МРНТИ 06.73.55 https://doi.org/10.26577/jerba202414712

I.V. Mishchenko[1]*, M.G. Krayushkin[1], S.I. Mezhov[1], I.S. Bianchi[2]

[1]Altai State University, Russia, Barnaul
[2]Federel university of Santa Catarina, Brazil, Florianopolis
*e-mail: mis.iv@mail.ru

IMPROVEMENT OF MIGRATION BALANCE FORECASTING WITHIN THE FRAMEWORK OF MANAGEMENT OF SOCIO-ECONOMIC DEVELOPMENT OF SINGLE-INDUSTRY TOWNS ON THE BASIS OF ARTIFICIAL INTELLIGENCE (on the materials of the Republic of Kazakhstan)

In this study, models of artificial neural networks of migration balances are developed in order to improve the efficiency of management of socio-economic development of single-industry towns in the Republic of Kazakhstan. Now there are no universal tools for forecasting indicators of socio-economic development in general and characterising migration processes in particular. However, the volume of budget allocations to address human resources issues in single-industry towns, the creation of social facilities and the implementation of other activities that are significant for economic, social and infrastructural development, the direction of development of single-industry towns depend on the forecast of migration balance. In addition, the forecast of migration balance is important for identifying core areas and their subsequent priority development. In this article, a substantial analysis of researchers' works is carried out, and it is determined that artificial intelligence models, in particular, the most adaptive neural networks are not used in forecasting the migration balance. The purpose of this study is to develop models of artificial neural networks of migration balance to improve the efficiency of management of socio-economic development of single-industry towns in the Republic of Kazakhstan. The result of the research is a methodological approach and a toolkit for forecasting the migration balance for single-industry towns in the Republic of Kazakhstan. The developed approach to forecasting and the toolkit are universal in the field of forecasting socio-economic indicators. In addition, the results described in the article can be used in other studies in the field of forecasting and planning. In particular, the developed toolkit can be used to assess the effectiveness of management decisions, for example, in the implementation of evidence-based policy for the development of single-industry towns.

Key words: migration balance, single-industry towns, artificial intelligence models, artificial neural networks, model error, management of socio-economic development.

И.В. Мищенко[1]*, М.Г. Краюшкин[1], С.И. Межов[1], И.С. Бианчи[2]

[1]Алтай мемлекеттік университеті, Ресей, Барнаул қ.
[2]Санта Катарина Федералдық Университеті, Бразилия, Флорианополис қ.
*e-mail: mis.iv@mail.ru

Жасанды интеллект негізінде моноқалалардың әлеуметтік-экономикалық дамуын басқару шеңберінде (Қазақстан Республикасының материалдарында) көші-қон сальдосын болжауды жетілдіру

Бұл зерттеуде Қазақстан Республикасы моноқалаларының әлеуметтік-экономикалық дамуын басқарудың тиімділігін арттыру мақсатында көші-қон сальдосының жасанды нейрондық желілерінің модельдері әзірленді. Қазіргі уақытта жалпы әлеуметтік-экономикалық даму көрсеткіштерін болжаудың және атап айтқанда көші-қон процестерін сипаттайтын әмбебап құралдар жоқ. Алайда, моноқалаларды дамыту бағыттары, моноқалалардағы кадрлық мәселелерді шешуге, әлеуметтік объектілерді құруға және экономикалық, әлеуметтік және инфрақұрылымдық даму үшін маңызды басқа да іс-шараларды іске асыруға бағытталған бюджеттік қаражат көлемі көші-қон сальдосының болжамына байланысты. Сонымен қатар, тірек аумақтарды анықтау және оларды кейіннен басым дамыту мақсатында көші-қон сальдосының болжамы маңызды. Бұл мақалада зерттеушілердің жұмысына мазмұнды талдау жасалды, оның нәтижелері бойынша жасанды интеллект модельдері, атап айтқанда, ең бейімделгіш нейрондық желілер көші-қон сальдосын болжауда қолданылмайтындығы анықталды. Бұл зерттеудің мақсаты-

Қазақстан Республикасы моноқалаларының әлеуметтік-экономикалық дамуын басқарудың тиімділігін арттыру үшін көші-қон сальдосының жасанды нейрондық желілерінің модельдерін әзірлеу. Зерттеу нәтижесі Қазақстан Республикасының моноқалалары үшін көші-қон сальдосын болжаудың әдістемелік тәсілі мен құралдары болып табылады. Болжауға әзірленген тәсіл мен құралдар жиынтығы әлеуметтік-экономикалық көрсеткіштерді болжау саласында әмбебап болып табылады. Сонымен қатар, мақалада сипатталған нәтижелер болжау, жоспарлау саласындағы басқа зерттеулерде қолданылуы мүмкін. Атап айтқанда, әзірленген құралдар жиынтығын басқару шешімдерінің тиімділігін бағалау үшін қолдануға болады, мысалы моноқалаларды дамыту мақсатында дәлелді саясатты іске асыру кезінде.

Түйін сөздер: көші-қон сальдосы, моноқалалар, жасанды интеллект модельдері, жасанды нейрондық желілер, модель қатесі, әлеуметтік-экономикалық дамуды басқару.

И.В. Мищенко*[1], М.Г. Краюшкин[1], С.И. Межов[1], И.С. Бианчи[2]

[1]Алтайский государственный университет, Россия, г. Барнаул

[2]Федеральный университет Санта Катарины, Бразилия, г. Флорианополис

*e-mail: mis.iv@mail.ru

Совершенствование прогнозирования сальдо миграции в рамках управления социально-экономическим развитием моногородов на основе искусственного интеллекта (на материалах Республики Казахстан)

В данном исследовании разработаны модели искусственных нейронных сетей сальдо миграции с целью повышения эффективности управления социально-экономическим развитием моногородов Республики Казахстан. На данный момент не существует универсальных инструментов прогнозирования показателей социально-экономического развития в целом и характеризующих миграционные процессы в частности. Однако объем бюджетных ассигнований, направляемый на решение кадровых вопросов в моногородах, создание социальных объектов и реализацию других мероприятий, значимых для экономического, социального и инфраструктурного развития, направления развития моногородов зависят от прогноза сальдо миграции. Кроме того, прогноз сальдо миграции важен с целью определения опорных территорий и их последующего приоритетного развития. В данной статье проведен содержательный анализ работ исследователей, по результатам которого определено, что модели искусственного интеллекта, в частности наиболее адаптивные нейронные сети не используются при прогнозировании сальдо миграции. Цель данного исследования – разработка моделей искусственных нейронных сетей сальдо миграции для повышения эффективности управления социально-экономическим развитием моногородов Республики Казахстан. Результатом исследования является методический подход и инструментарий прогнозирования сальдо миграции для моногородов Республики Казахстан. Разработанный подход к прогнозированию и инструментарий являются универсальными в области прогнозирования социально-экономических показателей. Кроме того, результаты, описанные в статье, могут быть использованы в других исследованиях в области прогнозирования, планирования. В частности, разработанный инструментарий можно применять для оценки эффективности управленческих решений, например, при реализации доказательной политики с целью развития моногородов.

Ключевые слова: сальдо миграции, моногорода, модели искусственного интеллекта, искусственные нейронные сети, ошибка модели, управление социально-экономическим развитием.

Introduction

One of the important mechanisms of space development is population migration. In the conditions of the global world, population migration is changing its character. If at the beginning of the 20th century the main population movements were associated with wars and emergencies, now population migration is a conscious process of searching for better living conditions and application of labor.

At the same time, uncontrolled population migration can lead to a sharp contraction of economic space and loss of territorial integrity of the state. The task of the authorities is to manage migration processes competently. For this purpose, it is necessary to understand what factors influence this process and to create conditions for controlling migration processes.

Unfortunately, now there is no clear strategy and policy for the development of single-industry towns in the Republic of Kazakhstan. The study of demographic trends in these cities plays a primary role in building a clear policy and development strategy in relation to these cities. In recent years, there has been a strong outflow of population from single-industry towns, which also creates a problem for their further development (Akhmetova, 2023:

86). Therefore, the study of demographic trends and conditions of demographic sustainability of single-industry towns, as well as the development of mechanisms for managing these processes is becoming increasingly important. (Turgel, 2016: 30)

To solve the problem of migration in single-industry towns requires a significant amount of budget allocations to address human resources issues in single-industry towns, the creation of social facilities and the implementation of other activities that are significant for economic, social and infrastructural development. Thus, the depreciation of water supply and sewerage networks in single-industry towns averages 61%, heat networks and power lines – 55% (Single-industry towns of Kazakhstan).

