then it represents an irreversible cessation of vital activity of the body.

The ratio of the birth rate and death rate determines the nature of natural population growth. To measure the mortality rate, there is a whole set of indicators that allow you to measure total mortality, identify its age-related differences, assess mortality from various causes, and finally determine the average life expectancy at the current mortality rate.

2.1 Demographic aspects of population ageing in Uzbekistan

Mortality is the process of generation extinction, which consists of many individual deaths that occur at different ages.

Deaths registered in the Republic of Uzbekistan January-December 2024 the total number of deaths was 131.7 thousand people, including 72.3 thousand men and 59.4 thousand women. In urban settlements, the same values were 74.5 thousand people, in rural areas-57.2 thousand [33,52,57,65,85,92].

Causes of death — diseases, pathological conditions, or injuries that led to or contributed to death, as well as the circumstances of an accident or act of violence that caused a fatal injury.

Among the registered deaths in January-December 2024, 57.2 % were diseases of the circulatory system, 9.5 % - neoplasms, 6.5 % - respiratory diseases, 5.8 % - accidents, poisoning and injuries, 4.0 % - diseases of the digestive system, 1.2 % - infectious and parasitic diseases, 15.8 % - other diseases [22,52,57,65,85,92].

The highest proportion of deaths was recorded in Samarkand - 10.9 %, Ferghana-10.4% regions, Tashkent city-9.6 %, Tashkent - 9.4 % and Andijan - 9.3% regions.

The proportion of deaths is relatively small in Syrdarya - 2.5 %, Navoi - 2.8 %, Jizzakh - 3.6 %, Khorezm - 5.2% and Bukhara-5.3% regions [17.52,57,65,85,92].

By region, the highest mortality rate was recorded in the city of Tashkent - 5.5 ppm, in the Tashkent region-5.4 ppm, and the lowest indicator was 4.2 ppm in the Jizzakh region.

The totality of deaths determines the order of extinction of a real or hypothetical generation. Statistical description of the order of extinction is provided by mortality tables.

Mortality tables – a numerical model of mortality, which is a system of interrelated, age-ordered series of numbers describing the process of extinction of a certain theoretical generation, with a fixed initial number, called the root of the table. These are historically the first (they began to be compiled from the end of the XVII century) and one of the most widespread demographic statistical tables [10,52,57,65,85,92].

Along with indicators of the order of extinction, demographics use indicators of the mortality rate – age and total mortality rates.

The most commonly used indicator is the total mortality rate (m), calculated as the ratio of the total number of deaths over a certain period (M) to the average population (S), usually expressed in % [10,52,57,65,85,92]. The dynamics of this coefficient over a number of years allows us to judge the change in the overall mortality rate.

Table 2.1 Fromthe statistical report on population mortality[2]

Age, years	Number to those who lived f people who lived up t	Probability of living up to the next age	Probability of death during the year	Number of people who live up to the age of x years	Upcoming number of people years of life of life	Average life expectancy Average life expectancy
x	lx	px	qx	Lx	Tx	ex
0						
1-4						
5-9						
...						

When people talk about "high" or "low" mortality, they mean exactly these indicators. The overall mortality rate depends on the age structure of the population and is therefore only suitable for approximate comparison of the mortality rates of populations or a single population over different time periods. But for each specific population at the moment, this indicator is an important characteristic, which generalizes the actual demographic processes occurring in the population and affecting the growth rate of its population [10,52,57,65,85,92].

Table 2.2 Total fatality rate analysis[3]

Coefficient value	Level Characteristic
Greater Than 20	Very High
16-20	High
13-15	Above Average
11-12	Medium
9-10	Below Average
7-8	Low
To 7	Very Low

[2] The mortality table provides a statistical summary of the extinction process presented by John Graunt.
[3] Table of the analysis of the total mortality rate, presented by John Graunt

The process of generation extinction depends on a large number of biological and social factors of mortality (natural and climatic, genetic, economic, cultural, etc.) [15,52,57,65,85,92]. From the point of view of demographic analysis of mortality, it is most important to divide them into two groups:

- endogenous-a conditionally distinguished group of causes of death caused by diseases associated primarily with internal processes in the human body itself (diseases of the circulatory system, malignant neoplasms, etc.).
- esogenic-agroup of causes of death associated with environmental exposure (accidents, injuries, poisoning, infectious and parasitic diseases, etc.).

The process of mortality, as a rule, has its own characteristics in men and women. In the past, women often had significantly higher mortality rates and lower life expectancy than men. This was caused by high maternal mortality (mortality of women at the end of pregnancy, during childbirth and in the postpartum period), less care for girls born, and other factors.

Socio-economic development has changed the position of women in society, sharply reduced the dependence of women's lives on the action of exogenous factors, which ultimately led to a change in the ratio of male-female mortality [15,52,57,65,85,92].

There are very significant differences in mortality among different social groups of society. Numerous studies show that the rate of generational extinction increases markedly as people's income, social status, education level, and other social status indicators decline.

The cause of death is determined by the relevant authority or doctor. At the same time, there is only one leading or initial cause of death [10,52,57,65,85,92]. It is established in accordance with the International Classification of Diseases, Injuries and Causes of Death (ICD).

Table 2.3 Categories of causes of death according to the International Classification of Diseases, 10th revision[4]

Class I	Certain infectious and parasitic diseases (A00-B99)
Class II	Neoplasms (C00-D48)
Class III	Diseases of the blood, hematopoietic organs and individual disorders involving the immune mechanism (D50-D89)
Class IV	Endocrine system diseases, eating disorders and metabolic disorders (E00-E90)
Class V	Mental and Behavioral disorders (F00-F99)
Class VI	Diseases of the nervous system (G00-G99)
Class VII	Diseases of the eye and its appendage (H00-H59)
Class VIII	Ear and mastoid diseases (H60-H95)
Class IX	Diseases of the circulatory system (I00-I99)
Class X	Respiratory diseases (J00-J99)
Class XI	Diseases of the digestive system (K00-K93)
Class XII	Diseases of the skin and subcutaneous tissue (L00-L99)
Class XIII	Musculoskeletal and connective tissue diseases (M00-M99)
Class XIV	Diseases of the genitourinary system (N00-N99)
Class XV	Pregnancy, childbirth and the postpartum period (O00-O99)
Class XVI	Selected perinatal conditions (P00-P96)
Class XVII	Some infectious and parasitic diseases (A00-B99)
Class XVIII	Neoplasms (C00-D48)
Class XIX	Diseases of the blood, hematopoietic organs and individual disorders involving the immune mechanism (D50-D89)
Class XX	Endocrine system diseases, eating disorders and metabolic disorders (E00-E90)
Class XXI	Mental and Behavioral disorders (F00-F99)
Class XXII	Diseases of the nervous system (G00-G99)

General patterns of changes in the structure of mortality due to global causes are called "epidemiological transition". The essence of the concept of epidemiological transition is a radical transition from the predominance of exogenous causes of mortality to endogenous and quasi-endogenous causes.

[4] Note: A short version based on the International Statistical Classification of Diseases and Health-Related Problems, 10th revision, adopted by the 43rd World Health Assembly (ICD-10).

Life expectancy: conditions and prospects Each person's life span is determined by a combination of biological and social processes, their individual innate vitality, and the conditions in which they live.

Life expectancy – the interval between birth and death, equal to the age of death. Life expectancy, averaged for the generation born, is an indicator of demographic statistics, which is a generalized characteristic of mortality. Equally common in demography is the concept of life expectancy-the interval between a certain age and the age of death; and a number of average characteristics of life expectancy, which are calculated within the framework of mortality tables. The most common indicator of this group is the average life expectancy [15,52,57,65,85,92] (life expectancy) - it is equal to the arithmetic mean of the distribution of those who live to a certain age of 10 years (by the duration of the remaining life) in accordance with the order of extinction recorded in the mortality tables.

Depopulation – a decrease in the absolute population of a country, or its narrowed reproduction, in which the number of subsequent generations is less than the previous ones. In reality, depopulation occurs if the total mortality rate exceeds the total birth rate, i.e. there is a population decline.

Self-preservation behavior is a system of actions and relationships aimed at maintaining health during the full life cycle, at extending the life span within this cycle.

Self-preservation behavior has a structure that can be represented as a sequence of mental components: self-preservation needs, attitudes, motives, interests, plans, decisions, actions, and results of actions.

Average ideal life expectancy-characterizes an individual's idea of the best number of years of life in general.

The average desired life expectancy is an indicator that characterizes an individual's idea of the duration of their life under the most favorable conditions.

Average life expectancy-characterizes the real intentions of an individual to live a certain number of years, taking into account the specific circumstances of his life.

2.2 Analysis of demographic mortality in Uzbekistan due to external factors

Population aging is an increase in the share of elderly and elderly people in the total population. In demography, it is customary to distinguish aging from the top (increasing life expectancy and reducing mortality in older age groups) and aging from the bottom (reducing the birth rate). [8,52,65,85,92].

When assessing aging, the following coefficients are used:

$$W_{60+} = \frac{S_{60+}}{S} \cdot 100\%; W_{65+} = \frac{S_{65+}}{S} \cdot 100\% \qquad (2.1)$$

where S_{60+}, S_{65+} is the number of persons aged 60 and over, 65 and over; S is the total population [8,52,65,85,92].

In Uzbekistan, the criterion for measuring the aging of the population is generally considered to be the age of 65 years and older. In this case, the J. Beaujeu-Garnier – E. Rosset scale is used to measure demographic aging Э. Россета [8,49,52,65,85,92].

Table 2.4 Demographic aging assessment scale by J. Beaujeu-Garnier and E. Rosset[5]

Proportion of people aged 60 years and older, %	Aging scale
Less than 8	Demographic youth
8-10	First threshold of old age
10-12	Prologue to the golden age
12 and above	Demographic old age
12-14	First stage of demographic aging
14-16	Average value of demographic aging
16-18	Increased longevity of the population
18 and above	Significant proportion of the elderly population

If the criterion for measuring population distribution is age 65 and older, then the UN Demographic Age Scale is used.

[5] The table of measurement of demographic aging is presented by J. God-Garnier and E. Rosset.

The aging of the population has a number of social and economic consequences: an increase in the burden on pension funds with a decrease in the share of the working-age population; an increase in the burden on social infrastructure, primarily on the healthcare system; changes in the level and structure of consumption, etc.

Table 2.5 United Nations Scale for measuring Demographic ageing[6]

Percentage of people aged 65 years and older, %	Aging scale
Less than 4	Young population
4-7	Population on the threshold of old age
More than 7	Old population

A combination of mortality factors determines the causes of death. The leading causes of death in Uzbekistan include cardiovascular diseases, external causes of death (poisoning, suffocation, on-frequent cases, etc.), oncological diseases [8,52,65,85,92].

The process of mortality is specific for men and women and is associated with life expectancy, which is understood as the interval between birth and death equal to the age of death [8,52,65,85,92].

The average life expectancy in Uzbekistan in 2024 was 65-70 years: for men-64.33, for women – 76.11 years. Uzbekistan leads the world in terms of the gap between the average life expectancy of men and the average life expectancy of women by 11.8, years.

One of the factors of such a gap is the super mortality of men.

The super mortality of men is explained by both biological reasons (lower resistance of the male body compared to the female to the influence of exogenous factors) and social ones (injuries, smoking, alcohol, etc.) [1].

Special attention in demography is paid to infant mortality – the mortality of children in the first year of life. It is generally accepted that this is an indicator of the

[6] The table of demographic aging is presented by the UN.

state of the population's land area. The main causes of infant mortality are diseases of the perinatal period (the period from the 28th week of pregnancy to the first seven days of a newborn's life) [5,52,65,85,92], congenital malformations, and respiratory diseases. As of 2024, the infant mortality rate in Uzbekistan was 11.7 deaths per 1,000 births.

The decrease in mortality and increase in the average life expectancy of the population are due to the environment, the standard of living, and the efficiency of sanitary and medical services.

2.2.1 Methods of statistical analysis of the mortality rate in the Republic of Uzbekistan

The main mortality indicators include the total mortality rate, which is calculated using the formula:

$$m = \frac{M}{\tilde{P}T} \cdot 1000‰ \qquad (2.2)$$

where M is the number of deaths for a given period; $\tilde{P}$ is the average population; *and* T is the length of the period (in years) [25,52,65,85,92].

This indicator is influenced mainly by the age-sex structure, the birth rate of the population.

A more accurate estimate of mortality can be given by special coefficients, for example, the age-related mortality rate:

$$m^x = \frac{M^x}{P^x T} \cdot 1000‰ \qquad (2.3)$$

where M^x isthe absolute number of males in a given agegroup for a certain period; P^x is the average population in a given age group; T is the length of the period (in years) [25,52,65,85,92].

The infant mortality rate (at the age of 0 to 1 year) pis calculated as follows [39,52,65,85,92].:

$$m_0^t = \frac{M_0^t}{N^t} \cdot 1000\% \qquad (2.4)$$

where $M_0^{m0t \text{ is the}}$ number of children who died during the 1st year of life in the current year; $N^{nt \text{ is the number}}$ of live births in the current year

A more accurate representation of infant mortality is given by the following coefficient:

$$m_0^t = \frac{M_0^t}{{}^2/_3 N^t + {}^1/_3 N^{t-1}} \cdot 1000\% \qquad (2.5)$$

where M_0^tm0t is the number of children who died during the 1st year of life in the current year; ${}^2/_3\, N^t$-2/3 of children born in the current year; ${}^1/_3 N^{t-1}$-1/3 of children born in the previous year

In most cases, infant deat his caused by the mother's lifestyle during conception and pregnancy.

A special place in the system of mortality indicators is occupied by mortality tables. The first such tables, as already mentioned above, were developed by J. R. R. Tolkien. A grant.

Mortality tables are quantitative models of mortality, its level and age characteristics, which represent a system of interrelated relations describing the process of extinction of a certain generation with a fixed initial number, called the root of the table [5,52,65,85,92].

Mortality tables can be divided into the following types:

- depending on the coverage of population groups: full (one-year age intervals are used) and short (five-year or ten-year age intervals are used).
- depending on the gender: male and female.
- depending on the type of information: general and special (causes of death).
- depending on the research method: tables with conditional generation and tables with real generation [5,52,65,85,92].

Mortality tables cover the following key metrics:

- l_x predictor of survival to age x
- $l_0$the baseline number of live births in the mortality table, standardized as 100,000;

- d_x number of deaths in age group x
- px displays the probability of living to the next year of life, reaching the age (x+1).
- q_x denotes the probability of mortality at a given age x.
- $L_x$denotes the number of peopleliving in the age range between x and x+1 years [44,52,65,85,92].
- T_x is the number of person-years of the upcoming life for those who have reached the age $of\ x$.
- e_x projected life expectancy at age x

Relationships between table indicators:

$$d_x = l_x - l_x + n; \tag{2.6}$$

$$q_x = \frac{d_x}{l_x}; \tag{2.7}$$

$$p_x = \frac{l_{x+n}}{l_x} = 1 - q_x; \tag{2.8}$$

$$L_x = \frac{l_x + l_{x+1}}{2}; \tag{2.9}$$

$$T_{x-1} = T_x + L_{x-1}; \tag{2.10}$$

$$e_x = \frac{T_x}{l_x}; \tag{2.11}$$

The development and study of demographic tables of mortality [24,52,65,85,92] provides identification of loss trends and reveals, based on life expectancy, the integration of various demographic groups into economic activity.

2.3 Formation and development of family demographics in Uzbekistan

Family – an association of people based on marriage or blood relationship, connected by common life and mutual responsibility.

The family is the object of research in a number of sciences: sociology, psychology, pedagogy, etc. From the demographic point of view, the family is one of the conditions for population reproduction.

Throughout his life, the individual consistently lives in three families: the parent's, his own, and the family of his children.

Developing, the family goes through several stages, the sequence of which is the life cycle of the family. Traditionally, demographics distinguish the following stages of the family life cycle [3,52,65,85,92]:

- family formation – entering into the first marriage;
- the beginning of childbearing – the birth of the first child.
- end of childbearing – birth of the last child.
- "empty nest" – marriage and separation of the last child from the family.
- termination of the family – the death of one of the spouses.

There are different types of family structures, and they are distinguished based on a number of criteria.

According to the structure of kinship relations, there are:

- nuclear (simple) families consisting of a married couple with unmarried children;
- extended families that include other relatives, including your spouse's relatives.

According to marital status, families are divided into:

- for full families, i.e. those with both parents present.
- and single-parent families where one of the spouses is absent.

According to the time of the family's existence, there are:

- young families (up to 3 years of cohabitation);
- families of average married age (from 3 to 10 years);

- families of older married age (from 10 to 20 years);
- older married families (over 20 years old).

Another important criterion is childhood. In accordance with it , it is customary to distinguish the following types of families:

- small families with 1-2 children.
- medium-sized families with 3-4 children.
- large families with 5 or more children.

The family performs a wide range of social functions,among which the demographic ones include reproductive, educational, social stability and the function of creating conditions that promote life expectancy [3,52,65,85,92].

Marriage is a socially sanctioned and regulated form of relationship between a man and a woman, defining their rights and responsibilities to each other and to their children.

Demographics view marriage as a factor in starting a family and having children. At the same time, for demographic science, actual marriage (marital relations without legal consolidation) is also of interest, since it is associated with extramarital birth.

Historically formed forms of marriage are monogamy (monogamy) and polygamy (polygamy). Varieties of polygamy are polygyny (polygamy) –the marriage of one-man with several men and women, and polyandry – much courage) - the marriage of one woman with several men.

Modern society is characterized by a narrowing of the spread of polygamy [3,52,65,85,92].

Marriage is a form of relationship between a man and a woman that determines their rights and obligations towards each other and their children. Legal relations between a husband and wife are established as a result of registration of their marriage in the civil registration authorities (Civil Registry Office).

The number of registered marriages in the Republic of Uzbekistan in January-December 2024 amounted to 179.4 thousand units and, compared to the corresponding period of the previous year [42,52,65,85,92], decreased by 5.1

thousand units. If we compare it with the same period in 2020, it also decreased by 4.6 thousand units.

In January-December 2024, the number of registered marriages amounted to 179.4 thousand units, of which 93.7 thousand, or 52.2% - in urban areas and 85.7 thousand, or 47.8% - in rural areas.

In January-December 2024, the average age of women married was 22.5 years, and the average age of men was 27.4 years. The largest share of registered marriages falls on women under the age of 25 – 80.0 % of all marriages.

2.3.1 Main directions of development of marriage and family relations in Uzbekistan

In modern Western countries and in Uzbekistan, there is a reduction in the number of family members, which is caused by a decrease in the birth rate and the nuclearization of the family.

Marriage age — in accordance with the Family Code of the Republic of Uzbekistan, the marriage age for men and women is set at eighteen years. If there are good reasons, in exceptional cases, the khokims of a district or city at the place of state registration of marriage may, at the request of persons wishing to marry, reduce the age of marriage, but not by more than one year.

However, local executive authorities are also allowed to register official marriages at an earlier age, if there is a good reason for this. The average age of entering into a formal marriage in Uzbekistan is 27-30 years for men and 23-27 years for women [19].

The highest percentage of marriages was registered in Samarkand region-11.4 %, Ferghana region-10.8 %, Kashkadarya region-10.0 %, Tashkent city-9.2 % and Andijan region-8.4 %.

The number of marriages is relatively low in the Syrdarya region-2.6 %, Navoi region-3.2 %, Jizzakh region-4.2 %, the Republic of Karakalpakstan-5.3 % and Bukhara region-5.5 % [38].

The highest marriage rate by region was 7.2 ppm in the city of Tashkent, 7.0 ppm in the Navoi region, and the lowest indicator-5.9 ppm-was in the Andijan region and 6.1 ppm-in the Namangan and Tashkent regions [25,37,88].

In Uzbekistan, alternative forms of marriage and family are becoming increasingly common: cohabitation, visiting (guest) marriage.

The situation in the marriage market depends on the number of potential marriage partners and may be local (male and female territories). Today, brides in the marriage market are looking for peers, and men can not meet the demand for young brides. The proportion of young men and women (under 30) who have never been married is increasing. The share of illegitimate children in the total number of births is growing [3,52,65,85,92].

The greatest probability of divorce is represented by marriages concluded at a young age, as well as between people who have a significant age difference. The lowest probability of divorce is shown by marriages concluded at the maximum marriage age and repeated marriages. The probability of divorce in childless families and in families with one child is higher than in families with two or more children. Divorce rates are higher in the urban population than in the rural one.

Divorce (dissolution of marriage) – the final legal termination of a marriage during the life of the spouses, which gives the parties the right to remarry. It is considered terminated after the divorce is registered in the Civil Registry Office and courts.

Men are more likely to remarry than women. Divorced people are more likely to remarry than widowed people. The largest share of remarriages occurs in the first years of termination of marriage. Women with one child and no children are more likely to remarry than women with 2 or more children.

In January-December 2024, the number of divorces amounted to 34,0 thousand units and over the past four years has increased significantly. So, compared to 2020, their number increased by 14.0 thousand units, or 1.7 times.

In January-December 2024, the number of divorces amounted to 34.0 thousand units, of which 21.1 thousand units were registered in urban areas (62.0 %), and 12.9 thousand units - in rural areas (38.0 %).

The number of divorces in childless marriages in January-December 2024 was 16,135 cases. The number of divorces with one child in January-September 2024 was 9,863 cases. The number of divorces with two or more children in January-December 2024 was 7,986 cases.

In January-December 2024, the average age of divorced men was 35.2 years, women-32.4 years. The largest share of divorces falls on women under the age of 35, which is 64.3 % of their total number.

The highest percentage of divorces was 13.0% in Tashkent city, 10.7 % in Andijan region, 10.6 % in Ferghana region, 10.2 % in Samarkand region and 10.1 % in Tashkent region.

The number of divorces is relatively low in Navoi - 2.7 % of the total number of divorces, Syrdarya - 3.3 %, Jizzakh-3.8% regions, the Republic of Karakalpakstan-4.0 % and Khorezm region-4.2 %.

The highest divorce rate by region was 1.9 ppm in Tashkent, 1.7 ppm in Syrdarya region, the lowest rate-0.8 ppm in Kashkadarya region, 0.9 ppm in the Republic of Karakalpakstan

2.3.23.2 Demographic data on marriage and divorce rates in the Republic of Uzbekistan

The total marriage rate – the ratio of the number of marriages to the average population size for a given period, is calculated using the formula:

$$CNR = \frac{N}{\tilde{P} \cdot T} \cdot 1000‰ \qquad (2.12)$$

where N is the number of marriages performed during the period; $\tilde{P}$ is the average annual population; T is the length of the period (in years)

The special marriage rate for the entire population is defined as follows:

$$SNR = \frac{N}{\tilde{P}_{16+}} \cdot 1000‰ \quad (2.13)$$

where N is the number of marriagesperformed; $\tilde{P}_{P16+}$ is the average annual population size at the marriageable age [39,52,65,85,92].

The special marriage coefficient for the able-bodied population is calculated separately for men and women using the formula:

$$SNR = \frac{N}{\tilde{M}^{h}_{16+}} \cdot 1000‰ \quad (2.14)$$

where N is the number of marriages; $\widetilde{performed};\,^{h}_{M16+}$ is the average annual number of unmarried men/women of marriageable age (single, widowed, divorced).

Total divorce rate – the ratio of the total number of divorces to the average population size for a given period. It is calculated as follows:

$$CNR = \frac{D}{\tilde{P} \cdot T} \cdot 1000‰ \quad (2.15)$$

where D is the number of divorces per period; P is the average annual population; T is the length of the period (in years) [17,52,65,85,92].

A special age-specific divorce rate is also determined separately for the male and female population.

Calculation formula:

$$ASDR = \frac{{}_{n}D_{x}}{{}_{n}F_{x}} \cdot 1000‰ \quad (2.16)$$

where ${}_{n}D_{ndx\ is\ the\ number}$ of divorces for men/women of this age; ${}_{n}F_{nfx\ is\ the\ average\ annual\ number\ of}$ men / women of this age.

2.4 Features of migration trends in Uzbekistan

Migration of the population Latin migratio – relocation, movement of people (migrants) across the borders of certain territories with a change of place of residence forever or for a longer or shorter time. Migration is usually considered in a broad and narrow sense. In the narrow sense, it is a complete type of territorial displacement, ending with a change of permanent place of residence. In the broadest sense, these are any territorial movements that occur between different localities of one or severaladministrative-territorialunits, regardless of the duration, regularity and target orientation of these movements.

Migration has three stages:

- formation of migration mobility (the ability of the individual to migrate), certain migration attitudes, psychological readiness for resettlement;
- actually, moving;
- increasing the survival rate of new settlers as an objective social process of changing the existing way of life by improving the new social environment [5,52,65,85,92] through social activities.

Migration functions are specific roles performed by migration in society. The following functions are highlighted in demographics:

- mobility development – ensuring a certain level of spatial mobility, which determines both the turnover of the composition of residents of different districts, and the diversity of their places of residence [11,852,65,85,92];
- a redistributive function involving the allocation of productive forces between individual territories of the country, including between natural zones, districts, and different types of rural and urban settlements.
- selective function, which consists in the fact that uneven participation in migration of various socio-demographic groups leads to changes in the qualities and composition of the population of different territories.

Experience shows that men, especially those of working age, are more actively involved in migration than women.

Demographic science distinguishes the following types of migration:

- By the nature of the intersecting borders:

1) internal migration – movement of the population within the country from villages to cities, from cities to villages, from one region to another.
2) external migration is the movement of the population from one country to another.

- By implementation method:

1) voluntary migration;

2) forced migration (exile, expulsion, deportation).

- According to the implementation form:

1) organized migration – carried out with the participation of state and public bodies and with their help;

2) unorganized migration-is carried out by the forces and means of migrants themselves [18,52,65,85,92].

- By duration:

1) permanent migration.
2) temporary version.
3) seasonal;
4) the pendulum one.

- By territorial coverage:

1) intercontinental migration;
2) intra-continental migration.

- For the following reasons:

1) economic migration;
2) social services;
3) political issues.
4) national;
5) environmental issues.
6) religious, etc.

- By media type:

1) migration of the rural population (migration flows: village–city, city–village);
2) migration of the urban population (migration flows: city–city, city–village).

In addition, there are:

- emigration – relocation to another country for permanent or temporary residence, in most cases with a change of citizenship.
- immigration – entry into the country for permanent or temporary residence of citizens [18,52,65,85,92] of another country, in most cases with obtaining a new citizenship.

