The Use of Intelligent Mathematical Models for Regional Investment Distribution Processes Analysis

Jamshid S. Tukhtabaev[1], Umid A. Otajanov[1], Shakhnoza T. Nurullaeva[1], Saodat A. Saydullaeva[1], Moxigul I. Kutbitdinova[1], Gulshan M. Abdulxayeva[1], Nafisa Odiljonovna[1]

[1] Tashkent State University of Economics, Uzbekistan
Emails: jamshidtukhtabaev@gmail.com; umid.otajanov25@hotmail.com; shakhnoza.nurullaeva32@gmail.com; Saodat.saydullaeva@hotmail.com; moxigul.kutbitdinova@gmail.com; Gulshan.abdulxayeva@hotmail.com; nafisa.odiljonovna67@gmail.com

Abstract

In this article, the artificial neural network mathematical model is used for Regional Investment Distribution Processes Analysis in the regions of the Republic of Uzbekistan; forecasts are made using this model, and the results are compared with the results determined using the trend and panel methods, and the preferred method is defined. Multi-layer perceptron, radial-basis grid, generalized-regression grid, and recurrent grid can be used to solve the forecasting problem. In the study, a program for intellectual analysis and forecasting of socio-economic development indicators of the regions of the Republic of Uzbekistan using the generalized regression network was developed. This program makes it possible to extract the most necessary factors from other methods even in the presence of multi-factor indicators and determine the future forecast result under their influence. According to the results of the forecast determined using the intellectual mathematical model developed because of the research, by 2025, the volume of the gross regional product of Andijan region is expected to be equal to 95607.34 billion soums, and in Samarkand region, it is expected to be equal to 80419.73 billion soums, in Tashkent city it is expected to be 259301.8 billion soums. According to the error levels of the results determined by the intellectual mathematical method, it represents an average error of 1.13% compared to the forecast period. If we determine the result of the trend by the level of error, it is equal to an average of 4.96% error compared to the forecast period, and these results prove the superiority of the intellectual mathematical method developed in the research.

Keywords: Intelligent models; gross regional product; investment; model; neural network; layer; intellectual mathematical model; investment potential forecast.

1. Introduction

The stable socio-economic development of the regions, together with the general laws of the socio-economic development of the country, is determined by such features as the share of export products related to the composition of the gross regional product in the total volume of production in the region, competitive products in the main sectors of the economy, scientific potential, and income of the population. Therefore, the problems that arise in ensuring the socio-economic development of the region in modern conditions have their own territorial characteristics. In order to solve the problems of the socio-economic development of the region, it is necessary to strengthen the regulatory role of the state in determining the regional economic policy, managing the territory, and to develop an effective system, means and methods of state regulation. Also, the sustainable socio-economic development of regions depends on the level of self-sufficiency with resources and the conditions for the implementation of effective budget, finance, credit, tax and price policy.

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The sustainable socio-economic development of the regions, along with the General Laws of the socio-economic development of the country, is determined by such characteristics as the share of export products in the total volume of production in the region, competitive output in the main sectors of the economy, scientific potential, incomes of the population. Therefore, in modern conditions, the problems that arise in ensuring the socio-economic development of the territory acquire specific territorial characteristics. In order to solve the problems of socio-economic development of territory, it requires a development of an effective system, means and methods of state regulation, strengthening the regulatory role of the state in determining a territorial economic policy and managing the territory. Moreover, the sustainable socio-economic development of regions depends on a level of self-sufficiency with resources and conditions for an effective budget's implementation, finance, credit, tax and pricing policy.

It means the socio-economic indicators of a region's development, which support a process of sustainable socio-economic development of the region, determined by its economic potential (production, financial, labor, natural, scientific, innovative, investment). It should be noted that one of the main means of state regulation of the region's stable socio-economic development in these conditions is the forecast. The main means of regulation and forecasting by the state is the economic and mathematical natural value of the balance of production and distribution of regional products[1]. Based on this, various calculations can be made to determine an interaction of changes in the economic situation in one of system's elements on others' economy.