In addition, the forecast of migration balance is important for identifying core areas and their subsequent priority development.

Now there are no universal tools for forecasting indicators of socio-economic development in general and migration balance in particular.

A substantive analysis of researchers' works has shown that the most common methodological approaches to demographic forecasting, including the migration balance, are:

- time series modelling.
- construction of regression models.

However, the main disadvantage of these models is their poor adaptability to changes in the socio-economic situation in the region, which negatively affects the accuracy of the forecast.

The aim of the study is to develop models of artificial neural networks of migration balances in order to improve the efficiency of management of socio-economic development of single-industry towns in the Republic of Kazakhstan.

Objectives of the study:

- Determination of factors that have the strongest influence on migration in single-industry towns;
- development of a methodological approach for building a forecast of migration balance in single-industry towns;
- development of tools for forecasting migration balance in single-industry towns;
- approbation of the developed toolkit in the management of socio-economic development of single-industry towns.

The object of this research is the system of management of socio-economic development of single-industry towns in the Republic of Kazakhstan, the subject is economic and managerial relations arising in the management of single-industry town development when using the migration balance forecast.

Literature review

Content analysis of the works of researchers has shown that the most common methodological approaches to forecasting migration processes are:

- On the basis of time series analysis and modelling.
- Based on the construction and use of regression models.

This conclusion is based on a substantive analysis of the works of more than 30 researchers.

A significant contribution to the development of tools for building computer models of migration balances was made by: Meadows D. (Meadows, 2007: 16), Simon G.A. (Simon, 1978: 7), Forrester J. (Forrester, 2003: 56; Forrester, 1974: 35) and others. In the works, the aforementioned researchers also focused on the possibility of predicting migration processes using regression and time series models. However, the main disadvantage of these models is their poor adaptability to changes in the socio-economic situation, which negatively affects accuracy.

A constructive analysis of studies, including the most recent ones from 2023-2024, which used artificial neural network models to build migration forecasts, showed that forecasts using neural networks are built either for the whole country or non-adaptive algorithms are used in the process of building neural networks. In turn, such neural network forecasts have little or no value for managing socio-economic development (Lutfiani,, 2018; Bheemanna, 2023; Mohammad, 2023; Rajesh, 2024).

In turn, the scientific problem can be defined as follows: the use of subjective, non-adaptive methodological approaches to forecasting indicators of socio-economic development leads to high forecast error and, as a consequence, inefficient management of single-industry towns' development. This has a negative impact on the living standards of the population.

Methodology

The study is based on the data of the National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan, works of researchers engaged in forecasting migration processes, as well as the development and analysis of algorithms for building artificial intelligence models.

Autocorrelation and cluster analysis are used in the development of tools for the formation of the information base, and artificial neural networks are used for modelling.

Neural network training was chosen as a paradigm: with a teacher; learning rule – error correction; architecture – multilayer neural network; training algorithm (optimiser) – BFGS.

When building models of artificial neural networks with a teacher during error correction, the parameters of the neural network are determined in such a way that the actual data are as close as possible to the values obtained by the model, i.e. that the model error is minimal (it is found by the test sample). To solve the forecasting problem, it is important that the accuracy of the model is as high as possible, because the effectiveness of management of socio-economic development of single-industry towns depends on the accuracy of the forecast. Therefore, neural network training with a teacher and the learning-error-correction rule were chosen as the paradigm.

Only multilayer neural networks are needed to solve the prediction problem. After all, when a large number of parameters are taken into account, the probability of increasing the accuracy of modelling increases.

The BFGS algorithm was chosen as an optimizer because it is one of the most efficient ways of optimisation. Numerous publications on the effectiveness of using this algorithm to solve complex problems not only in forecasting, the use of this algorithm in modern neural network modelling systems proves the feasibility of its application within the framework of the study (Poluhin, 2019:135).

The structure of the artificial neuron can be represented as follows (Fig. 1).

The scheme of operation of the BFGS algorithm is shown in Figure 2.

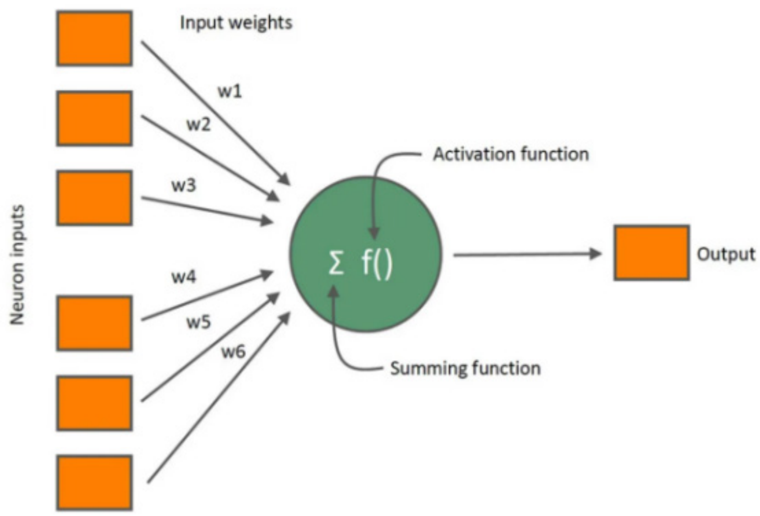

Figure 1 – Structure of an artificial neuron
Note: compiled by the authors

Given starting point x_0, convergence tolerance $\epsilon > 0$,
inverse Hessian approximation H_0;
$k \leftarrow 0$;
while $\|\nabla f_k\| > \epsilon$;
Compute search direction

$$p_k = -H_k \nabla f_k;$$

Set $x_{k+1} = x_k + \alpha_k p_k$ where α_k is computed from a line search
procedure to satisfy the Wolfe conditions
Define $s_k = x_{k+1} - x_k$ and $y_k = \nabla f_{k+1} - \nabla f_k$;
Compute H_{k+1}
$k \leftarrow k + 1$;
end (while)

Figure 2 – Schematic diagram of BFGS algorithm operation
Note: compiled by the authors

The algorithm works as follows: at the first iteration the initial weight coefficients of links in the neural network are determined. At the next iterations the weight coefficients are changed until the value of the error on the test sample becomes minimal.

The STATISTICA software package version 13 is used for forming the information base, building neural network models and forecasting on their basis.

Results and discussion

Modern neural network models, compared to time series and regression models, are significantly more accurate, they have a more extensive degree of applicability and are more adaptive. Using specialised software products, they can be built by a specialist without in-depth knowledge of neural network modelling (Pattanayak, 2019:35).

Accordingly, to improve the accuracy of migration balance forecasts, it is advisable to use an approach based on the construction of artificial intelligence models, namely artificial neural networks.

The characteristics of the approach developed in the research are:

- Construction of models that conceptually work in a similar way as an expert who develops a forecast.
- Using only adaptive algorithms for building neural network models.

The approach based on the construction and use of neural networks can also be applied to the forecasting of other indicators. In particular, the neural network approach has already shown its usefulness in planning socio-economic development in the study devoted to the development of tools for forecasting one of the most important parameters of socio-economic development forecast – the consumer price index (Mezhov, 2022: 121)

At the first stage of building artificial intelligence models of migration balance for single-industry towns we took data on migration balance (thousand people) and factors affecting it from 2013 to 2022 (Bureau of National Statistics):

- Unemployment rate (%).
- Real money income index (in per cent of the previous year).
- Water supply; sewerage system, control of waste collection and distribution.
- Dynamics of the number of hospitals (units).
- Dynamics of the number of pre-school institutions (units).
- Supply of electricity, gas, steam, hot water and conditioned air.
- Commissioning of residential buildings (thousand square metres of total area).
- Main indicators of school development in single-industry towns of the Republic of Kazakhstan.
- Number of colleges in single-industry towns.
- Dynamics of the number of universities.
- Number of organisations (enterprises) carrying out R&D (units).
- The level of youth unemployment of 15-28 years old (%).

Then a correlation analysis was carried out to identify the factors that most strongly influence the migration balance. The results are presented in Table 1.