The number of arrivals is the absolute number of arrivals consisting of those who have moved to the region from outside. These data are determined by the internal affairs bodies as a result of processing and statistical accounting of arrivals, compiled during their registration at the place of stay.

Всего прибывших в Республику УзбекистанThe total number of arrivals to the Republic of Uzbekistan in January-December 2024 was 186.8 thousand people, including 80.0 thousand men and 106.8 thousand women. The number of arrivals in urban areas reached 141.2 thousand, in rural areas – 45.6 thousand.

In January-December 2024, by age group, 11.3 % of arrivals were younger than working age, 81.1 % were of working age, and 7.6 % were older than working age.

The largest share of arrivals for permanent residence in the Republic of Uzbekistan from abroad (in % of their total number) is accounted for by arrivals from the Russian Federation (37.8 %) and Kazakhstan (24.7%). 10.0% of arrivals were registered from Tajikistan, 6.2% from Kyrgyzstan, 2.5% from Turkmenistan, and 18.8% from other countries.

Figure 2.1. Number of people who arrived in the Republic of Uzbekistan for permanent residence from abroad January-December 2024

The largest share of immigrants was 38.4% in the city of Tashkent, 13.3% in the Tashkent region, 5.8% in the Samarkand region, 5.3 % in the Ferghana region and 5.0% in the Navoi region.

The share of immigrants is relatively small in Namangan region-1.4 %, Andijan region-3.0 %, Jizzakh region-3.0 %, Syrdarya region-3.1 % and Bukhara region-3.7 %.

The highest rate of arrivals by region was 31.2 per mille in Tashkent, 11.4 per mille in Navoi region, 10.8 per mille in Tashkent region, the lowest rate-1.1 per mille was recorded in Namangan region, 2.2 per mille in Andijan region and 3.2 per mille in Ferghana region.

2.4.1 Current migration trends in the Republic of Uzbekistan

For the first time, the patterns of migration processes were determined in the XIX century by the English geographer and cartographer Ernst Georg Ravenstein.

Later, in science, they were called the laws of migration. Migrationlaws are expressed as follows:

- most migrants travel short distances.
- migration is carried out step by step.
- long-distance migrants are attracted to industrial and commercial centers [18,52,65,85,92].
- each migration flow generates a counter flow.
- urban dwellers are less able to migrate than natives of rural areas.
- women are more predisposed to migration than men (later, in1889, R.Avenstein clarified that this applies only to internal movements, while external migration is dominated by men).
- most migrants are adults. families rarely move outside the country where they were born.

- the population of large cities increases more due to migration growth than due to natural growth.
- the volume of migration increases in proportion to the development of industry, trade and transport.
- migrations are mainly directed from agricultural areas to industrial and commercial centers.
- the main reasons for migration are economic.

The main current trends in international migration include the following: In the twentieth century, the main centers of immigration were Canada, the United States, and Australia. Inter-continental migration declined after World War II, but intra-continental migration flows increased. Today, central Europe is home to 12-13 million migrants –foreign workers from Asia and Southern Europe. The United Arab Emirates, Qatar, Saudi Arabia, Bahrain, and Kuwait as oil-producing countries have become new territories of labor migration for workers from Syria [18,52,65,85,92], India, Pakistan, Egypt, and others. Traditionally, the United States and Canada remain attractive for migration, with approximately 7 million foreign workers млн человек [18,52,65,85,92]. One of the new trends in population migration over the past decade is an increase in the share of refugees from conflict zones in the total number of migrants.

The number of dropouts is the absolute number of dropouts, consisting of those who left for a particular region from outside its borders. This indicator is determined by the internal affairs bodies as a result of processing the statistical record of those who left, compiled when they were registered at the place of departure.

The main modern trends of Uzbek migration areas follow. The influx of population to rural areas is increasing. This is due to the loss of attractiveness of the urban image and lifestyle, and the increase in the cost of living in large cities. The outflow of population from the northern territories rich in natural resources is increasing.

The northern regions are losing their genetic potential – the population adapted to living in difficult climatic conditions. The aggravation of international conflicts leads to an increase in the flow of internally displaced persons and refugees. Ecologically favorable regions lose human resources, and such a phenomenon as ecological unemployment appears. The flow of foreign labor to Uzbekistan from the CIS countries (Tajikistan, Kyrgyzstan, China, etc.) is increasing, and labor migration exchange between the subjects of the Russian Federation is becoming more active.

In January-December 2024, the number of people who left the country was 193.5 thousand, including 83.2 thousand men and 110.3 thousand women. Those who left cities made up 134.2 thousand people, and those who left rural areas-59.3 thousand. [52,65,75,85,92].

In January-December 2024, by age group, 11.8 % of those who dropped out were younger than working age, 80.3 % were of working age, and 7.9 % were older than working age.

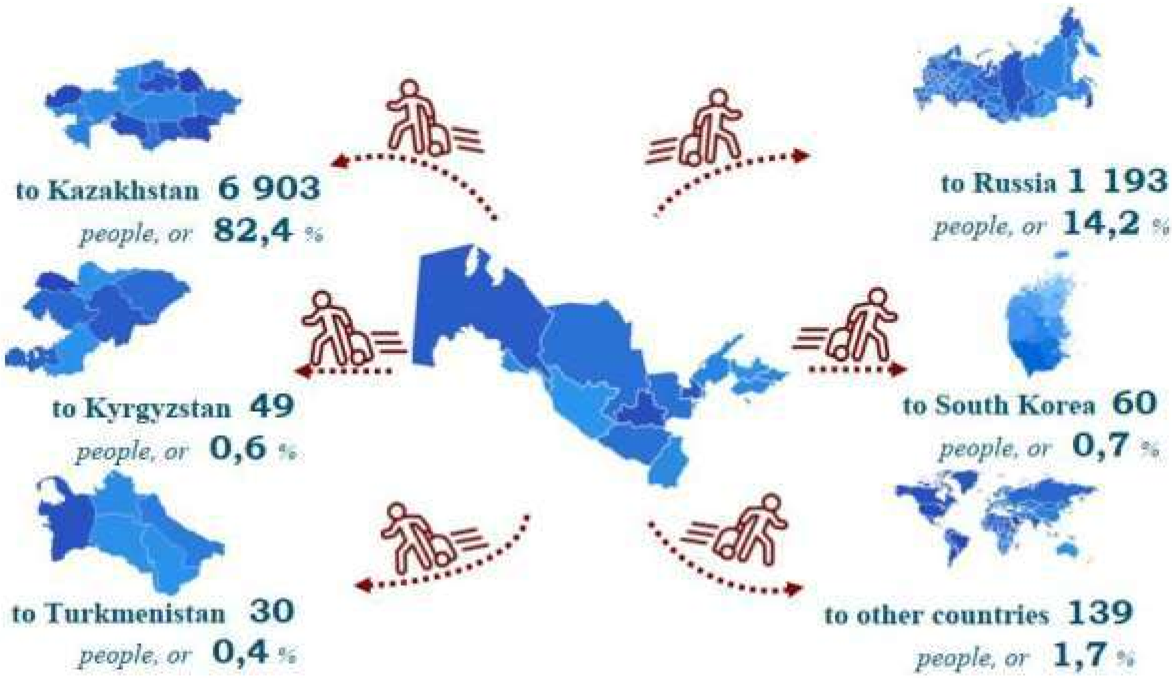

Figure 2.2. Number of people who left the Republic of Uzbekistan for permanent residence in foreign countries

The main share of those who left for permanent residence from the Republic of Uzbekistan to foreign countries falls on Kazakhstan (82.4 %). This is followed by the Russian Federation (14.2 %), South Korea (0.7 %), Kyrgyzstan (0.6 %), Turkmenistan (0.4 %), and other countries (1.7 %).

The largest share of immigrants falls on the city of Tashkent – 28.8 %, Tashkent region-11.7 %, Kashkadarya region-7.1 %, Samarkand region-6.6 % and the Republic of Karakalpakstan-6.0 %.

The share of immigrants is relatively small in Namangan region - 2.2 %, Syrdarya region-3.3 %, Andijan region-3.6 %, Jizzakh region-3.8 % and Khorezm region-4.9 %.

The highest level of disposal by region was formed in Tashkent - 24.2 ppm, 12.9 ppm - in Navoi region, 9.9 ppm - in Tashkent region, the lowest indicator was 1.8 ppm in Namangan region, 2.7 ppm - in Andijan region and 3.8 ppm-in Ferghana region.

2.4.2 Statistical data on migration processes in Uzbekistan

Migration turnover is the number of people who have moved to and from a given territory over a certain period of time:

$$O = N + Y \quad (2.17)$$

where N is the number of arrivals; Y is the number of departures.

Migration balance – mechanical population growth [11,852,65,85,92], the difference between the number of arrivals toa territory and the numberof departures from it for a certain period of time:

$$C = N - Y \quad (2.18)$$

where $k_n$kn is the arrival rate; N is the number of arrivals; S is the average population

Attrition rate – the number of departures from a given territory per 1000 people per year:

$$k_n \frac{N}{\tilde{S}} * 1000\% \quad (2.19)$$

where $k_n$kn denotes the profit ratio; N indicates the number of arrivals; S represents the average size of the population.

The attrition rate is a statistical indicator that reflects the number of people who have left a certain geographical area, reduced to the calculation per thousand populations for an annual period.

$$k_y \frac{Y}{\tilde{S}} * 1000\% \ (2.20)$$

where ky_y denotes the attrition rate; Y represents the number of people who left the territory; S represents the average number of inhabitants.

The migration coefficient is an indicator that reflects the volume of arrivals and departures from the territory, calculated for every 1000 inhabitants:

$$k_{mo} \frac{N+Y}{\tilde{S}} * 1000\% \ (2.21)$$

k_{mo}, or the migration turnover coefficient, is calculated as the sum of the number of gains and losses of the population divided by the average population size for a certain period [11,6,52,65,85,92].

The migration coefficient is the ratio of the increase or decrease in the population as a result of migration to the total population, expressed for every 1000 inhabitants.

$$k_{mp} \frac{N-Y}{\tilde{S}} * 1000\% \ (2.22)$$

where k_{mp} denotes the migration growth rate, and S is the average populationsize.

The migration efficiency coefficient reflects the percentage ratio of the number of migration increases or decreases to the total volume of migration movement of the population in a particular territory.

$$E = \frac{N-Y}{P+Y} 1000\% \quad (2.23)$$

where E denotes the efficiency coefficient of migration flows; N represents the number of people who arrived, and Y represents the number of people who left.

2.5 Main results and conclusions of the second chaptere

The demographic development prospects of the Republic of Uzbekistan represent an important aspect that determines the future of the country in various spheres, including the economy, social sphere and culture. Uzbekistan, which has one of the youngest populations in the world, faces opportunities and challenges associated with demographic changes. This condition requires careful analysis and prognosis.

First, population growth, which is expected in the coming decades, can become a powerful resource for economic development. According to the World Bank, a young population provides labor for various sectors of the economy, which can contribute to increased productivity and economic growth. However, it should be noted that successful development depends on creating a sufficient number of jobs. In addition, there is a need to provide adequate education and training for young people. This requires investment in educational institutions, advanced training programs, and the development of skills that are in demand in the labor market.

Secondly, the demographic transition associated with an increase in the proportion of older people will require Uzbekistan to adapt its social policy. According to UN forecasts, the share of people over 65 in the country will grow significantly by 2050. This will create a need to develop measures to ensure pension provision, health care and social protection for the older generation. It is also important to understand that the needs of older people may require new services and products, which can lead to the development of new sectors of the economy, such as health services and social services.

Third, migration issues must be taken into account. Uzbekistan is traditionally a country from which able-bodied citizens migrate in search of better living and working conditions. According to the International Organization for Migration, a significant number of Uzbeks travel abroad in search of earnings. This can lead to a shortage of labor in some sectors of the economy, which requires the development of an effective migration policy. Measures are needed to create attractive conditions for the return of migrants and their integration into the country's economy.

In addition, demographic changes can have an impact on social stability and interethnic relations. Uzbekistan is a multiethnic country, and it is important to ensure the harmonious coexistence of various ethnic groups. This requires active work in the area of intercultural dialogue and integration, which may include language, cultural awareness and collaborative initiatives. Maintaining social harmony becomes especially relevant in the context of globalization and increasing migration flows.

The prospects for the demographic development of the Republic of Uzbekistan largely depend on how the country manages its demographic resources. Effective policies in the areas of education, health, social protection and migration will contribute not only to sustainable economic growth, but also to social stability. This is key for the country's future, as successful management of demographic challenges can lead to an improved quality of life for all citizens and the creation of a more balanced and sustainable society.

Chapter 3. Development of a model for analyzing demographic processes in the Republic of Uzbekistan

The model presented in this study focuses on studying the demographic structure by gender and age in Uzbekistan. By excluding the balance projections, we obtain key findings that provide an overview of the demographic composition and population size that is expected in the future. This analysis combines in the final data essays of all citizens of Uzbekistan, based on their statistical indicators. It should be emphasized that the data shown have a predictive and therefore probabilistic aspect, with special attention being paid to numerical values that reflect the average predictive scenario.

As previously noted, information for individual years in the context of the average forecast scenario is reflected in tables that include generalized data and detailed values for the gender-age component.

Predictive data clearly indicate that over the next 30 years, the population of the Republic of Uzbekistan will show stable growth. The population is projected to reach between 43 and 46.8 million, with the highest expected population density around 44.8 million. Thus, during the period under review, the total population is expected to increase by 37 %, with possible fluctuations in this indicator ranging from 32% to 43 %.

In the coming period, it is noted that the dynamics of population growth will undergo changes. Annual population growth is expected to slow significantly in the first eight years, from an initial reading of 1.6 % to 1.0 %. After this period, the growth rate will temporarily remain at the same level, but it is expected to fall further after 2040. These variations in the growth rate are associated with the characteristics of the age-sex distribution of the population at the initial stage. At the same time, the total population will continue to increase, even in the face of a projected increase in migration outflows, which are expected to reach their peak by the early 2030s, being set at the level of 40 thousand people annually.

Consequently, population dynamics will remain a fundamental element in the demography of Uzbekistan, however, its impact is expected to decrease from 536,000 to less than 300,000 people annually by the middle of the 21st century.

3.1. Modeling of demographic processes in the Republic of Uzbekistan

In demographic research, forecasting plays a key role in analyzing and predicting socio-economic dynamics of the population in the broad context of social transformation.

Predicting demographic changes, including estimating the future number of residents, their age and gender composition, birth rates, mortality rates, and life expectancy, plays a key role in the strategic development of economic and social sectors such as education, medicine, social security, and pension insurance.

This set of predictions is particularly significant in the context of making strategically important decisions at the state level, which is reflected in the activation of public interest in the implementation of Decree of the President of the Republic of Uzbekistan No. UP-37 dated February 21, 2024 on the implementation of the State Program within the framework of the development strategy "Uzbekistan – 2030".

This regulatory act sets out the goals of improving demographic indicators, including increasing the average life expectancy to 75 years, which is an indicator of success in implementing this strategic initiative.

The increased need for monitoring the current demographic situation, analysis of the composition of demographic statistics, and careful consideration by the scientific world of the issues of achieving national goals provoked the definition of the subject of this study.

The study examined key aspects of modeling demographic trends in the Republic of Uzbekistan, including birth rate, mortality, infant mortality and marital union dynamics, based on monthly data provided by the Statistics Agency under the President of the Republic of Uzbekistan for the forecast period from 2024 to 2050.

International scientific studies have shown that, in addition to standard demographic approaches, ARIMA models provide reliable forecasts of demographic characteristics, such as population size, birth and death rates, and life expectancy of the population [2,52,65,8,52,65,86,92].

The aim of this study is to evaluate the effectiveness of current statistical forecasting methods, as well as to improve statistical approaches to analyzing [4,52,65,84,52,65,6,92] and predicting seasonal fluctuations in demographic indicators. As part of the work, an in-depth analysis of the use of SARIMA models for demographic research in the Republic of Uzbekistan will be carried out, which will demonstrate the effectiveness and potential of predictive capabilities of statistical modeling based on this class of models.

3.1.1 Methods and approaches to the analysis of demographic phenomena

Study of seasonal population fluctuations using statistics. In the process of developing demographic forecasts, scientists use a variety of methodologies: from mathematical algorithms to cohort analysis and statistical analysis. ARIMA, a simulation developed by Box and Jenkins to study economic trends, has become widely used in various fields, including demography, due to its flexibility and effectiveness in identifying time dependencies.

The study, conducted by Box and Jenkins, carried out analytical work on modeling demographic indicators, including population size, marriage rates, fertility and mortality. To predict the population dynamics, we used the ARIMA method with parameters (1,1,0) based on logarithmic transformation of the data. In the analysis of fertility indicators, ARIMA models with different parameter structures were used: (4,1,1) and (3,1,2), which made it possible to more accurately estimate the rate of birth rate change over time.

ARIMA-models for predicting the average life expectancy of men and women for women and ARIMA (1,1,1) for men [6,52,65,8,52,65,86,92].

The continued development of time series analysis methods has led to the creation of SARIMA models adapted for analyzing data with pronounced seasonality. These models have become widely used by the scientific community for accurate forecasting of time sequences [47,52,65,847,52,65,6,92] and are the foundation for the seasonal correction algorithm such as X-13-ARIMA, used by the State Statistics Committee of the Republic of Uzbekistan, as well as the TRAMO/SEATS approach. The TRAMO model, designed to analyze time series based on ARIMA noise, missed observations, and anomalous values, is effectively used to estimate and create forecasts, taking into account all possible distortions in the original data.

The SEATS method (Signal Extraction in ARIMA Time Series) decomposes the time sequence into hidden components using the ARIMA process.

Victor Gomez and Augustin Maravall developed the software for both models.

The use of algorithms for performing calculations based on TRAMO and SEATS models is integrated into the analytical platform under Windows OS. In the case of Linux, additional integration is required to use these methods.

TRAMO "Time Series Regression with ARIMA noise, missed observations and outliers" is a program for estimating, predicting and interpolating regression models with missed values and ARIMA errors in the presence of several types of outliers (no restrictions are imposed on the location of missed observations in the series [52,65,71,871,86,92]).

The X-13-ARIMA-SEATS software, based on seasonal adjustment approaches and modeling using ARIMA models, operates in a fully autonomous mode.

A time series usually consists of three main components that can be analyzed and predicted separately: the long-term direction of change or trend, periodically recurring fluctuations-seasonal fluctuations, and non-permanent, random changes called the irregular component.

A trend is a component that reflects long-term market fluctuations that exceed the duration of seasonal variations.

The seasonal component reflects periodic fluctuations, covering annual changeable calendar features: varying working days, floating holiday dates, and the presence of a leap year.

The irregular component represents random changes in time series, covering both background noise and anomalous deviations of various nature.

The objective of the methodology is to create a simulation of the observed time sequence using a seasonal ARIMA (SARIMA) model to isolate elements from its construction through spectral analyses.

It can increase the spread of non-constant data components, while at the same time reducing fluctuations associated with seasonality. Methods based on ARIMA models are highly sensitive to data anomalies, which prevents accurate identification of time components with predictable behavior. In response to these limitations, combined approaches were proposed that integrate regression analysis using indicator variables and error modeling based on ARIMA principles, which led to the creation of TRAMO-SEATS systems.

The main component of the software product assumes that the initial sequence of data is stationary or can be reduced to a stationary state through the use of fixed-order differences.

The importance of the stationary state of time series is not in doubt in ARIMA modeling, especially when it comes to data analysis in the field of socio-economic research, where the results are influenced by deterministic effects and structural anomalies, creating difficulties for effective application of the ARIMA model. To solve this problem, the TRAMO software tool is used, whose task is to identify and correct the above deterministic effects in order to achieve stationarity of the time series. TRAMO takes a comprehensive approach, combining regression analysis with ARIMA models to evaluate the current state, predict future values, and interpolate data, thereby providing more reliable and accurate time series modeling.

SEATS starts by fitting the ARIMA model to a stationary linear series obtained by TRAMO. This model is determined by applying an automatic model identification procedure based on constraints concerning the orders of seasonal and non-seasonal polynomials [52,65,70,870,86,92].

The X-11-ARIMA procedure involves preprocessing the data by adding estimated values at the initial and final stages of the time series before performing seasonal adjustment. This is achieved by applying methods of extrapolation and retrospective forecasting based on ARIMA models. This approach can significantly reduce the amount of adjustments and delays in the final generation of estimates, which helps to increase the selection of the seasonal component of the analyzed data.

The final update of the X-type series approaches is the X-13-ARIMA-SEATS method integrated into the JDemetra+software package. In a simplified version, its designation in the program and in the following text is "X-13".

The X-13 method provides comprehensive functions for analyzing time series and selecting suitable models through regression analysis based on ARIMA. It includes the SEATS and X-11 procedures for detailed data review. Alternative approaches to seasonal adjustment, such as TRAMO / SEATS, focus on identifying the main signal behind noise through the decomposition of the time series using ARIMA, which ensures partiality in the characteristics of the studied series and its components, on the basis of which the detailed models obtained using ARIMA and the general model of the observed series are harmonized.

In the TRAMO/SEATS approach, the TRAMO segment is used for primary data modification. The abbreviation "TRAMO" stands for "Time Series Regression with Arima Time Noise, Missing Regression Observations, and Outliers" [Noise, Missing Observations, and Outliers) 52,65,70,870,86,92].

The software solution, designed for automated identification, analytical estimation, projection of future values and data augmentation usingRegression-ARIMA models, facilitates both the expansion of time series with forecasts and the identification of anomalies using suitable regression models. This tool can function independently to detect anomalies or predict results. However, its main application is to prepare data for seasonal adjustment, which is performed before using basic statistical methods. The TRAMO procedure is closely related to the preparatory stage of the X-13 method, since both TRAMO and X-13 use the same analytical approach based on the Reg-ARIMA model.

At the TRAMO stage, a time series is prepared, which is then passed to the SEATS procedure for further processing. In the SEATS procedure, a time series that has already been cleared of anomalies and the influence of regression factors is filtered. The process involves evaluating the seasonally adjusted series and extracting its main components: seasonal, trend-cyclical, and residual components. SEATS, which stands for "Signal Extraction in ARIMA time series", uses ARIMA models to analyze and decompose time series into components.

This program is designed to decompose time series into its component elements using an algorithm based on the ARIMA model. SEATS was developed based on the original software created with the aim of seasonal data adaptation.

The methodologies, X-13 and TRAMO / SEATS, share a number of analytical principles. First, they apply data adjustments to account for anomalies using regression analysis. Next comes the stage of identifying and evaluating the main elements of the analyzed time series: the trend to the cycle, seasonality, random fluctuations, and if necessary, an intermediate component is also highlighted.

The X-13 filter is selected from a pre-formed filter range, while SEATS applies a decomposition based on the ARIMA model. In addition, the results of their work and qualitative assessment represent different aspects.

3.1.2. Fundamentals of demography, procedures for generating and calculating key demographic indices

We have studied certain characteristics of time series that are suitable for building models. Now let's turn our attention to the main elements of time series analysis, which represent deeper aspects of data.

Time series components

- The trend in time series analysis reflects the long-term trend of data changes, revealing their main direction of development. There are uptrends characterized by an increase in values, downtrends indicating a decrease in values, and stable trends where the data remains constant.

- Seasonality: Regular and predictable changes in time series data that occur at fixed time intervals, such as months, quarters, or years.
- Cyclicity: These are changes in time sequences of data over long periods, without strict periodicity. These cyclical fluctuations can be caused by economic situations, political events, or other exogenous variables.
- Irregularities or residuals in time series analysis refer to components that result from spontaneous, unpredictable fluctuations that do not correlate with major changes, such as a trend over time (trend), seasonal fluctuations, or cyclical variations.

It should be emphasized that not every time series includes all of these elements.

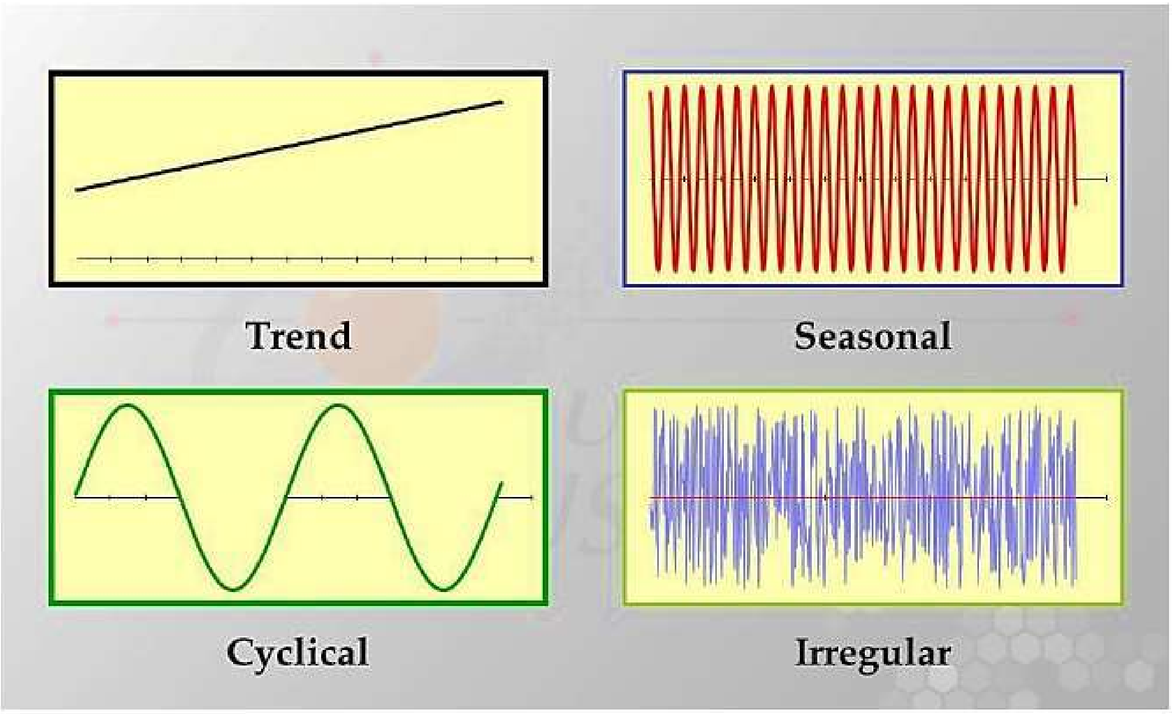

Figure 3.1. Constraints in time series analysis

Time series research, while having a broad field of application, faces various obstacles and challenges, awareness of which is critically important. Here are a few key limitations:

- The study of time sequences is based on the assumption that they are stationary, which makes it less adaptable to changing processes.
- missing data can cause analysis results to be distorted, especially when they are non-random.
- time series are often affected by multiple exogenous variables.
- lack of information or short-term time sequences reduce the potential for analytical research.