2. Literature Review

Artificial neural networks have been used and researched by many foreign experts to predict investment processes, portfolio investments and their characteristics, and financial time series prediction and portfolio optimization using artificial neural networks. For example, U.Sharp, G.Alexander, Dj.Bailey in their world-famous book "Investments"[2] covered goals and means of financing in a detailed and understandable manner, described all types of securities and stock markets, reflected their theory and practice, who considered the methods of investment management, reflected the problems of investment globalization with the help of specific examples, graphs, tables.

L.Dj.Gitman, M.D.Djongs cited recommendations for assessing the global aspects of investment activity, role of investment in the economy, strategies and tools for achieving investment goals, participants in the investment process, types of investments and investors, investment tools, and most importantly, its attractiveness in involving investments in the regions[3].

Campbell McConnell, Stanley Brue widely studies the most important problems of the economy: macro and microeconomics, national income, employment, credit, financial and tax policy, the world economy[4].

Söhnke Bartram, Jürgen Branke, Mehrshad Motahari investigated artificial intelligence in asset management by increasing efficiency, accuracy and consistency in portfolio management; risk modeling and forecasting through trading and risk management[5].

Meanwhile, A.Nazif Catik, Mehmet Karaçukas carried out forecasting and analysis of inflation using alternative one-dimensional time series models of artificial neural networks for Turkey[6].

In Michael Furtwaengler's study, Tobias used neural networks to to find estimates close to acceptable indicators to determine a strictly optimal hedgeristic strategy on the main market dynamics of the concept of risk convex boundaries[7].

Samuel Björklund, Tobias Uhlinlar developed an artificial neural network model that predicts the expected profitability of financial time series in order to optimize portfolio weights. In a related context, they constructed a portfolio optimization model using stochastic computing to evaluate the use of future earnings forecasting. They developed an artificial neural network for financial time series forecasting and portfolio optimization[8].

Martin T.Hagan, Howard B.Demuth, Mark H.Bealelar developed a clear and detailed description of the basic architectures of neural networks and their training rules. In addition, the basic neural networks are presented sequentially, their training methods and practical problem solving are shown[9].

A number of experts-scientists conducted research in the field of the CIS countries, in particular, Yu.P.Zaychenko researched ambiguous logic and ambiguous neural network systems, which are part of artificial intelligence, and their application in various practical issues[10].

V.V.Kruglov and V.V.Borisov considered issues related to the theory of artificial neural networks, built modern software shell-simulators of neural networks, as well as neural network expert systems for solving problems of image recognition, clustering, forecasting, optimization and contributed greatly to the creation of their usage[11].

A.B.Barsky conducted research on the use of neural network technologies in the construction of information and management systems in science, economics, finance and art. He created simple methods of teaching in static and dynamic modes. He made researches on the characteristics of decision-making systems[12].

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In our country, S.S.Gulomov academician, conducted scientific researches on development of the national economy, improving an investment environment of the regions. Meanwhile, J.Sh.Tukhtabaev, B.R.Tillaeva, R.Kh.Alimov, N.M. Mahmudov investigated methods of improving the investment potential and effective use of investment and B.T.Baykhanov researched directions of modeling of intersectoral distribution of investments on the basis of ambiguous logic [13; 14; 15; 16; 17].

However, important aspects such as methods of introducing information systems into economic sectors, principles of modeling based on intelligent neural network systems, efficiency of using intellectual neural network systems in the economy, their interrelationship and conditions for development of the digital economy have not been studied in-depth scientifically and theoretically. In the development of the economy's digitalization, scientific development of innovative technologies & ideas and therefore improvement of the legal-normative basis is of great importance. Short, medium, long-term forecasting and decision-making models that worked well in the past may no longer meet today's requirements that creates a necessity for improvement of those models or creation of new ones. This problem further increases the relevance of this research topic.

3. Methodology

In order to solve the problem of prognosis, we must first choose how neurons need to be connected to each other, as well as the weight values in these bonds, respectively. One element can affect another, depending on the established relationship. In this case, the weight of the links determines the impact force.

A simple network has a direct signal transmission structure, where the signals pass through invisible elements at the input and finally arrive at the output element. This structure is stable. If the net is repeated (i.e. involves the transfer of communication to distant neurons back to nearby neurons), it can become unstable and have very complex dynamics. Recurrent nets are of great interest to researchers in the field of neural nets, however, properly structured neural nets have been used to solve effectively practical issues to this day.