Table 1 – *Correlation coefficients*

Factor affecting the migration balance	Pearson correlation coefficient value
Unemployment rate	-0,75778
Real money income index	0,742508
Water supply; sewerage system, control over waste collection and distribution	0,51744
Dynamics of the number of hospitals	0,823862
Dynamics of the number of pre-school institutions	0,832707
Electricity, gas, steam, hot water and conditioned air supply	0,711722
Commissioning of residential buildings	0,39744
Key indicators of school development	0,29512
Number of colleges in single-industry towns	0,428152
Dynamics of the number of universities	9,54E-17
Number of R&D organisations (enterprises)	0,378317
Youth unemployment rate 15-28 years old	-0,51174

Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan when using correlation analysis

Based on the analysis of the relationship between the migration balance and the factors affecting it (Table 1), it can be seen that the strongest impact on migration in single-industry towns is:

- Unemployment rate.

- Index of real monetary incomes.
- Dynamics of the number of hospitals.
- Dynamics of the number of pre-school institutions.
- Supply of electricity, gas, steam, hot water and conditioned air.

In the second stage, autocorrelation analysis was performed to identify the trend.

Table 2 – Autocorrelations on the dynamics of the indicator "migration balance"

1 time interval	2 time interval	3 time interval	4 time interval	5 time interval
0,53	0,74	0,54	-0,33	-0,26
0,72	0,53	0,51	-0,45	-0,27
0,63	0,66	0,67	-0,39	-0,29
0,70	0,73	0,51	0,30	0,23
1,00	1,00	1,00	0,20	0,11
0,58	-0,09	-0,11	0,04	-0,03
-0,59	-0,60	-0,45	-0,41	-0,49
0,03	-0,30	-0,24	-0,13	-0,38
0,16	0,34	-0,13	-0,41	-0,36
0,54	0,52	0,51	-0,42	0,44
-0,99	-0,06	0,12	0,01	-0,02
0,54	0,56	0,72	-0,38	0,22
-0,20	-0,40	0,18	-0,47	-0,33
-0,22	0,19	0,03	-0,41	-0,39
0,53	0,63	-0,06	0,16	0,16
0,81	0,63	0,35	0,19	-0,08
0,75	0,72	0,29	0,01	-0,18
0,20	-0,07	0,29	-0,01	0,18
0,71	0,24	-0,58	-0,04	-0,03
0,31	0,46	-0,49	-0,01	0,45
0,06	-0,05	0,51	-0,31	0,10
0,11	-0,40	0,32	0,17	0,10
0,82	0,57	0,80	0,81	0,55
0,54	0,81	0,53	0,73	0,78
0,58	0,68	-0,42	-0,31	0,40
0,61	0,25	-0,42	-0,34	-0,21
1,00	1,00	0,91	0,45	0,55

Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan when using autocorrelation analysis

Table 2 shows the values of the autocorrelation coefficients (for example, on time interval 1, the values of the autocorrelation coefficients between the current migration balance value and its value a year ago are presented). Statistically significant autocorrelation coefficients are highlighted in color. The calculation of autocorrelation coefficients was carried out in order to determine on which lags there is a trend. As a result of the study, it was determined that on average there is a steady trend in 3 time interval. Accordingly, it is necessary to build artificial intelligence models as follows: take 2 years to train the model, 1 year to test the model. In turn, the test sample is the closest values to the forecast period. Experts build a forecast in a similar way. In addition to trend analysis, they assess the data as close as possible to the forecast period in order to take into account changes in the socio-economic situation (within the study, this is a test sample). According to the results of autocorrelation analysis, we can see that it is reasonable to build models using data from 2017 to 2022.

Then cluster analysis was carried out using tree clustering and k-means methods to identify data sets for further modelling.

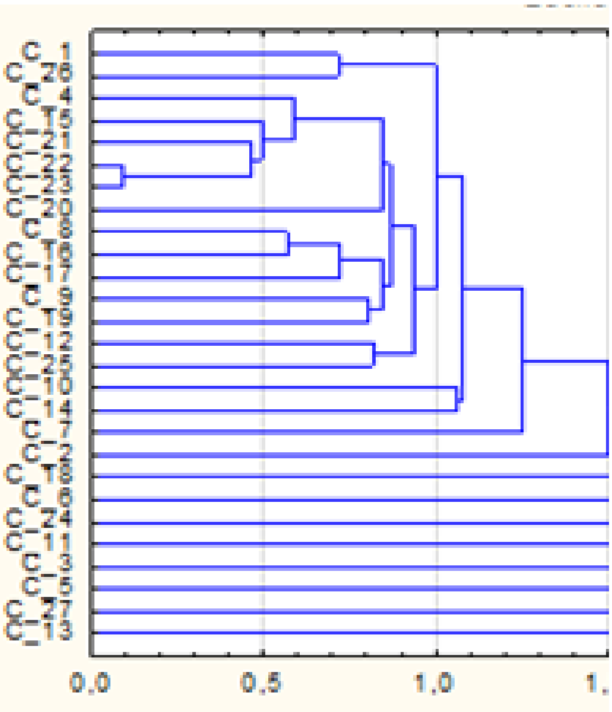

Figure 3 – Graphical result of tree clustering
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan when using tree clustering

Figure 3 shows that it is reasonable to build 3 or 4 clusters to make the clusters of high quality for further modelling. Let's build 3 clusters.

Based on the analysis of Table 3, it can be seen that the clusters are obtained qualitatively because the distance from the center of the cluster is less than 1 everywhere.

Then the construction of neural network models for the corresponding clusters was carried out.

Absolute verification of the models for the first cluster is presented in Figures 4-6.

Table 3 – Clusters

Single-industry town	Distance from the center of the cluster
1 cluster	
Abay	0,559895
Altai	0,232837
Zhanaozen	0,712964
Zhanatas	0,398467
Zhezkazgan	0,245847
Kurchatov	0,164480
Lisakovsk	0,275964
Ridder	0,423842
Saran	0,465675
Satpayev	0,737099
Serebryansk	0,225387
Stepnogorsk	0,402340
Tekeli	0,367825
Khromtau	0,459599
Shakhtinsk	0,785444
2 cluster	
Aksai	0,488831
Balkhash	0,649816
Karatau	0,390149
Rudnyi	0,788840
Temirtau	0,760065
3 cluster	
Aksu	0,880354
Arkalyk	0,999928
Zhitikara	0,529747
Karazhal	0,607448
Kentau	0,379088
Kulsary	0,564300
Ekibastuz	0,424137
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan when using clustering by the k-means method	

The accuracy of the neural network models for the first cluster is more than 93 per cent.

Absolute verification of the models for the second cluster is presented in Figures 7-9.

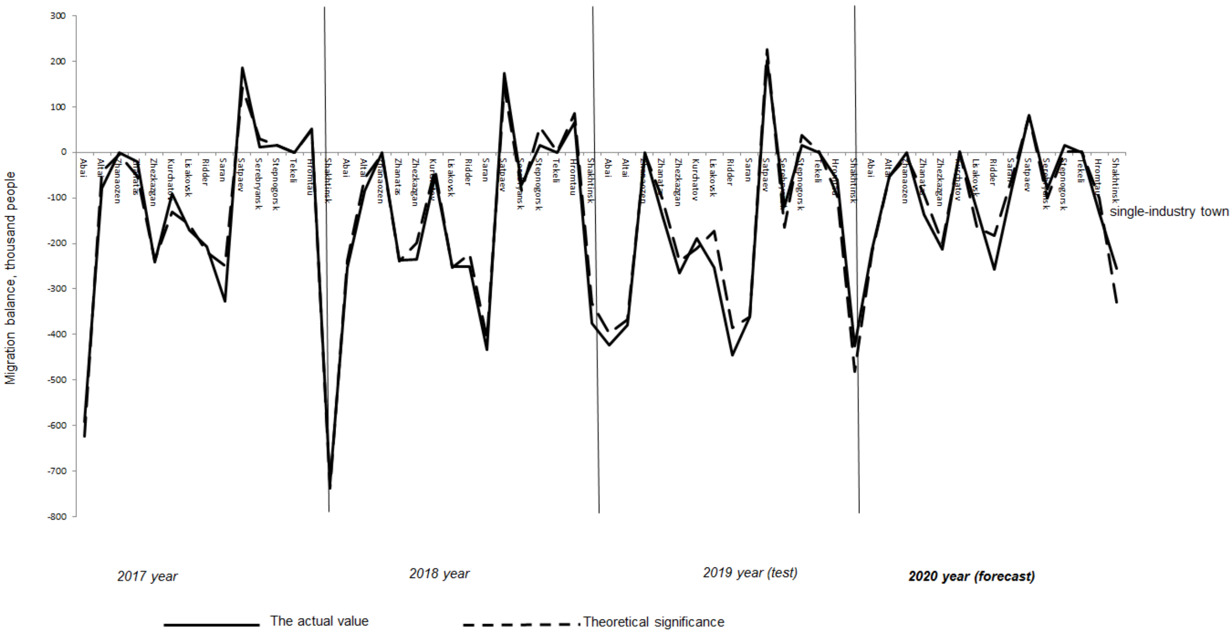

Figure 4 – Model quality assessment for 1 cluster (retrospective for 2020)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