Here it is important to elaborate on two important concepts: stationary and no constant time sequences.

time series that are stationary must meet the following criteria:

- the average value of the sequence is stable over time, that is, the mathematical expectation remains unchanged.
- auto covariance, or covariance between values of a single time series, is determined solely by the time interval between these values, ignoring their specific position at the beginning or end of the series.
- the variation of a stationary time series remains constant over time.

When parameters such as mean, variance, and covariance show time-scale variability, the dataset is classified as non-stationary.

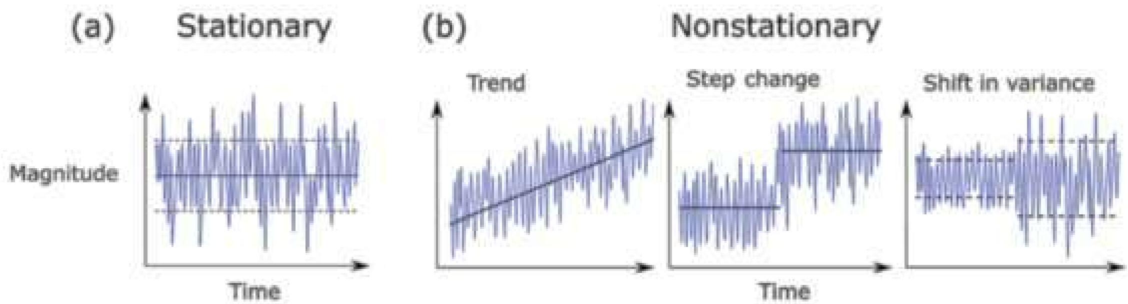

Figure 3.2. Methods for stationarity analysis and non-stationarity analysis in time series

In the process of data analysis for time series, it is critical to determine whether it has the stationarity property. This is achieved by applying specialized statistical methods. To assess stationarity, two key tests are mainly used [9,52,65,70,852,65,70,86,92]:

- Dickey-Fuller (ADF-test) taking into account autocorrelation [62,65,70,870,86,92].
- Kvitk-Phillips-Schmidt-Busn criterion (KPSS test)

The ADF test (Augmented Dickey-Fuller test) is designed to test the stationarity of time series, taking into account autocorrelation and integration of order d. It relies on the t-statistic, calculated as the ratio of the estimate of the autoregressive parameter to the standard error of this estimate.

The ADF test is the most common statistical test [66,65,70,870,86,92] for checking stationarity. It allows you to determine whether a time series contains a unit root, which indicates that it is non-stationary. It is based on the following hypotheses:

- The null hypothesis (h_0) [26,65,70,8,65,70,86,92] states that the time series is non-stationary due to the presence of a unit root.
- The alternative hypothesis (h_1) states that the analyzed time series is stationary, i.e. it is not characterized by the presence of a unit root.

The test outcome is set by the p-level of significance:

- When the p-value exceeds 0.05, there is no reason to reject the null hypothesis (h_0), which indicates that the time series is non-stationary.
- If the p-value is less than or equal to 0.05, the alternative hypothesis (h_1) is accepted as true. This indicates the stationarity of the time series [63,65,70,8,65,70,86,92].

The ADF test (Augmented Dickey-Fuller) uses the adfuller function ad fuller contained in the stat tools module of the statsmodels.tsa package.This function uses a number of parameters:

- x - a sequence of temporary data to be analyzed.
- maxlag is the largest number of delays used in the advanced Dickey-Fuller stationarity test. If there is no explicit indication, its value is set by default.
- regression is a type of regression analysis in testing that is determined by the type of dependencies: "c" for only a constant term, "CT «includes a constant term

and a linear trend,"ctt"covers a constant term, linear and quadratic trends, and"nc" involves analysis without using a constant term and a trend.

- Autolag is a method for determining the ideal number of lags, using either" AIC "(Akaike Information Criterion)," BIC "(Bayesian information criterion, also known as the Schwartz test), or" t-stat" (t-statistical significance criterion).

The function outputs the following results:

- adf_stat-implementation of a statistical indicator for checking Dickey-Fuller.
- p-value, used to evaluate the statistical significance of test results.
- usedlag - the number of delays applied in the analysis.
- nobs - the number of marked time points in the initial data sequence.
- Critical values are thresholds in statistical hypothesis testing that define boundaries for rejecting or not rejecting a null hypothesis at established significance levels.
- ICBEST is a metric for determining the ideal number of lagging values in a model.

Kvitk-Phillips-Schmidt-Shin test (KPSS test) [4,65,70,8,65,70,86,92]. This KPSS test evaluates the stationarity of a time series by testing the null hypothesis of a stable level, based on an analysis of the variation of the combined partial sums relative to a linear trend.

Unlike the Dickey-Fuller test (ADF), which examines the basic assumption about the presence of a non-stationary process, the KPSS test is aimed at testing the basic hypothesis of data stationarity, taking into account a certain trend, in the context of a possible alternative indicating the presence of a unit root. This check is based on the following assumptions:

- The H_0 hypothesis asserts the stationarity of the time series, excluding the presence of a unit root.
- alternative assumption (h_1): the time series shows non-stationarity, indicating the presence of a unit root.

3.1.3. Converting dynamic data to static data

Let's briefly discuss the methods used to transform non-stationary time series into stationary ones, which is necessary for their effective analysis and forecasting. We have three key approaches in our arsenal:

- (detrending).
- (data processing).

Trend analysis through detrending. This approach involves excluding the trend component from the initial data set to demonstrate only deviations from the detected trend. This helps detect cyclically repeated patterns within the data.

Various approaches to determining the direction of a trend include:

- The moving average calculation is the determination of the average indicator for a specific period in a series of data. This method helps to reduce volatility and identify the main directions of trend development.
- The linear regression method is designed to identify relationships between variables by approximating the observed relationship with a linear function. The parameters of this function are determined by applying the least squares method, minimizing its sum of squares of differences between real and predicted values.
- The exponential smoothing technique is based on a principle that asserts the highest relevance of recent observations compared to previous ones. Applying exponential weights to data causes them to decrease in significance exponentially as their age increases.
- Метод The Holt-Winter method, developing the principle of exponential smoothing, integrates the analysis of seasonal fluctuations.

Methods for processing time series. In the previous chapters, an introduction to the basics of time series analysis was given, including the study of their characteristics, key elements, limitations, and ways to reduce non-stationary time series to a stationary form. The time has come to pay attention to effective tools that help predict future values [21,65,70,8,65,70,86,92], interpret data, and extract important information from time series analysis.

Time series analytics uses a variety of techniques, among which the most common are:

- Autoregressive process (AR): A modeling approach that predicts the future value of a dependent variable by analyzing its past observations.
- Moving averages (MA) are time series methods where the future values of a variable are predicted by averaging the difference between actual values and their forecasts from past periods.
- The ARMA (авторегрессионнаяMoving Average Autoregressive Model) model integrates aspects of autoregression (AR) with moving average (MA) models.
- ARIMA (Autoregressive Integrated Moving Average) is an extension of the ARMA model that can be adapted for analyzing data with non-stationary time series.
- Autoregressive Model (AR)

The autoregressive model (AR) is a basic technique that allows you to estimate future indicators of time sequences based on their historical data. This analytical tool is widely used in predictive analytics when there is an obvious correlation between subsequent and previous values in a series.

The autoregression model (AR) is actually a linear regression, where the predictors are the previous values of the same time series [26,65,70,8,65,70,86,92], shifted in time by a certain number of steps, known as lag.

To develop a model, use AutoReg from ar_model, which is part of statsmodels. tsa. To demonstrate how to generate predictive data in this and other situations, we will perform a forecast for the next 365 days.

ARMA (AutoRegressive Moving Average) and ARIMA (AutoRegressive Integrated Moving Average) are statistical models used for time series analysis and forecasting. ARMA, which combines autoregressive and moving average, describes weakly stationary time series using autoregressive and moving average components reflected in two polynomials, respectively.

ARIMA, or autoregressive integrated moving average, is a statistical time-series forecasting model.

The main difference between the ARMA and ARIMA models is the use of integration. ARIMA applies differentiation to model changes between consecutive observations, allowing analysis of non-stationary time series. In contrast, ARMA is efficient for stationary time series and does not require a differentiation process to analyze them.

- Autoregression-applies historical data to predict subsequent values.
- The MA (Moving Average) model uses historical error data in a time series to predict future values [21,65,70,8,65,70,86,92].
- I = = > Applies series differentiation to achieve stationarity of the data.
- AR + I + MA = ARIMA

ARMA is best suited for predicting stationary series. To support both stationary and non-stationary series, the ARIMA model was developed [21,65,70,8,65,70,86,92].

The ARMA and ARIMA methods are characterized by a trio of parameters [26,65,70,8,65,70,86,92]:

- p (autoregressive lags): The number of previous observations in the time series used to estimate the present indicator.
- q (moving average delays): The number of misses in forecasting past milestones that are taken into account when creating an updated forecast.
- d (difference of orders): The number of data differentiations performed to achieve stationarity, which implies removing trends and seasonal fluctuations. In the context of the ARMA model, the order of differentiation is usually zero, since the ARMA model assumes that there is no need to differentiate data.

To determine the parameters of these models, it is important to study the autocorrelation function (ACF) and the partial autocorrelation function (PACF).

- Autocorrelation function (ACF).
- The Partial Autocorrelation Function (PACF) determines the correlation between time series, taking into account lags.

ACF measures the degree of similarity between the value of a time series and its past values with different time lags. In other words, the ACF measures the correlation between the time deviations of the series [4,65,70,8,65,70,86,92] and its lags by various lags [26,65,70,8,65,70,86,92].

A correlation coefficient approaching the values of 1 or -1 shows a high degree of correlation between variables at different time points, while a coefficient near 0 indicates that there is no correlation.

In real-world conditions, the autocorrelation function (ACF) helps to detect seasonality or cyclicity in time series data.

PACF is similar to the autocorrelation function, but a bit more complex to understand. PACF shows a direct correlation between the current value and its past values, taking into account time lags. However, it excludes the influence of intermediate values on this correlation [26,65,70,8,65,70,86,92].

In other words, the partial autocorrelation function (PACF) focuses solely on the direct effect of the previous data on the present value, without taking into account the indirect effect passing through other intermediate data points.

PACF is often used in determining the order of the autoregressive part (AR) of the ARMA and ARIMA models, helping to determine the number of lags that should be included in the AR model [26,65,70,8,65,70,86,92].

The study of autocorrelation functions (ACF) and partial autocorrelation functions (PACF) play a key role in analyzing time series, determining internal dependencies, and selecting adequate predictive models [20,65,70,8,65,70,86,92].

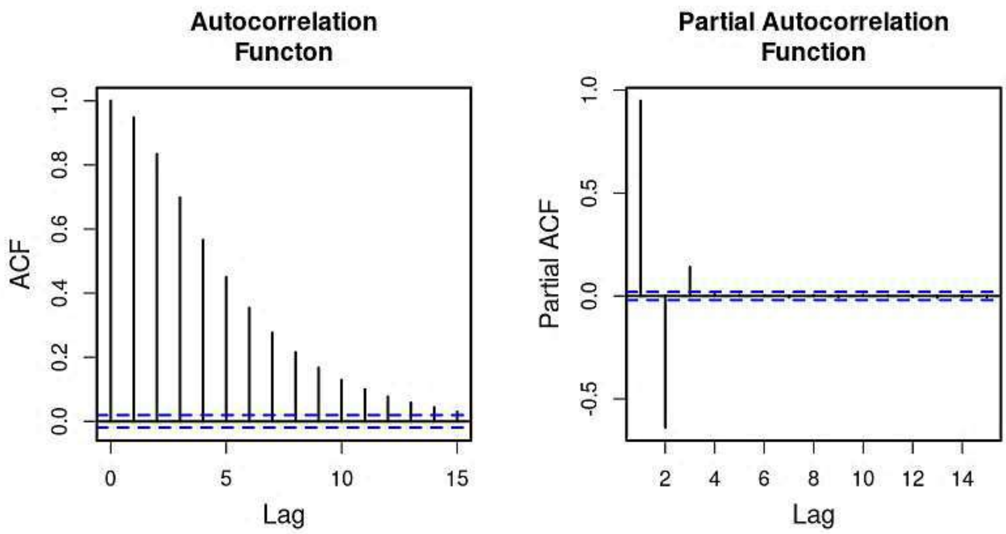

Figure 3.3. Graphs of autocorrelation and partial autocorrelation functions

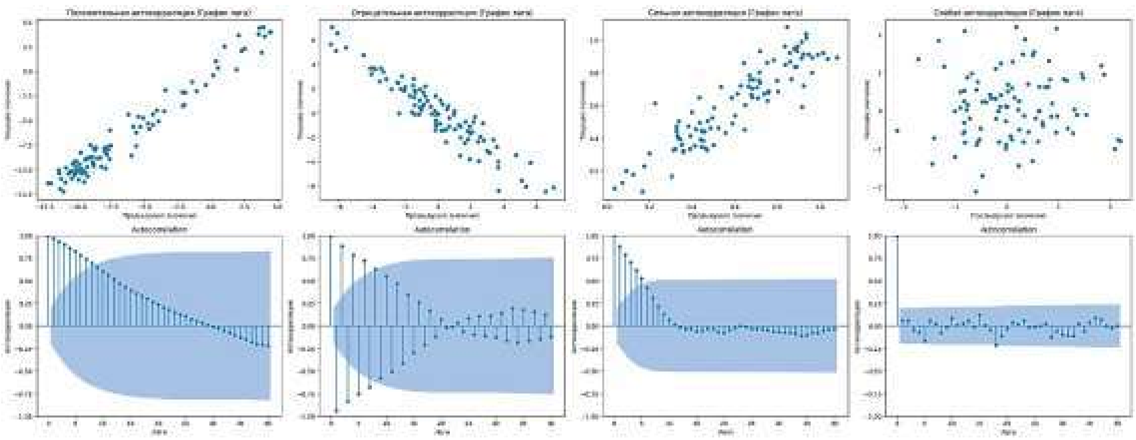

Figure 3.4. Analysis of ACF and PACF correlograms

- Autoregressive component (AR): When the autocorrelation function (ACF) slowly declines and the partial autocorrelation function (PACF) abruptly stops after several delays, this signals the need to integrate the autoregressive element into the model. The dimension of the AR component, i.e. the number of delays, is determined based on the PACF.
- Moving average component (MA): in the case of a slow decline in the partial autocorrelation function (PACF) and a sharp decline in the autocorrelation function (ACF) after several indents, this suggests that it is advisable to introduce a moving average component into the model. Its order can be determined by ACF analysis.

The study of the autocorrelation function (ACF) and partial autocorrelation function (PACF) contributes to determining the best parameters for autoregressive-moving average (ARMA) models The study of autocorrelation functions (ACF) and partial autocorrelation functions (PACF) play a key role in time series analysis, determining internal dependencies, and selecting adequate predictive models [21,65,70,8,65,70,86,92] and an autoregressive integrated moving average (ARIMA), improving their predictive accuracy and accurate representation of time series.

For the study of autocorrelation and partial autocorrelation functions, Python uses the methods plot_acfacf() and plot_pacf() from the Study of Autocorrelation Functions (ACF) and partial Autocorrelation functions (PACF). They play a key role in analyzing time series, determining internal dependencies, and selecting adequate predictive models [26,65,70,8,65,70,86,92] of the stats models library stats models.

Pronounced maxima are observed on the autocorrelation function (ACF) at lags of 1, 5, 10, and 15, emphasizing the presence of a seasonal effect in the studied time sequence with an interval of approximately 5 lags. At the same time, significant autocorrelation values are noticeable at intermediate lags, for example, at 2, 3, 4 and subsequent ones, which may indicate the presence of a multi-level autocorrelation structure with multiple autocorrelation components. Investigation of the partial autocorrelation function (PACF) can additionally help in identifying and interpreting these structures.

[11]:

ARDL Model Results

Dep. Variable:	y	No. Observations:	55
Model:	ARDL(2, 1, 2, 3)	Log Likelihood	136.252
Method:	Conditional MLE	S.D. of innovations	0.019
Date:	Thu, 14 Nov 2024	AIC	-246.504
Time:	17:07:19	BIC	-220.890
Sample:	3	HQIC	-236.654
	55		

	coef	std err	z	P>|z|	[0.025	0.975]
const	2.4440	0.546	4.479	0.000	1.342	3.546
y.L1	0.2695	0.139	1.944	0.059	-0.011	0.550
y.L2	0.3409	0.114	2.993	0.005	0.111	0.571
x0.L0	0.6344	0.145	4.368	0.000	0.341	0.928
x0.L1	-0.2426	0.159	-1.527	0.134	-0.563	0.078
x1.L0	-1.1316	0.359	-3.157	0.003	-1.856	-0.408
x1.L1	0.1056	0.640	0.165	0.870	-1.186	1.397
x1.L2	-0.8347	0.497	-1.679	0.101	-1.839	0.170
x2.L0	0.2849	0.614	0.464	0.645	-0.954	1.524
x2.L1	0.0433	0.805	0.054	0.957	-1.582	1.669
x2.L2	0.4429	0.770	0.575	0.568	-1.112	1.998
x2.L3	0.3671	0.515	0.713	0.480	-0.673	1.408

Figure 3.5. Partial autocorrelation function in Python

The Рисунокpartial autocorrelation function (PACF) figure shows pronounced autocorrelation peaks at the initial time shifts, in particular at lags 1 and 5, which become less pronounced as the time shift increases. This indicates the presence of an autoregressive component in the data. The presence of significant peaks at longer time shifts, such as lags starting from 5 and higher, confirms the hypothesis of seasonal fluctuations in the time series.

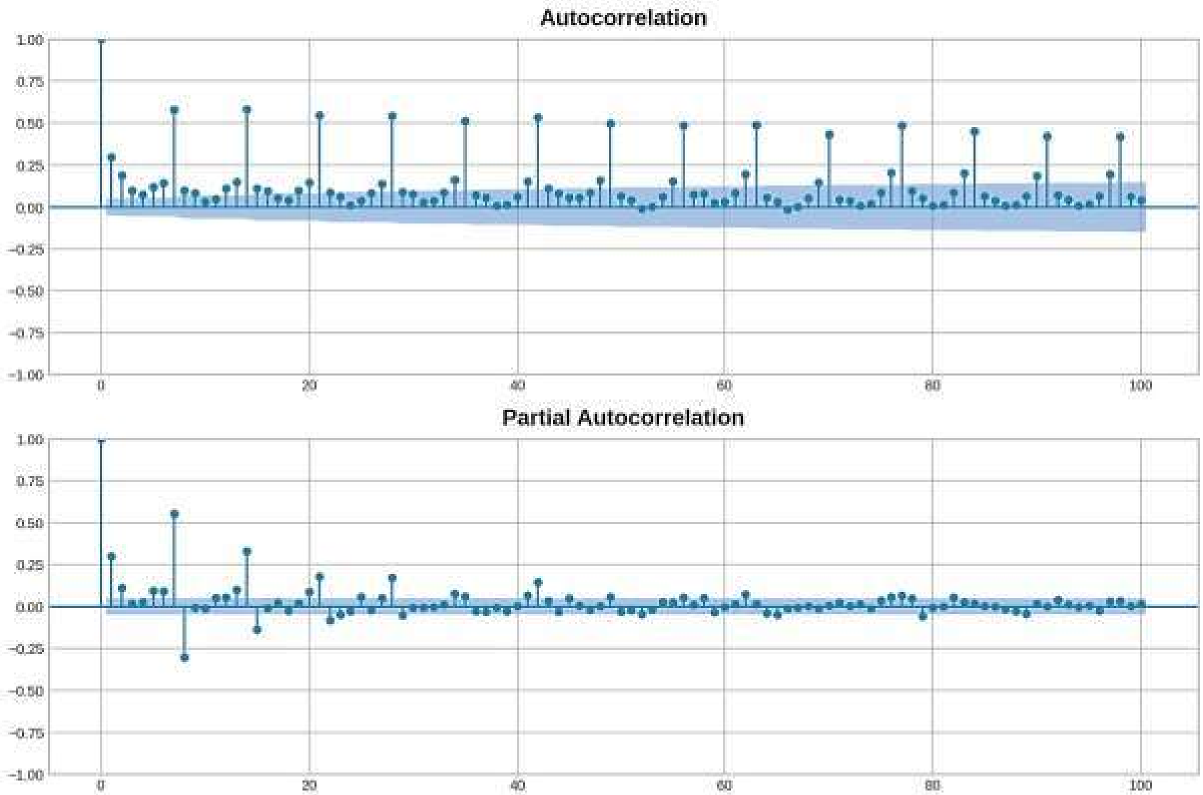

Figure 3.6. Plot of the partial autocorrelation function (PACF) together with the autocorrelation function (ACF)

Conclusions and selection of parameters:

AR (p) parameters:

The partial autocorrelation (PACF) plot shows significant outliers for the initial lags, such as the 1st and 5th, which suggests the presence of an autoregressive (AR) component in the time series. This indicates that the optimal value of the p parameter for the AR model can be approximately 5 or 10.

MA (q) parameters:

The autocorrelation function (ACF) shows high peaks at certain lags, indicating the presence of a moving average (MA) component in the data. The estimate of the order of q of this component can be approximately 5 or 10.

Seasonality:

Pronounced maxima on the autocorrelation function (ACF) and partial autocorrelation function (PACF) with lags of about 5 indicate the presence of seasonality in the time series under consideration. When modeling using ARIMA, the inclusion of seasonal components in the model will allow you to adequately take this factor into account.

In Python, ARMA and ARIMA models are developed using the statsmodels.tsa.arima_model module_model, which provides an ARIMA class specialized for analyzing and predicting time series data.

Methods of the ARIMA class:

- fit(): defines the model parameters.
- predict(): generates a forecast using the trained model.
- forecast(): calculates a forecast for a certain number of future periods.
- summary(): provides generalized data on model outputs.

In fact, the models we have analyzed can be applied in Python by using the ARIMA class. Consider the parameter order=(p, d, q) and potential combinations of these variables:

- (1, 0, 0): This structure assumes the use of a single lag of the time series for auto regression without integrating the moving average component, denoted as авторегрессионнойthe first-order autoregressive model AR(1) [21,65,70,8,65,70,86,92].
- (0, 0, 1) denotes a model that does not have an autoregressive component and uses only one lagged value of the forecast error to form a moving average, which is typical for the first-order moving average model MA(1).
- (1, 0, 1): This model actively applies one time series lag for the autoregressive component and one forecast error lag for the moving average component, representing the integrated ARMA model(1,1) [21,65,70,8,65,70,86,92].

```
[7]: det_proc.range("2025-01", "2026-01")
```

[7]:

	const	sin(1,12)	cos(1,12)	sin(2,12)	cos(2,12)
2025-01	1.0	-8.660254e-01	5.000000e-01	-8.660254e-01	-0.5
2025-02	1.0	-5.000000e-01	8.660254e-01	-8.660254e-01	0.5
2025-03	1.0	-1.224647e-15	1.000000e+00	-2.449294e-15	1.0
2025-04	1.0	5.000000e-01	8.660254e-01	8.660254e-01	0.5
2025-05	1.0	8.660254e-01	5.000000e-01	8.660254e-01	-0.5
2025-06	1.0	1.000000e+00	-4.904777e-16	-9.809554e-16	-1.0
2025-07	1.0	8.660254e-01	-5.000000e-01	-8.660254e-01	-0.5
2025-08	1.0	5.000000e-01	-8.660254e-01	-8.660254e-01	0.5
2025-09	1.0	4.899825e-15	-1.000000e+00	-9.799650e-15	1.0
2025-10	1.0	-5.000000e-01	-8.660254e-01	8.660254e-01	0.5
2025-11	1.0	-8.660254e-01	-5.000000e-01	8.660254e-01	-0.5
2025-12	1.0	-1.000000e+00	-3.184701e-15	6.369401e-15	-1.0
2026-01	1.0	-8.660254e-01	5.000000e-01	-8.660254e-01	-0.5

Figure 3.7. Applying the ARMA model to a stationary time sequence

- (1, 1, 1): Describes ARIMA(1, 1, 1), where the autoregressive part includes one lag value, the integrated part is represented by one differentiation order, and the moving average part relies on one previous predictive remainder.

It should be emphasized that the selection of a forecasting method is determined by the characteristics of time series and the presence of various components in them. Before using a specific approach, it is extremely important to achieve time series stability.

The use of moving average methods for data smoothing effectively reduces random noise, making it easier to identify long-term development directions. The decomposition of time series into components: trend, seasonal fluctuations and the residual part, contributes to a deeper analysis and understanding of their internal structure.

This integrated method improves the accuracy of predictions and contributes to the development of rational solutions based on the analyzed information, turning time series modeling into an effective tool for a wide range of practical tasks.

ARIMA (English Autoregressive Integrated Moving Average), sometimes the Box – Jenkins model, integrated autoregressive-moving average model – a model and methodology for time series analysis.

It is a supplement to ARIMA models, purposefully designed for the analysis of non-stationary time series [21,65,70,8,65,70,86,92], which can be converted to stationary ones by calculating differences of a given order from the initial data series, defining them as integrated or difference-stationary series. The essence of the model is that the differences in time series data of a particular order follow a certain model.

The application of the methodology of statistical analysis through SARIMA models in the study ensured the creation of accurate models with a high level of statistical reliability and predictability.

SARIMA- is метод a forecasting method, that uses модель the SARIMA (англ. Seasonal AutoRegressive Integrated Moving Average) model. This model combines the methods of autoregression, integrated moving average, and seasonality, which allows you to predict the future values of a series based on its previous values, taking into account seasonal patterns. SARIMA is widely used in economics and finance to predict stock prices, stock market indices, etc . [58,65,70,8,65,70,86,92].

The analysis of the stationarity of time series taking into account seasonal fluctuations was carried out using the HEGY test [58,65,70,8,65,70,86,92].

