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Agent-Based Model for Forecasting the Impact of the Population Life Quality on Migration Movement in the Context of the Russian Federation Federal Districts

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ABSTRACT

The Russian Federation is characterized by an extremely uneven distribution of the population across the country, which contributes to the asymmetry of economic and socio-demographic development of the regions, a shortage of qualified specialists for the development of the resources of Siberia and the Far East, and an increase in global risks in general. In this regard, the use of modern management technologies, in particular, multi-agent simulation modeling, to support decision-making on managing migration processes becomes relevant. Since the main incentive for active citizens to change their place of residence is investing in the development of the region and providing the necessary conditions for a comfortable life, the purpose of the study is to develop an agent-based model for forecasting the impact of the population life quality on migration flows between the federal districts of the Russian Federation. One of the tasks solved using the model is to track the direction of migrant movement relative to the Republic of Bashkortostan when changing the controlled parameters. The simulation model was designed using modern CASE tools; UML diagrams and a mnemonic diagram of the decision-making support process for managing the demographic development of the region were built in the course of the work. Scenario experiments were conducted to predict changes in the population size in the study areas. Within the framework of the research, the authors applied the object-oriented methodology of simulation model design, agent-based approach for its implementation, as well as an agent-oriented approach for its implementation and statistical analysis methods when setting up experiments. The toolkit developed as a result of the study can be used by the representatives of executive authorities and government officials to develop a balanced resettlement policy, assess the possibility and conditions for developing regions of the Russian Federation with low population density.

Keywords: population forecasting; migration; agent-based model; federal districts of the Russian Federation; population life quality; resettlement; Far East; Republic of Bashkortostan

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INTRODUCTION

Russia is the world-largest country in terms of territory. It possesses significant natural resources, which offer unlimited opportunities for successful development and prosperity in the conditions of a well-maintained State policy. The Russian Federation has eight federal districts, which differ greatly in terms of socio-economic development and in natural and climatic conditions. For example, nearly 65 per cent of the country's territory is a permafrost-soil area, most of which is located in the Siberian Federal District (SFD) and the Far Eastern Federal District (FEFD). At the same time, Russia is specific by an extremely uneven density of population. For example, as of 1 January 2024, the Moscow's density was 5134.64 inhabitants per square kilometer and only 0.07 inhabitants per square kilometer in the Chukotka Autonomous Area. The main reasons for this are the harsh climatic conditions and the lack or poor development of infrastructure in the northern and far eastern parts of the country.

A significant gap in the indicators of population density in different regions of Russia leads to their differentiation in terms of socio-economic situation, since the main driver of the development of the territory and the development of its natural potential is the availability of a sufficient number of suitably qualified personnel. The problem of uneven distribution of population is one of the most serious obstacles to the successful development of the state, which requires the development of an effective policy of settlement of citizens in the territories of the federal districts [1]. In this regard, the objectives to generate instruments for developing balanced territorial settlement schemes become urgent. Currently, the application of multi-agent simulation modelling methods are still more in demand, since they can be successfully used to formulate strategic plans for the development of territories [2]. Many scientists are involved in working out agent-based models. In particular, the models are used to forecast demographic indicators and employment of the population in the regions of the country [3], which makes it possible to model public management processes by means of the change of a number of exogenous variables, to generate scenarios of experiments and to select optimal management decisions. The study [4] presents an agent-based model of population forecasting in the AnyLogic simulation environment. Experiments with the use of agent-based model contribute to the formation of the forecast of population change for the perspective up to 10 years in large and small cities of the Republic of Bashkortostan.

The authors of the article [5] propose an agent-based model of interaction between two categories of population: migrants and native inhabitants, which can be used to manage the human resource potential of enterprises based on the forecast values of demographic and migration indicators. Dutch researchers presented an agent-based model of internal migration under the conditions of the increasing risk of coastal flooding in France [6]. The agent parameters were determined using national statistics, and the model was calibrated on the basis of a household survey on the adaptation degree. An international team of researchers proposed an agent-based model of labour migration and farmland abandonment in China based on a very high resolution satellite visual footage, Global Positioning System, household surveys and census data [7]. The book [8] presents an agent-based labour market model to follow the life cycle of an individual from birth to retirement.

The problem of uneven distribution of human settlements is not only manifested in the context of federal districts, but also at the regional level. For example, the Republic of Bashkortostan (RB) has a tendency of concentration of inhabitants in large urban agglomerations and depopulation in the rural areas [9].

Besides, the migration outflow of population from Bashkortostan is another negative trend for

the development of the republic's economy. This mainly deals with young age groups: high school graduates leave the region to study in the leading universities of Russia, or young specialists who graduated from educational institutions in Bashkortostan and search for employment opportunities with a higher salary [10].

The federal cities — Moscow and St. Petersburg — are popular destinations for the residents of Bashkortostan. They are attracted by higher living standards, developed infrastructure, career opportunities and a whole variety of educational institutions. Bashkortostan trains personnel for the oil industry, therefore, such specialists move to the northern regions, where salaries are much higher, mainly to the Tyumen region. Bashkortostan's neighbouring Samara and Chelyabinsk areas, as well as Tatarstan Republic, are all attractive to would-be students from districts bordering of these constituent entities of the Russian Federation. After studying there, youngsters find jobs, start families and settle to live there permanently [11].

As mentioned above, regions in federal districts and in the subjects of the Russian Federation with a high quality of life are attractive for migration. It should be noted that this indicator is integral and includes such factors as accessibility of good education and qualified medical care, sufficient infrastructure development, income level, state of communications, economy, ecology. Besides, both geographical location and climate may be important for the choice of a place of residence [12].

Foreign researchers point out a close relationship between demographic or migration processes and the population life quality. To explore the latter, scientists in Norway studied environmental aspects, transport mobility, city development planning (location of stores, kindergartens, schools, universities, park areas) for the indigenous population and immigrants [13]. Indian scientists found out, that the education level is of the paramount importance for the quality of life among the adult population in rural areas of the Punjab province [14]. In Finland, the quality of life-style of citizens was analysed by means of the QoL Bref scale developed by the World Health Organization (WHO) and this article reflects the results of this work [15]. The researchers prioritised the health status of the population as the most important indicator, utilised the WHO four-dimensional model for assessment of physical, psychological, social and environmental aspects of life quality.

Moreover, physical health parameters encompass medication dependence, mobility, sleep and performance. The psychological dimension includes assessments of life-style satisfaction, the degree of meaningfulness of life, the individual's appearance, self-esteem and lack of negative feelings. The social factor is related to satisfaction with social relationships, social support, etc. The environmental dimension involves the feeling of personal and economic security, quality of the living environment, access to necessary information and satisfaction with the provision of health services, transport and leisure activities. Vietnamese experts used the same WHO model for their research to report [16] factors affecting the population life quality in Vietnamese coastal communities affected by natural disasters (floods and storms).

The study was aimed to develop an agent-based model by means of the AnyLogic tool environment for forecasting the impact of population life quality on migration processes, which is applied to solve two problems. The first problem pertains to track down the migration outflow from and inflow to the Republic of Bashkortostan within the framework of the federal districts of the Russian Federation. The second problem deals with the forecasting of demographic development in federal districts in accordance with the authorities' decisions to comprehensively develop specific territories via the implementation of investment programmes aimed at enhancing the quality of life of the population.