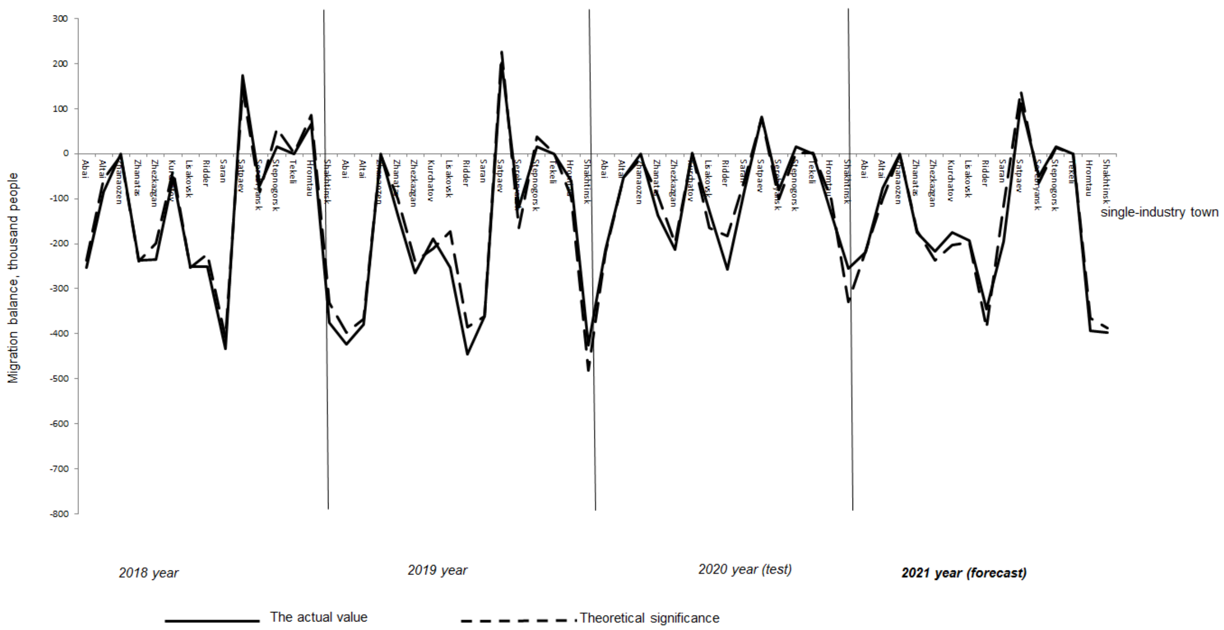

Figure 5 – Model quality assessment for 1 cluster (retrospective for 2021)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

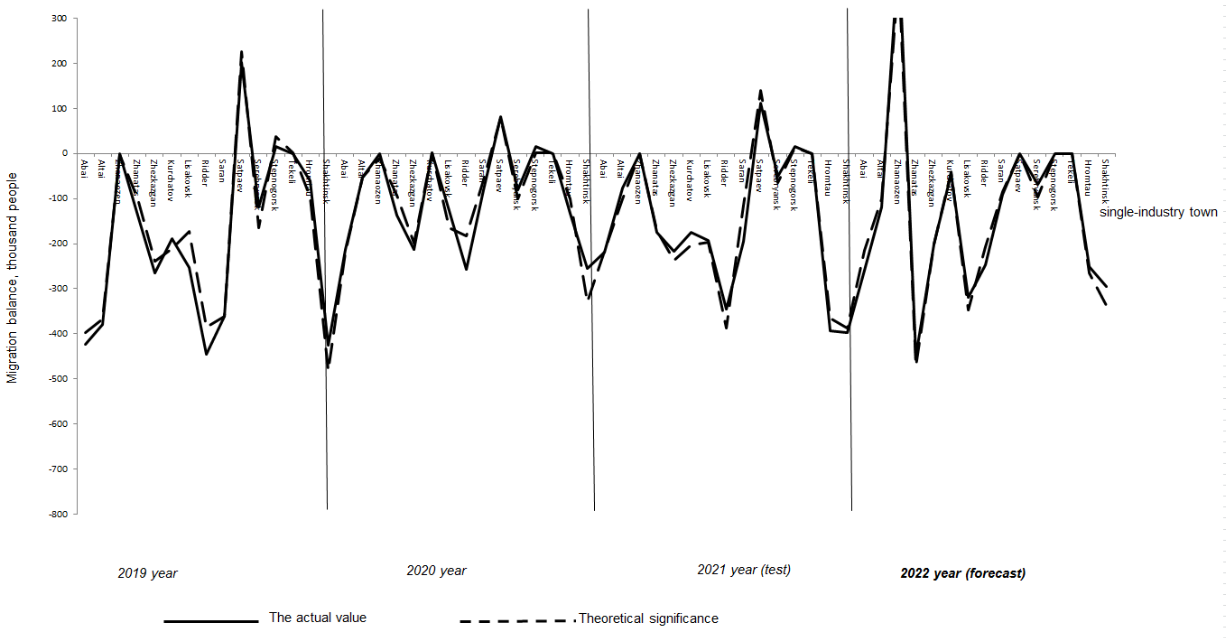

Figure 6 – Model quality assessment for cluster 1 (retrospective forecast for 2022)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

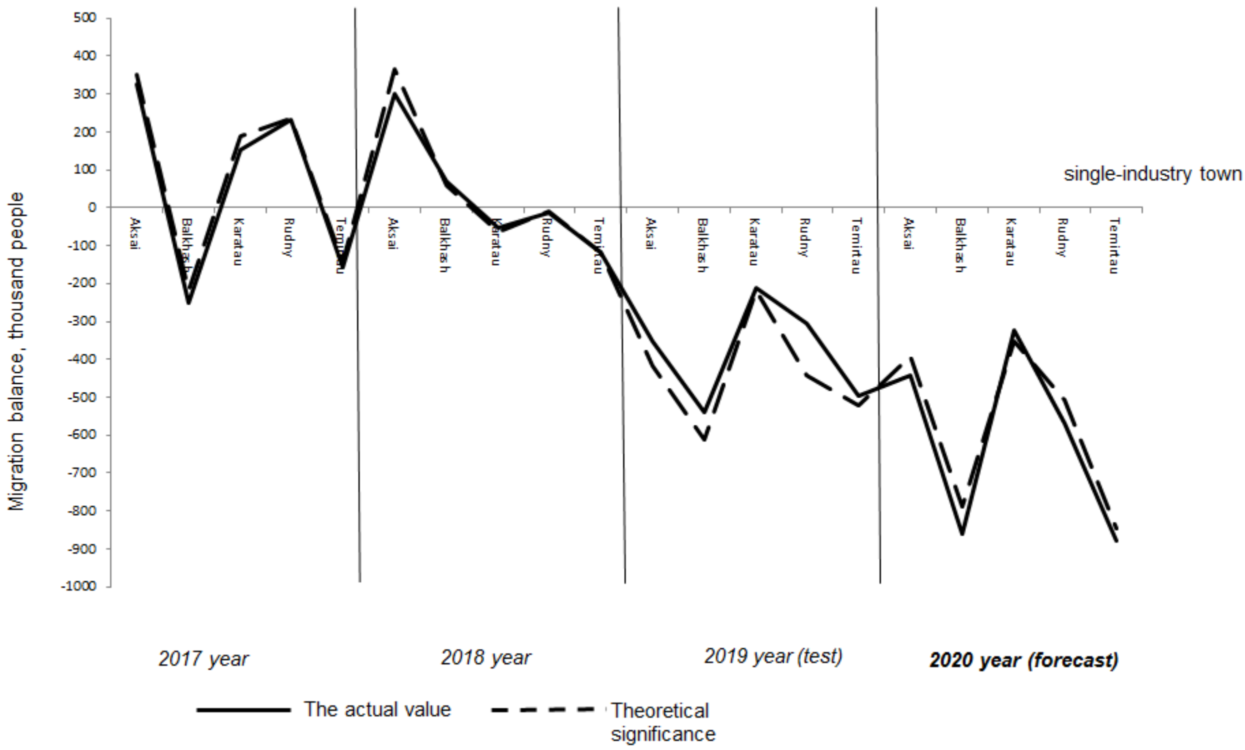

Figure 7 – Model quality assessment for cluster 2 (retrospective to 2020)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