The HEGY method developed byHylleberg, Engle, Granger, and Yoois a standard approach for identifying seasonal unit roots in time series. This procedure formed the basis of the theory of seasonal integration and contributed to the formation of strategies for its analysis.

In the course of the study, the parameters under consideration had specific characteristics that were taken into account when developing the model.

Birth and death rates were characterized by second-and first-order integration, respectively, and both time series showed stable seasonal fluctuations. Data on completed marriages showed the first level of both general and seasonal integration, indicating a regular change in this indicator over time. At the same time, infant mortality statistics did not reveal any cyclical or seasonal trends, which was established based on the study of the autocorrelation function and analysis of period grams, confirming its stationary nature.

In the study, both point and interval forecast estimates were formed for the studied parameters for 2024 [2,65,70,8,65,70,86,92].

In the study, in addition to analyzing the effectiveness of SARIMA-methods forecasts, the time intervals of the Holt-Winters exponential smoothing model are estimated for comparison.

Метод The Holt-Winters method is an adapted version of exponential smoothing, specifically designed for processing time series with seasonal fluctuations. Unlike basic exponential smoothing, this technique additionally involves designing an exponential trend, i.e. the direction of changes in values in a time series, and additive seasonality, which indicates regular changes in data that repeat at certain intervals.

3.2. Theoretical basis for creating models

This chapter will introduce various definitions and symbols. The analyzed time series consists of the values y_1 , $y_{y1,y2} \dots y_n$, yn, reflecting a certain indicator of the population, namely, the number of births in Uzbekistan by month in thousands of people from 2024 to 2050, as shown in Figure 3.88. This series is considered as a sequence of realizations of random variables obeying a certain stochastic process. The Box-Jenkins approach is used to model and predict data using ARIMA / SARIMA models, which involves going through a series of specific steps.

Step 1. Checking the stationarity of time series. A random process is considered weakly stationary when its mean, variance, and autocovariance y_t yt do not change with time t: $E\ yt(y_t) = \mu < \infty, V(y_t\ ) = \ yt\ = \ y_0, cov\big(y_{yt}\ ,\ yt_{t-k}\big) - k\ =_k$yk, autocovariance.

The diversity of demographic phenomena is not constant; the elements of these processes are formed under the influence of various factors classified into four main types.

Stable elements define the main direction of dynamics of the considered variable $_t$yt.

For example, the sequence of the number of newborns by month, shown in Graph 3.8 for the period from 2024 to 2050, shows a visually obvious parabolic increase, while the data on the number of deaths by month in Uzbekistan, shown in Figure 3.99, shows a linear, downward movement [2,65,70,8,65,70,86,92].

It should be emphasized that in the subsequent analysis [2,65,70,8,65,70,86,92], it is critically important to be able to distinguish between two types of trends: deterministic and stochastic.

Seasonal impacts cause periodic fluctuations in the analyzed data in specific seasons of the year. Figuresк3.8-3.99, кроме show cyclical elements in addition to development trends. As mentioned above, birth and death rates in Uzbekistan are affected by cyclical factors.

It should be noted that the dynamics of demographic indicators do not always show clear directions of change, as exemplified by the data on the number of registered marriages in Uzbekistan [4,65,70,8,65,70,86,92] for different months, as shown in Figure 3.3. There is a periodicity in the data, however, it is difficult to identify a stable trend. Nevertheless, after 2023, a noticeable decline in the specified index is recorded. You can analyze the time interval based on the cyclical change graph and autocorrelation data.

Periodic dependence is defined as a correlation interaction of order k between $the\ i-th$ and $(i+k)\ -\ th$ elements of the sequence, expressed in terms of the correlation function $p(k)$, which depends on the lag interval [2,65,70,8,65,70,86,92].

In econometrics, distributed lag is a time series analysis, where regression analysis includes not only current indicators of the explanatory factor, but also its data for past intervals.

Key terms and computational expressions used in the study to study time intervals in time sequences. The sample autocorrelation function $p\ (k)$ in accordance with the shift k is calculated using the formula:

$$\hat{p}(k) = corr(y_t\ ,\ y_{t-k}) = \frac{\frac{1}{T-k}\sum_{t=k}^{T}(y_t - \hat{\mu})(y_{t-k} - \hat{\mu})}{1/_T \sum_{t=k}^{T}(y_t - \hat{\mu})^2} \qquad (3.1)$$

T-denotes the duration of the time series, m - is the sample mean, and $p(k)$ is a series of autocorrelation coefficients between y_t и $y_{yt\ and\ yt-k}$ [12,65,70,8,65,70,86,92].

The characteristic equation of the ARIMA model is an algebraic formula used to study the stationarity and reversibility of a time series modeled by an equation of this type [2,65,70,8,65,70,86,92]:

$$\alpha_p(L)y_t = \theta_q(L)\varepsilon_t, \qquad (3.2)$$

$$\alpha_p(L) = 1 - \alpha_1 L - \alpha_2\, L^2 \ldots - \alpha_p\, L^p, \qquad (3.3)$$

$$\theta_q(L) = 1 + \theta_1\, L + \theta_2\, L^2 \ldots + \theta_q\, L^q, \qquad (3.4)$$

$$L^k y_t =\ y_{t-k} \qquad (3.5)$$

To investigate stationarity, we formulate an equation describing the autoregressive (AR) component, known as the characteristic equation.

$$1 - \alpha_1 z - \alpha_1 z^2 \ldots - \alpha_p z^p = 0 \qquad (3.6)$$

To study the possibility of restoring the initial state of the system, an equation is compiled that describes the characteristics of the moving average auto regression process (ARMA), specifically its moving average component (MA).

$$1 + \theta_1 z - \theta_2 z^2 \ldots - \alpha_q z^q = 0 \qquad (3.7)$$

When the modules of the roots resulting from the characteristic equations exceed the value one, this indicates the stationarity and inevitability of the time series, respectively.

The unit root. This is a term used when studying the characteristic polynomial of a time series. When its roots are found to be equal to one [2,65,70,8,65,70,86,92], this indicates that the time series being analyzed is non-stationary.

For example, a time series that represents a non-stationary random walk process $y_t = y_{yt=yt-1} + et_t$with a characteristic equation in the form $1 - z = 0$. Solving this equation, we find that the root of z is one [4,65,70,8,65,70,86,92].

The Dickey-Fuller test is a statistical tool [4,65,70,8,65,70,86,92]used in the fields of empirical statistics and econometric analysis, designed to study time sequences of data in order to determine their stationary nature.

The unit root test is a method in the field of statistics for determining the stationarity or non-stationarity of a time series. It is also known as the unit root test. The analysis is based on checking the test equation$y_t yt = a_{yt-1} + e\ t_t a < 1$, which indicates the study of the existence of a random walk process characterized by non-stationarity. If the value of the coefficient a is less than 1, the time series can be considered as stationary in the context of autoregression, which corresponds to the autoregressive process AR.

The process of testing hypotheses about the stationarity of the time series should be described.

The initial hypothesis H_0H0 assumes that a = 1, which indicates the non-stationarity of the time series [4,65,70,8,65,70,86,92], while the alternative hypothesis H1 states that a < 1, which indicates the stationarity of the series. The transformed first difference equation $\Delta y_t = \beta\ y_{t-1} + \varepsilon_t$, where β is equal to a-1, is used for analysis.

In this context, the null hypothesis $H_0 H0: \beta = 0$ indicates a non-stationary process, and $H_{H1}: \beta < 0$ indicates a stationary process. The estimate of the parameter β and its standard error are calculated by the least squares method (OLS), after which the observed value $t_t$of the nab statistic [1,65,70,8,65,70,86,92]is calculated:

$$\check{t}_t set = \check{t} = \frac{\breve{\beta}}{S(\breve{\beta})} \sim DF \qquad (3.8)$$

The distribution of t-statistics differs from the standard t-distribution, since its values are determined based on the formula of the test equation, which includes the possible presence of a constant component and development trends. Data on the distribution are given in the publication of the developers of this test [1,65,70,8,65,70,86,92].

The integrability criterion $y_{of\ the\ sequence}$ yt is established based on the number of necessary iterations of the first differences $\Delta y_t yt \ = y_t - y_{yt\ -\ yt-1}$applied to the initial non-stationary time series to transform it into a stationary form [1,65,70,8,65,70,86,92].

This attribute is denoted as $I\ (d)$, where $I(0)$ indicates that the time series is already stationary, $I(1)$ indicates that the series reaches stationarity after performing one iteration of the difference, $I\ (2)$ indicates that it reaches stationarity after two differences, and so on. By analogy, the concept of seasonal integrability $Is(d)$is defined, for which seasonal differences $\Delta_{12}y_t \ = \ y_t - y_{t-12}$are used to identify and correct seasonal fluctuations [1,65,70,8,65,70,86,92].

Using the Holt-Winters method, a predictive model was created that was adapted to predict data with exponential growth and seasonal variations added.

Модель The Holt-Winters Model, which incorporates seasonal fluctuations, Holt-Winters Modelwas presented as follows:

$$\hat{y}_{t-\tau} = \{\hat{a}_t + \tau \cdot \hat{b}_t\} \cdot \hat{S}_{t-L+\tau} \tag{3.9}$$

$$\breve{a}_t = \alpha \frac{y_t}{\breve{S}(t-L)} + (1-\alpha)\{\breve{a}_{t-1} + \breve{b}_{t-1}\} \tag{3.10}$$

$$\breve{b}_t = \beta\{\breve{a}_t + \breve{a}_{t-1}\} + (1+\beta)\ \breve{b}_{t-1} \tag{3.11}$$

$$\breve{S}_t = y\frac{y_t}{\breve{a}_t} + (1-y)\breve{S}(t-L) \tag{3.12}$$

In a linear trend model, a_t and b_t represent parameters that determine the direction and rate of trend change, while S_t represents seasonality, that is, periodic fluctuations characteristic of the time series under consideration. The coefficients α, β and γ are smoothing parameters, each of which lies in the range from 0 to 1, and determine the degree of influence of current observations, trend and seasonal components on updating the predicted values, respectively. L indicates the length of the seasonal period, which is 12 months for monthly data, and τ indicates the forecast horizon, that is, how far forward in time the predicted values extend.

The root of mean square deviation (RMSE) serves as a key indicator of performance in evaluating regression predictive models, along with another important parameter.

Table 3.1. Configuration parameters in Holt-Winters methods[7]

Indicator	Adaptation parameters		
	α	β	γ
birth	0.673673	0.730730	0.64642
mort	0.504504	0.050	0.110110
mar	0.132	0.042	0.400400

In the context of time series analysis, in addition to the standard autocorrelation function $p(k)$ ACF, which measures the cross-correlation between time values at different lags, the concept of a partial autocorrelation function PACF is also used. This function detects the level of correlation between time series y_t и $y_{samples\ yt\ and\ yt-kk}$, [2,65,70,8,65,70,86,92] , while excluding the influence of all intermediate time samples y_{t-1}, $y_{yt-1,yt-2}$, ..., $y_{yt-kk+1}$. PACF is similar to calculating partial correlation in statistics, providing a more accurate representation about relationships in data when analyzing time series.

In time series analytics, correlograms that include graphs of the autocorrelation function (ACF) and partial autocorrelation function (PACF) are key tools for identifying seasonal patterns. When studying seasonal monthly time series, the ACF and PACF graphs clearly show elevations on lags corresponding to periods of 12, 24, 36, and so on months, which indicates the presence of autocorrelations with these intervals between time points. This phenomenon is an indicator of seasonal fluctuations, which can have a noticeable impact on the behavior of the time series. In the context of checking for stationarity, the analysis of correlogram data is a critical step that allows you to study the structure of time series in depth.

Cyclical impacts contribute to fluctuations in the studied attribute caused by long periods, including changes in the population.

[7] Note. Adaptation parameters were selected automatically in Stata based on RMSE minimization.

Random effects that cannot be predicted affect the creation of values in the data sequence, giving it a stochastic or probabilistic character.

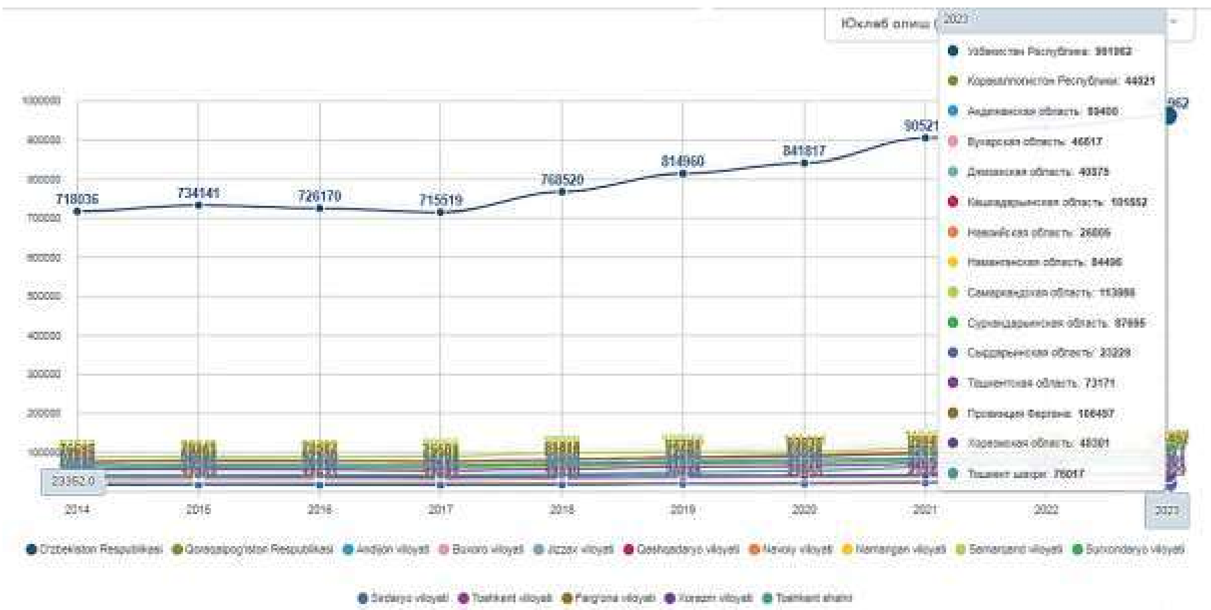

Figure 3.8. Number of newborns in Uzbekistan, thousand people

There are various methods for establishing the stationarity of a time series.

First of all, visual research of time series: detection of a trend of growth or decline, or cyclist, as well as changes in the variability of data over time serves as a certain sign of non-stationarity of the sequence.

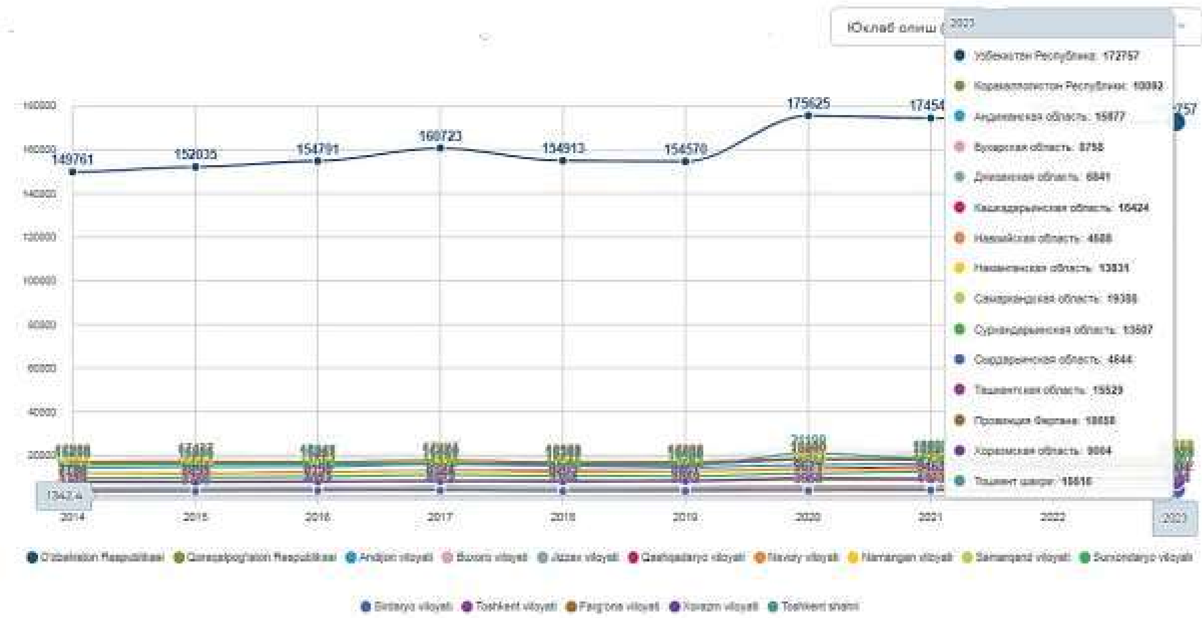

Figure 3.9. Number of deaths in Uzbekistan, in thousands.

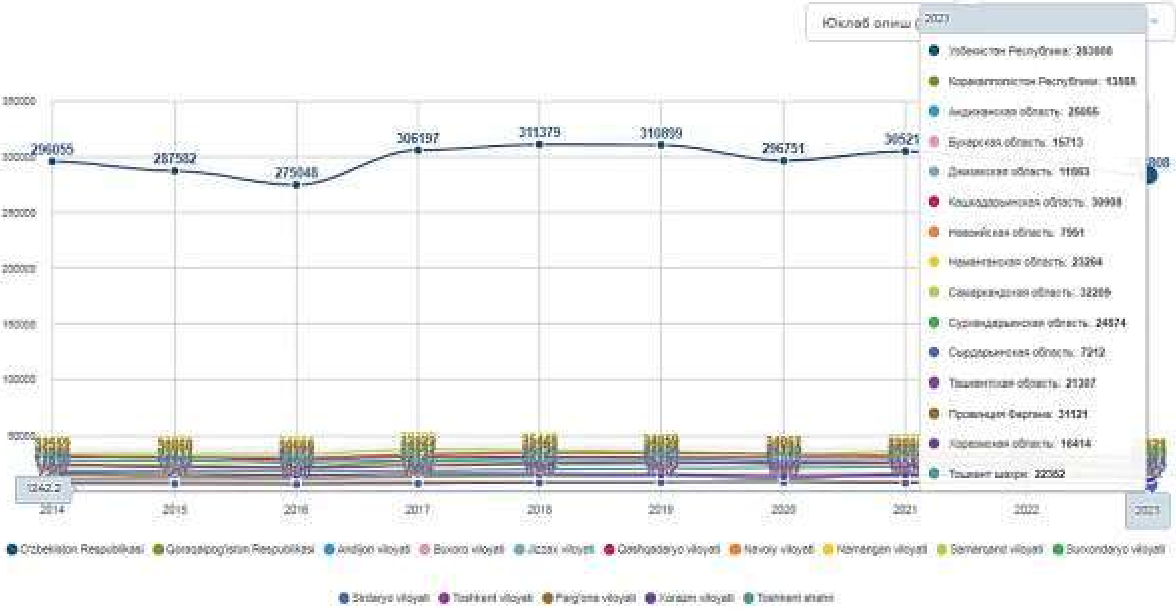

Figure 3.10. Number of officially registered marriages in Uzbekistan, thous.

Secondly, the study of the correlogram of the autocorrelation function (ACF) and the partial autocorrelation function (PACF) shows that for stationary time series, the values of these functions "rapidly decrease" after several initial time intervals.

The third aspect concerns the use of specialized statistical methods, namely tests for the presence of a single root [2,65,70,8,65,70,86,92].

Unit root is the main term used in studying the characteristic equation of a system. In the case when at least one of the solutions of this equation is one, the process to be investigated demonstrates non-stationarity.

Thus, for a nonstationary random walk process defined by the equation $y_t = y_{yt=yt-1} + et_{,the}$characteristic equation $1 - z = 0$ leads to the solution where the root $is\ z = 1$.

For example, if the lagged first differences are added to the regression models in the ADF test, the distribution of the Dickey-Fuller statistics, and, accordingly, the critical thresholds, remain unchanged. This approach is calledФуллерathe Augmented Dickey -Fuller (Dickey-FullerADF) test.

The Dickey-Fuller test is a method of data analysis used to determine the presence of stationarity in time series, also known as the unit root method. This test operates with a specific equation: $y_t yt = a_{yt-1+} + et_t$, where the study focuses on the study of the random walk model. In fact, such a model assumes the absence of stationarity. When the value of the coefficient $a < 1$, it indicates the presence of a stationary process in the autoregressive model (AR), which is a model where the current value of the time series is expressed in terms of its previous values.

Therefore, the initial hypotheses are formulated:$zero$ $_0$H0, which assumes that $a = 1$, which indicates the presence of a non-stationary process, and $alternative_{H1}$, according to which $a < 1$, which characterizes the process as stationary. The study then proceeds using the difference equation $\Delta y\, yt_t = \beta\, y_{yt-1} + \varepsilon\, t_t$, where β is the difference between a and unity. In this context, revised hypotheses are formulated: the null H_0H0 asserts that $\beta = 0$, which means non-stationarity, and $the\ alternative_{H1}$ asserts that $\beta < 0$, indicating stationarity. The parameter β and its standard error are estimated using the least squares method (OLS), which is used to calculate $t_{the\ t}$nab statistic[2,65,70,8,65,70,86,92]:

$$\check{t}_t set = \check{t} = \frac{\breve{\beta}}{S(\breve{\beta})} \sim DF \qquad (3.13)$$

The distribution of t-statistics deviates from the standard distribution of t-statistics [2,65,70,8,65,70,86,92]; its indicators are the contour of the equation formed from the uniqueness of the structure of the tested equation, which includes possible constants or trends. These results are systematized in the research report of this test.

Тест The Phillips-Perron test is intended for situations where the assumptions about uncorrelated errors and their constant variance in the analyzed model are violated. This means that errors may exhibit autocorrelation, differ in the level of variance, and do not follow a normal distribution. Due to these features, the PP test is applicable to a wider range of time series.

The PP test is recommended for use in cases of severe seasonality and significant structural changes.

The Kwiatkowski-Phillips-Schmidt-Schin KPSS test determines whether a time series is stationary around a mean or linear trend, or non-stationary due to the unit root. A stationary time series is a series in which statistical properties, such as the mean and variance, remain constant over time.

In the context of applying the Augmented Dickey-Fuller (ADF) test and the Phillips-Perron (PP) test, it is based on testing the hypothesis of the presence of a unit root indicating the non-stationarity of the time series. The alternative assumes that it is stationary, possibly with the addition of a constant term or trend. In contrast, when performing the KPSS test (Kwiatkowski-Phillips-Schmidt-Shin test), the initial hypothesis assumes the stationarity of the time series and the absence of a unit root, which means that it is constant in time without a trend [2,65,70,8,65,70,86,92].

Stage 2: Defining and analyzing the model. The general view of the ARMA $(p, q)\ model$ (Autoregression and Moving Average) is presented as follows [2,65,70,8,65,70,86,92].

$$\alpha_p(L)y_t = \theta_q(L)\varepsilon_t \quad (3.14)$$

where $\varepsilon_{e\ t}$ is white noise, it is a stochastic process with the characteristics: zero mathematical expectation and covariance function equal to zero [2,65,70,8,65,70,86,92] in all cases except one, while the variance remains unchanged and is equal$y_0 = to\ y0 = \sigma^2$, denoted.

$$L\ y_t = y_{t-1}, L^k\ y_t = y_{t-k} \text{ is the shift operator.} \quad (3.15)$$

$$\alpha_p(L) = 1 - \alpha_1 L - \alpha_2 L^2 \dots \alpha_p L^p, \quad (3.16)$$

$$\theta_q(L) = 1 + \theta_1 L + \theta_2 L^2 \dots \theta_q L^q \quad (3.17)$$

When analyzing demographic processes, experts often work with non-stationary time series, which can be converted to stationary ones using the sequential difference method to simplify the analysis. The first step of this method is to calculate the first difference, which is defined as $\Delta y_t yt\ = y_t - y_{yt\ -\ yt-1}$.

Essentially, the first difference represents the process of moving from the initial value to its changes.

If we transform a random process $y_t$yt by d applying the sequential difference operator d-fold until stationarity is achieved, obtaining a process $\Delta^d y_t$yt that corresponds to the model of [2,65,70,8,65,70,86,92] auto regression and moving average ARMA .(p, q), then this original process y_t yt is classified as an integrated ARIMA process (p, d, q). This process is considered as an integrated ARIMA process p, d, q. it has a general analytical form.

$$\alpha_p(L)\Delta^d y_t = \theta_q(L)\varepsilon_t \tag{3.18}$$

In real-world problems, analysts encounter time series whose inerrability does not exceed two, i.e. these series reach stationarity after moving to their first or second differences. To estimate the parameters of ARIMA models, the maximum likelihood method is usually used [2,65,70,8,65,70,86,92].

At the third stage, the model is checked for adequacy. The term "adequacy" in the context of ARIMA/SARIMA models refers to the satisfaction of the basic assumptions of these models, including the analysis of roots obtained from the equations defining the model, checking the residuals for autocorrelation, and their compliance with the normal distribution [2,4,65,70,8,4,65,70,86,92].

The characteristic equation of the ARMA model is an algebraic expression used to study stationarity and reversibility in the framework of processes defined by equations [2,65,70,8,65,70,86,92] of a certain type.

$$\alpha_p(L)y_t = \theta_q(L)\varepsilon_t, \tag{3.19}$$

$$\alpha_p(L) = 1 - \alpha_1 L - \alpha_2 L^2 \ldots - \alpha_p L^p, \tag{3.20}$$

$$\theta_q(L) = 1 + \theta_1 L + \theta_2 L^2 \ldots + \theta_q L^q, \tag{3.21}$$

$$L^k y_t = y_{t-k} \tag{3.22}$$

To investigate stationarity, we formulate an equation describing the AR component in the following form:

$$1 - \alpha_1 z - \alpha_1 z^2 \ldots - \alpha_p z^p = 0 \tag{3.23}$$

To study the reversibility of the process, we formulate a characteristic equation for the autoregressive part of the following type:

$$1 + \theta_1 z - \theta_2 z^2 \ldots - \alpha_q z^q = 0 \tag{3.24}$$

When the absolute values of the roots of the characteristic equations exceed one, this indicates the stationarity and invertibility of the time series, respectively.