RESEARCH METHODS

Designing a simulation model on the basis of object-oriented approach

Agent-based modelling is a newly-developing approach to describe complicated socio-economic processes, including migration and population reproduction. There are many systems to use it for developing models. Platform AnyLogic takes the top position in the list of software product for general purpose simulation modelling [17]. This agent-based modelling software has a few indisputable advantages: the professional tool integrated with GIS maps has extensive animation and visualisation capabilities, and it is able to handle large volumes of input Big data. The simulation model was designed using the CASE tool Enterprise Architect with an object-oriented approach. Its UML diagrams describe the functionality and the structure of the stored data memory for developing support system of solutions.

MS Visio was used to create a mnemonic scheme of the business process of decision-support system to control the demographic development of territories (*Fig. 1*).

A certain number of state entities deal with national migration policy. The key role is played by the Ministry of the Interior and its structural subdivision, the Main Directorate for Migration Issues. The Presidential Administration, the Ministry of Labour and Social Protection of the Russian Federation and the Federal Security Service are the leading federal executive bodies in charge of national migration policy. A supporting function is entrusted to the ministries, services and agencies, such as the Ministry of Science and Higher Education of the Russian Federation, the Ministry of Development of the Far East and the Arctic of the Russian Federation, the Federal Labour and Employment Service, the Federal Tax Service, the Federal State Statistics Service. [18]

The Enterprise Architect case-tool was used to create a diagram of decision-making support activities for managing the demographic development of territories (*Fig. 2*).

The agent-based model (which operates as a decision support tool) contains a database of both initial statistical indicators for analysis and modelling results, as well as an add-ons system of represented by exogenous variables which could be specified by the user. The core is a simulation model of demographic and migration processes. It also contains a system to visually evaluate the simulation results.

Government policy is modelled by changing the exogenous parameters, which can be specified in the system. The model in question forecasts the development of the demographic and socio-economic potential of the territory and ensures the possibility of scenario evaluation of management decision-making process. The system verifies target and planned values of socio-economic development indicators in order to determine the effectiveness of the State policy. In case of deviations revealed, it is possible to develop a whole set of corrective measures.

A class diagram constructed below describes the structure of the database (*Fig. 3*).

The input parameters of the model are the following: the area of the Federal district (or constituent entity of the Russian Federation), population size and density, an integral indicator of the quality of life that takes into account many factors that represent both the development of the region and the opportunities for education and employment, as well as the comfort of life on the given territory.

The agent-based model makes it possible to set up a variety of scenarios for experiments by changing three indicators: the inhabitants' quality of life, the volume of investment in the development of the economy and infrastructure of the region, as well as the average wage. It also makes it possible to estimate the forecast of changes in the results in relation to migration processes. Regarding the purpose of the study, the median or modal wage values can be used

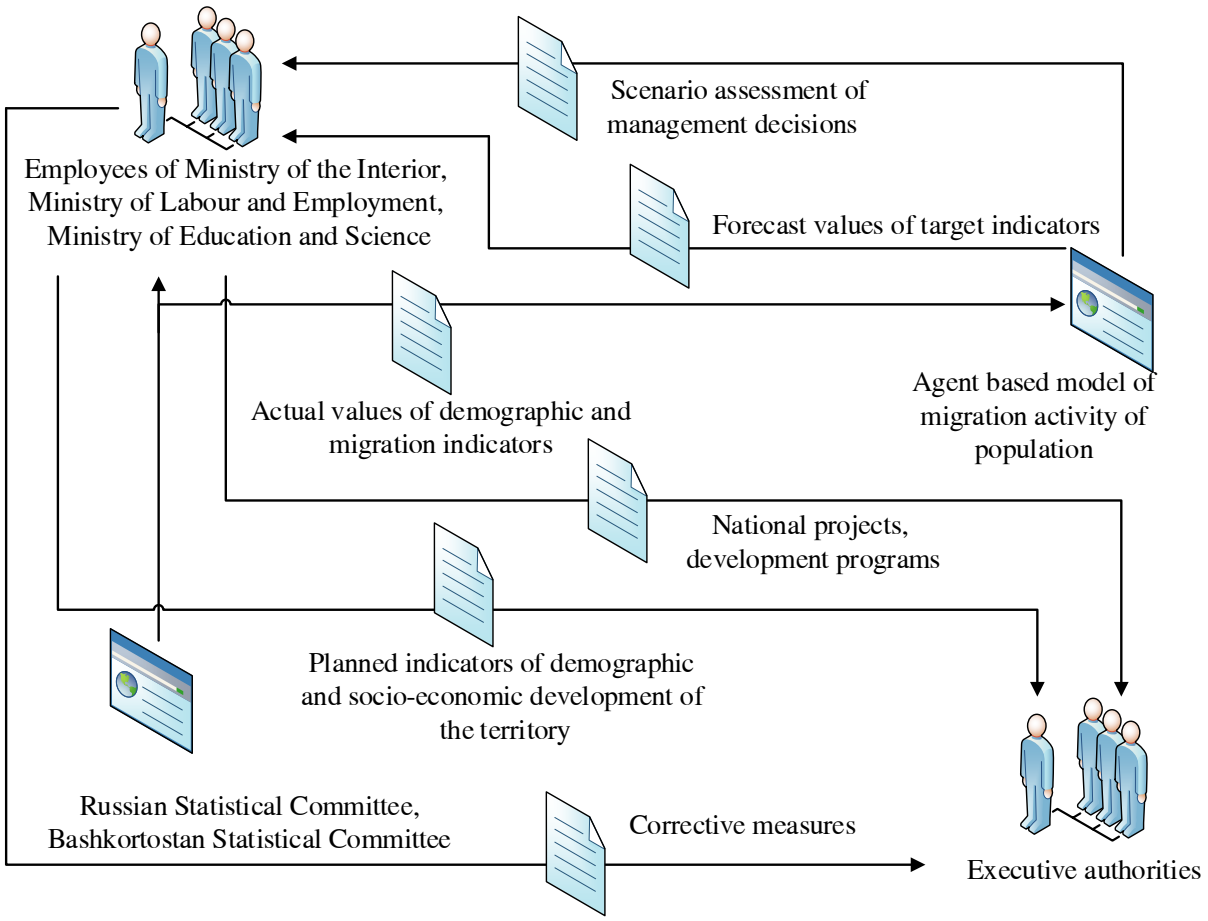


Fig. 1. **Mnemonic diagram of the decision-making support process for managing the demographic development of the territories**

Source: compiled by the authors.

in the model to ensure a more reliable assessment of the level of attractiveness of jobs in a constituent entity (or Federal district) of the Russian Federation. The median wage value is not affected by extremely high or low incomes, meanwhile the modal wage value is suitable for determining the most common level of earnings among workers and employees. At the same time, the model itself, as a flexible tool, allows to use a whole variety of options for measuring wages. This ensures a vast degree of reliability of experimental calculations for various problem statements. In the meanwhile, a number of measuring instruments could be used altogether, as controlled parameters of the model, for example, to solve the problems of predicting the degree of migration intensity.