Neurons are regularly divided into layers. The input layer serves only to enter the values of the input parameters. Each of the hidden and output neurons is connected to all elements of the previous layer. During an operation (use) of the network, the values of the input variables are given to the input elements, and then the neurons of the intermediate and output layers work sequentially. Each of them calculates its activation value. The activation value is then modified using the activation function, resulting in the output of a neuron. Multi-layer perceptron, radial-basis grid, generalized-regression grid and recurrent grid can be used to solve the forecasting problem (Fig.1).

In the study, a program for intellectual analysis and forecasting of socio-economic development indicators of the regions of the Republic of Uzbekistan using a generalized regression network was developed.

It also makes it possible to increase the number of neurons in the hidden layer, select forecast models and quickly implement many scenarios. It should be noted that if the forecast's result determined by the neural network technology is determined only based on the available data, the developed program also increases the possibility of achieving a determined forecast by allowing to create a rule based on the connections between factors and the level of their influence on the resulting factor.

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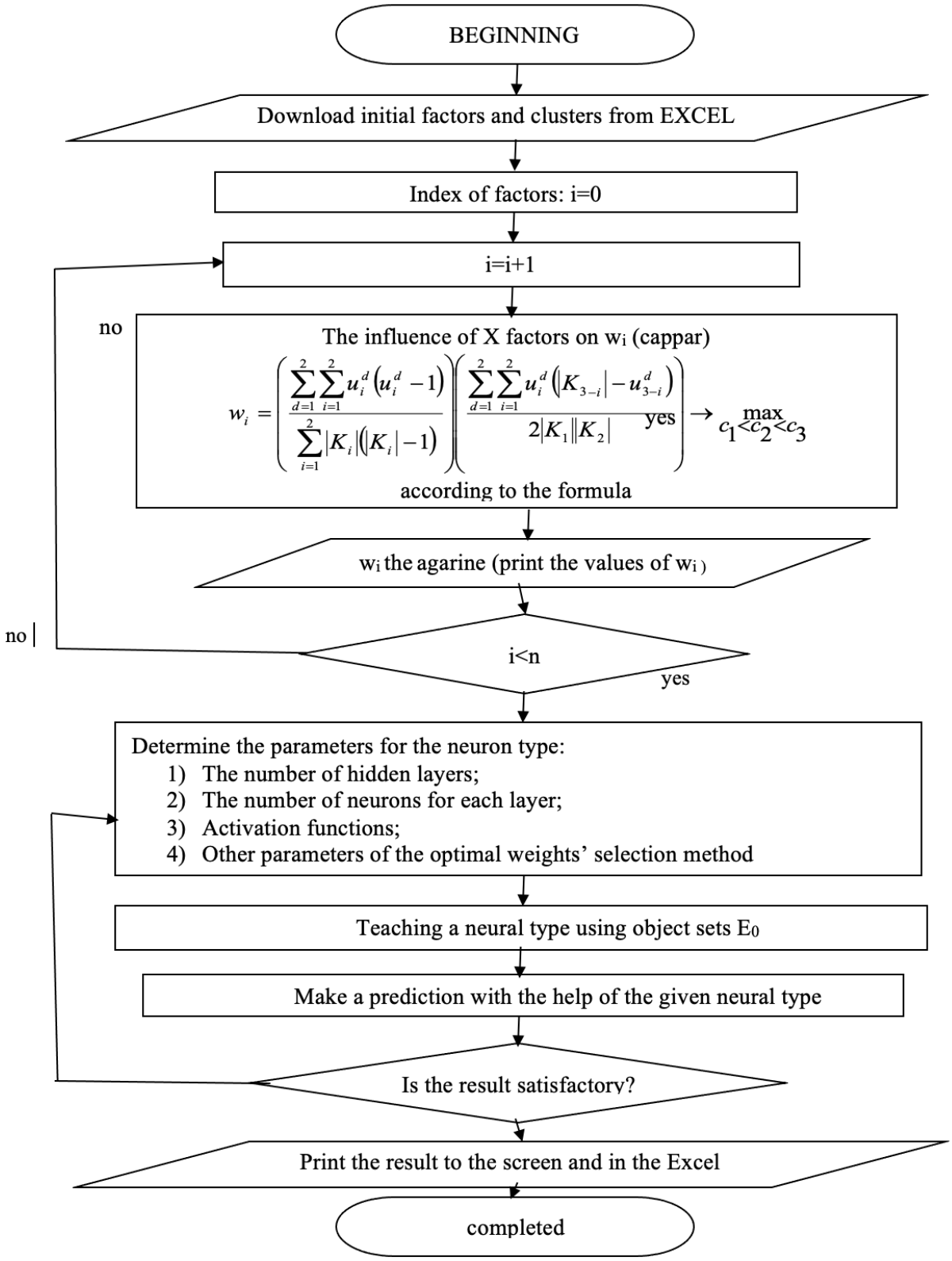