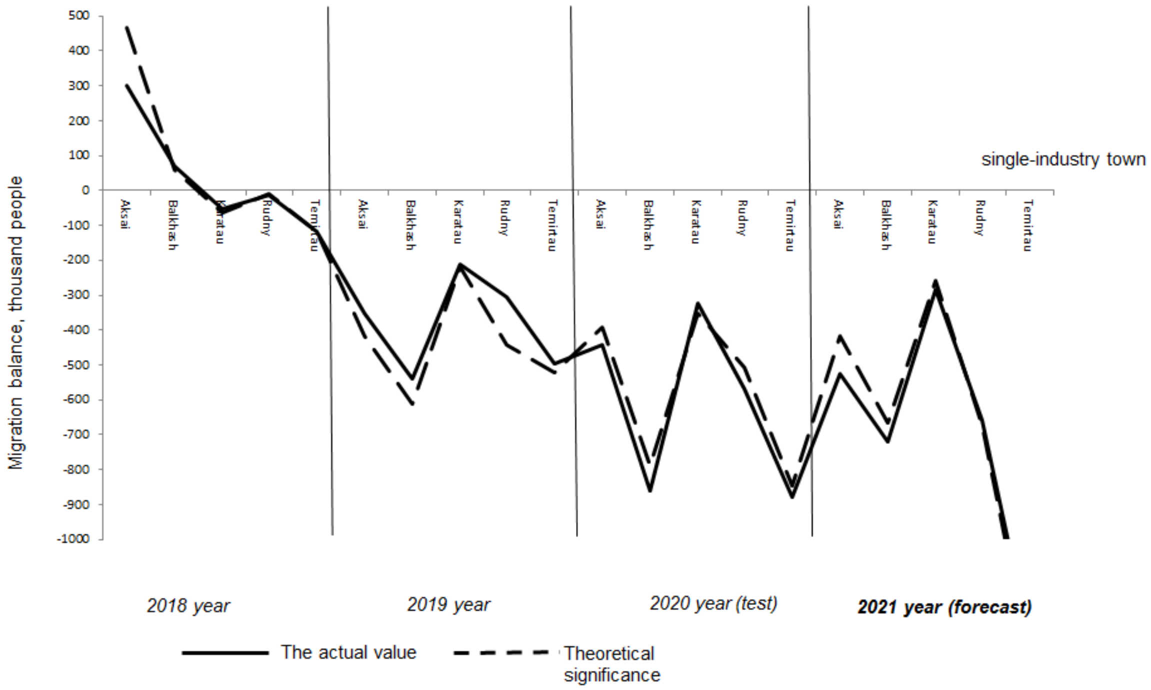

Figure 8 – Model quality assessment for cluster 2 (retrospective to 2021)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

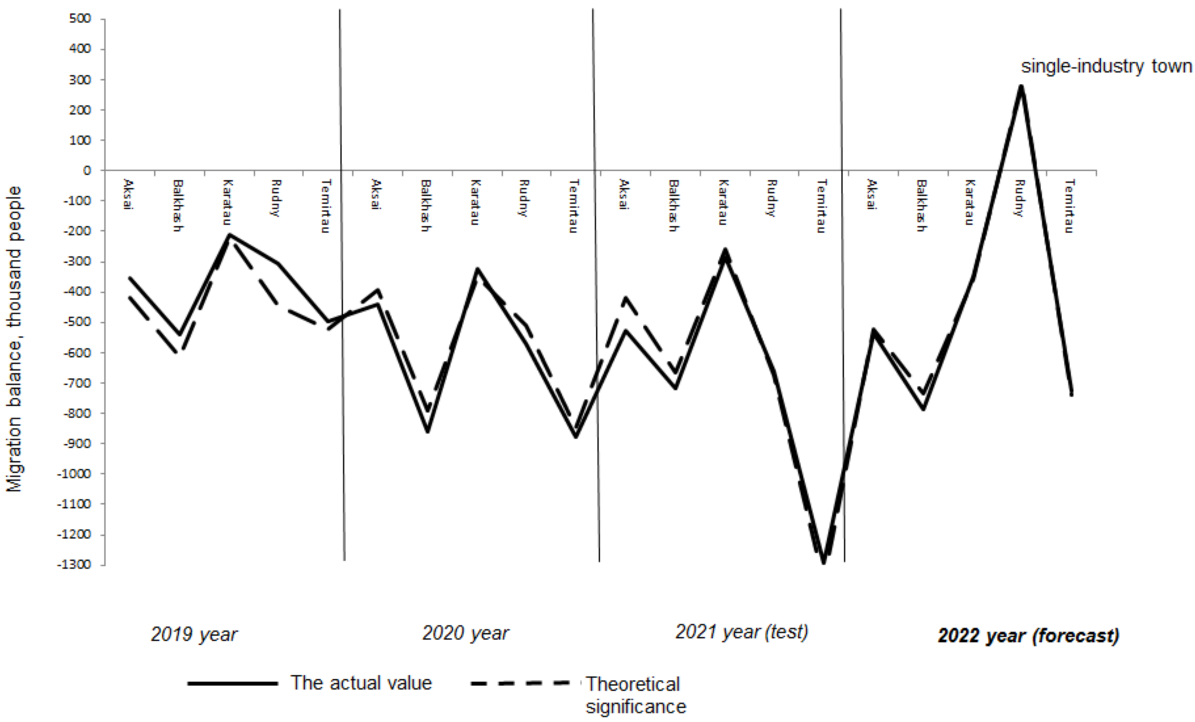

Figure 9 – Model quality assessment for cluster 2 (retrospective forecast for 2022)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

The accuracy of the neural network models for the second cluster is more than 95 per cent.

The accuracy of the neural network models for the third cluster is more than 95 per cent.

The graph of the neural network for the 3rd cluster is presented in Figure 13.

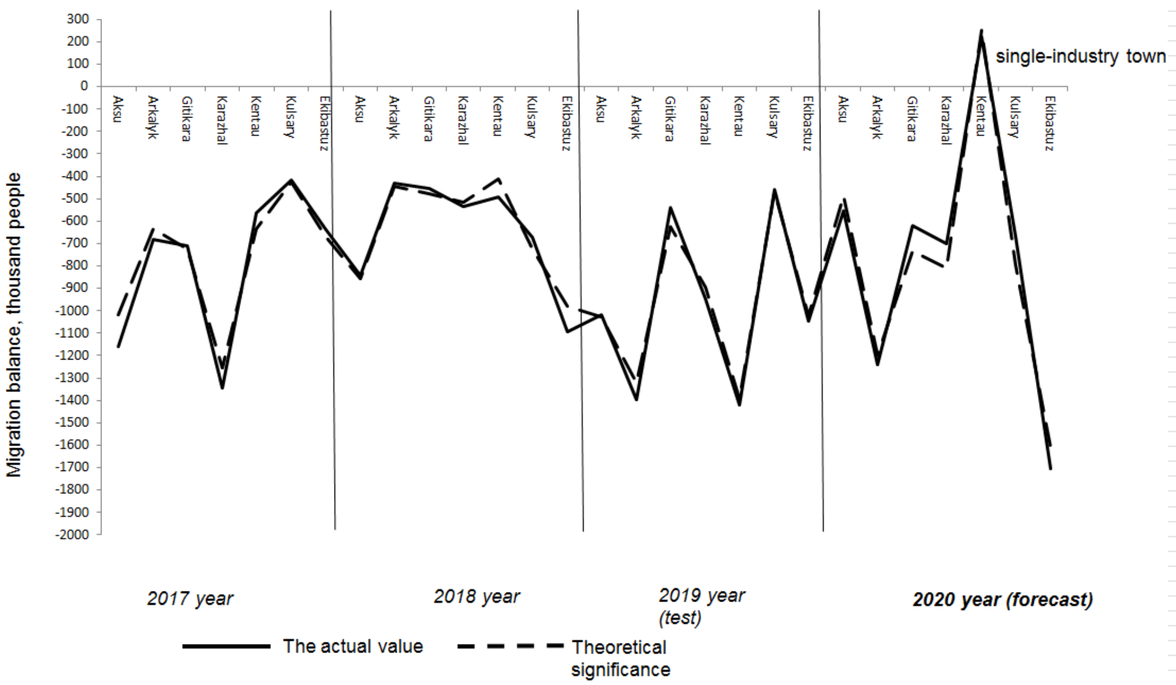

Figure 10 – Model quality assessment for Cluster 3 (retrospective to 2020)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