Implementation of a simulation model based on an agent-based approach

An agent based model has been developed to forecast migration dynamics in the framework of Federal districts as a function of changes in the population life quality and its main components, including average wages and investment in regional infrastructure. If compared to the econometric model, it is more advanced for analysis of complex socio-economic processes: the compilation of econometric dependencies requires much more volume of statistical data,

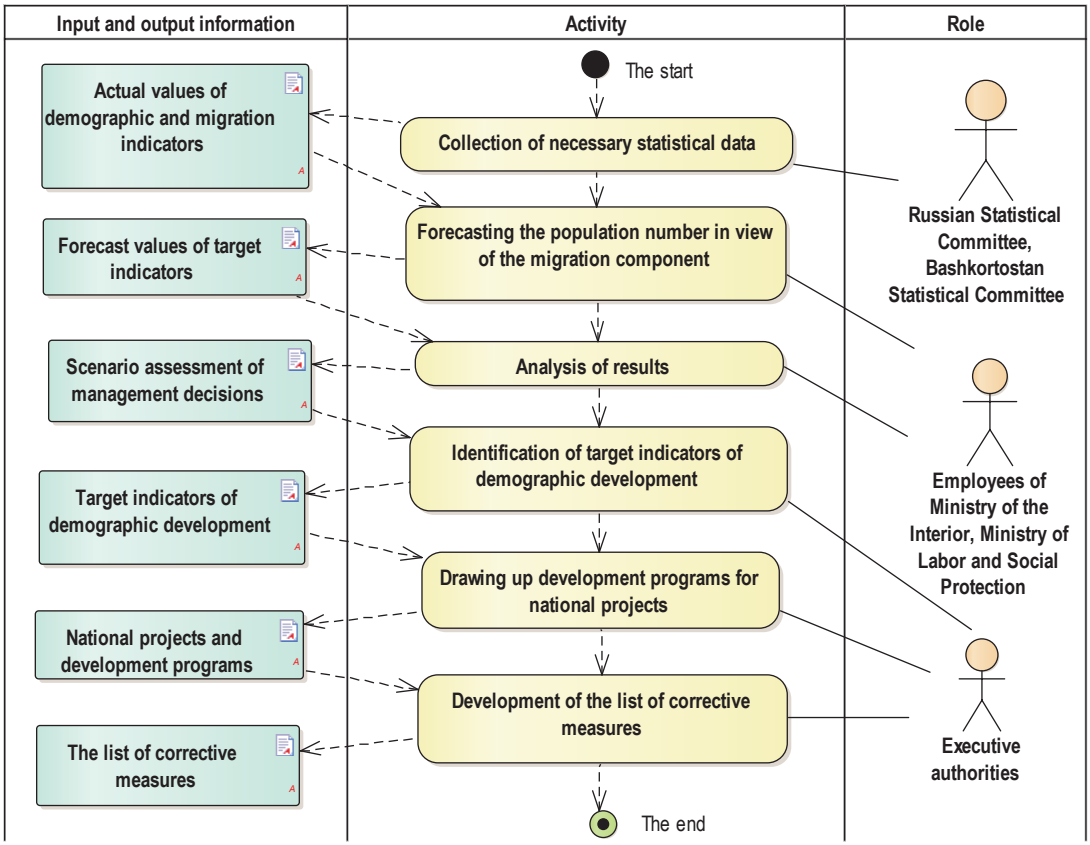


Fig. 2. **Activity diagram of decision-making support for territorial development management**

Source: compiled by the authors.

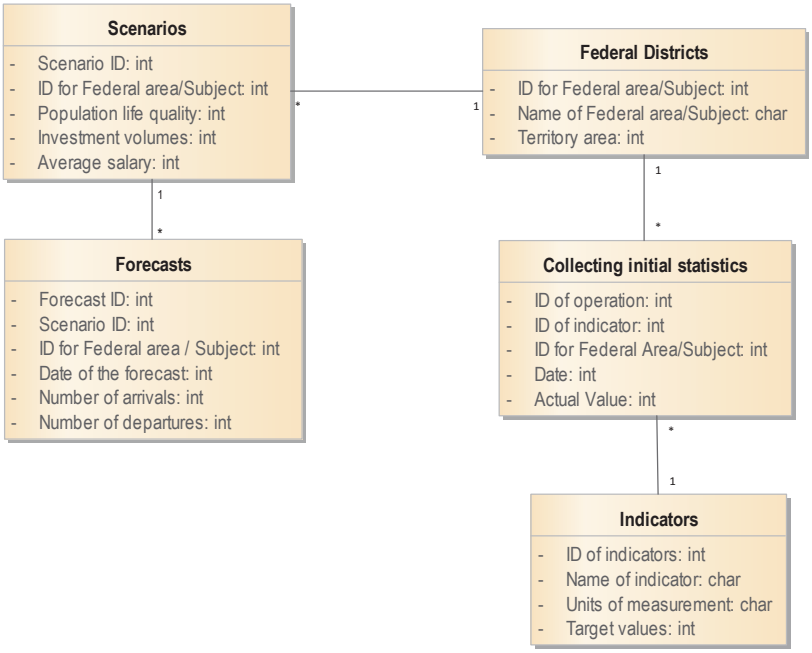


Fig. 3. **Class diagram of decision-making support for migration management**

Source: compiled by the authors.

which are not always possible to collect. Besides, the econometric approach only offers adequate results if the region's economy indicates the stability of development, without drastic ups and downs. However, in reality, the need to calculate forecast assessments of the evaluated indicators often occurs in case of emergency, like war, pandemics, or global economic crises. In case of sharp changes in the economic situation related to military conflicts, international situation, fluctuations in the prices of raw materials, introduction of technological innovations in production, it is necessary to forecast the dynamics of migration with preliminary justification of the plan of the corresponding scenario experiment, adjustment of the controlled parameters to take into account the most critical factors within the framework of the solved problem: for example, such as unemployment rate, accumulated inflation, cost of oil on the world market, etc.

The agent based model contains such agents, as residents, enterprises, educational institutions and regions.

Two main states of mind are characteristic for the agent entitled "Resident" (*Fig. 4*): if he/she is satisfied or dissatisfied with the life quality in the region, and the main factor in his/her assessment of the level of wages.

Transitions are triggered by the factor of dissatisfaction with the living standards, employment termination and loss of income, in case of decreasing or, conversely, increasing level of income.

The quality of life of the region's population is impacted by the level of economic development, which is expressed in the growing gross regional product to ensure the functioning of local enterprises.

Fig. 5 displays the level of conditions (growing, stable, unstable) for the agent "Enterprise". The activity of enterprises leads to either an increase or a decrease in the level of profit, which is graphically presented in the state diagram. In the first case, it requires to hire additional employees. In the second case, enterprises start to lay off employees and search for ways to reduce costs, for example, moving to regions with cheaper labour force, material resources and rental prices.

Fig. 6 displays a simulation model generated in the AnyLogic environment on the map of the Russian Federation with eight Federal districts and one of the subjects: the Republic of Bashkortostan.