Figure 1: Algorithm for analyzing and forecasting intervals between factors in a cluster for PYTHON 3.6[18]

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In addition, it helps to easily establish the link between the parameters of the base functions and training data in multidimensional space. Therefore, it is easy to find satisfactory conditions for the initial process of teaching with the teacher.

In accordance with the topic's plan, the implementation of forecasting consists of a number of stages, which can be seen from the following algorithm (Fig.2).

The developed program helps to identify two issues:

- to determine the factors' weight affecting the value of GDP both quantitatively and qualitatively (in the range of 0 to 1)
- to determine the forecast of the republic's GDP (or GRP) for the following years using intelligent mathematical models and neural networks.

4. Results And Analysis

The following Figure 1 shows the forecast of Tashkent City's GDP for 2022-2025 as a result of selected 47 factors from 64 factors using the developed program (fig 2).

This, in turn, provides an opportunity to make complete and accurate conclusions about the process, as well as confirm the scientificity of decision-making.

t	years	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	...	X_{42}	X_{43}	X_{44}	X_{45}	X_{46}	X_{47}
1	2010	4291,58	4044,46	2394,9	3887,0	99,9	6984,4	3,3	1431,0	1228,4	663516,0	6750,2		2495	10077	319,2	3309	1440,9	8678,5
2	2011	5201,4	4336,19	2928,1	4722,9	100,0	9628,9	3,4	1434,9	1866,5	668785,0	6875,7		2610	9899	313,4	3523,1	1525,6	11207,1
3	2012	6458,7	5384,35	3634,7	5755,4	99,3	12516,4	3,3	1447,0	2300,5	675361,0	6914,1		2676	9747	315,2	5433,1	2320,9	14091,1
4	2013	6678,9	6294,3	4339,9	6941,4	100,0	15531,3	3,4	1442,0	2725,6	680946,0	7008,8		2537	10003	321,9	4977,1	2115,3	16967,3
5	2014	7599,0	7146,0	5361,1	8373,8	100,0	15468,5	3,6	1440,2	3460,1	685756,0	7044,6		2520	9942	324,1	5969,5	2517,4	21203,7
6	2015	8816,6	8383,2	6540,0	9700,5	100,0	18986,1	3,8	1441,3	4113,0	578689,0	7099,6		2849	9847	329,2	6854,6	2864,2	26178,7
7	2016	10631,5	10086,8	7998,4	12235,9	100,0	23511,9	3,6	1445,4	4633,4	583426,0	7165,2		2842	10618	335,7	10221,1	4216,5	33118,2
8	2017	12937,7	11770,1	9591,6	15815,0	100,0	30459,6	4,5	1454,1	6197,9	589025,0	7257,9		2594	9616	345,7	11799,3	4786,9	40720,4
9	2018	15804,6	13344,1	11857,7	20171,94	100,0	43274,1	7,9033	1466,34	10822,1	604064,4	7380		2122	9832	356,25	21866,81	8710	53287,1
10	2019	17319,7	14603,3	13133,8	22374,23	100,0	48063	8,537	1470,55	11954	591474,4	7455,56		2107	9818	362	24384,34	9692	74527,6
11	2020	18834,8	15862,5	14410	24576,51	100,0	52852	9,1707	1474,76	13085,8	578884,4	7531,12		2092	9804	367,75	26901,87	10674	97108,5
12	2021	20349,8	17121,7	15686,1	26778,8	100,0	57640,9	9,8044	1478,97	14217,7	566294,4	7606,67		2077	9790	373,5	29419,41	11656	121324,9
13	2022	21864,9	18381	16962,3	28981,09	100,0	62429,8	10,4381	1483,18	15349,5	553704,4	7682,23		2062	9776	379,25	31936,94	12638	147604,1
14	2023	23380	19640,2	18238,4	31183,37	100,0	67218,8	11,0718	1487,39	16481,4	541114,4	7757,78		2047	9762	385	34454,48	13620	179466,2
15	2024	24895,1	20899,4	19514,6	33385,66	100,0	72007,7	11,7055	1491,6	17613,2	528524,4	7833,34		2032	9748	390,75	36972,01	14602	216528,7
16	2025	26410,1	22158,7	20790,7	35587,95	100,0	76796,7	12,3392	1495,81	18745,1	515934,4	7908,9		2017	9734	396,5	39489,54	15584	259301,8