Various metrics are used to analyze the effectiveness and comparative evaluation of the developed ARIMA models: it is important that the estimates of the model parameters have statistical significance, and the time series of residuals correspond to the characteristics of white noise, which allows the use of the autocorrelation function (ACF), which checks the condition of zero autocorrelation $\rho_k pk = 0$ for all lags k, and the Leung-Box criterion to estimate autocorrelation on a group of consecutive lags.

Q-тест The Leung-Box Q-test is a statistical verification method used to detect autocorrelation relationships in time series data. This approach combines the analysis of multiple autocorrelation coefficients, estimating their combined deviation from zero, instead of examining each coefficient separately for randomness.

In the context of identifying the most suitable of a number of adequate ARIMA models, preference is given to the one that has the minimum number of parameters while maintaining a high level of statistical indicators of selection accuracy.

To make this choice, model evaluation criteria are widely used, among which the Akaike Information Criterion (AIC), developed to compare the quality of various statistical models based on their internal information efficiency, and the Schwartz information criterion, also known as BIC (Bayesian Information Criterion), designed to evaluate models within the framework of the Bayesian approach, taking into account the number of parameters in the model.

Stage 4: Creating a forecast. The calculation of future values was based on the principle of calculating conditional mathematical expectations for the simulated processes, and the duration of the forecast period was up to 12 months. To select the most appropriate forecasting methodology, we analyzed the predictive effectiveness of models, including evaluating their accuracy using error metrics detailed in Table 3.2.

Table 3.2. Prediction accuracy parameters[8]

Estimation of prediction accuracy	Calculation formula
Standard Deviation, RMSE (Root Mean Squared Error)	$RMSE = \sqrt{\frac{\sum_{i=1}^{h}(\hat{y}_{T,i} - y_{T+i})^2}{h}}$
Average relative percentage error, MAPE (Mean Absolute Percentage Error)	$MAPE = \frac{1}{h}\sum_{i=1}^{h}\left\lvert\frac{\hat{y}_{T,i} - y_{T+i}}{y_t}\right\rvert * 100\%$
MPE (Mean Mean Percentage Error), or Mean Percentage Error	$MPE = \frac{1}{h}\sum_{i=1}^{h}\frac{y_{T+i} - \hat{y}_{T,i}}{y_{T+i}} * 100\%$
Mean Absolute error, % (Mean Absolute Error)	$MAE\frac{1}{h}\lvert\hat{y}_{T,i} - y_{T+i}\rvert$

MAPE and MPE are absolute measures of forecast quality: the forecast is considered good if the values are less than 10%. RMSE and MAY are relative measures and depend on the indicator's units of measurement. RMSE is most often used to compare forecasts for different models [2,65,70,8,65,70,86,92].

It should be emphasized that in order to assess the accuracy of the predicted values, the sample under study, which includes 125 units of observations, was purposefully divided into two key groups: the training [2,65,70,8,65,70,86,92] subgroup, which included the first 112 records, and the test subgroup, which included the last 2 0 records. This approach, where the test group is allocated approximately 10% of the total number of observations in the data set, is a standard procedure for evaluating the quality of a model based on unknown data.

3.3 Statistical methods of analysis and modeling of periodic demographic data

Seasonal Holt-Winters methods based on the exponential smoothing method (Holt-Winters - HW model) were used to estimate the accuracy of predictions - HW) [2,65,70,8,65,70,86,92].

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[8] Note: $\hat{y}_{T,it}$ are the predicted values of the series at time $T + i$ steps forward, $y_t$are the observed values of the series at time $T + i$, h is the prediction horizon.

Метод The Holt-Winters method develops the concept of exponential smoothing, adapting it to analyze seasonal data. This model expands the field of application to include exponential trend change (the direction and rate of changes in data over a time period) and an additive form of seasonality (uniform time changes characteristic of certain periods).

Модель прогнозирования The Holt-Winters Seasonally Adjusted Forecasting Model (Holt-Winters Model) was studied as follows:

$$\hat{y}_{t-\tau} = \{\hat{a}_t + \tau \cdot \hat{b}_t\} \cdot \hat{S}_{t-L+\tau} \quad (3.25)$$

$$\hat{a}_t = \alpha \frac{y_t}{\hat{S}(t-L)} + (1-\alpha)\{\hat{a}_{t-1} + \hat{b}_{t-1}\} \quad (3.26)$$

$$\hat{b}_t = \beta\{\hat{a}_t + \hat{a}_{t-1}\} + (1+\beta)\hat{b}_{t-1} \quad (3.27)$$

$$\hat{S}_t = y\frac{y_t}{\hat{a}_t} + (1-y)\hat{S}(t-L) \quad (3.28)$$

where a_t, b_t denote the linear trend coefficients, S_t-the seasonal component, $0 < \alpha, \beta, y < 1$– smoothing coefficients, $L = 12t$ indicates the frequency of monthly data, τ – the forecast period, as indicated in Table 3.3.

To assess the statistical significance of differences between the predictive abilities of different models, the Diebold-Mariano test was used.

Тест Диболда-МарианоTheDiebold - Mariano testis a statistical tool used to evaluate and compare the performance of two different time series forecasting models. A special feature of the test is its ability to adapt to a wide range of non-standard distributions of prediction errors.

Table 3.33. Tuning characteristics in Holt-Winters smoothing models[9]

Indicator	Adaptation parameters		
	α	β	γ
birth	0.673673	0.730730	0.642642
mort	0.504504	0.152,152	0.110110
mar	0.124	0.420420	0.400400

[9] Note. Adaptation parameters were selected automatically in Stata based on RMSE minimization.

In particular, the Diebold-Mariano test does not require that errors follow the assumptions of a normal distribution, have zero mathematical expectation, or lack autocorrelation. This test can work effectively even in the presence of errors with abnormal characteristics, including laughter, as well as serial and cross-correlation.

This criterion provides reliability for a wide range of loss functions, covering those that are not limited to quadratic, symmetric, or even continuous in nature. In addition, the distribution of prediction errors may deviate from the Gaussian distribution, including errors with a non-zero mean and showing correlations in both time sequence and instantaneous coincidence.

This point is critical, given that the analyzed forecasts relate to the same time series, based on similar data sets, which implies the possibility of a high degree of correlation between errors. However, in a broader sense, forecasting errors often show a serial correlation, and the presented methodological approach allows us to adequately take into account this specific feature.

There are also adaptations of the criterion for analyzing unidirectional hypotheses and short sequences of data over time.

SARIMA. One of the extensions of ARIMA models is seasonality accounting, estimating the so-called SARIMA models that combine the seasonal component and the usual ARIMA model. In seasonal SARIMA models, it is also necessary to estimate additional parameters of seasonal components: SARIMA$(pP_{,} d, q)(Ps_{,ds,qs}, Q_s)), where_s$ps

$D_{is\ the\ seasonal\ autoregression\ order,ds\ is\ the}$ seasonal difference $Q_s$order, and qs is the seasonal moving average order. In general, the multiplicative seasonal model SARIMA (p, d, q) $(P_{Ps}, D_{,}DS,_{qs})$, written through the lag operator, has the form [2,65,70,8,65,70,86,92].

$$\alpha_p(L)\alpha_{p_s}(L)\Delta^d\Delta_s^D y_t = \theta_q(L)\theta_{Q_s}(L)\varepsilon_t \quad (3.29)$$

where

$$\alpha_{p_s}(L) = 1 - \alpha_{S1}L^5 - \alpha_{S2}L^{2s} .. - \alpha_{sP}L^{Ps} \quad (3.30)$$

$$\theta_{Q_s}(L) = 1 + \theta_{S1}L^5 - \theta_{S2}L^{2s} .. - \theta_{sQ}L^{Qs} \quad (3.31)$$

The process of analyzing SARIMA models corresponds to the method of analyzing ARIMA models, but there are specific details concerning the establishment of the level of seasonal differentiation $D_{of\ Ds}$.

To identify the level of seasonal integration, specialized methods are used to check the presence of seasonal unit roots [20,65,70,8,65,70,86,92]. It should be emphasized that traditional methods of single root diagnosis, such as ADF (Augmented Dickey-Fuller test), PP (Phillips-Perron test), and KPSS (Kwiatkowski-Phillips-Schmidt-Shin test), become ineffective in analyzing seasonal data. In this regard, their adapted versions are used for an adequate assessment of seasonal integration.

In our study, we use the HEGY test, which is a modern methodological tool for diagnosing the stationarity of time series, allowing us to identify both seasonal and non-seasonal unit roots.

The HEGY test, developed by scientists Hylleber, Engle, Granger and Yoo, has become widely recognized in the field of seasonal time series analysis for identifying single roots. This method of testing has become widely used and recognized in academic circles, becoming the starting point for many studies aimed at its refinement and adaptation to various operating conditions. It is important to note that the concept underlying the HEGY method contributed to the formation of the concept of seasonal integration and the subsequent development of methods for its analysis. In this regard, in my research, the HEGY test will be considered with particularly careful attention in comparison with other similar methods.

We initiate parameters for studying the stationarity of time sequences. Let's set the symbols for the subsequent display of outputs:

- birth rate - the number of newborns in Uzbekistan, broken down by month (thousand people);
- mort - statistics of mortality in Uzbekistan, expressed in thousands of people on a monthly basis.
- mar is a series of data showing the number of officially registered marriages in Uzbekistan (expressed in thousands), broken down by month.

- inf is an indicator that shows the number of children who died before the age of one year (people).

The definition of the period for conducting the analysis (from October 2023 to November 2024, the total number of data points in the time series is 127) is set by restrictions on the availability of seasonal statistical data for the parameters of interest on the official website Агентствоof the Statistics Agency of the Republic of Uzbekistan under the President for the duration of the study.

Initially, a three-component testing method was used to analyze the stationarity of sequences:

- performing the Dickey-Fuller test (ADF), the Phillips-Perron test (PP), and the Kwiatkowski, Phillips, Schmidt, and Shin test (KPSS) [9] for time series stationarity using different model settings: including only the constant term; the constant term, and the linear trend; as well as the constant term, linear trend, and seasonal dummyvariables [46,65,70,8,65,70,86,92].

Data analysis performed using generally accepted methods, such as the Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests [9], does not allow us to draw a categorical conclusion about the integrability of the time series under study. The problem is that the presence of seasonal fluctuations in the analyzed data has a significant impact on the characteristics of the series, distorting the resultsof checking their stationarity.

These testing methods inherently do not take into account the presence of non-deterministic seasonality, which cannot be adequately described using deterministic components, for example, using seasonal indicator variables [4,65,70,8,65,70,86,92].

Birth rate time series. Figure 3.1111 shows a visualization of the birth rate time series. There are noticeable features, such as an obvious parabolic trend and pronounced seasonality, indicating the non-stationarity of this time series.

Birth statistics for 2023 show a significant increase in the number of newborns in the summer months, mainly in July, August and September, while the least active months in this regard are February and April, according to schedule 3.11.

Study of periodicity in the studied parameters.

Interpretation of the birth time series correlogram birth illustrated in Figure 3.1212reveals trend movement (a gradual decrease in the autocorrelation function (ACF) at the initial lags) and seasonal fluctuations (expressed by ACF maxima at lags commensurate with the seasonality interval, such as k = 12, 24, 36, while a decrease in the amplitude is observed) [20,65,70,8,65,70,86.92].

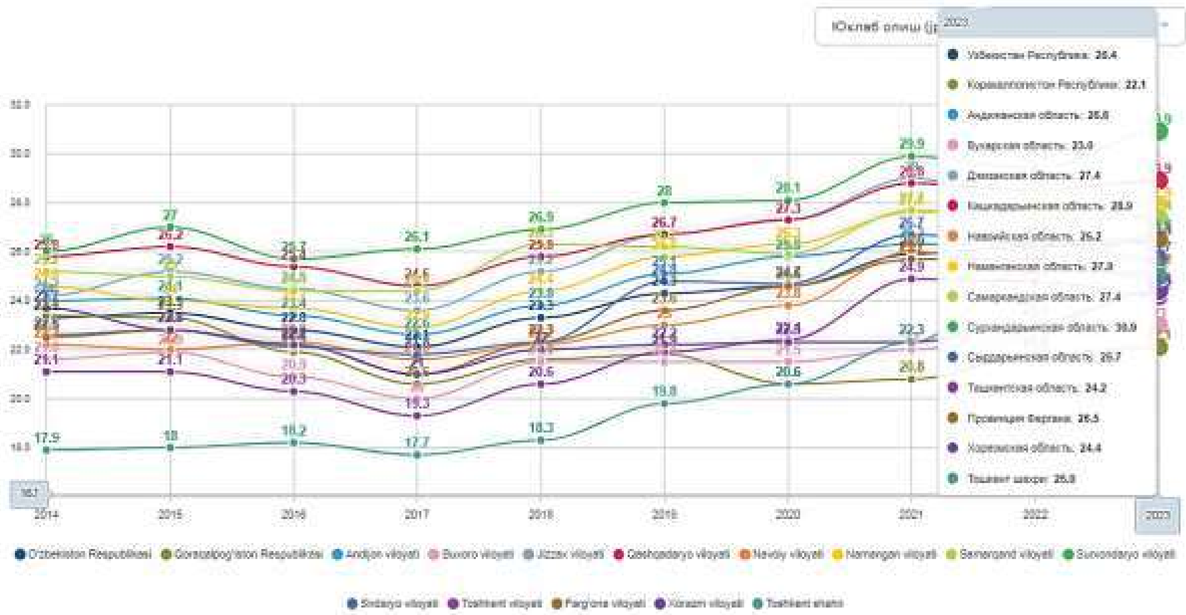


Figure 3.11. Statistics of registered newborns in Uzbekistan: annual comparison, thous.

The results of the in-depth analysis were determined by [20,65,70,8,65,70,86,92]. The Dickey-Fuller test (ADF), the Phillips-Perron study (PP), and the Kwiatkowski-Phillips-Schmidt-Shin test (KPSS).

To evaluate the birth indicator at different stages, namely at the first and second difference, the data are presented in Table 3.4, indicating the ambiguity of the results obtained.

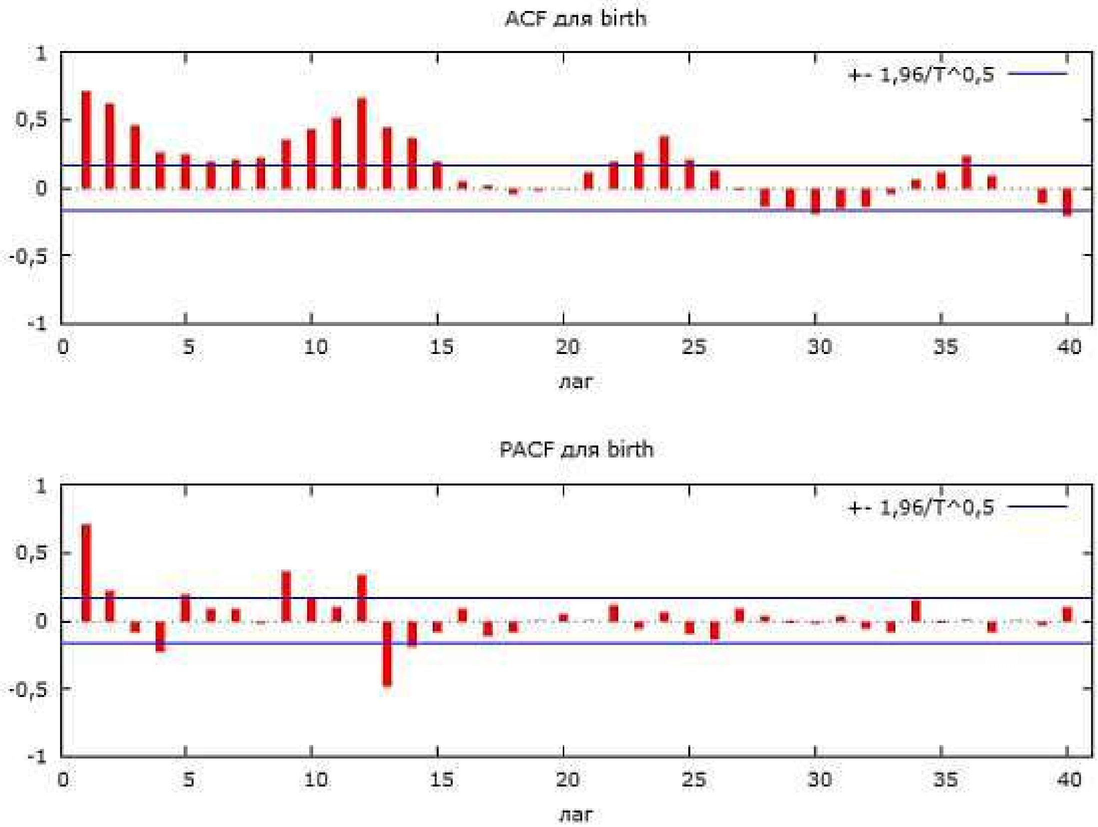


Figure 3.12 Graph of the time series of fertility data

With a significance of 5%, the results of the ADF test show that it is impossible to reject the hypothesis of the presence of a unit root in the time series at the level that indicates its non-stationarity and the absence of both linear and parabolic trends [2,65,70,8,65,70,86,92]. Also, the KPSS test, which checks the series for stationarity, demonstrates the rejection of the null hypothesis of stationarity for all the considered variations, confirming the non-stationary nature of the series.

Thus, the results of the Phillips-Perron test indicate that the time series is stationary, indicating that the null hypothesis of the presence of a unit root is rejected.

When studying the results of the Dickey-Fuller test on the first difference of the "birth" time series, a deterministic linear trend can be detected (refutation of the null hypothesis at a 5% significance level for this specification) [4,65,70,8,65,70,86,92].

Therefore, we can conclude that for the birth series, the integration order is $d = 2 \; or \; d = 1$, which implies the need to include the linear deterministic trend [2,65,70,8,65,70,86,92] in subsequent analytical models. However, given the conflicting data obtained, it is also extremely important to analyze the seasonal integrability of this time series.

Dannihilated mort. A visualization of the mort time series is shown in Figure 3.14. As mentioned earlier, this series has a linear downward trend and seasonal fluctuations, confirming its non-stationary nature.

Table 3.4. Outcomes of stationarity analysis for fertility data[10]

Time Series	Test	Test Specification	Statistic value	P - value
birth	ADF	1	-0,410	0,478
		2	0,3047	0,989
		3	0,0301	0,897
		4	-2,9403	0,967
	PP	1	-3,5054	0,023
		2	-5,4668	0,044
		1	0, 9506	0,027
	KPSS	2	0,3654	0,000
		3	0,7553	0,004
		1	-2,5386	0,547
Δbirth	ADF	2	-3,6880	0,020
		3	-4,6994	0,462
	PP	1	-7,5892	0,140
		2	-1,4041	0,085
		1	0,9480	> 0,5
	KPSS	2	0,7100	> 0,7
		3	0,3240	> 0,8
Δ^2birth	ADF	1	-1,3793	0,012
	PP	1	-4,904	0,140
	KPSS	1	0,3760	> 0,7

Ha Figure 3.13 shows that the maximum number of deaths is recorded in January and March, while the decrease in the number of deaths is observed in the summer-autumn period (July-September), reflecting a long-standing trend.

[10] Note: 1 – with a constant, 2 – with a constant and a trend, 3 – with a constant, trend and seasonal dummy variables, 4 – with a constant and a quadratic trend.

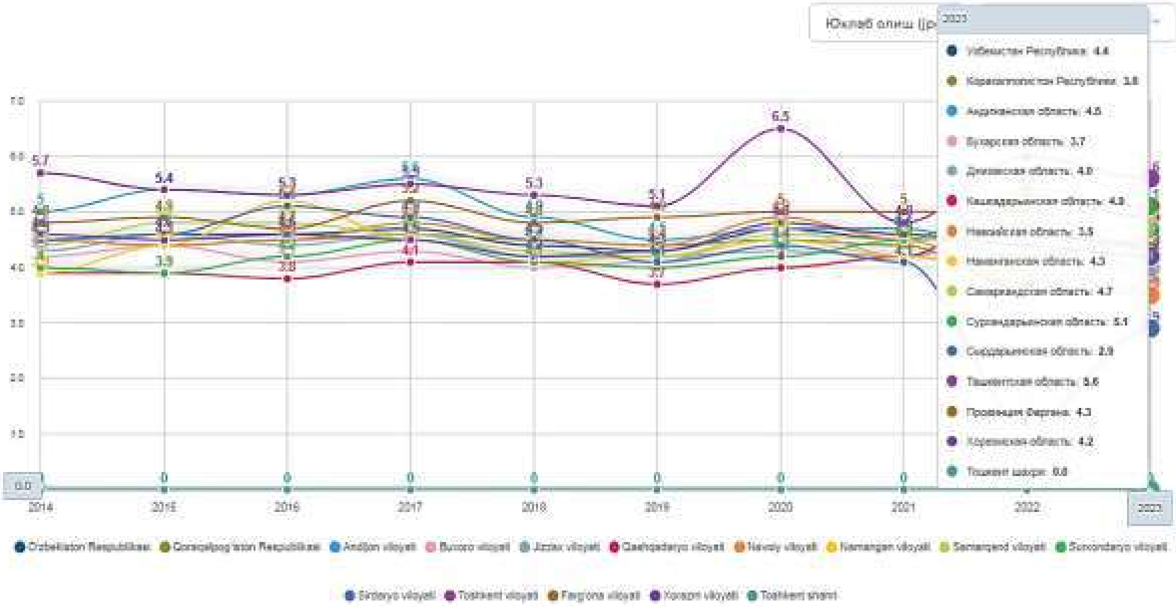


Figure 3.13 Mortality in Uzbekistan: analysis by year, in thousands.

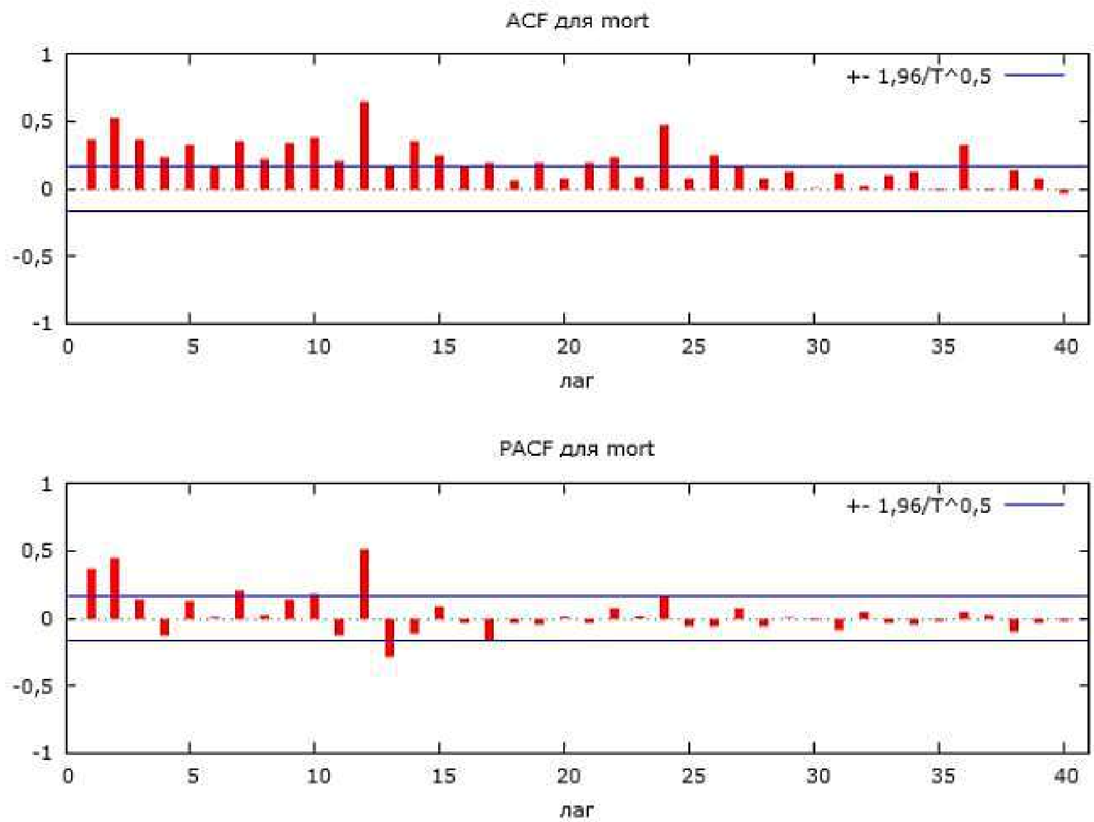


Figure 3.14 Representation of the correlation relationship in the mortality time series

The period from 2020 to 2022 was exceptional, when from February to November there was a noticeable increase in excess compared to the annual level due to the Covid-19 coronavirus pandemic, classified as an international emergency in Uzbekistan.

The study of the mort time series correlogram mortin Figure3.14 reveals the trend component (decrease in the autocorrelation function, ACF, at the initial lags) and seasonal fluctuations (pronounced ACF maxima at lags that are multiples of the seasonal period (k = 12, 24, 36), while the amplitude gradually decreases).

Table 3.5 presents the results of the hospital check for a sample of mortality data.

As a result of the analysis of time series, dissonances in conclusions reappeared: The Dickey-Fuller (ADF) and Kwiatkowski-Phillips-Schmidt-Shin (KPSS) tests demonstrate the presence of non-stationarity in the data, while the Phillips-Perron (PP) test [4,65,70,8,65,70,86,92] confirms the stationary nature of the process, refuting the hypothesis of the presence of non-stationarity in the data. a single root at the significance level of 0.01.

The time series mar, and its representation in Figure 3.1515, when carefully examined, does not reveal a clear upward or downward trend, indicating that there is no trend.

Table 3.5. Results of mort sequence stationarity analysismort[11]

Time Series	Test	Test Specification	Statistic value	P-value
mort	ADF	1	-0,17535	0,478
		2	0,3047	0,989
		3	0,0301	0,897
	PP	1	-2,9403	0,967
		2	-3,5054	0,023
		1	-5,4668	0,044
	KPSS	2	0, 9506	0,027
		3	0,3654	0,000

Instead, the analysis allows us to observe a clearly traceable seasonality, characterized by an increase in activity in the summer Months-July, August and

[11] Примечание: 1 – с константой, 2 – с константой и трендом, 3 – с константой и сезонными фиктивными переменными.