On the map, agents which represent the indigenous population are shown as blue dots and migrant agents as red dots. The pop-down menu opens the indicators of size and density population, average wages, investment volume and the number of enterprises by Federal district. To set the control parameters, one should select the Federal district, or region of interest and set the value of the change for investment volume, average wages and the integral indicator of the life quality. The simulation can generate diagrams displaying the intensity of migration flows and the ratio between the number of indigenous inhabitants and the number of migrants who have arrived in the region.

Separately, "the Statistics" method helps to forecast the number of people moving into and out of the region, and, consequently, the migration increase/decrease of the population.

RESULTS

Analysis of statistics on migration and life quality in the Republic of Bashkortostan and the Russian Federation

The Agency for Strategic Initiatives has developed a regional social standard that determines to set up a Quality of Life Council[1] in each region of the country, because improving this indicator is a priority for the Government of the Russian Federation. Such entity was es-

[1] Regional Social Standard. Official website of the Agency for Strategic Initiatives. URL: https://files-ice.asi.ru/iblock/946/946d0385e1f6780979bcdbb98fff7b95/Regionalnyy-sotsialnyy-standart.pdf (accessed on 15.08.2024).

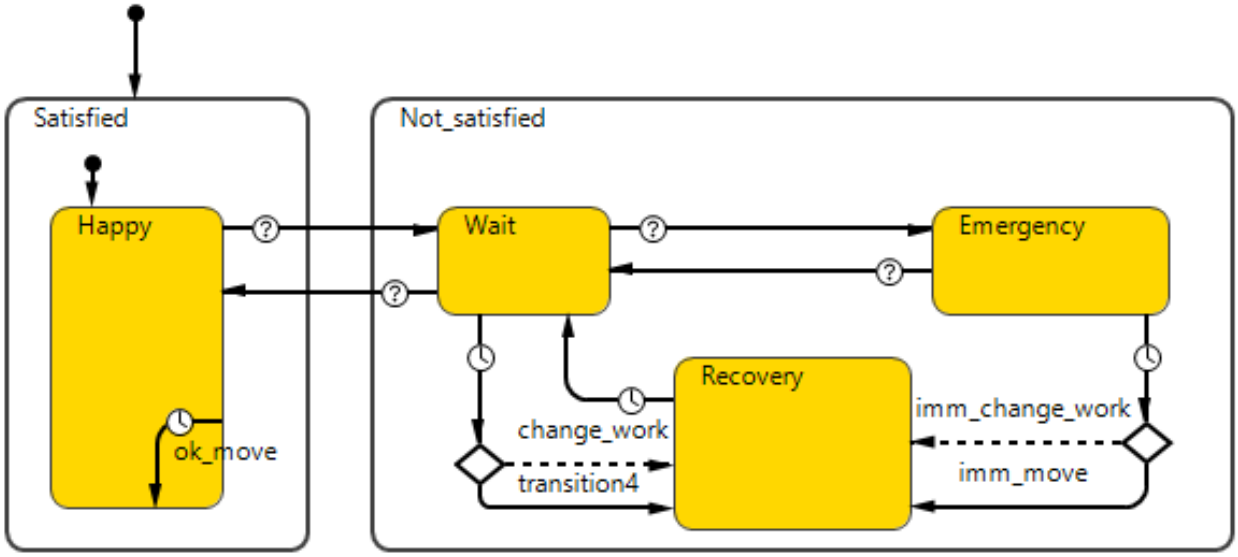


Fig. 4. **Diagram of the condition of agent "Resident" built in AnyLogic**

Source: compiled by the authors.

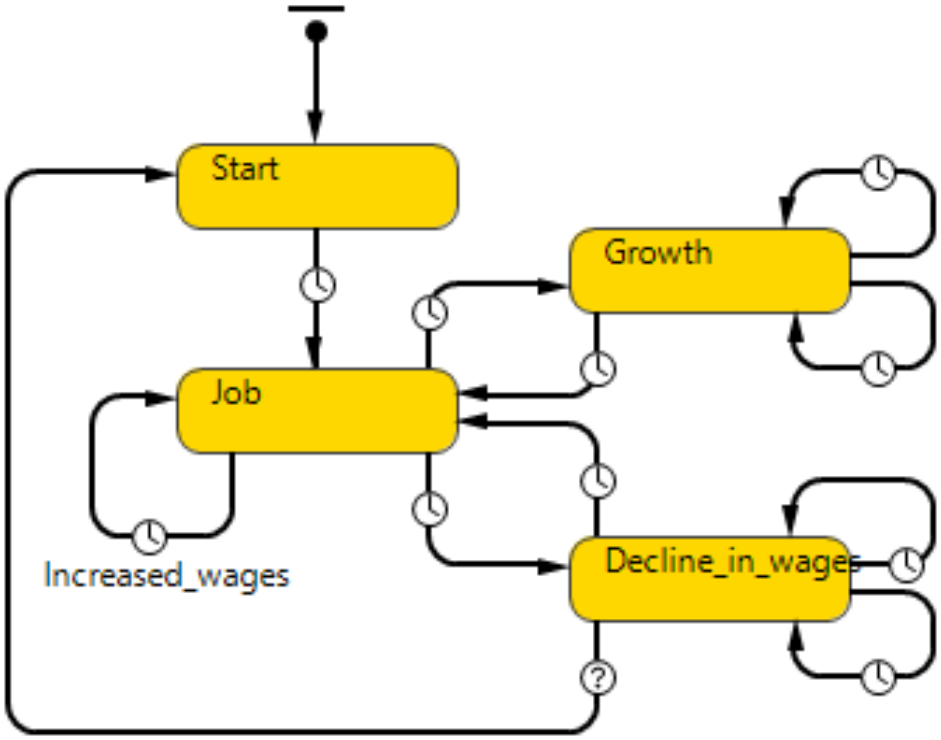


Fig. 5. **State chart of the agent "Enterprise" built in AnyLogic**

Source: compiled by the authors.

tablished in the Republic of Bashkortostan in 2023. The standard provides for the introduction of a human-centric approach in the attitude culture of public administration. The topics of the document include such areas as health care, social services, education, culture,