Figure 2: Forecast of the Tashkent city's GDP for 2022-2025 in accordance with the program

With the help of program presented in the research methodology above, the forecasts of both Andijan and Samarkand regions with a high level of potential along with results of economic analysis are determined. It should be noted that the advantages of this program are based on the characteristics, possibilities and potential of each region, depending on the factors affecting a change of each region and forecast value based on the various formulas in the function package. Despite the fact that this process is performed under a closed layer, the activation of the program can be selected through the function button. The intellectual forecast values of each region determined as a result of the actions that are listed in Table 1 below.

Table 1: Intellectual forecast of regions with a high level of potential (billion UZS)[19]

Years	Andijan region	Samarkand region	Tashkent city
2021	43225.47	52842.35	121324.9
2022	56550.65	57363.36	147604.1
2023	67736	64646.71	179466.2
2024	80690.64	72340.72	216528.7
2025	95607.34	80419.73	259301.8

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As can be seen from the information of Table 1, in 2022, the volume of gross regional product (GRP) in the Andijan region will be 56550.65 billion that indicates 30.8% increase from the value of 2021 (43.225.47 billion UZS). By 2025, the gross regional product of the Andijan region is expected to reach 95.607.34 billion UZS. as a result of a consistent increase of tasks in the socio-economic development program established in the region.

By 2025, the volume of GRP in Samarkand region will increase by 52.2% to 80419.73 billion in 4 years compared to 2021 (52842.35 billion UZS). According to the forecast's results determined in Tashkent, in 2022, the volume of gross regional product production will increase by 21.7% (reaching 147604.1 billion UZS) in comparison with 2021 (121324.9 billion UZS) and by 2025, this indicator will increase by 113.7% on average in 4 years and is expected to reach 259301.8 billion UZS.

Based on the topic's scope, it is required to use the panel method to conduct an econometric analysis using 64 factors and to identify change models from the observed data in 2010-2021.

There are many methods of economic analysis, one of which is a panel research. The panel research is a type of repeated investigation, which is a study of the same subject after a certain period. Repetition of the study means that it is carried out in a similar way to the method used at the first stage. Thanks to the panel research, there is an opportunity to help determine what qualitative changes have occurred in our object over time. On this basis, it will be possible to determine the dynamics of temporary changes in the properties of the object and determine the trend of its development. Thanks to panel research, there is an opportunity to determine what qualitative changes have occurred in our object over time. On this basis, it will be possible to determine dynamics of temporary changes in the object's properties and determine a trend of its development.

The panel research method has certain advantages. They are mainly due to the fact that the research method is prolonged with the growth of time[20]. With the help of it, you can analyze changes in a certain period and compare the results of previous studies with current ones. In simple words, it is possible to trace the relationship between the present and the event that happened some time ago based on obtained information. This helps to study a general tendency of behavior or process changes.