September-and noticeable drops in May, which remains stable throughout the entire time interval under consideration, as shown in Figure 3.1414 [20,65,70,8,65,70,86,92].

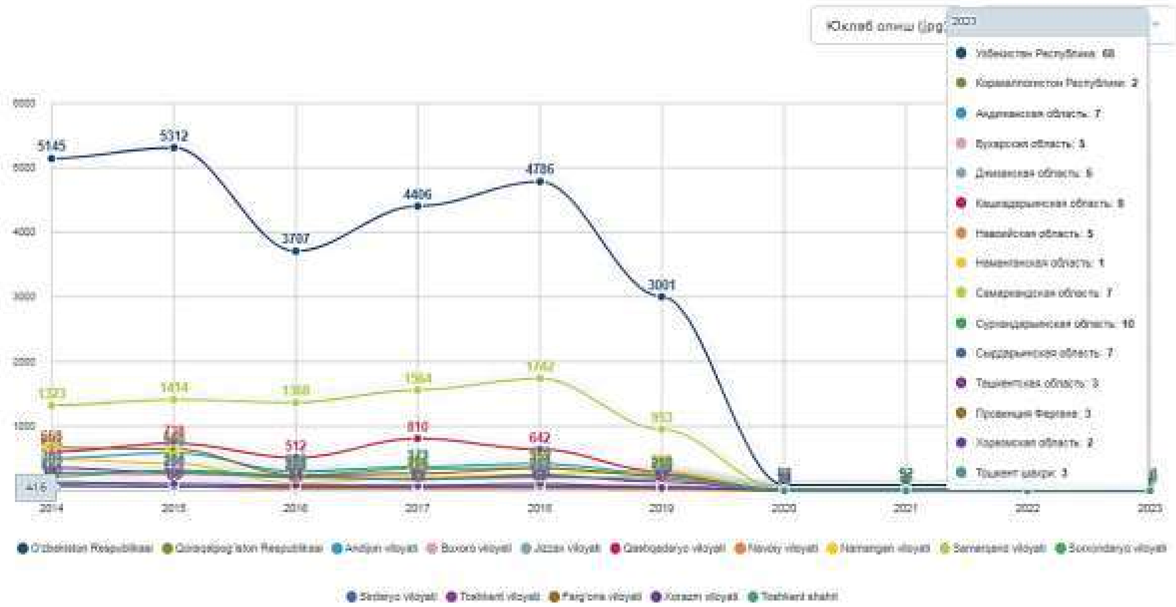


Figure 3.15 Statistics of officially registered marriage unions in Uzbekistan by year, thous.

Analysis of the autocorrelation function (ACF) of the time series MAR shown in Figure 3.1515suggests the presence of a seasonal component with a period S = 12 [20,65,70,8,65,70,86,92].

Pronounced peaks of autocorrelation are observed at intervals that are multiples of the seasonal cycle (k = 12, 24, 36), while the strength of the relationship does not decrease with time, in contrast to the ACF diagrams for the series of data on fertility (birth) and mortality (mort) [20,65,70,8,65,70,86,92], where such stability is not observed.

Data on checking the stationarity of the mar series are presented in Table 3.6.

The sequence of data in the inflation time series is illustrated in the graph shown in Figure3.17. Since 2020, a stable and significant decline has been observed [4,65,70,8,65,70,86,92].

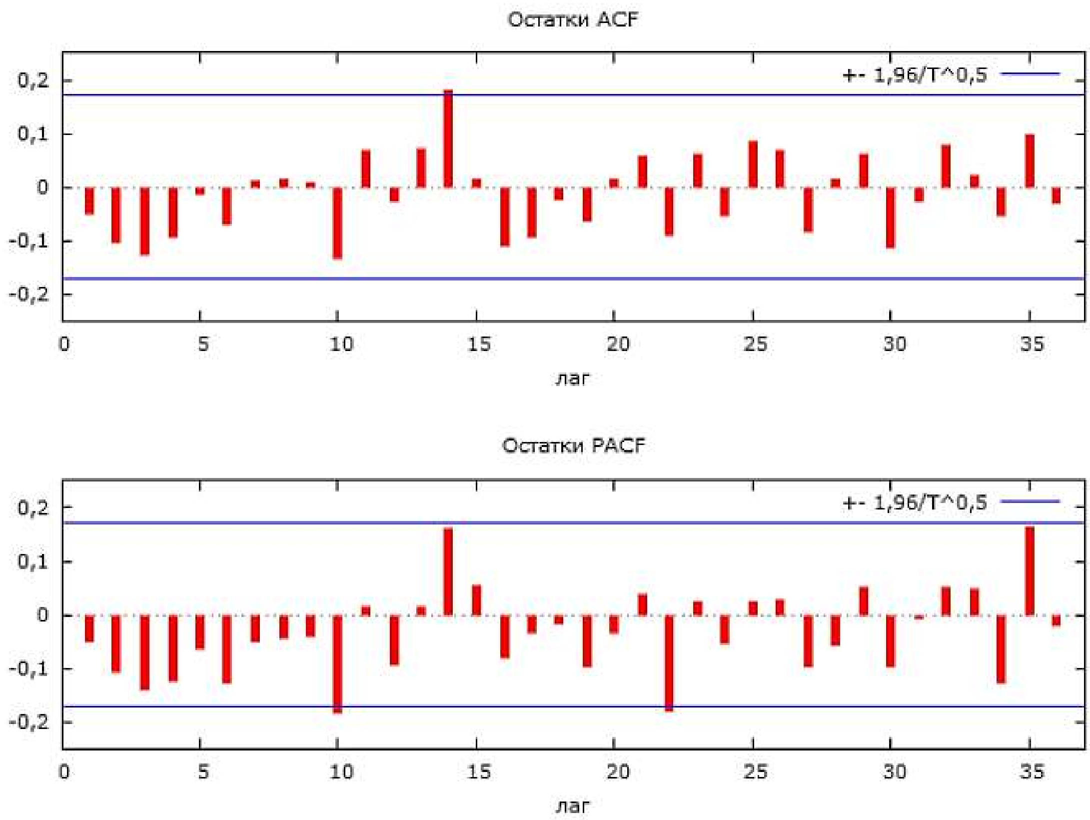


Figure 3.16 Correlation diagram for the mar sequence

Table 3.6. Results of testing for stationarity of mar sequences[12]

Time Series	Test	Test Specification	Statistic value	P-value
of mar	ADF	1	-0,875	0,695
		2	0,3047	0,989
		3	0,0301	0,897
	PP	1	-2,9403	0,967
		2	-3,5054	0,023
		1	-5,4668	<0,044
	KPSS	2	0, 9506	<0,027
		3	0,3654	0,000

The existence of seasonal fluctuations in information limits the ability to definitively state the presence of a stationary nature of the process.

[12] Note: 1 – with a constant, 2 – with a constant and a trend, 3 – with a constant and seasonal dummy variable.

Although data analysis reveals months with increased and reduced infant mortality (see Figure 3.1-8), it should be emphasized that this indicator does not depend on cyclical or seasonal changes [2,65,70,8,65,70,86,92].

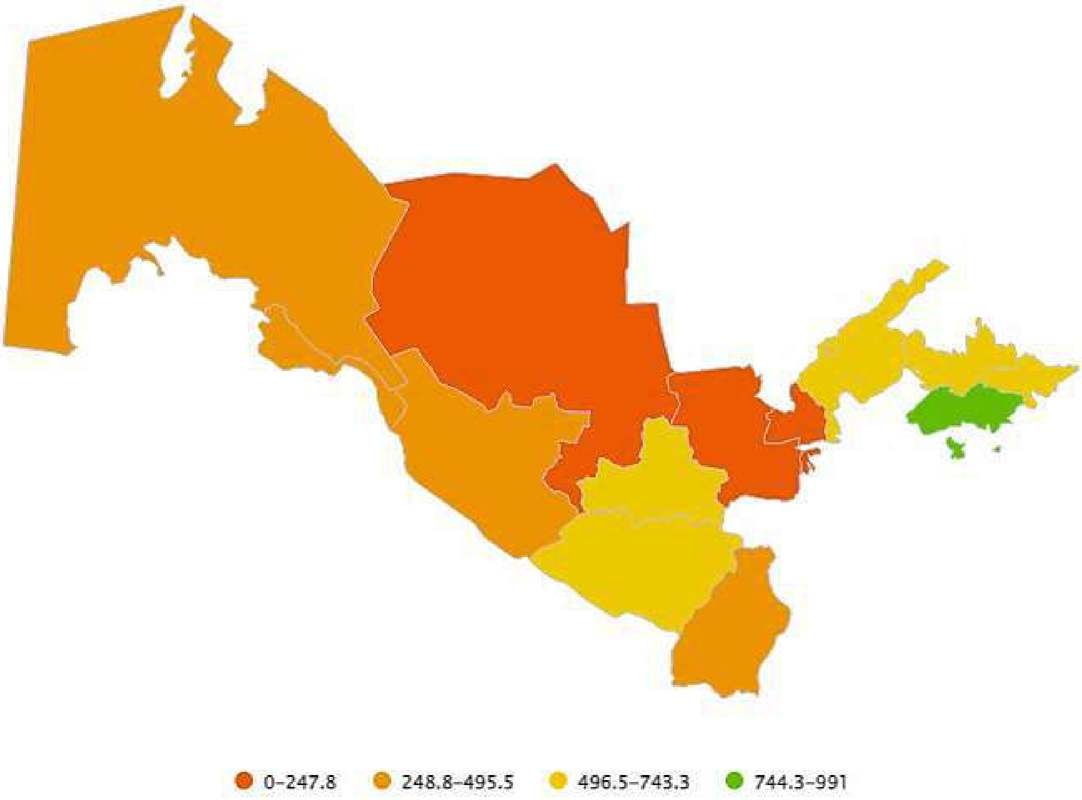


Figure 3.17. Statistics of children who died in the first year of life in Uzbekistan, in thousands

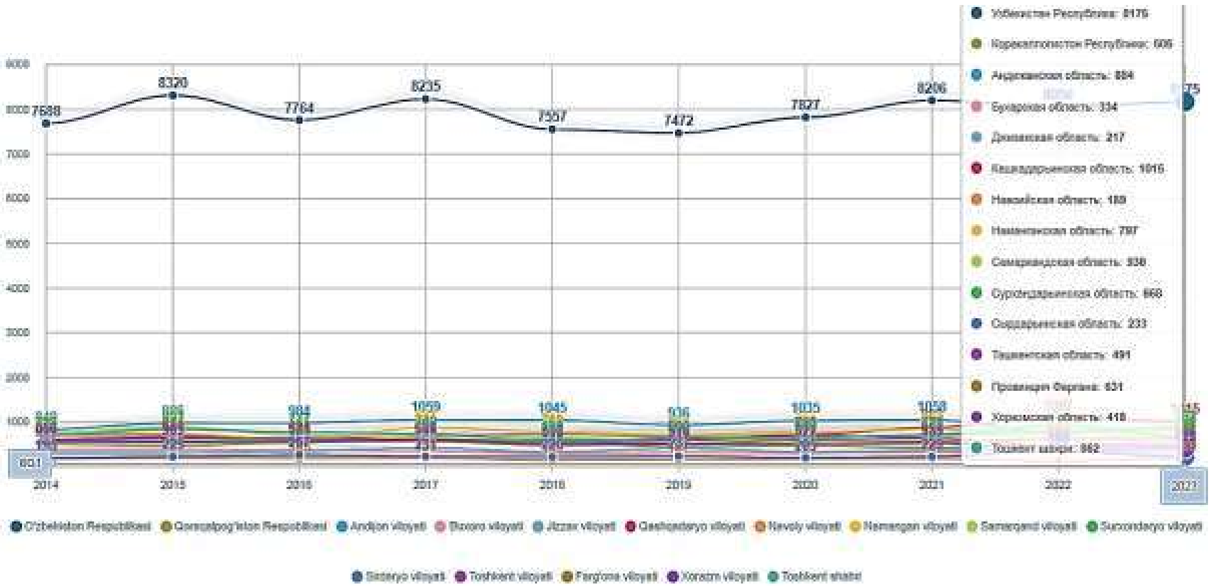


Figure 3.18. Number of registered deaths of children in the first year of life in Uzbekistan, in thousands.

Consideration of the correlogram of the time series shown in Figure 3.1-9 (a) and the correlogram of its first differentiation shown in Figure 3.1-9 (b), in order to exclude the trend effect, supports the conclusions of experts in the field of demography about the non-presence of seasonal fluctuations.

Graphs3.19 (a) and 3.19 (b) show no obvious peaks, which usually correspond to seasonal fluctuations, in lags that are multiples of the 12-month seasonal cycle.

In addition, there is a certain regularity with an interval of three graphs, as shown in Figure3.19 (b), which is confirmed by peaks on the periodogram (Figure 3.20). However, additional arguments are required to simulate this regularity.

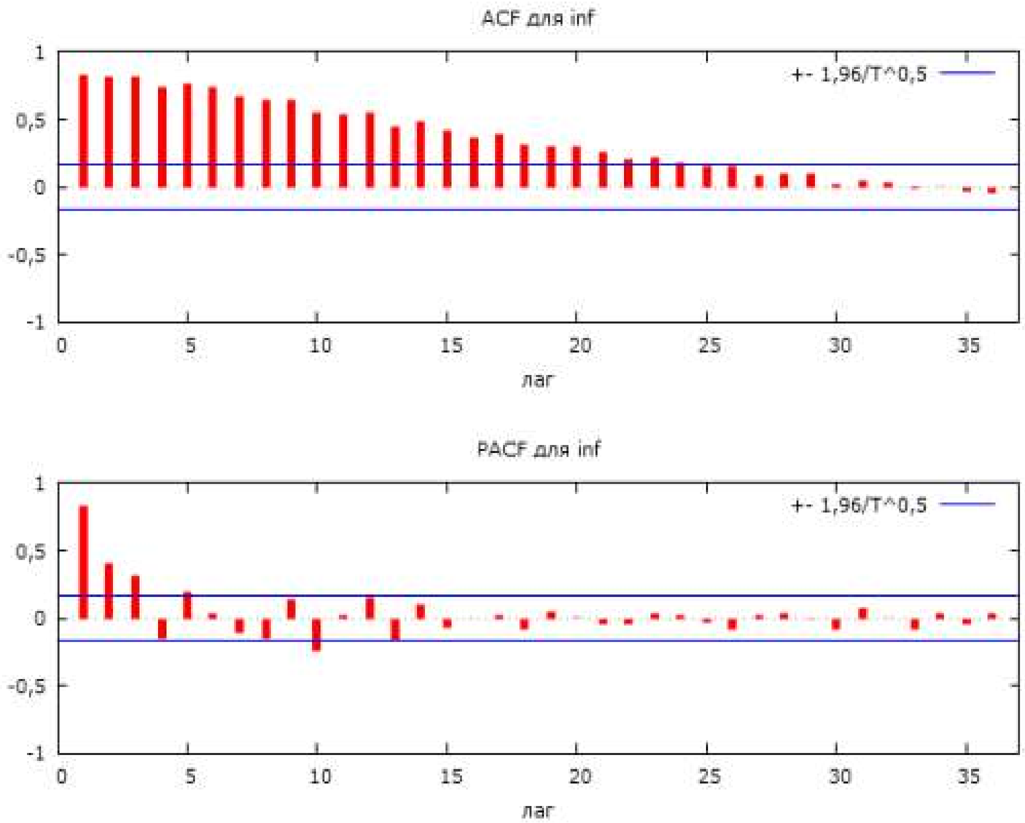


Figure 3.19 Correlograms of the inf (a)time series

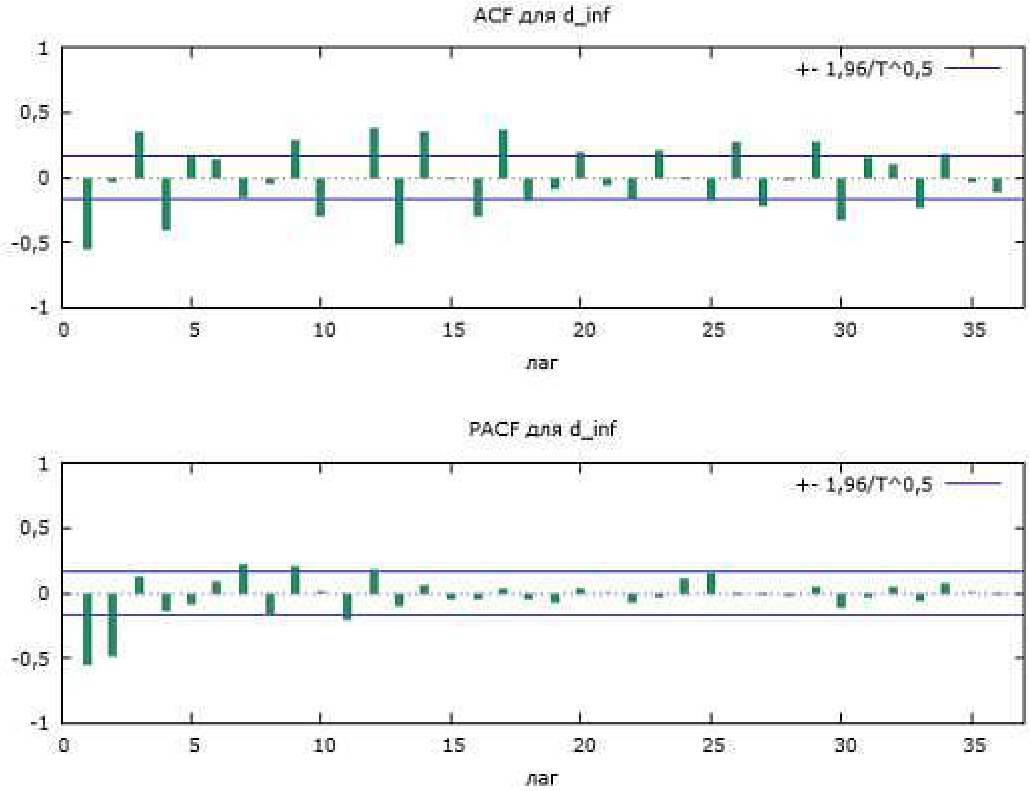


Figure 3.19 Correlograms of the analysis of differences in the Δ inf (b)series

Consequently, several series with infinite values were excluded from the subsequent review due to the lack of a seasonal component, while the main task of this study was precisely to study seasonal fluctuations.

3.3.1 Study of periodicity and unit roots in demographic time series

The use of traditional criteria for determining the presence of a single root for the analysis of seasonal time series often leads to ambiguous results. This makes it difficult to determine the degree of integration of the analyzed processes.

In the subsequent analysis, HEGY tests were used to identify seasonal and cyclical stationarities in parallel. An adapted version of the HEGY test was used to analyze monthly data series [4,65,70,8,65,70,86,92].

To assess the stability of the test results when changing its versions, various test modifications are analyzed.

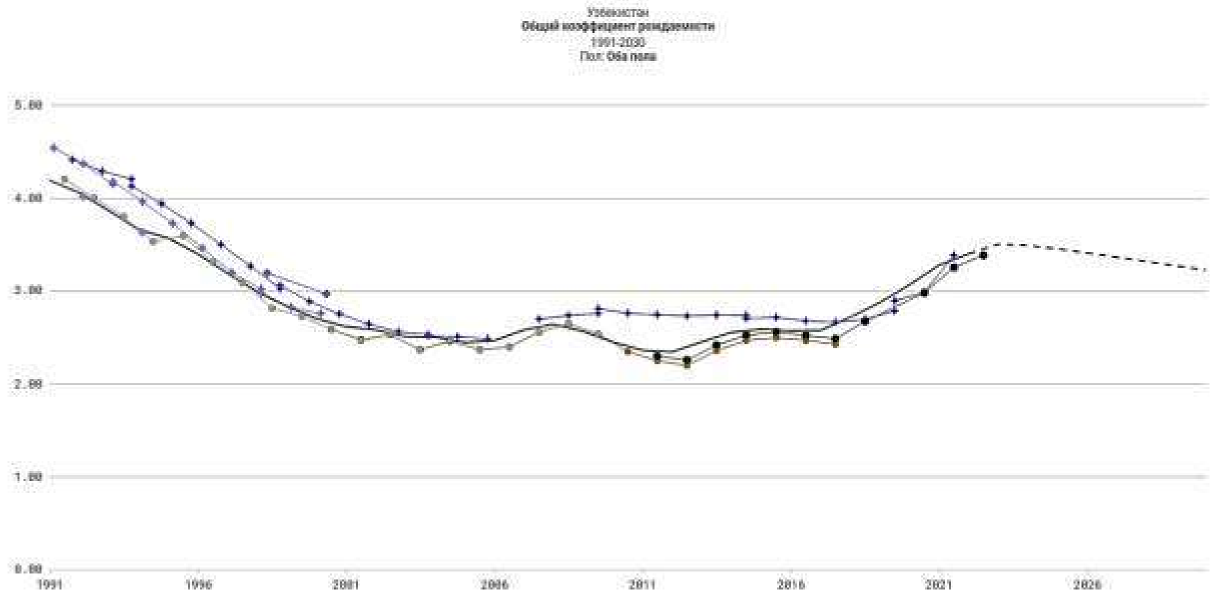


Figure 3.20 Periodogram of changes for Δ information

Table 3.7. Generalized conclusions on checking time series for seasonal unitary roots[13]

Time series	With constant	With constant and seasonal dummyvariables	With constant and trend	With constant, trend, seasonal dummyvariables
birth	unit semi monthly	-annual monthly	**unit semi -annual monthly**	unit
mort	**unit semi monthly**	-annual monthly	unit semi	-annual unit
mar	**unit semi -annual monthly**	unit monthly	unit semi -annual monthly	unit monthly unit

The results of our analysis of demographic time series using the HEGYtest are summarized in Table 3.7.

[13] Note: The test equation of the seasonal difference of the HEGY criterion for monthly data assumes the presence of 12 single roots: the root +1 corresponds to a non–seasonal single root, -1 to a semi–annual root, complex roots ±i to quarterly roots, (0.5(1.44±i)) to monthly roots, etc.

It should be noted that the presence of single roots was found under the condition that the null hypothesis was not rejected at a significance level of 5%.

In Table 3.7, the main findings on presence in different time series are highlighted in bold, while detailed results of statistical tests for a specific model are found in Table 3.8.

Table 3.8. Results of testing HEGY for seasonal unit roots for the birth variable[14]

Time series	Test modification	Statistic value	P-value
birth	With constant and trend	t1 = 0.19	0.68599
		t2 = -2.62	0.19761
		F1 = 0.06	0.89938
		t1 = -2.81	0.18908
$\Delta birth$	With constant and trend	t2 = -1.62	0.79071
		F1 = 0.71	0.40338
		t1 = -1.40	0.00020
$\Delta 2^2\ birth$	With constant	t2 = -1.34	0.28331
		F1 = 0.50	0.62449

Table 3.9. Conclusions from the HEGY check for seasonal unit roots, using modifications

Time series	Test modification	Statistic value	P-value	Output
birth	With constant and trend	t1 = 0.50	0.9590	Unit, semi -annual unit root, deterministic seasonality
		t2 = -1.62	0.9761	
		F1 = 0.61	0.9938	
mort	With constant	t1 = -1.24	0.9354	Unit, semi -annual unit root, deterministic seasonality
		t2 = -1.40	0.8232	
		F1 = 3.68	0.1862	
mar	S constant	t1 = 0.36	0.3785	Unit, semi-annual and monthly unit roots
		t2 = -0.19	0.4557	
		F1 = 0.64	0.4136	

[14] Note: to Tables 3.8. and 3.9, t1 statistics correspond to the hypothesis of the presence of a non–seasonal single root, t2 to the hypothesis of the presence of a semi–annual seasonal single root, F1 to the hypothesis of the presence of a monthly seasonal single root.

Analysis of the results of checking for the presence of stationary and non-stationary (seasonal and non-seasonal) unit roots [2,65,70,8,65,70,86,92] in the data reveals the specific characteristics of the studied time sequences.

Thus, the time series under consideration are classified as non-stationary, with an integration level $of\ d = 1$ for the variables mort and mar, and a level $of\ d = 2$ for the variable birth, according to the data in Table 3.8.

The results of applying the HEGY test to check stationarity on the first and second differences are presented in Table 3.9.

Колонки The birth and mort columns show predictable seasonality, which makes it possible to include seasonal indicator variables for the corresponding months in the SARIMA model to account for them [20,65,70,8,65,70,86,92]. While the data in mar are characterized by a noticeable stochastic seasonality with the level of seasonal integration D_{DS} equal to 1.

3.4 Results of the study of demographic processes

Forecasting demographic dynamics, in particular the number of newborns. After the analysis, during which various configurations of SARIMA models were evaluated and compared, taking into account their levels of auto regression and moving averages, and on the basis of deterministic seasonality data revealed by HEGY testing, the optimal SARIMA $(2,2,1) \times (1,0,0)\ model\ was\ selected$ with the integration of seasonal indicator variables for the most accurate analysis of the results. The forecast is [1,65,70,8,65,70,86,92].