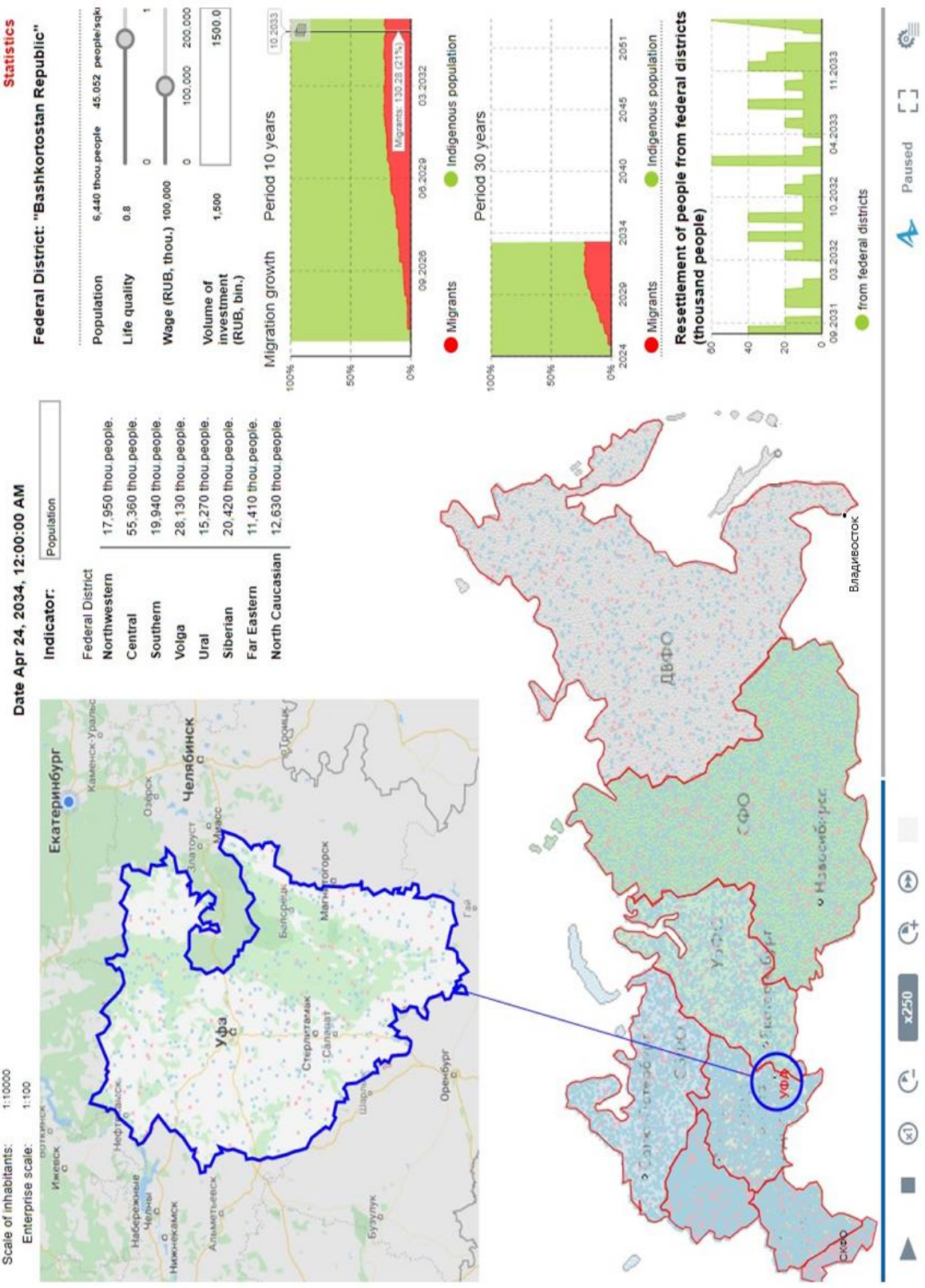


Fig. 6. **Agent-based model for forecasting the impact of life quality on migration processes by Federal districts**

Source: compiled by the authors.

development and improvement of the urban environment.

Data on the population life quality published by the RIA Rating Centre for Economic Research are aimed to conduct scenario experiments. In contrast to Rosstat estimates, which focus primarily on analysing income, expenditure, purchasing power of citizens, housing affordability, etc., the method proposed by RIA Rating for calculating the integral indicator of the population life quality uses the information from both Rosstat and the Ministry of Health of Russia, the Ministry of Finance of Russia, the Bank of Russia and other open sources.

The rating is based on 66 indicators which are grouped into 11 sections with the 100-point scale rating score. At the same time, this methodology takes into account, in addition to the listed criteria, environmental and climatic conditions, safety of residence, public health and education levels, provision of social infrastructure facilities, development of the territory and public convenience of transport infrastructure, etc. Hence, the most complete and accurate set of data is collected for assessing the life quality and the level of attractiveness of territories for migration, which is necessary for the research work provided.

RIA Rating annually prepares life quality ranking-lists of regions. Over the past five years, Moscow, St. Petersburg and the Moscow region have been traditionally in the top list. In 2023, the Republic of Bashkortostan held the 19th position, which, was a progress, compared to the last five years: in 2020, the Republic of Bashkortostan was ranked 29th.

Table 1 presents the results of the calculation of the rating of some regions of the Russian Federation over the last five years — in addition to the indicators of the leading regions, it includes

Table 1

Indicators of the population life quality

Region	Rating scores of the life quality					Average salary for the year of 2024 (in Rubles)	Investments in fixed capital in 2022 (in Rubles)
	Year						
	2019	2020	2021	2022	2023		
Moscow	79.2	82.1	81.3	82.9	83.6	152 859	5 917 986
St-Petersburg	77.3	80.6	80.2	82.3	82.3	101 892	997 478
Moscow region	74.5	76.1	75.8	78.2	79.9	91 809	1 329 379
Republic of Sakha (Yakutia)	37.9	39.1	39.2	42	44.3	119 338	616 285
Krasnoyarsk region	46.7	45.3	48	52.2	54	89 627	747 818
Republic of Bashkortostan	50.4	50	53.6	58.2	61.5	62 957	512 388

Source: compiled by the authors based on the Rosstat data. URL: https://rosstat.gov.ru/folder/210/document/13238 (accessed on 12.08.2024), URL: https://rosstat.gov.ru/labor_market_employment_salaries# (accessed on 12.08.2024); RIA Novosti. URL: https://ria.ru/20240212/kachestvo_zhizni-1926120093.html (accessed on 12.08.2024).

data for comparison from Krasnoyarsk Krai and the Sakha Republic (Yakutia). These are the two largest territory subjects of the Siberian and Far Eastern Federal Districts with the lowest population density in the country.

Table 1 also displays the figures of average monthly nominal wages of workers in the selected regions for the time frame period from January to May 2024. At the same time, the average wage in the Far Eastern Federal District as a whole for the same period was 91.970 Rubles, and in the Siberian Federal District — 72.574 Rubles. Thus, one can come to the conclusion, that this financial indicator is important, but not a decisive criterion for the integral indicator of the population life quality, since in such largest subjects of these federal districts the rating of the life quality turned out to be quite low, despite the relatively high level of income. The reason is insufficient infrastructure and the harsh climatic conditions in these regions.

Table 1 also provides information on the volume of investment in fixed assets [18]. This indicator is 2.512.408 million Rubles for the Far Eastern Federal District, 2.823.190 million Rubles for the Siberian Federal District, and 9.367.418 million Rubles for the Central Federal District. The gap in funding for the Central Federal District Rubles, in particular for Moscow, in comparison with other federal districts is extremely large, which indicates the uneven development of infrastructure in the urban centre and in the periphery. This is, of course, the reason for the migration of the population to the centre.

The indicators of migration growth/loss in the Republic of Bashkortostan lead to the conclusion, that the native population leave the Republic and migrants from Central Asia, Armenia, Vietnam and Turkey coming to the Republic to find the job. The situation turned out to be quite different only in 2021, when the pandemic restrictions measure were adopted (*Table 2*).