In this sense, we will carry out panel analyzes using the Eviews program, using 46 factors for 2010-2021 in 14 selected areas. Initially, according to $0.01 \leq \alpha \leq 0.1$ conditions, the significance of 19 factors (X1, X2, X5, X6, X7, X11, X13, X17, X22, X24, X26, X27, X29, X30, X38, X39, X41, X44, X45, X46) was determined. Afterwards, 14 factors remained (X1, X2, X5, X6, X13, X17, X22, X26, X27, X30, X37, X39, X41, X45) under the condition of multicollinearity $r_{x1,x2} \geq 0.8$ when checked by the correlation coefficient. According to the distribution law from the remaining 14 factors, (X1, X2, X5, X17, X26, X27, X37, X41), 8 reliable factors were sorted.

During defining the multi-factor regression equation of the GRP volume of Tashkent city, Andijan and Samarkand regions using these selected factors, the volume of X26 (agricultural product in the regions' sector (in the current grades) and X27 (in the regions' sector, the volume of agricultural, forestry and fishery products (services) (at current prices billion UZS)) special attention was paid to factors. First of all, it can be seen that these factors do not relevant for the Tashkent city, but it can be seen that they have multicollinearity compared to other factors in the other two regions (Table 2).

Table 2: Correlation of the factors influencing GRP of the Andijan region

	X1	**X2**	**X5**	**X17**	**X26**	**X27**	**X37**	**X41**
X1	1							
X2	0.99511	1						
X5	0.64541	0.62234	1					
X17	0.83229	0.81485	0.46068	1				
X26	**0.99383**	**0.98734**	**0.94579**	**0.84888**	**1**			
X27	**0.99310**	**0.98712**	**0.84710**	**0.84589**	**0.99997**	1		
X37	0.3805	0.43290	0.389315	0.386335	0.415904	0.411505	1	
X41	-0.19268	-0.26112	-0.22094	-0.15471	-0.22132	-0.21697	-0.63775	1

As can be seen from the table information, the factors X26 and X27 have multicollinearity in connection with other factors and these factors can be discarded when constructing the regression equation. In the same way, the coefficient of correlation between the factors selected for the GRP of Samarkand region is determined (Table 3).

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Table 3: Correlation of the factors influencing GRP of the Samarkand region

	X47	***X1***	***X2***	***X5***	***X17***	***X26***	***X27***	***X37***	***X41***
X47	1								
X1	0.984727	1							
X2	0.991321	0.795963	1						
X5	-0.86336	-0.70104	-0.91394	1					
X17	0.931757	0.633317	0.723529	-0.74319	1				
X26	**0.99791**	**0.988299**	**0.990581**	**-0.86097**	**0.929602**	**1**			
X27	**0.997602**	**0.988531**	**0.990599**	**-0.86143**	**0.929971**	**0.999975**	1		
X37	0.447117	0.340493	0.388892	-0.18014	0.505953	0.407914	0.406805	1	
X41	-0.84556	-0.75861	-0.80485	0.704305	-0.69327	-0.8238	-0.82193	-0.5789	1

According to the multicollinearity condition, the multicollinearity of factors X26 and X27 with other factors was also found in this table. This, in turn, means that only 6 factors out of 46 factors have a strong impact on GDP, and according to these factors, the forecast results of the regions are reflected in the table below (Table 4).

Table 4: Multifactor panel forecast of Tashkent city, Andijan and Samarkand regions

Years	**Tashkent city**	**Andijan region**	**Samarkand region**
2021	120825.4	44801.6	51862.3
2022	148214.3	54561.19	58447.36
2023	180208.1	65353.03	65868.35
2024	217423.9	77851.92	73707.75
2025	260373.8	92243.85	81939.44

As can be seen from the table, in 2021, the Tashkent city's GRP will be 120825.4 billion UZS, Andijan region - 44801.6 billion UZS and Samarkand region - 51862.3 billion UZS. By 2025, Tashkent's GRP will be increased by 115.5% compared to 2021 to 260373.8 billion UZS, whereas the Andijan region's GRP will be grown by 105.9% (92243.85 billion UZS) and the Samarkand region's GRP will be increased by 57.99% (81939.44 UZS).

Unfortunately, the panel method, like other research methods, is not without its shortcomings. The main disadvantage of this method is the complexity of process in the initial stages. When it comes to large-scale research, it is important to note that it is difficult to gather, debrief a large enough group and squeeze many factors that arise from the research into criteria. It is also worth noting that the inability to determine whether the influence of factors individually and combined has a different level of influence in the panel program, led to the development of a new methodology in this regard.