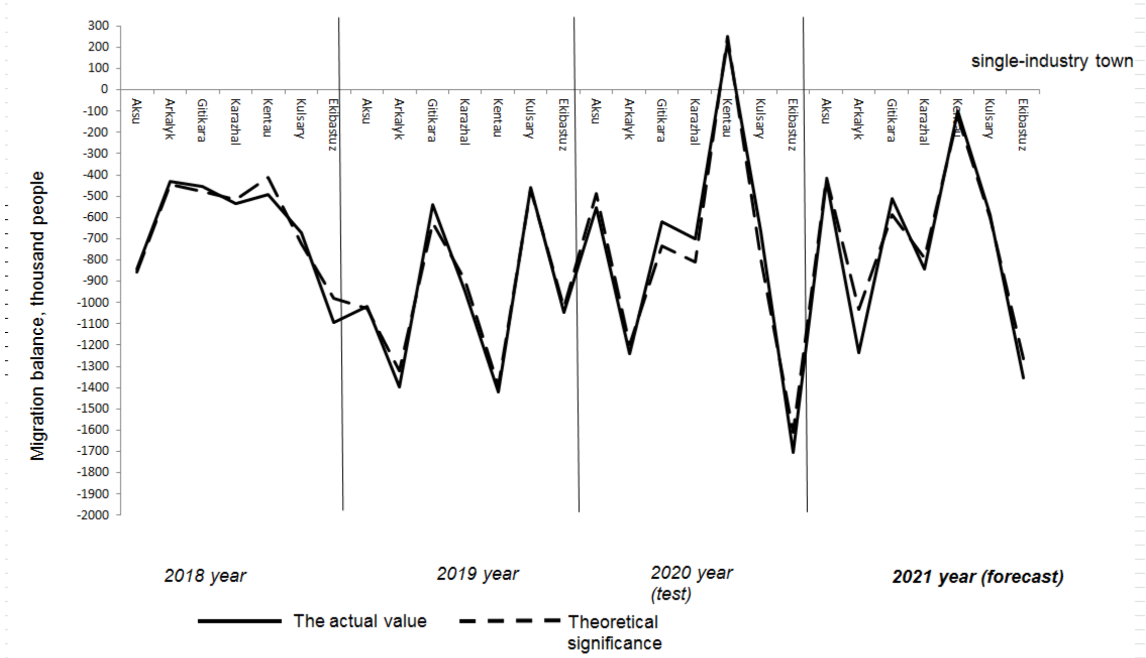

Figure 11 – Model quality assessment for cluster 3 (retrospective to 2021).
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

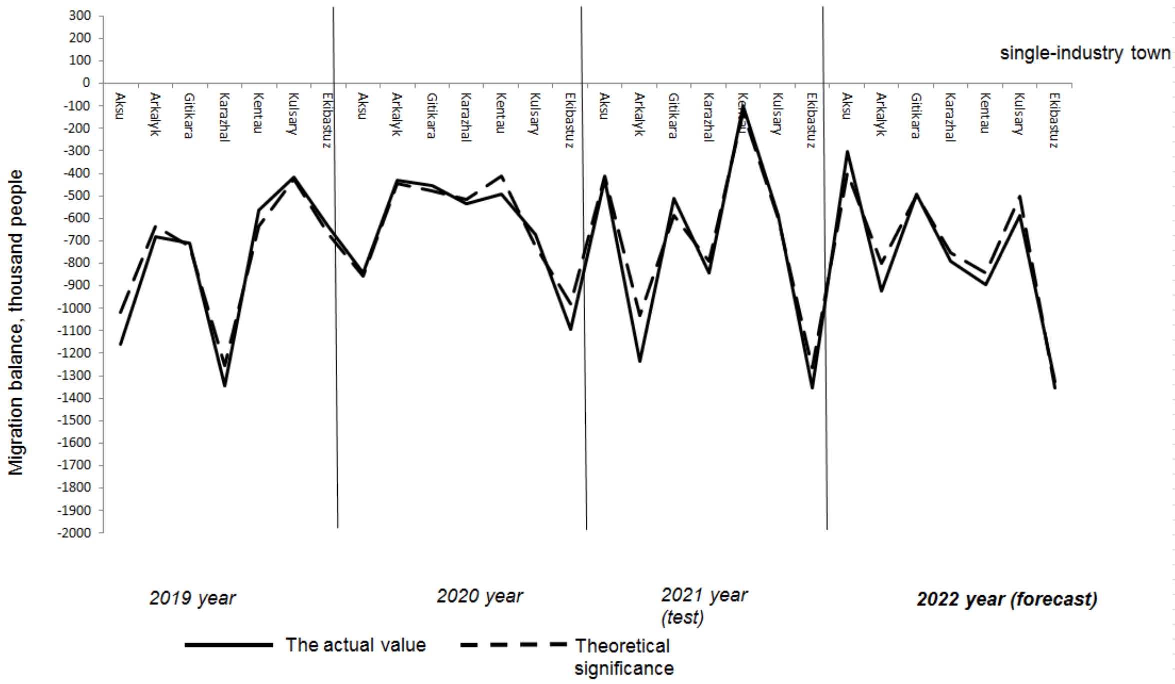

Figure 12 – Model quality assessment for cluster 3 (retrospective forecast for 2022)
Note: compiled by the author according to official data of the Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan and the results obtained from the neural network model constructed by the authors of the article

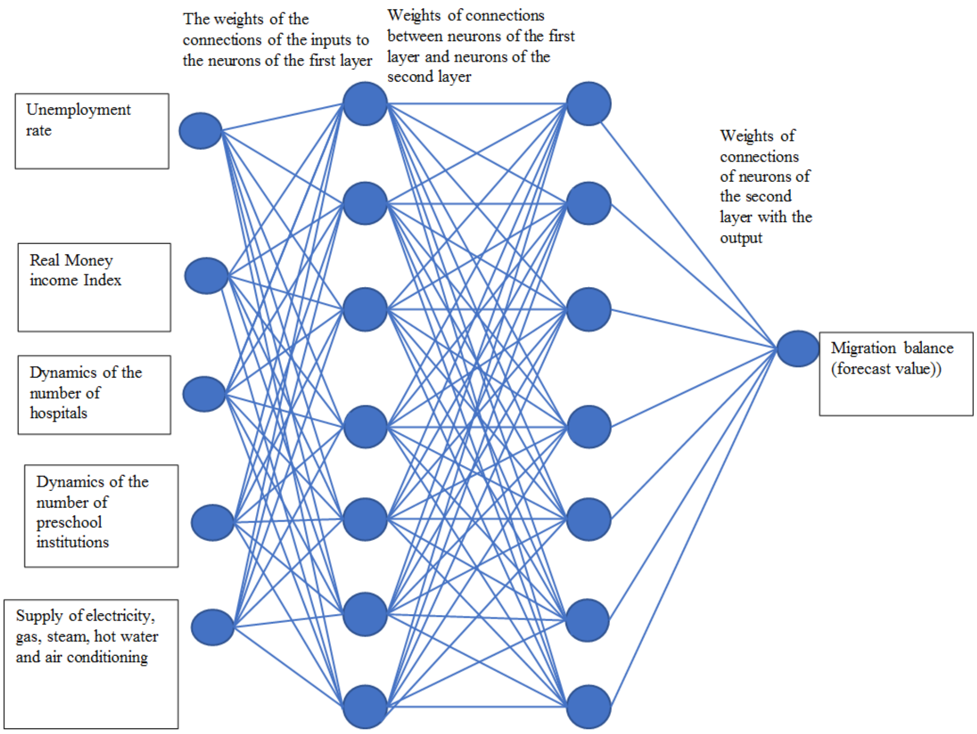

Figure 13 – Neural network graph for the 3rd cluster
Note: compiled by the authors

The forecasts based on the application of neural network models are quite accurate, which confirms the feasibility of using the developed toolkit.