Official statistics on migration throughout federal districts of the Russian Federation show that the Central, Southern and Northwestern Federal Districts are the most attractive for migrants (*Table 3*). As to the Far Eastern Federal District is concerned, the situation here is alarming due to an out-migration of the local inhabitants. Besides, labour migrants from other countries are not enthused to settle in this region, which requires management decisions to change the current state of affairs.

Scenario experiments to forecast migration in the Republic of Bashkortostan

To forecast the migration situation in the Republic of Bashkortostan within the framework of changes in the life quality, investment volume and average wages, experiments were held using a simulation model according to the scenario parameters specified in *Table 4*.

The developed agent-based model helps to make long-term forecasts. In scenario No. 2, one can see an increase in the share of the population by 20 per cent over 10 years. If the current situation for the selected indicators does not

Table 2

Migration increase/decrease in the Republic of Bashkortostan

Types of migration	January-May 2024	2023	2022	2021
Interregional (the number of persons)	-995	-2451	-1860	5855
International (the number of persons)	2295	1531	381	9024

Source: developed by the authors based on the data from territorial body of the Federal state statistics service for the Republic of Bashkortostan URL: https://02.rosstat.gov.ru/folder/25491?ysclid=m0p3q9k7h6318966351 (accessed on 15.08.2024).

Table 3

Migration growth / loss by the federal districts for 2023

Federal Districts	In-migration increase, total, arrived per 10 thousand people of population	Out of it due to movements:			
		Within the territory of Russia due to movements, arrived per 10 thousand people of population	International total arrivals per 10 thousand people of population	Including:	
				the CIS countries, total arrivals per 10 thousand people of population	with other foreign countries, total arrivals per 10 thousand people of population
Central	122 406	76 869	45 537	42 485	3 052
North-Western	35 691	30 339	5 352	4 534	818
Southern	53 024	46 106	6 918	5 023	1 895
North-Caucasian	–10 401	–10 104	–297	–252	–45
Volga	–723	–16 738	16 015	14 859	1 156
Ural	27 514	1 020	26 494	26 655	–161
Siberian	–9 704	–20 116	10 412	10 012	400
Far Eastern	–14 178	–13 699	–479	–3 277	2 798

Source: developed by the authors based on the data of Rosstat. URL: https://rosstat.gov.ru/compendium/document/13283 (accessed on 15.08.2024).

Table 4

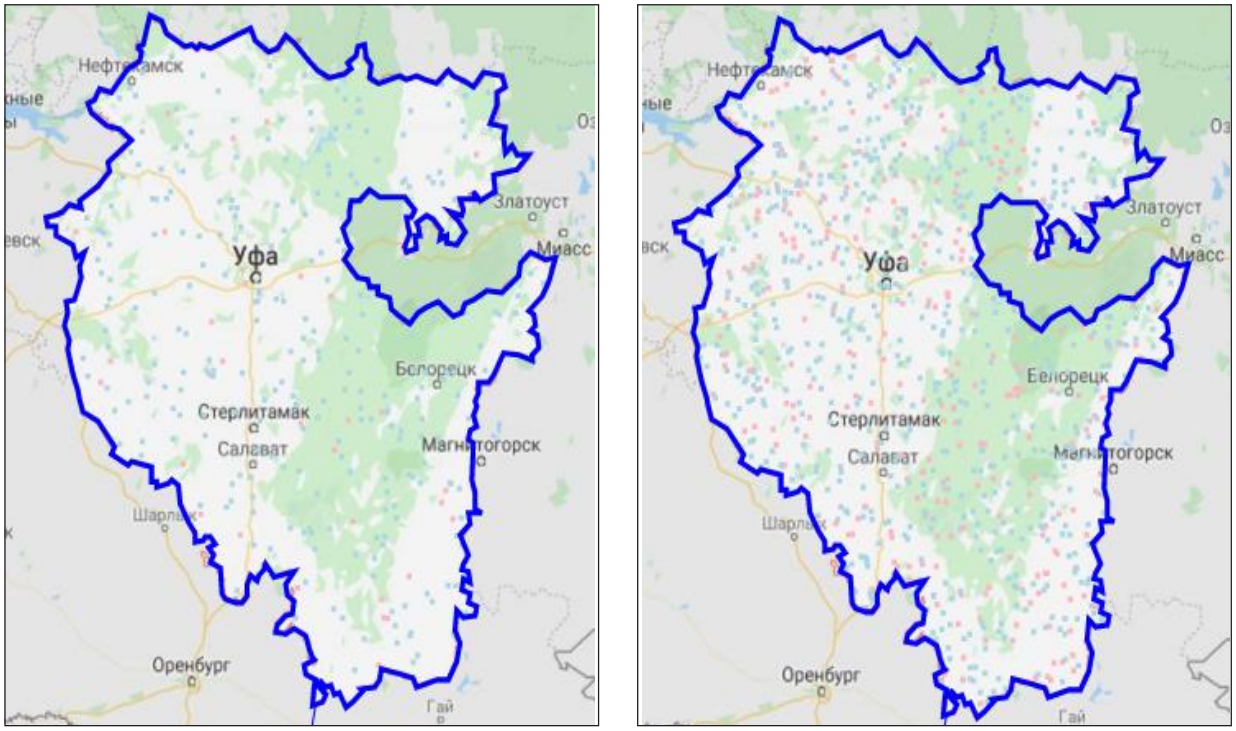
Scenario modeling parameters for the Republic of Bashkortostan

Scenario parameter	Scenario No. 1	Scenario No. 2	Scenario No. 3	Scenario No. 4
Volume of investment in fixed assets (in billions of Rubles)	500	1000	3000	1000
Wages (in Rubles)	63 000	80 000	80 000	100 000
Life qualitya	0.6	0.8	0.8	0.8

Source: compiled by the authors.

Note: **a —** life quality has no units of measurement (dimensionless value), that is, an integral indicator is from 0 to 1.

change, for example, in view of scenario No. 1, the flow of migrants will not stop, but will decrease to 11 per cent. Scenario No. 3 implies a significant increase in investment in the region: six times as much as today, while maintaining the same level of wages. Intensive infrastructure development can increase migration growth by 29 per cent. The scenario No. 4 indicates the



Scenario 1 Scenario 4

Fig. 7. **Distribution of migrant agents across the territory of the Republic of Bashkortostan under different scenario conditions**

Source: compiled by the authors.

twofold increase of the volume of investment in the development of the republic, then the average salary will grow to 100 thousand Rubles, and the inflow of migrants will reach 19 per cent. Thus, we can conclude that investment in the development of the region's infrastructure plays a significant role in increasing attractiveness for migrants. *Fig. 7* shows the distribution of migrant agents (marked as red dots) and local agents (marked as blue dots).

The density of colour spots on the maps allows us to assess the attractiveness of Bashkortostan for migrant labour force.

Scenario experiments for forecasting migration in the Far Eastern Federal District

To forecast migration in the Far Eastern Federal District, a number of experiments were conducted, the parameters of which are specified in *Table 5*.

The implementation of scenario No. 1 indicates a migration outflow from the Far Eastern Federal District: the population decreases by another 20 per cent in 10 years.