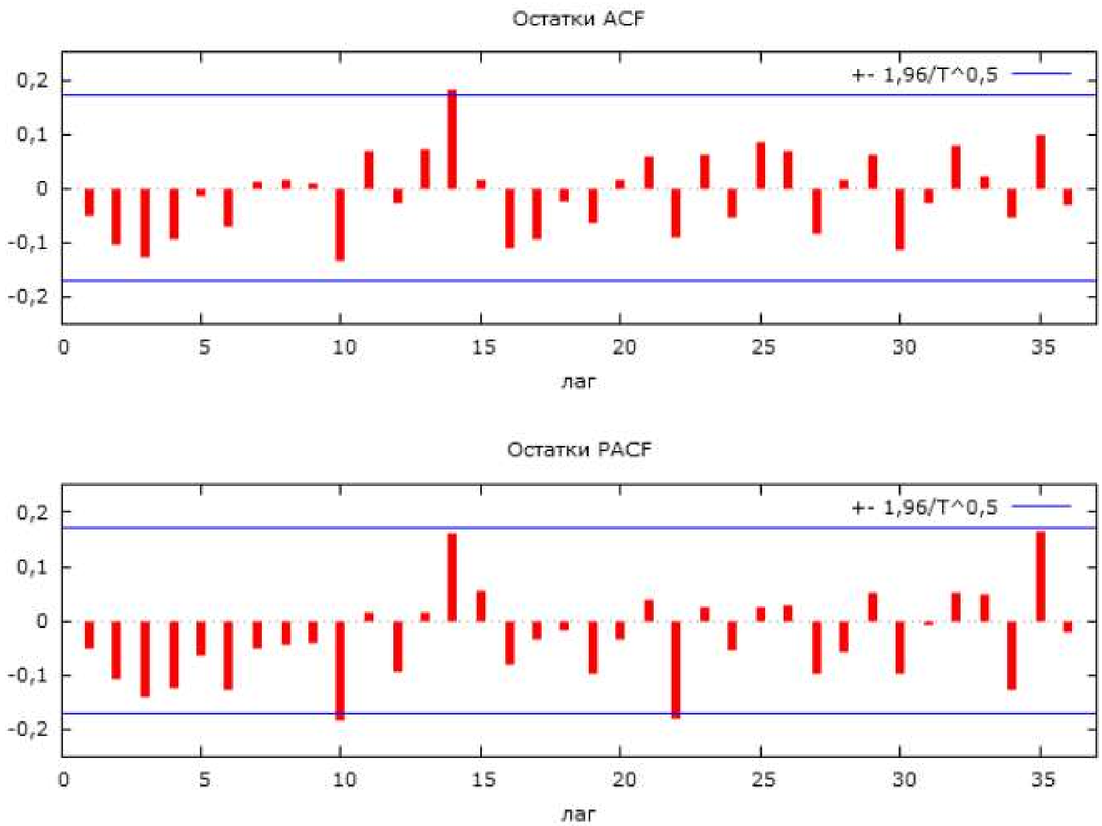
Dummy variables, also known as dummy variables or binary variables, are variables that can only take two possible values: 0 or 1. These variables are used to encode qualitative data in quantitative form, facilitating their analysis in statistical and econometric models [1,65,70,8,65,70,86,92].

The dummy variable for the month, denoted as dm_i, can take the value 1 if it is month i, and 0 if all other months are considered. Table 3.10 shows the resulting estimates of this model [1,65,70,8,65,70,86,92].

$$(1 - \alpha_1 L - \alpha_1 L^2)(1 - \alpha_{12} L^{12})\Delta^2 y_t = \theta_0 + (1 + \theta_1 L + \theta_3 L^3)\varepsilon_t + \\ + \sum_{i-2}^{12} \beta_i dm_i \quad (3.32)$$

In the analyzed model, all the roots of the characteristic equation have absolute values exceeding one, indicating the invertibility and stationarity of the time series. The autocorrelation indices for the residuals are zero, and the indicator for the Leung-Box Statistics Q is 15.20 (with a p-value of 0.5151) for 12the first 12 lags, proving the absence of autocorrelation in the residuals [2,65,70,8,65,70,86,92]. These data confirm that the residual series is a noise process corresponding to white noise.

Figure3.21 shows a correlogram of model residuals for birth, illustrating the elimination of any autocorrelation up to the 36th lag.



РисFigure 3.21. Correlogram of regression model residuals for fertility data

To analyze the normality of the distribution of residues, the Pearson agreement criterion $\chi^{2\ was\ used}$. The results of calculations $\chi(2)^2 = 4.11$ for two degrees of freedom (2) indicate that there are no grounds for rejecting the hypothesis of the normality of the distribution of residues. This confirms that the considered set of residuals can be considered a set of values generated in accordance with the normal distribution, with the accepted significance level of 5%.

In addition to analyzing the adequacy of the model to identify its ability to predict qualitatively, we used indicators of forecast accuracy, such as: root-mean-square error (RMSE) of 9.43, average percentage error (MPE) of 0.06, and average absolute percentage error (MAPE) of 4.81.

It should be emphasized that the recorded parameters of prediction accuracy indicate solid predictive capabilities of the developed SARIMA model.

Table 3.10. SARIMA model evaluation results for fertility data[15]

	Coefficient	of St. error	z	P-value
Dependent variable: $\Delta^2 birth$				
θ_0	3,948**	1,672	2,361	0,018
α_1	-1,050***	0,067	-15,704	0,000
α_2	-0,800***	0,083	-9,664	0,000
α_{12}	0,166*	0,096	1,742	0,082
θ_1	-0,476***	0,103	-4,632	0,000
θ_3	-0,455***	0,087	-5,220	0,000
dm2	-8,487***	2,513	-3,378	0,0007
dm3	4,105**	1,755	2,339	0,019
dm4	-8,773***	2,181	-4,022	0,000
dm5	6,636**	2,914	2,278	0,023
dm6	-4,528**	2,225	-2,035	0,042
dm7	10,454***	2,629	3,977	0,000
dm8	-9,849***	2,360	-4,174	0,000
dm9-18	-18,659***	2,948	-6,330	0,000
dm10-12	-12,110***	3,049	-3,972	0,000
dm11-10	-10,068***	2,337	-4,308	0,000
dm12	3,895	3,917	0,994	0,320
σStandard deviation is equal to 3.48; the Akaike information criterion is 713.45, while the Bayesian information criterion shows 764.65. The Leung-Box test with 20 lags has a value of 20.51 with a significance level of 0.15. Pearson's criterion for 2 degrees of freedom is 4.11 with a p-value of 0.12.				

[15] Note: *** – statistical significance of the coefficient at the 1% level, ** – at the 5% level, * – at the 10% level.

Figure 3.22 shows current data on the birth rate in Uzbekistan and forecasts generated using the SARIMA model, including the developed 95% confidence interval for predictions up to November 2024.

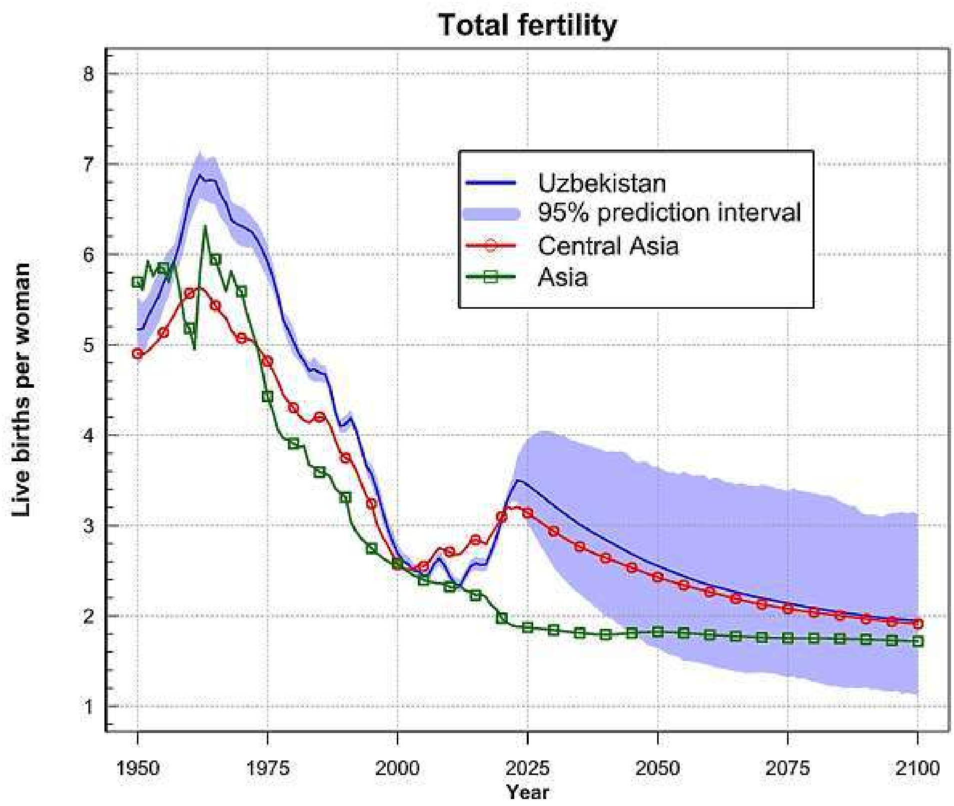


Figure 3.22 Chart of those born in Uzbekistan: actual data and predicted values obtained using the SARIMA model, taking into account the 95% confidence interval, in thousands.

Table 3.11 provides predictive data on the number of newborns in Uzbekistan based on the developed SARIMA model, including their 95% confidence intervals [4,65,70,8,65,70,86,92].

Analysis of demographic trend models indicates a steady decline in the birth rate in Uzbekistan in 2020, supported by the overall decline in the number of newborns described by demographers. This reduction will be observed on a monthly basis, as the preliminary seasonal adjustments clarify.

Analysts predict the maximum number of newborns in October 2025, reaching 90.887 thousand, while the minimum number of births is expected in February of the same year, amounting to 62.249 thousand.

Projection of the number of deaths. Analysis of the ARIMA (1,1,1) model, enriched with seasonal indicator variables dmi_i, revealed high statistical characteristics for mort in mathematical terms.

Table 3.11. Projection of the number of newborns in Uzbekistan based on the SARIMA model

Date	Forecast, thousand	St. error	95% confidence interval of the forecast	Seasonal increments (compared to the corresponding period of the previous year)	
				thousand	%
November 2023	52.076	1.226	(50.636, 49.472)	53.302	-28.4
December 2023	80.186	1.888	(77.970, 76.152)	82.074	-67.2
January 2024	70.276	1.654	(68.333, 66.762)	71.930	-52.9
February 2024	64.019	1.507	(62.249, 60.818)	65.526	-43.9
March 2024	66.687	1.570	(64.844, 63.352)	68.257	-47.7
April 2024	67.228	1.583	(65.370, 63.866)	68.811	-48.4
May 2024	71.215	1.676	(69.246, 67.654)	72.891	-54.4
June 2024	70.775	1.666	(68.818., 67.217)	72.441	-53.7
July 2024	89.337	2.103	(86.868., 84,870)	91.440	-85.5
August 2024	87.031	2.049	(84.626, 82.679)	89.080	-81.2
September 2024	91.370	2.151	(88.844., 86.801)	93.521	-89.5
October 2024	93.471	2.000	(90.887, 88.797)	95.671	-93.6

In the context of statistical analysis and modeling, the dummyvariable, denoted as dmi_i for month i, can take a value of 1, indicating that it belongs to month i, and a value of 0, indicating that it does not belong,thus covering all other months. Table 3.12 shows in detail the results of evaluating this model [4,65,70,8,65,70,86,92].

$$(1 - \alpha_1 L)\Delta y_t = \theta_0 + (1 + \theta_1 L)\varepsilon_t + \sum_{t-2}^{12} \beta_i dm_i \qquad (3.33)$$

In the analysis of this model, all values of the roots of the characteristic equation exceed unity in absolute value, indicating its stationary nature of the system.

The autocorrelation levels for the residuals tend to zero, showing no autocorrelation, which is confirmed Льюингаby the Lewing–Box Q statistic of 32.71 with a p value of 1.50 for the analysis of the first 20 lags. In addition, the residue correlogram showing autocorrelation up to 36 lags, shown in Figure 3.2323 for the mortality model (mort), also indicates the absence of autocorrelation [4,65,70,8,65,70,86,92].

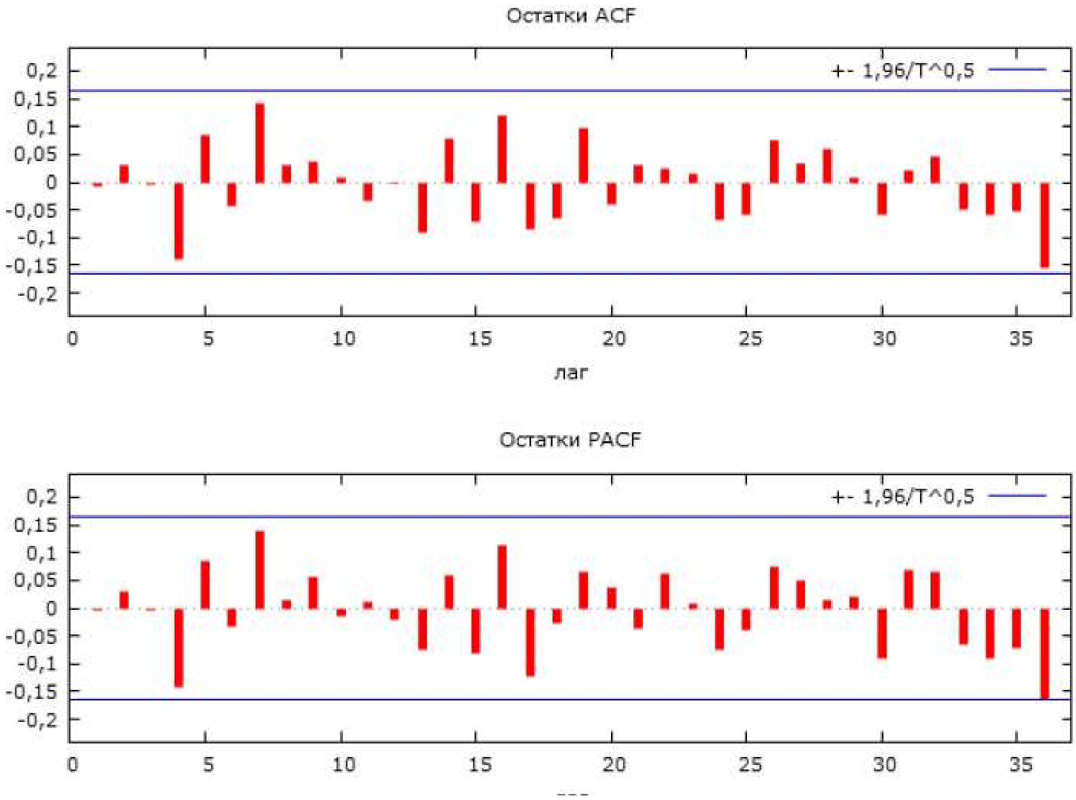


Figure 3.23Correlogram of analysis residuals based on the mortality model

Prediction accuracy criteria such as RMSE (Mean Square Error) with a value of 4.54, MPE (Mean Percentage Error) = -0.04, and MAPE (Mean Absolute Percentage Error) [64,65,70,8,65,70,86,92] = 2.11 indicate the effectiveness and reliability of the developed ARIMA model for predictions.

Figure 3.24 shows actual data on mortality in Uzbekistan by month (in thousands of people), forecasts formed using the ARIMA methodology, and an estimate with 95% confidence for the prediction interval until the end of December 2024 [20,65,70,8,65,70,86,92].

Table 3.12. Results of ARIMA modeling for the mort variable[16]

	Coefficient	of St. error	z
Dependent variable: Δ^2mort			
θ_0	-0,164	0,038	-4,291
α_1	0,467	0,108	4,310
θ_1	-0,956	0,061	-15,685
dm2	-22,924	1,494	-15,346
dm3	-7,886	1,810	-4,358
dm4	-17,971	1,940	-9,264
dm5	-11,291	1,998	-5,652
dm6	-20,389	2,023	-10,080
dm7	-17,480	2,031	-8,608
dm8	-19,707	2,026	-9,727
dm9	-24,767	2,005	-12,351
dm10	-14,770	1,954	-7,559
dm11	-23,142	1,835	-12,612
dm12	-12,687	1,544	-8,219
standard deviation is 4.53. The Akaike information criterion is 863.58, while the Bayesian information criterion reaches 907.92. The Q-statistic indicator for 20 delays is 17.23, with a p-value of 0.51, indicating insufficient grounds for rejecting the null hypothesis about the randomness of the series. The chi-square statistic with 2 degrees of freedom is 1.92, with a p-value of 0.38, also indicating a lack of evidence for rejecting the null hypothesis.			

Table 3.13 shows the predicted mort valuesderived using the ARIMA model, including 95% confidence intervals, as well as the calculated average seasonal increase based on these forecast values [20,65,70,8,65,70,86,92].

Statistical forecasts indicate a gradual decrease in mortality in Uzbekistan during 2019, excluding December 2020, as well as September and November 2021, when an increase in the number of deaths was recorded, which is reflected in the positive dynamics of the mortality index.

[16] Note: All coefficients are statistically significant at the 1% level.

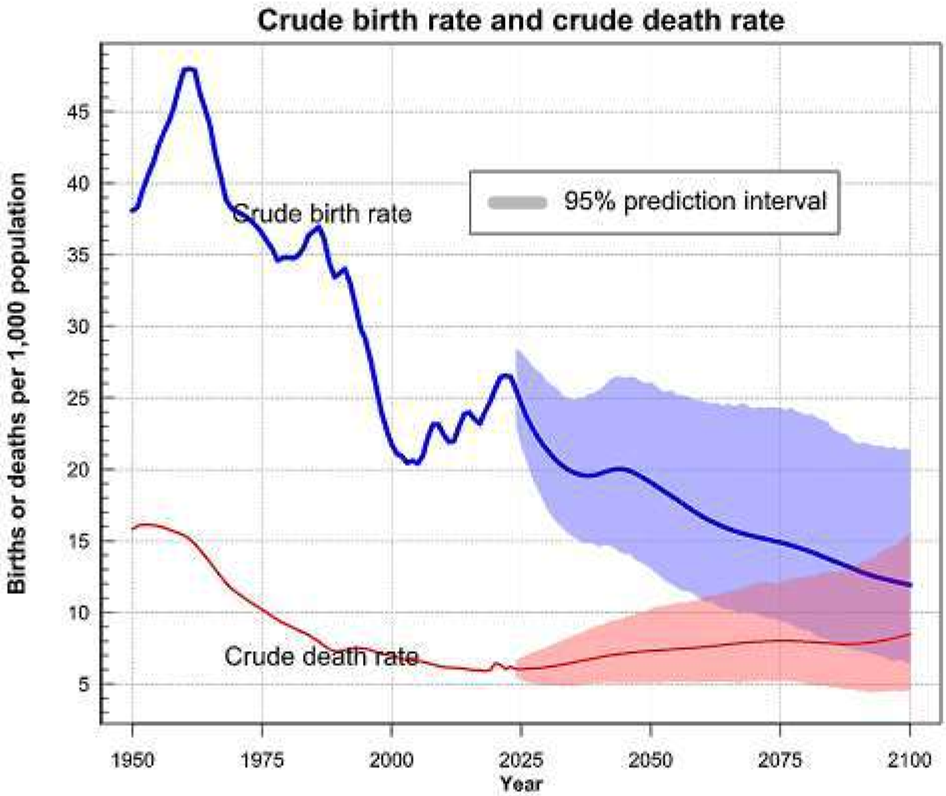


Figure 3.24 Mortality graphи in Uzbekistan: real and projected indicators obtained using ARIMA analysis, taking into account the 95% confidence interval, in thousands.

According to forecasts, the maximum population decline (10.956 thousand people) will occur in January 2025. The peak number of deaths is expected in August 2025 (18.194 thousand people), while there is a decrease in the population by 1.25%. In November 2025, the minimum number of deaths is expected (12.426 thousand people). with a significant population increase of 3.45%.

Table 3.13 shows the predicted mort values derived using the ARIMA model, including 95% confidence intervals, as well as the calculated average seasonal increase based on these forecast values [20,65,70,8,65,70,86,92].

Table 3.13. Projected mortality data in Uzbekistan using the ARIMA model

Date	Forecast, thousand	St. error	95% confidence interval of the forecast	Seasonal increments (compared to the corresponding period of the previous year)	
				thousand	%
November 2023	13.343	0.262	(12.426, 12.675)	13.081	-1.68
December 2023	15.985	0.313	(15.185, 14.888)	15.672	-2.41
January 2024	11.533	0.226	(10.956, 10.741)	11.307	-1.25
February 2024	15.685	0.308	(14.900, 14.608)	15.377	-2.31
March 2024	13.783	0.270	(13.093, 12.837)	13.513	-1.79
April 2024	13.267	0.260	(12.603, 12.356)	13.007	-1.66
May 2024	13.549	0.266	(12.871, 12.618)	13.283	-1.73
June 2024	15.225	0.299	(14.492, 14.179)	14.926	-2.18
July 2024	18.018	0.353	(17.117, 16.781)	17.665	-3.06
August 2024	19.152	0.376	(18.194, 17.837)	18.776	-3.45
September 2024	14.096	0.276	(13.391, 13.129)	13.820	-1.87
October 2024	14.378	0.278	(13.659, 13.395)	14.100	-1.96

Analysis of the forecast of the number of officially registered marriages. In the process of constructing the model for marthe mar variable, both standard and seasonal differentiation were used.

The SARIMA model with parameters (2,1,0) for a short period and (3,1,0) 12 for a long period showed decent results presented in the form of an equation. Detailed estimates of this model can be found in table 3.14.

$$(1-\alpha_1 L+\alpha_2 L^2)(1+\alpha_{12}L^{12}+\alpha_{24}L^{24}+\alpha_{36}L^{36})\Delta\Delta_{12}y_t = \\ =\theta_0+\varepsilon_t \qquad (3.34)$$

Table 3.14. SARIMA model forecasts for mar

	Coefficient	of St. error	z
Dependent variable: $\Delta\, \Delta_{12} mar$			
θ_0	-0,117	0,173	-0,6761
α_1	-0,966	0,071	-13,605
α_{2}	-0,585	0,070	-8,3131
α_{12}	-0,658	0,085	-7,6944
α_{24}	-0,567	0,090	-6,2793
α_{36}	-0,444	0,086	-5,1431
standard deviation is 11.84. The Akaike Information criterion (AIC) and Bayesian information criterion (BIC) are 1039.487 and 1059.560, respectively. The Ljung-Box Q-test on the 20th lag showed a value of 19.23, with a significance of p=0.2, which indicates that there is no autocorrelation in the model residuals. The chi-square test with 2 degrees of freedom revealed a value of 1.906 with a significance level of p=0.38, not allowing us to reject the null hypothesis that the model adequately corresponds to the observed data.			

Based on the results of applying the Leung-Box criterion calculated for twenty lags, we obtained a Q-statistic of 19.23 and a p-value of0.2. This indicates that the time series of residuals in the model under consideration demonstrates the characteristics of a random process, or white noise.

A graphical representation of the autocorrelation analysis of residuals for a range of up to 36 lags is shown in the correlogram shown in Figure3.25 for the multiplicative autoregressive integrated moving average (MAR) model.

The SARIMA model's accuracy parameters, namely RMSE of 5,15.1%, MPE of -1.860,860%, and MAPE of2.19494%, confirm its reliable predictive capabilities. An MPE value in the negative zone indicates a slight underestimation in the predicted values.

The MAPE analysis shows that the forecast for March showed the least satisfactory results. The findings indicate that a similar seasonal trend will continue in the coming year, according to previous observations.

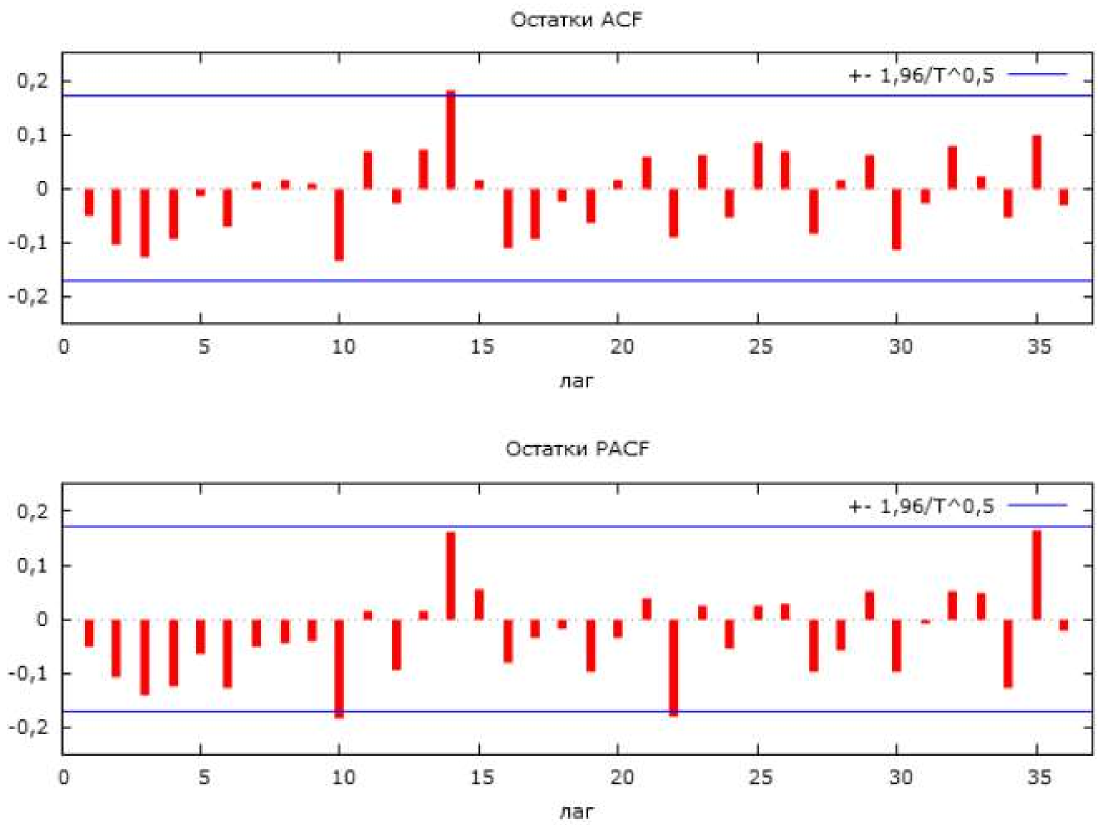


Figure 3.25 Correlogram of prediction errors for mar

B Figure 3.25 shows an analysis of the number of registered marriages per month in Uzbekistan, both actual data and forecasts made using the SARIMA model. In addition, the graph showsa 95% confidence interval for these forecasts up to December 2024 [4,65,70,8,65,70,86,92].

Table 3.15 presents estimated forecasts for the mort variable generated using the ARIMA model, together with 95% confidence intervals [4,65,70,8,65,70,86,92] for these forecasts. The table also shows the average seasonal increases calculated based on these projected data.

Analysis of modeling data shows a projected decrease in the number of officially registered marriages [2,65,70,8,65,70,86,92] in the period 2023-2024. However, it is necessary to emphasize the high degree of variation of this indicator, measured in thousands, with an average value of 23.853, a minimum value of 14.204, a maximum value of 36.324, with a standard deviation of 0.689.