A medium-term basic forecast of the migration growth balance for single-industry towns for 2024-2026 was built, provided that trends in the dynamics of factor attributes are preserved.

Table 4 – Forecast of migration balance

Monotown	2023 (estimate)	2024 (estimate)	2025 (forecast)	2026 (forecast)
Abay	-288	-296	-302	-333
Aksai	-636	-706	-791	-854
Aksu	-324	-339	-441	-481
Altai	-135	-157	-162	-173
Arkalyk	-851	-996	-981	-1308
Balkhash	-893	-923	-981	-1177
Zhanaozen	-0,5	-0,6	-0,7	-1
Zhanatas	-543	-573	-622	-678
Zhezkazgan	-222	-253	-315	-335
Zhitikara	-489	-507	-637	-669
Karazhal	-908	-914	-925	-995
Karatau	-297	-348	-399	-463
Kentau	-828	-1028	-1273	-1430
Kulsary	-503	-564	-588	-641
Kurchatov	-54	-75	-110	-120
Lisakovsk	-269	-309	-342	-425
Ridder	-254	-285	-343	-369
Rudnyi	270	313	405	417
Saran	-75	-85	-100	-120
Satpayev	174	184	205	264
Serebryansk	-58	-77	-89	-100
Stepnogorsk	15	18	18	19
Tekeli	-0,26	-0,29	-0,49	-0,54
Temirtau	-604	-780	-925	-986
Khromtau	-246	-283	-324	-366
Shakhtinsk	-273	-302	-333	-371
Ekibastuz	-1340	-1384	-1424	-1592

Note: compiled by the authors based on the results obtained from the neural network models built by the authors

Based on the analysis of Table 4, it can be seen that almost all single-industry towns are experiencing migration loss. To change the situation, it is necessary to implement effective economic, social, and other measures to reduce the migration loss of the population.

An increase is needed the level of wages, developing public-private partnerships, improving the business climate, and creating special preferential lending programmes for small and medium-sized businesses. These measures are the basis of a stimulating regional policy that leads to the emergence of "growth zones".

Social measures include measures of social support of citizens, maintaining a sufficient level of social attractiveness of territories. This is possible through the development of the school and pre-school education system, provision of affordable and qualified medical care, etc. These measures are the basis of compensatory policy. These measures are the basis of the compensatory policy (Mishchenko, 2024:81).

Infrastructural measures are among the key ones. They include the availability of necessary engineering and transport infrastructure.

Since the majority of single-industry towns in Kazakhstan are based on mining and processing specialisation, it is important to monitor the application of a system of measures to support environmental safety in these territories.

It is also necessary to use measures of territorial marketing, creation of a positive image of the city. Such measures include assessment of the attractiveness of a single-industry town, ranking model of competitive advantages, opportunities and ways of their realization, a real image of a single-industry town should be created by forming a desirable image (Akhmetova, 2023: 96).

According to the analysis conducted and taking into account the limited financial resources allocated for the implementation of regional policy, we propose the following. For single-industry towns of the first cluster it is proposed to pursue a stimulating policy. This group of territories is characterized by a more stable migration situation. Thus, in the single-industry towns Rudnyi, Satpayev, Stepnogorsk migration growth is forecasted. These cities may become stronghold settlements. In order to maintain migration growth in these cities it is necessary to accelerate their development, which will be an impetus for the development of the regions in which they are located.

For the 2nd cluster we propose the use of compensatory measures to smooth the level of socio-economic development and create more favorable conditions for living in them.

The situation with single-industry towns of cluster 3 is the most difficult. We propose to use the shift method of work organization for this cluster. This will attract additional labor force and allow for a more rational regional policy on the distribution of limited financial resources.

As for infrastructural and environmental measures, they should be implemented in all single-industry towns of the Republic of Kazakhstan as basic.

The developed toolkit can be applied not only for the purposes of forecasting, but also for the purposes of assessing the effectiveness of management decisions, in particular, when implementing evidence-based policy for the development of single-industry towns.

By influencing the factors it is possible to assess how migration in single-industry towns will change. Thus, using the toolkit, it is possible to determine how and by how much the factors need to be influenced in order for the migration balance to change by a certain number of per cent. This is important for the development of strategies, budgets and other development plans.

Accordingly, using the toolkit developed in the framework of the research, it is possible to create conservative (based on the assumption of unfavorable environmental situation, significant deterioration of external economic conditions, accelerating inflation, rising cost of financial resources), basic (assuming moderate development of the social sphere, economy and infrastructure) and target scenarios (assuming accelerated development of the social sphere, economy and infrastructure) of single-industry towns' development and carry out quantitative assessment

The use of the toolkit will lead to the interconnection (balancing) of indicators in the development of single-industry towns' development strategies.

Also on the basis of the toolkit it is possible to assess the effectiveness of management decisions aimed at the development of single-industry towns, which in turn will lead to optimization of budget expenditure allocation.

In order to accelerate the development of single-industry towns, it is necessary to priorities the factors that have a significant impact on migration.

It is for these single-industry towns it is advisable to develop plans for their long-term development. It is advisable to create special economic zones in single-industry towns, develop infrastructure, including through the provision of infrastructure budget loans. This will have a positive impact on the growth of real incomes of citizens, reduction of unemployment. In turn, these factors have a maximum impact on the dynamics of migration.

Agglomeration processes in our time are a natural process. Accordingly, priority attention should be given to support single-industry towns with a high concentration of production, educational institutions and scientific organizations. In turn, this will contribute to the innovative development of the economy, growth of employment and income of citizens.

Conclusion

Based on the above, the following conclusions can be drawn:

- Firstly, the factors that have the strongest impact on migration in single-industry towns have been identified. These are unemployment rate, real money income index, dynamics of the number of hospitals, dynamics of the number of pre-school institutions, supply of electricity, gas, steam, hot water and conditioned air;

- secondly, a methodological approach for building a forecast of migration balance in single-industry towns was developed. The characteristics of the approach developed in the framework of the research are: building models that conceptually work in a similar way as the expert who develops the forecast, using only adaptive algorithms for building neural network models;

- Thirdly, a toolkit for building a forecast of migration balances in single-industry towns has been developed. The constructed models are very accurate. For some models the accuracy reaches 98 per cent;

- Fourthly, the developed toolkit was tested in the management of socio-economic development of single-industry towns. It was determined that migration growth is forecasted in the single-industry towns Rudnyi, Satpayev, Stepnogorsk. These cities will probably become stronghold settlements. In order to maintain the migration growth in these cities it is necessary to accelerate development. By influencing the factors it is possible to estimate how migration in single-industry towns will change. Thus, using the toolkit, it is possible to determine how and by how much the factors need to be influenced in order for the migration balance to change by a certain number of per cent. This is important for the development of strategies, budgets and other development plans. In general, the development of single-industry towns requires prioritising factors that have a significant impact on migration.