The scenario No. 2 implements the forecasted volume of investments to be increased twofold and the average salary raised by 30 per cent, the integral indicator of the life quality will grow by 30 per cent, so that the migration situation will improve by 12 per cent. Never the less, such influx of labour force will not be sufficient for the vast Far Eastern territory.

Scenario No. 3 assumes a threefold increase in investment in the Far Eastern Federal District and the payment of an average monthly salary similar to that in Moscow. In this case, the number of migrants will increase by 25 per cent.

Scenario No. 4 simulates all regulated indicators will be equal to the level of Moscow, including the volume of investment in infrastructure and in

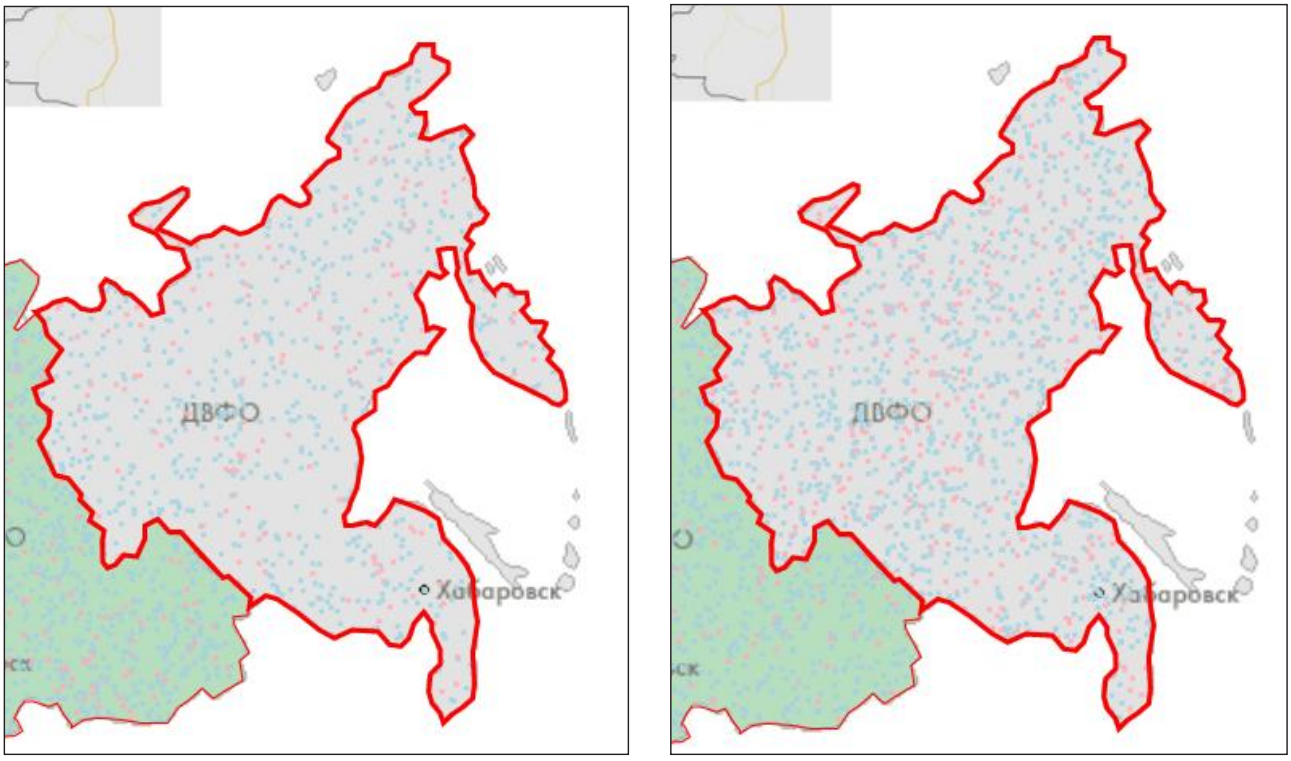
Table 5

Scenario modeling parameters for the Far Eastern Federal District

Scenario parameter	Scenario No. 1	Scenario No. 2	Scenario No. 3	Scenario No. 4
Investment volume, in billion Rubles	2500	5000	7000	9000
Wages in Rubles	92 000	120 000	150 000	150 000
Life qualitya	0.45	0.6	0.8	0.8

Source: compiled by the authors.

Note: **a —** life quality has no units of measurement (dimensionless value), that is, an integral indicator is from 0 to 1.



Scenario 1 Scenario 4

Fig. 8. **Distribution of migrant agents on the territory of the Far Eastern Federal District under various scenario options**

Source: compiled by the authors.

this case 45per cent increase in local population could be predicted.

Fig. 8 shows the comparative results of the implementation of scenarios No. 1 and 4 under the condition of minimum and maximum values of the controlled parameters. Scenario No. 4 shows the attraction of a larger number of migrant agents and also demonstrates that an increase in the life quality contributes to the growth of the indigenous population.

Due to rather a harsh climatic conditions, peculiarities of food production and delivery, the price of the consumer goods basket in the Far Eastern Federal District is higher than the average one in Russia. Thus, the growth of the life quality depends much on the growth of people's incomes. Low quality of medical and educational services, as well as insufficient transportation links, have a strong impact on the out-migration of the population. Investment in the region's infrastructure will help to curb the out-migration of the local inhabitants and attract qualified specialists to develop and explore the region.

CONCLUSION

The abovementioned developed agent-based model is designed to build prognosis of internal labour force and educational migration (migrants are assumed as citizens of the Russian Federation). The analysis of the legislative framework measures has revealed that the legal regulation regarding foreign citizens entering the country is developing and becomes more upgraded, meanwhile the issues of internal migration control are not given due attention. The proposed agent-oriented model should become a reliable instrument to make effective management decisions to coordinate the re-location of the population throughout the territory of the Russian Federation.

Such phenomena as demographic ageing of population, emigration of young people and the drop of birth rate are common for the Republic of Bashkortostan as a whole. All this has a negative impact on the development of sectors of the economy related to consumption, such as construction, trade, housing and utilities. Economy would not grow in the environment of dramatic drop of domestic consumption and a lack of skilled labour force.

In the Republic of Bashkortostan, the number of students has notably decreased due to a reduction in university admissions. This has led to a mass migration of young people who needed to obtain a proper education. Correspondingly, the number of teachers in educational institutions has decreased as well due to the emigration of highly qualified personnel. The solution for this problem would be a new system of innovative scientific and educational projects able to provide professional skills with competitive advantages in the labour market.

To stop the migration outflow, it is necessary to set priorities for the territorial development measures of the Republic, aimed at provision of a comfortable living environment for the population and opportunities for human self-actualisation, under the strict conditions that socially significant services are available in the places of residence.

The research work [19] point out, that internal education-oriented migration contributes to the depopulation throughout the Siberia and the Far East: the most talented young people leave to Moscow and St-Petersburg for better education and, eventually, they never return to their native land. This creates a "domino effect": their parents, close relatives and friends abandon the region to follow their children. This situation poses a terminal security threat to the eastern part of the country. To solve this problem of education-oriented migration of the Far East, it is highly advisable to open there branches of leading universities of Moscow and St. Petersburg and to conduct student exchanges between these universities and their distant brunches.