It should be noted that in order to check the reliability of values determined by the program developed as a result of this study, we think it is appropriate to compare them with the forecast values determined by the trend equations that represent the trend of the rows in the EXCEL program. According to it, the forecast results of the socio-economic potential of Andijan, Samarkand regions and the city of Tashkent are presented in Table 5 below.

Table 5: Trend forecast of regions with high potential within the territories (billion UZS)

Years	Andijan region $y = 0.431x^4 - 8.8x^3 + 112x^2 - 278.99x + 488.44$ $R^2 = 0.9959$	Samarkand region $y = -0.1705x^4 + 11.825x^3 - 72.726x^2 + 243.11x + 273.81$ $R^2 = 0.9986$	Tashkent city $y = -0.015x^5 + 2.3x^4 - 48.642x^3 + 470x^2 - 1137.5x + 993.46$ $R^2 = 0.9962$
2021	46346.2	49659.3	119947.18
2022	55820.6	56394.8	146992.76
2023	66861.5	63555.2	178722.9
2024	79648.9	71119.3	215631.89
2025	94373.1	79061.9	258227.84

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It is possible to check the model's reliability and adequacy based on the comparison of the results obtained by all three methods[18]. Therefore, it is necessary to estimate the volume of gross regional products actually produced by the regions in 2021 based on values determined by the methods (Table 6).

Table 6: Comparative analysis of the methods' results for 2019 (billion UZS)

Regions	Real	Intellectual		Trend		Panel method		Error rate, %		
		Calculation	Difference	Calculation	Difference	Calculation	Difference	Intelligence	Trend	Panel
Andijan	43790.8	43225.47	565.3	46346.2	-2555.4	44801.6	-1010.8	0.013	0.058	0.023
Samarkand	53749.9	52842.35	907.6	49659.3	4090.6	51862.3	1887.6	0.017	0.076	0.035
Tashkent city	121829.5	121324.93	504.6	119947.2	1882.3	120825.4	1004.1	0.004	0.015	0.008

This comparison could also be concluded by analyzing the differences in the forecast results of all three methods. However, in this case, the high differences between them cast doubt on the conclusion's accuracy about the methods' reliability. Therefore, it is appropriate in the study to examine the differences between the actual values and the values obtained by the methods.

According to the results of Table 6, the reliability and superiority of the intellectual mathematical model was derived from the trend and panel methods. Because, if we pay attention to the error level of the results determined by the intellectual mathematical method, it represents an average error of 1.13% compared to the forecast period and error level of panel method's result is an average of 2.2%. If we find the trend's result by the error level as well, it is equal to an average of 4.96% compared to the forecast period, and these results show the superiority of the intellectual mathematical method that was designed in the research.

5. Conclusion And Suggestions

The analysis and in-depth study of regional investment distribution processes requires improvement due to the large number of factors. The abundance of factors in turn constitutes a set of spatial indicators. In many cases, in practice, it is advisable to divide these spatial indicators into two half-planes, which are considered as a whole plane in the conditions of quick analysis and decision-making. According to the forecast results, which was determined using the intellectual mathematical model developed as the study's result, the volume of gross regional product in Andijan region in 2022 is ammounted to 56550.65 billion UZS, which indicates a 30.8% increase in comparison with 2021 (43.225.47 billion UZS). By 2025, the gross regional product of Andijan region will reach 95.607.34 billion UZS.

By 2025, the volume of the gross regional product in Samarkand region is expected to increase by 52.2% to 80419.73 billion in 4 years compared to 2021 (52842.35 billion UZS). According to the forecast's results of Tashkent city, in 2022, the volume of gross regional product production is projected to increase by 21.7% compared to 2021 (121324.9 billion UZS) and reach 147604.1 billion UZS by 2025, this indicator will increase by 113.7% on average in 4 years and reach 259301.8 billion UZS.

According to the results' error level determined by the intellectual mathematical method, the average error is 1.13% compared to the forecast period, and error level of the the panel method's result represents an average error of 2.2%. If we find the result of trend by the error level as well, the average error is equal to 4.96% compared to the forecast period, and these results prove the superiority of the intellectual mathematical method that was developed in the research.

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