Source of financing

This research has been funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan (BR18574200 «The revival of monotowns in the conditions of the creation of New Kazakhstan on the basis of territorial marketing»)

References

1. Bheemanna N., Megeri M. (2023) Prediction of India's demographic and economic variables using the neural network auto-regression model. *International Journal of Statistics and Applied Mathematics*, vol. 11, pp. 44-55.
2. Lutfiani S., Sri M., Hendrisman R. (2018) Forecasting the mortality rates of Indonesian population by using neural network. *International Conference on Mathematics: Pure, Applied and Computation*, IOP Conf. Series: Journal of Physics: Conf. Series: 974; pp. 1-7.
3. Mezhov S., Krayushkin M. (2022) Comparative Analysis of Methods of Forecasting the Consumer Price Index for Food Products (on the Example of the Altai Territory). *Proceedings of International Conference on Applied Innovation in IT*, vol.10, Issue 1, pp. 119-124.
4. Mishchenko I. V., Mishchenko Val.V. (2023) Differentiated Approach To Functioning and Development of Single-Industry Towns in Kazakhstan. *The Journal of Economic research and Business administration*, vol.3, pp. 74-83.
5. Mohammad M. F., Azad A.S.l, Soran H.M. (2023) Comparison Markov Chain and Neural Network Models for Forecasting Population Growth Data in Iraq. *University of Kirkuk Journal for Administrative and Economic Science*, vol. 13(4), pp. 1-14.
6. Pattanayak S. (2019) Deep Learning with TensorFlow: A Mathematical Approach to Advanced Artificial Intelligence in Python: textbook / S. Pattanayak. – Apress, 480 p.
7. Rane R., Dubey A., Rasool A., Wadhvani R. (2023) Neural Network Based Mortality Prediction in Covid-19 Dataset. *University of Kirkuk International Conference on Artificial Intelligence of Things*, vol. 1929, pp. 354-366.
8. Simon H.A. (1978) Rationality as Process and as Product of Thought. *American Economic Review*, vol.68, no. 2, pp.1–16.
9. Ахметова З., Товма Н., Шуренов Н. Анализ демографических тенденций моногородов Восточно-Казахстанской области // Научный журнал. 2023. №3 (107), с. 85-99.

10. Бюро национальной статистики Агентства по стратегическому планированию и реформам Республики Казахстан [Электронный ресурс].URL: http://www.taldau.stat.gov.kz.
11. Медоуз Д. Пределы роста, 30 лет спустя: пер. с англ. / Д. Медоуз, Й. Рандерс, Д. Медоуз. – М.: Академкнига, 2007. – 342 с.
12. Моногорода Казахстана: программы принимаются, проблемы не решаются [Электронный ресурс] // Ритм Евразии. 2023. URL: https://dzen.ru/a/Y75-toE8Eg_tY_nj
13. Полухин П.В. Инструменты повышения эффективности численных алгоритмов обучения структуры динамических байесовских сетей // Вестник ВГУ, серия: системный анализ и информационные технологии. 2019, № 4, с. 132- 140.
14. Тургель И.Д., Божко Л.Л., Сюй Л. Государственная поддержка развития моногородов России и Казахстана // Вестник Финансового университета .2016. №2. с. 22-32.
15. Форрестер Дж. Динамика развития города: пер. с англ. / Дж. Форрестер. – М.: Прогресс, 1974. – 281 с.
16. Форрестер Дж. Мировая динамика: пер. с англ. / Дж. Форрестер. – М.: АСТ; СПб.: Terra Fantastica, 2003. – 379 с.

References

1. Ahmetova Z., Tovma N., Shurenov N. (2023) Analiz demograficheskih tendencij monogorodov Vostochno-Kazahstanskoj oblasti [Analysis of demographic trends of single-industry towns of East Kazakhstan region] *Nauchnyj zhurnal*, vol. l3 (107), pp. 85-99.
2. Bheemanna N., Megeri M. (2023) Prediction of India's demographic and economic variables using the neural network auto-regression model. *International Journal of Statistics and Applied Mathematics*, vol. 11, pp. 44-55.
3. Byuro nacional'noj statistiki Agentstva po strategicheskomu planirovaniyu i reformam Respubliki Kazahstan [Bureau of National Statistics of the Agency for Strategic Planning and Reforms of the Republic of Kazakhstan] [Elektronnyj resurs].URL: http://www.taldau.stat.gov.kz.
4. Forrester Dzh. (2003). Mirovaya dinamika [World dynamics]: per. s angl. / Dzh. Forrester. – M.: AST ; SPb. : Terra Fantastica. – 379 P.
5. Forrester Dzh. (1974) Dinamika razvitiya goroda [City development dynamics]: per. s angl. / Dzh. Forrester. – M.: Progress. – 281 P.
6. Lutfiani S., Sri M., Hendrisman R. (2018) Forecasting the mortality rates of Indonesian population by using neural network. *International Conference on Mathematics: Pure, Applied and Computation*, IOP Conf. Series: Journal of Physics: Conf. Series: 974; pp.1-7.
7. Medouz D. (2017) Predely rosta, 30 let spustya [Growth Limits, 30 Years Later]: per. s angl. / D. Medouz, J. Randers, D. Medouz. – M.: Akademkniga. – 342 P.
8. Mezhov S., Krayushkin M. (2022) Comparative Analysis of Methods of Forecasting the Consumer Price Index for Food Products (on the Example of the Altai Territory). *Proceedings of International Conference on Applied Innovation in IT*, vol.10, Issue 1, pp. 119-124.
9. Mishchenko I. V., Mishchenko Val.V. (2023) Differentiated Approach To Functioning and Development of Single-Industry Towns in Kazakhstan. *The Journal of Economic research and Business administration*, vol.3, pp. 74-83.
10. Mohammad M. F., Azad A.S.l, Soran H.M. (2023) Comparison Markov Chain and Neural Network Models for Forecasting Population Growth Data in Iraq. *University of Kirkuk Journal for Administrative and Economic Science*, vol. 13(4), pp. 1-14.
11. Monogoroda Kazahstana: programmy prinimayutsya, problemy ne reshayutsya (2023) [Single-industry cities of Kazakhstan: programs are accepted, problems are not solved] [Elektronnyj resurs] *Ritm Evrazii.* URL: https://dzen.ru/a/Y75-toE8Eg_tY_nj
12. Pattanayak S. (2019) Deep Learning with TensorFlow: A Mathematical Approach to Advanced Artificial Intelligence in Python: textbook / S. Pattanayak. – Apress, 480 p.
13. Poluhin P.V.(2019) Instrumenty povysheniya effektivnosti chislennyh algoritmov obucheniya struktury dinamicheskih bajesovskih setej [Tools to improve the efficiency of numerical algorithms for training the structure of dynamic Bayesian networks] *Vestnik VGU*, seriya: sistemnyj analiz i informacionnye tekhnologii, vol. 4, pp. 132- 140.
14. Rane R., Dubey A., Rasool A., Wadhvani R. (2023) Neural Network Based Mortality Prediction in Covid-19 Dataset. *University of Kirkuk International Conference on Artificial Intelligence of Things*, vol.1929, pp. 354-366.
15. Simon H.A. (1978) Rationality as Process and as Product of Thought. *American Economic Review*, vol.68, no. 2, pp.1–16.
16. Turgel I.D., Bojko L.L, Syui L (2016). Gosudarstvennaya podderjka razvitiya monogorodov Rossii i Kazahstana [State support for the development of single-industry towns in Russia and Kazakhstan]. *Vestnik Finansovogo universiteta* , vol. 2. pp. 22-32.

Авторлар туралы мәлімет:

Мищенко Инна Витальевна – (корреспондент автор) экономика ғылымдарының кандидаты, қауымдастырылған профессор, Алтай мемлекеттік университеті (Барнаул қ., Ресей, e-mail: mis.iv@mail.ru)

Краюшкин Максим Геннадьевич – аспирант, Алтай мемлекеттік университеті (Барнаул қ., Ресей, e-mail: Kramaks-97@mail.ru)

Межов Степан Игоревич – экономика ғылымдарының докторы, профессор, Алтай мемлекеттік университеті (Барнаул қ., Ресей, e-mail: megoff@mail.ru)

Бианчи Исайас Скалабрин – PhD, қауымдастырылған профессор, Санта-Катарина Федеральды университеті (Флорианополис қ., Бразилия, e-mail: isaias.bianchi@gmail.com)

Information about authors:

Mishchenko Inna – (corresponding author) candidate of economic sciences, Associate Professor. Altai State University (Barnaul, Russia, e-mail: mis.iv@mail.ru)

Krayushkin Maksim – applicant, Altai State University (Barnaul, Russia, e-mail: Kramaks-97@mail.ru)

Mezhov Stepan – doctor of economics sciences, Professor, Altai State University (Barnaul, Russia, e-mail: megoff@mail.ru)

Bianchi Isaias – PhD, Associate Professor, Federal university of Santa Catarina (Florianopolis, Brazil, e-mail: isaias.bianchi@gmail.com)

Поступило 12 февраля 2024 г.
Принято 26 февраля 2024 г.