In order to increase the birth rate, benefits and subsidies grants should be facilitated to purchase housing, to obtain special conditions for mortgages and the reduction in the interest rate depending on the number of children born in the family. It is also of great importance the prophylaxis of reproductive health among young people and the expansion of range of genetic screening tests for young families.

More new jobs with decent wages would attract more skilled workers and encourage labour force mobility. Rising wages would serve as an

incentive for inhabitants of the Far East to go in for self-education and development of their sustainable households. Nowadays, the income-to-expenditure ratio is inadequate for the majority of the population. An effective measure to improve the demographics of the region could be to exempt workers and employees with a certain period of job from paying income tax. Definitely, significant financial allocations are mandatory for all infrastructure and social programmes. At the same time, statistically, a huge gap exists between the volume of investment in the central regions of the country and in the periphery. Correction of such imbalances could successfully contribute to establishing a balanced territorial settlement policy.

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REFERENCES

1. Kritskaya A. A., Shumilina A. B., Dryaev M. R. Review of the problem of uneven settlement of residents across the territories of the federal districts of the Russian Federation and the formation of indices of rationality as tools of the demographic policy of the state. *The Scientific Heritage*. 2021;(63–5):21–31. (In Russ.). DOI: 10.24412/9215–0365–2021–63–5–21–31
2. Makarov V. L., Bakhtizin A. R., Sushko E. D. Agent-based models as a means of testing of management solutions. *Upravlencheskoe konsul'tirovanie = Administrative Consulting*. 2016;(12):16–25. URL: https://cyberleninka.ru/article/n/agent-orientirovannye-modeli-kak-instrument-aprobatsii-upravlencheskih-resheniy (In Russ.).
3. Kuznetsova O. I. Development of a simulation model of the Russian Federation for predicting indicators in the field of demography and labor. *Iskusstvennye obshchestva = Artificial Societies*. 2022;17(4):5. (In Russ.). DOI: 10.18254/S 207751800023565–0
4. Nizamutdinov M. M., Gaisina A. Sh., Davletova Z. A. Agent-based model of population forecasting by cities of the Republic of Bashkortostan. *Ekonomika i upravlenie: nauchno-prakticheskii zhurnal = Economics and Management: Research and Practice Journal*. 2023;(6):161–167. (In Russ.). DOI: 10.34773/EU.2023.6.30
5. Makarov V. L., Bakhtizin A. R., Beklaryan G. L., Akopov A. S., Strelkovskii N. V. Simulation of migration and demographic processes using FLAME GPU. *Business informatics*. 2022;16(1):7–21. (In Russ.: *Biznes-informatika = Business informatics*. 2022;16(1):7–21. DOI: 10.17323/2587–814X.2022.1. 7.21).
6. Tierolf L., Haer T., Botzen W. J.W., et al. A coupled agent-based model for France for simulating adaptation and migration decisions under future coastal flood risk. *Scientific Reports*. 2023;13:4176. DOI: 10.1038/s41598–023–31351-y
7. Zhang Q., Tao S., Walsh S. J., et al. Agent-based modeling of the effects of conservation policies on social-ecological feedbacks between cropland abandonment and labor migration. *Landscape Ecology*. 2023;38(12):4247–4263. DOI: 10.1007/s10980–022–01575-w
8. Boulahbel-Bachari S., El Saadi N. Understanding the labor market from the bottom up with an agent-based model. In: Silhavy R., Silhavy P., Prokopova Z., eds. Software engineering application in systems design (CoMeSySo-2022). Cham: Springer-Verlag; 2023:754–769. (Lecture Notes in Networks and Systems. Vol. 596). DOI: 10.1007/978–3–031–21435–6_65

9. Gaynanov D. A., Ataeva A. G. Balanced spatial development of the Republic of Bashkortostan: Problems and prospects. *Vestnik UGNTU. Nauka, obrazovanie, ekonomika. Seriya: Ekonomika = Bulletin USPTU. Science, Education, Economy. Series: Economy*. 2019;(1):7–15. (In Russ.). DOI: 10.17122/2541–8904–2019–1–27–7–15
10. Hilazheva G. F., Shamsutdinova N. K., Utyasheva I. B., Prudnikov V. B., Adigamova O. F., Yagafarova D. G. Migration outflow from Bashkortostan in the context of redistribution of human capital. *Vestnik UGNTU. Nauka, obrazovanie, ekonomika. Seriya: Ekonomika = Bulletin USPTU. Science, Education, Economy. Series: Economy*. 2017;(4):165–173. URL: https://cyberleninka.ru/article/n/migratsionnyy-ottok-iz-bashkortostana-v-kontekste-pereraspredeleniya-chelovecheskogo-kapitala (In Russ.).
11. Leshtaeva A. A., Vishnevskaya N. G. Migration in the Republic of Bashkortostan. *Skif. Voprosy studencheskoi nauki = Sciff. Issues of Students' Science*. 2017;(9):1–4. URL: https://cyberleninka.ru/article/n/migratsiya-v-respublike-bashkortostan (In Russ.).
12. Nizamutdinov M. M., Davletova Z. A. Conceptual model for predicting the impact of population life quality on migration and demographic processes. *Ekonomika i upravlenie: nauchno-prakticheskii zhurnal = Economics and Management: Research and Practice Journal*. 2024;(1):150–155. (In Russ.). DOI: 10.34773/EU.2024.1.27
13. Alvarez A. L., Müller-Eie D. Neighbourhood conditions and quality of life among local and immigrant population in Norway. *International Journal of Community Well-Being*. 2022;5(4):753–776. https://doi.org/10.1007/s42413–022–00183–5
14. Kasaudhan S., Saraswathy K. N., Chaudhary V. Quality of life and its sociodemographic determinants: A population-based study from rural Punjab, India. *Discover Social Science and Health*. 2024;4(1):26. DOI: 10.1007/s44155–024–00085–1
15. Mäki-Opas T., Pieper R., Vaarama M. Exploring the capability approach to quality of life in disadvantaged population groups. *Scientific Reports*. 2022;12:15248. DOI: 10.1038/s41598–022–18877–3
16. Nguyen G. T., Tran T. B., Le D. D., et al. Determining the factors impacting the quality of life among the general population in coastal communities in central Vietnam. *Scientific Reports*. 2024;14:6986. DOI: 10.1038/s41598–024–57672–0
17. Bragin A. V., Bakhtizin A. R., Makarov V. L. Modern software tools for agent-based modeling. *Iskusstvennye obshchestva = Artificial Societies*. 2022;17(4):12. (In Russ.). DOI: 10.18254/S 207751800023501–0
18. Trifonova K. V. The system of law enforcement in the field of migration: System analysis. *Uchenye zapiski Krymskogo federal'nogo universiteta imeni V. I. Vernadskogo. Yuridicheskie nauki = Scientific Notes of V. I. Vernadsky Crimean Federal University. Juridical Science*. 2021;7(4):89–99. (In Russ.). DOI: 10.29039/2413–1733–2021–7–4–89–99
19. Trofimov E. A. New approaches to internal educational migration. *Baikal Research Journal*. 2023;14(1):258–266. (In Russ.). DOI: 10.17150/2411–6262.2023.14(1).258–266

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