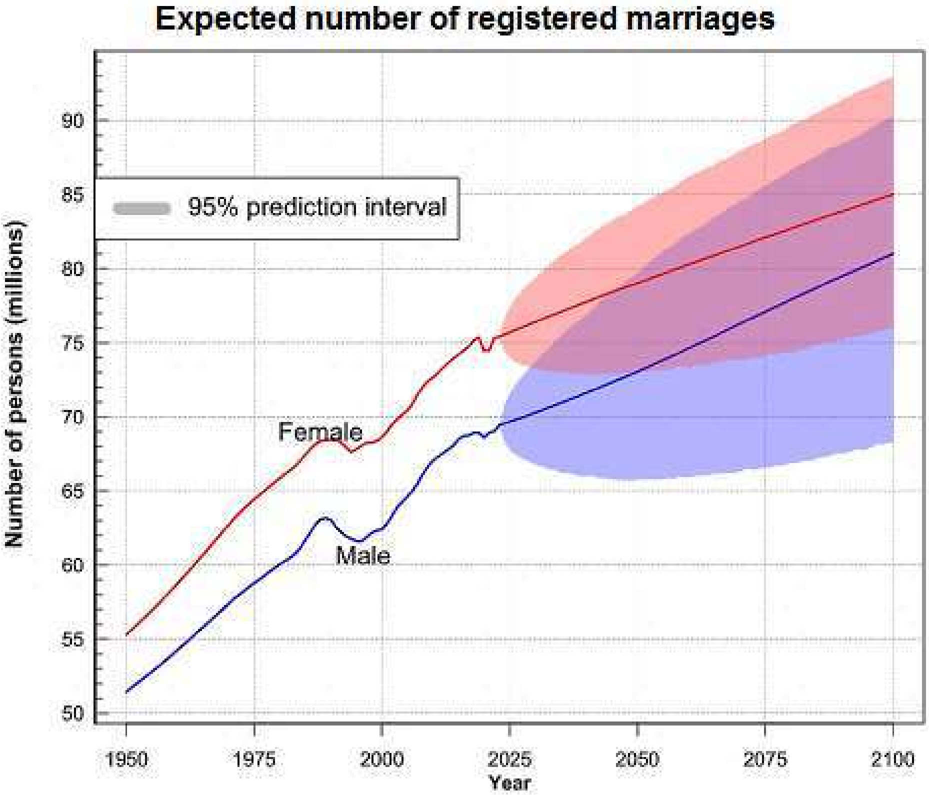


Figure 3.2626. Number of officially formed unions in Uzbekistan: actual and projected data obtained using the SARIMA model, with a 95% confidence interval, thous.

This indicates a significant uncertainty in the forecast, which is confirmed by a significant standard error size and, as a result, extended limits of the 95% confidence interval. For the months of March, May, and June, negative values of the lower bounds of the confidence interval were recorded, which indicates the need for careful interpretation of data, despite the qualitative properties of the [2,65,70,8,65,70,86,92] predictive model, and the need to integrate expert opinions of demographers for more accurate analysis.

A general analysis of the source data revealed a significant decrease in the number of marriages concluded, as exemplified by a 5.1% drop in November 2023 compared to November 2024. The constructed model demonstrated high sensitivity to these changes in dynamics.

Demographic researchers associate the decrease in the number of marriages concluded and dissolved with the trend of a "demographic wave": currently, the threshold of marriageable age is reached by numerically smaller generations born in

2006, while the percentage of couples who prefer to live together without official registration of their relationship is increasing.

The analysis of the effectiveness of predictive qualities between the SARIMA and Holt-Winters models is carried out with an emphasis on demographic indicators. The results demonstrate that the SARIMA model effectively reflects the dynamics of the demographic data under study.

In conclusion, a comparison of the predictive abilities of both models is presented, considering them from the point of view of forecasting quality standards. Special attention is paid to the analysis of seasonal fluctuations, where SARIMA showed superiority over the Holt-Winters model in all the analyzed parameters. Table 3.16 details the comparison results based on RMSE, MAPE, and MAE for the test sample segment.

Table 3.15. Indicators of the number of registered brands in the Republic of Uzbekistan, calculated using the SARIMA model

Date	Forecast, thousand	St. error	95% confidence interval of the forecast	Seasonal increments (compared to the corresponding month of the previous year)	
				thousand	%
November 2023	36.324	1.763	(32.832, 34.507)	34.561	-12
December 2023	29.694	1.441	(26.840, 28.209)	28.253	-8.02
January 2024	20.064	0.974	(18.135, 19.060)	19.090	-3.46
February 2024	16.792	0.815	(15.178, 15.952)	15.977	-2.42
March 2024	14.204	0.689	(12.839, 13.493)	13.515	-
1.73 April 2024	16.081	0.780	(14.535, 15.276)	15.301	-2.22
May 2024	17.781	0.863	(16.072, 16.891)	16.918	-2.72
June 2024	17.446	0.847	(15.769, 16.573)	16.599	-2.61
July 2024	25.091	1.218	(22.679, 23.836)	23.873	-5.4

continuation of the table 3.15

August 2024	30.164	1.464	(27,265, 28.655)	28.700	-7.82
September 2024	30.923	1.501	(27,950, 29.376)	29.422	-8.21
October 2024	31.681	1.537	(28,636, 30.096)	30.144	-8.62

Table 3.16. Estimation of forecasting efficiency using SARIMA and Holt-Winters (HW) models based on the test data segment (T = 20)[17]

Indicator	SARIMA			HW indicator			Статистика Diebold-Mariano statistics (p-value), MSE
	RMSE	MAPE	MAE	RMSE	MAPE	MAE	
birth	3.59	0.02	2.86	5.84	0.035	4.98	S (1) = 5.26 (p-value = 0.0)
mort	4.58	0.026	3.88	5.56	0.032	4.88	S (1) = 5.02 (p-value =0.0) 0.0)
mar	9.92	0.1165	8.63	12.90	0.117	9.02	S (1) = 1.46 (p-value = 0.14)

All calculated parameters for all criteria demonstrate the minimum values for SARIMA models, thus confirming their high predictive effectiveness.

The analysis performed using the Diebold-Mariano criterion demonstrates that at the significance level of 5%, differences in the predictive ability of models are absent only for the mar variable, whereas in the case of birth and mort variables, the advantage should be given to predictive estimates obtained using SARIMA models [2,65,70,8,65,70,86,92].

[17] Note: The null hypothesis in the Diebold-Mariano test: "there are no differences in predictions."

3.4.1 Study of population elements and dynamics through the use of model methods

The study analyzes various cases of using SARIMA models to simulate and predict demographic changes.

During the analysis, it was determined that the demographic phenomena under study demonstrate unique features. The section on fertility shows that the corresponding time series has a second-order integration, as well as a pronounced seasonal fluctuation, which is proposed to be corrected by including specific seasonal indicators - dummy variables-in the ARIMA model. In terms of mortality, first-order integration with also pronounced seasonality is revealed. Wedding statistics confirm the presence of first-order integration for both normal and seasonal fluctuations.

The study of infant mortality rates using autocorrelation and periodic analysis found no seasonal fluctuations, which coincides with the conclusions of experts in the field of demography about the influence of the seasonal component on this index in recent times.

All developed forecasting models based on the SARIMA methodology demonstrated their adequacy, and the obtained indicators of forecast accuracy confirmed their high predictive qualities. During the period when the study was undergoing the expert evaluation stage, the State Statistics Committee under the President of the Republic of Uzbekistan released up-to-date statistics on the studied indicators for the period from November 2023 to October 2024.

All registered statistical data (birth rate, death rate, number of registered marriages) fall withinthe 95% confidence interval, except for the indicator for the number of registered marriages for November 2025. An analysis of the predicted values compared to the officially published data is provided in Table 3.17.

To assess the quality of forecasts, we also took into account the Holt-Winters exponential smoothing modelsthat take into account seasonal fluctuations.

The study demonstrates that SARIMA models are superior in terms of forecasting quality [2,65,70,8,65,70,86,92].

Table 3.17. Analysis of comparison of predictive data from SARIMA models and officially released information[18]

Date	Birth, thousand people.		Mort, thousand people.		Mar, thousand	
	forecast*	publ. data	forecast data*	publ. data	forecast data*	publ. data
November 2024	93.470	88.796	14.382	13.662	30.866	29.322
December 2024	91.320	86.754	14.669	13.935	31.588	30.008
January 2025	93.603	88.922	15.139	14.382	31.793	30.203
February 2025	95.943	91.145	15.210	14.449	31.999	30.399
March 2025	98.342	93.434	15.281	14.516	32.206	30.595
April 2025	100.801	95.760	15.352	14.584	32.415	30.794
May 2025	103.321	98.154	15.424	14.652	32.625	30.993
June 2025	105.904	100.608	15.496	14.721	32.837	31.195
July 2025	108.552	103.124	15.568	14.789	33.050	31.397
August 2025	111.266	105.702	15.641	14.858	33.264	31.600
September 2025	114.048	108.345	15.714	14.928	33.480	31.806
October 2025	116.899	111.054	16.184	15.374	33.697	32.012

In the future, it is of interest to analyze the stability of the calculated model estimates, expanding their verification on the basis of long-term data to study the influence of "long memory" effects.

The statistical method of population forecasting described in the study can serve as one of the methods for analyzing demographic changes, which currently play a key role in the formulation of domestic strategies. This approach is

[18] Примечание: * – 95%-ный доверительный интервал прогноза на основе SARIMA-моделей.

particularly relevant for planning socio-economic development at the national level or for specific regions and is important in monitoring the implementation of demographic goals set out in the presidentialregulations.

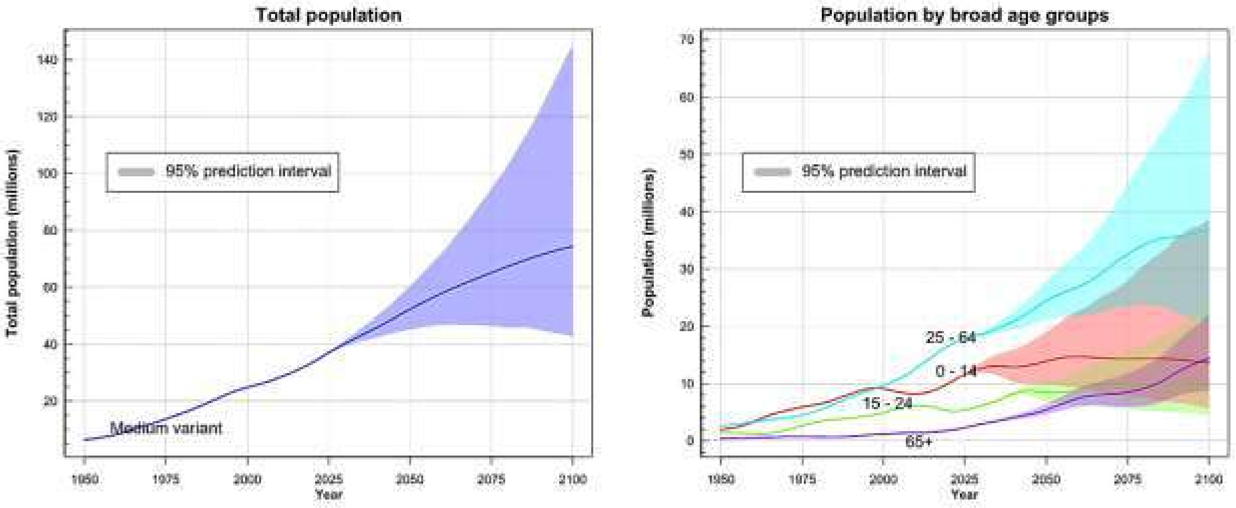


Figure 3.27. Demographic structure by age category in Uzbekistan: actual and projected data using the SARIMA method with a 95% confidence interval, thous.

This forecast was developed taking into account the specifics of current conditions. In this context, the final product proposed for analysis, which is a demographic forecast for the Republic of Uzbekistan, along with a preliminary analytical review, is distinguished by unique theoretical and methodological approaches. This uniqueness is due to several factors, including the limited access to the full volume of data on the country's demographic development before starting work on the forecast, which was caused by difficulties in accessing official population statistics for the expert community over the past time.

It is known that population estimates, even if performed using qualified methods, cannot replace official statistics. Accurate data were obtained thanks to cooperation with laboratories of the Statistics Agency under the President of the Republic of Uzbekistan.

Our audit demonstrates that there is no significant damage to the structural integrity of our databases, except for those changes that occurred as a result of the administrative adjustments mentioned above. However, it should be noted that not all information complies with internationally established statistical principles. This is especially true for data on the demographic composition and age-sex structure of the population, as they were collected without the recent general population census.

Probably the greatest difficulty in working with the data was caused by the implementation of the updated division of the territory into urban and rural zones, which directly affected the population statistics, changing its overall composition and demographic distribution. An additional factor complicating the analysis of time series was the calculation of the total population after conducting a targeted demographic study in the period 2020-2024.

In response to emerging problems, the time period from 2024 to 2050 was determined as optimal for analyzing the dynamics of all demographic parameters studied by us, while remaining within an acceptable statistical error. It is important to emphasize that we often had sufficient grounds for asserting the presence of certain trends in population development, due to their significant severity and stability.

We remind you that since January 2024, the population has increased by 163.5 thousand people, as a result of which by December 1, 2024, the total population reached 37,516,133 people.

Based on the data of the conducted research and referring to existing theories, we can state with a high degree of confidence that:

- The decline in the overall birth rate can be traced in both rural and urban areas. At the same time, the patterns of reproductive behavior will remain largely unchanged, showing no dramatic changes during the entire forecast period.
- It is expected that the reduction in the mortality rate contributes to an increase in life expectancy for both women and men. This process will be more pronounced in urban areas compared to rural ones, due to the expected improved access to quality health services for urban residents.
- The number of population movements within and outside the country will increase significantly. At the same time, the migration balance will also increase. It

is expected that when the projected migration indicators are reached (depending on the forecast scenario), these values will stabilize.

The final forecast data substantiates the assumption that:

- The population of the Republic of Uzbekistan is expected to actively increase, and it is predicted that by the end of 2050 it will approach the mark of 45 million people.
- In the future, there will be changes not only in the number of residents, but also in the demographic distribution by age. The median age of the population of Uzbekistan will grow by eight years, approaching the 37-year mark.
- The process of population aging in the country will be carried out mainly due to" aging from above", which is manifested in an increase in the number and proportion of elderly citizens.
- The population of people over 60 will increase by 6 million, which means that its volume will increase to more than three and a half times the current level.
- The number of people in the pre-productive age group, i.e. in the 0-17 age group, is expected to increase from the current 10.9 million to about 11.5 million, representing an increase of less than 6 percent.
- The population of people of working age, which includes men in the age category of 18-59 years and women in the range of 18-54 years, is expected to grow from 18.6 million to 23.4 million people, which shows an increase of 26% [23,65,70,8,65,70,86,92].
- The population of people of post-working age (men over 60 and women over 55) will increase from 3.2 to 9.8 million people, which will be more than a threefold increase.
- The population of older people, i.e. those over 80 years of age, will show a significant increase. At the starting point of 325 thousand people at the beginning of the forecast period, by the half of the century their number will reach about 1.5 million. This increase, more than 4.5 times, highlights the marked excess of the initial population.

There is no doubt that visible transformations have a significant impact on key aspects of public life, including the areas of social services, public protection, public health and market labor relations. In addition, these changes in these segments, driven by demographic dynamics, show complex correlations and dependencies, where conditions in one area can have a decisive impact on the pace and nature of progress in others.

Acceleration of the aging process of the demographic structure of society undoubtedly actualizes the task of ensuring the sustainability of pension provision, turning it into a key issue that requires immediate solutions within the framework of projected demographic shifts. Correction of the current relatively low age threshold for retirement is presumably an urgent measure in the process of optimizing the pension system.

An increase in the proportion of older people in the general population structure and an increase in life expectancy contribute to an increase in the need for health services. This circumstance, together with other factors, leads to the complication of already existing issues related to increasing financial costs for health care. At the same time, such demographic changes will imply a noticeable transformation in the distribution of the budgets of pensioners and household expenses of their families.

The anticipated transformation in the demographic composition also promises an escalation in the need for social support and welfare services for the population.

The demographic group at the age of working capacity, which forms the basis of potential employees, will show stable growth over the next 25 years, while experiencing the aging process.

Continued growth in the labor force is highly likely to be supported by raising the retirement age limits. This change will lead to the fact that individuals who under current conditions could retire, will remain in the category of economically active population. Accordingly, ensuring the increased demand for labor is a task of primary importance for both the current and future Cabinets of Ministers of the Republic of Uzbekistan. The main aspects that make this issue a priority are primarily related to the volume of this demand and, secondly, to the close relationship between the development of the labor market and progress in other sectors of the social structure.

Summarizing the key results of this forecast analysis, it should be noted that in the next 30 years, Uzbekistan expects a significant and dynamic population growth. This growth will be accompanied by even larger and somewhat unprecedented shifts in the age composition of the population, many of which have already begun to manifest themselves, becoming more and more obvious. Such demographic trends can lead to a number of serious challenges for the country in the future.

Therefore, it is extremely important to immediately start implementing concrete and real actions to solve this problem. This implies a thorough study of the forecasts and potential consequences of the demographic situation in Uzbekistan. It is necessary to conduct a detailed analysis of these impacts, as well as identify strategies to minimize or neutralize possible negative impacts. Finally, it is critical to select appropriate measures and ensure their effective implementation.

3.5 Main results and conclusions of the third chaptere

In the process of developing the demographic model of Uzbekistan, researchers identified key factors influencing population changes. Among them are the birth rate, death rate, dynamics of marriage, as well as the age composition of the population. This model is an effective analytical tool that provides a deep understanding of current demographic processes and provides an opportunity to predict future changes. This is critical for strategic planning at the state level.

The study of demographic trends is the basis for developing an effective national strategy. This analysis is also focused on addressing pressing issues, including the aging of society, labor shortages, and improving the standard of living of the population. The key point is the ability to analyze the impact of multiple elements. This includes the country's economic situation, various social initiatives, and legal modifications that can make significant adjustments to the demographic picture.

The study focuses on the critical role of a multidimensional approach in shaping demographic strategies. This strategy should include an analysis of both domestic population dynamics and international trends affecting population size and structure. Further policy optimization is needed to adapt to future challenges. The use of up-to-date data and the development of innovative methods will allow timely adjustment of demographic policy and build effective mechanisms to support long-term socio-economic progress in the Republic of Uzbekistan.

The created demographic model is a key tool for studying and predicting changes in the population structure. It facilitates the effective development and implementation of national demographic policies. This methodological approach makes it possible not only to adapt to current demographic trends, but also to anticipate future shifts, which contributes to improving the standard of living of the population and guarantees the socio-economic stability of the state.

Conclusion

In the dissertation work, a deep and multidimensional analysis of the demographic situation and its changes was carried out, using demographic modeling methods. This approach allowed us to better understand the changes and trends in the demography of Uzbekistan, which is important for understanding the overall processes in the Central Asian region. The study uses a methodology that involves analyzing a variety of demographic data, which helps to improve the accuracy of forecasts and the quality of analytical conclusions on demographic changes.

The collection and analysis of demographic data for Uzbekistan revealed a duality in the current situation: on the one hand, there is an impressive population growth, strengthening the potential of young people and improving a number of social parameters that underlie the prospects for sustainable socio-economic development of the state. On the other hand, such positive aspects are accompanied by difficulties: the gradual aging of society, the intensification of migration flows, and the need to guarantee decent living conditions for a rapidly growing population are the main challenges that require a well-developed and multidimensional strategy for solving them.

The study developed a model for analyzing demographic changes in Uzbekistan, demonstrating high efficiency and applicability in practice. It not only reflects current demographic trends, but also allows you to predict future changes in demographics that are key to developing strategies at the state level. These data serve as a foundation for formulating government programs and strategies aimed at addressing existing demographic challenges and improving population management policies.

ДDemographics in Uzbekistan are determined by a complex of interrelated economic, social, and environmental determinants. Effective modernization of demographic survey methods is key to the ability to predict and manage the population for harmonious development. The integration of the latest developments in information technology for deep analysis of demographic data promises to significantly strengthen this process. Competent regulation of the demographic situation, supported by evidence-based strategies and predictive modeling, becomes the starting point for socio-economic development and improving the well-being of the country's residents.

The research and its results will be valuable both for the academic community and for the authorities involved in regulating and strategically managing demographic processes in the Republic of Uzbekistan. The confidence that the formulated proposals and the developed algorithm will make a significant contribution to the formation of a dynamic and effective demographic strategy that provides for sustainable and balanced development of the population is based on careful analysis and research. This, in turn, will not only raise the living standards of the population, but also contribute to the country's dynamic economic progress against the backdrop of global changes.

The main findings of the predictive analysis will be carefully studied and discussed with the participation of state structures of Uzbekistan in order to ensure effective interaction and coordination between different levels of government in the process of adapting to current and foreseeable challenges. It is intended to identify specialized government agencies that have the necessary authority to initiate and implement strategies aimed at addressing the identified issues. The assessment is based on an analytical process that includes the use of derived predictive methods, such as creating model forecasts and performing simulation modeling, which provides an opportunity to better understand the potential direction of socio-economic changes in the context of demographic shifts.

The proposed methodology, which is based on the SARIMA model with 95% probability, stands out as a particularly effective tool for developing effective and promising strategies, programs, and policy initiatives. This not only contributes to the creation of a science-based basis for policy decisions at the state level, but also allows the results of such forecasts to be used for the development, support, implementation and monitoring of the implementation of specific state measures.

At the final stage of the analysis, I emphasize my commitment to contributing to the implementation of the conclusions of this forecast study, supporting its expanded application, including the development of subsequent forecasts, the creation of methodological and instrumental projections, as well as the development of complex simulation models that will be useful for the authorities of the Republic of Uzbekistan and other state institutions seeking partnerships in this area.

List of literature

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94. Vincenzo Della Mea, Mihai Horia Popescu, Kevin Roitero Underlying Cause of Death Identification from Death Certificates via Categorical Embeddings and Convolutional Neural Networks https://ieeexplore.ieee.org/document/9374316/authors

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Application

«УТВЕРЖДАЮ»
Руководитель
«Управление Статистики Ферганской области»
____
«___» ______________ 2024 г.

АКТ ВНЕДРЕНИЯ
О внедрении научных и практических результатов научного исследования

Настоящим актом подтверждается, что результаты диссертационной работы *Акрамовой Гулёры Абдихаликовны* на тему *«Анализ демографических систем и процессов на основе их моделирования»*
(наименование темы, № гос. регистрации)
на соискание ученой степени кандидата технических наук по специальности 2.3.1 – *«Системный анализ, управление и обработка информации»*, выполненной в *Санкт Петербурском государственном университете СпбГУ* приняты к внедрению на государственном учреждении «Управление Статистики Ферганской области»
(наименование предприятия, где осуществлялось внедрение)

1. Вид внедренных результатов: *Анализа демографических данных на основе государственного электронного реестра*
(эксплуатация изделия, работы, технологии; функционирование систем)

2. Характеристика масштаба внедрения: *единичное*
(уникальное, единичное, партия, массовое, серийное)

3. Форма внедрения: *Программный комплекс для анализа демографических данных на основе государственного электронного реестра*

4. Новизна результатов научно-исследовательских работ:
1. Разработан демографический паспорт регионов (районов и городов) Республики Узбекистан.

2. Методика направлена на повышение эффективности процессов, включает в себя рождаемость, смертность, миграцию, эмиграцию и другие факторы, влияющие на демографическое развитие общества.

3. Разработан алгоритм и методика глубокого анализа процессов, позволяющие прогнозировать демографическую ситуацию в стране, определять потребности общества в различных сферах и разрабатывать соответствующие меры государственной политики для обеспечения устойчивого развития нации.

4. Разработать программную реализацию созданной прикладной модели демографических процессов.

5. Внедрены:

– в проектные работы *комплекс для анализа демографических данных на основе государственного электронного реестра для* «Управление Статистики Ферганской области»

РОССИЙСКАЯ ФЕДЕРАЦИЯ

СВИДЕТЕЛЬСТВО

о государственной регистрации программы для ЭВМ

№ 2024666023

Программный комплекс для анализа демографических данных на основе государственного электронного реестра

Правообладатель: ***Акрамова Гулёра Абдихаликовна (UZ)***

Автор(ы): ***Акрамова Гулёра Абдихаликовна (UZ)***

Заявка № **2024664114**

Дата поступления **20 июня 2024 г.**

Дата государственной регистрации

в Реестре программ для ЭВМ ***09 июля 2024 г.***

Руководитель Федеральной службы

по интеллектуальной собственности

Ю.С. Зубов

РОССИЙСКАЯ ФЕДЕРАЦИЯ

RU2024666023

ФЕДЕРАЛЬНАЯ СЛУЖБА
ПО ИНТЕЛЛЕКТУАЛЬНОЙ СОБСТВЕННОСТИ

ГОСУДАРСТВЕННАЯ РЕГИСТРАЦИЯ ПРОГРАММЫ ДЛЯ ЭВМ

Номер регистрации (свидетельства):
2024666023
Дата регистрации: **09.07.2024**
Номер и дата поступления заявки:
2024664114 20.06.2024
Дата публикации и номер бюллетеня:
09.07.2024 Бюл. № 7

Контактные реквизиты:
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Akramova Gulyora Abdikhalikovna (UZ)
Правообладатель(и):
Акрамова Гулёра Абдихаликовна (UZ)

Название программы для ЭВМ:
Программный комплекс для анализа демографических данных на основе государственного электронного реестра

Реферат:
Программный комплекс предназначен для автоматизации процессов сбора, обработки, анализа и визуализации демографических данных. Он предоставляет пользователям удобный интерфейс для работы с данными, а также мощные аналитические инструменты для глубокого исследования демографических тенденций и взаимосвязей. Область применения: основными целями работы являются демографическое планирование комплекса, помощь государственным органам разрабатывать и корректировать программы демографической политики, прогнозировать численность населения, возрастную структуру и другие показатели. Функциональные возможности: комплекс состоит из файлов в форматах CSV, Excel, XML, JSON для поддержки импортирования данных, а также для прямого подключения к базам данных и API государственных реестров. Тип ЭВМ: любая, предоставляющая возможность работы с браузером в интернет; ОС: Windows, Linux, Mac.

Язык программирования:	Jupyter Notebook 7.1.3., Python 3.8.5
Объем программы для ЭВМ:	4151071744 Б