Models of Fuzzy Economics

Gorkhmaz Imanov

Legado Académico Nº 1

Models of Fuzzy Economics

Contribución a la Escuela de Economía Humanista de Barcelona

Gorkhmaz Imanov

Corresponding Academician for Azerbaijan

Real Academia de Ciencias Económicas y Financieras

Publicaciones de la Real Academia de Ciencias Económicas y Financieras

Real Academia de Ciencias Económicas y Financieras. Observatorio de Investigación Económico-Financiera

"Models of fuzzy economics". Contribución a la Escuela de Economía Humanista de Barcelona. / Real Academia de Ciencias Económicas y Financieras.

Bibliografía
ISBN- 978-84-09-68523-3

I. Título II. Imanov, Gorkhmaz III. Colección Legados Académicos

1. Economía 2. Legado 3. Académico 4. Escuela de Economía Humanista de Barcelona

La Academia no se hace responsable de las opiniones científicas expuestas en sus propias publicaciones.
(Art. 41 del Reglamento)

Editora: ©2024 Real Academia de Ciencias Económicas y Financieras, Barcelona.
Fotografías: ©2024 Real Academia de Ciencias Económicas y Financieras, Barcelona.
www.racef.es

Académica Coordinadora: Dra. Ana Maria Gil-Lafuente

ISBN - 978-84-09-68523-3

Depósito Legal: B 23732-2024

Obra producida en el ámbito de la subvención concedida a la Real Academia de Ciencias Económicas y Financieras por el Ministerio de Ciencia e Innovación.

Esta publicación no puede ser reproducida, ni total ni parcialmente, sin permiso previo, por escrito de la editora. Reservados todos los derechos.

Impreso y encuadernado en España por Ediciones Gráficas Rey, S.L. —c/Albert Einstein, 54 C/B, Nave 12-14-15
Cornellà de Llobregat—Barcelona

Impresión diciembre 2024

Esta publicación ha sido impresa en papel ecológico ECF libre de cloro elemental, para mitigar el impacto medioambiental

Models of Fuzzy Economics

Contribución a la Escuela de Economía Humanista de Barcelona

Gorkhmaz Imanov

La realización de esta publicación
ha sido posible gracias a

MINISTERIO
DE CIENCIA, INNOVACIÓN
Y UNIVERSIDADES

con la colaboración de

Fundación "la Caixa"

Legado Académico Nº 1

Gorkhmaz Imanov

Corresponding Academician for Azerbaijan

PREFACE

In 2006, on the recommendation of the founder of the Fuzzy Sets and Fuzzy Logic theory, Professor Lotfi Zadeh I started working with the founder of Fuzzy Economics, President of RACEF, Professor J. Gil-Aluja.

On the recommendation of Professor J. Gil-Aluja in 2007, my paper “Fuzzy Approach to Evaluating the Index of the Quality of Life of the Population” was published in the Fuzzy Economic Review journal.

Since 2007, I have participated in various Acts discussing the problems of the world economy proposed by Professor J. Gil-Aluja. In 2011, under the guidance of the Nobel Laureate, Professor Finn E. Kydland and Project Director, Dr. Anna Maria Gil Lafuente I participated in the project “New Markets for Economic Recovery: Azerbaijan”. The research results of this project were published by RACEF in 2011.

In the proposed book, I present my reports made in 2007-2024 in the RACEF Acts. The proposed book consists of 19 sections briefly described below:

The first section deals with Fuzzy sustainable development assessment models (2008), in which sustainability development level in the country is considered. To define the level, in the presented paper we offer a Fuzzy model for assessment of the sustainability level, a model for the forecasting of the poverty level based on Azerbaijan official statistical data.

In the second section, we investigated Problems uncertainty and fuzzy modelling of socioeconomic system (2007). Fuzzy logic was proposed as a tool for analysis and forecasting of socioeconomic system under influence of examined factors of uncertainty. Some fuzzy models for different level problems of economic system and as endogenous parameters socioeconomic system –index of population life quality have been developed.

Third section devoted to the problems fuzzy evolution of the environmental sustainability index (2008). On the basis of 14 parameters, we defined 6 strategic categories.

In fourth section, we proposed the fuzzy-probability model evaluation of the financial stability index (2011). With this purpose, fuzzy Markov model was employed. The problem relevant to the model was solved by using factual and macroeconomic information of the Azerbaijan.

In the fifth section, fuzzy estimation of quality of socioeconomic system (2013) was reviewed. For this purpose, we offered fuzzy models.

Problems of measuring national green economy development (2014) were considered in section 6. To meet this objective we used twelve indicators: Ecological quality, Renewable energy, Protection land, Green tourism, Quality of life, Green, Energy intensity, Organic agriculture, Worldwide governance index, International Innovation Index, Transport greenhouse gas emissions per capita.

Problems of oil prices and economic diversification in Azerbaijan (2015) was investigated in section 7. With this objective fuzzy sets theory and fuzzy logic, instruments were applied. Application of fuzzy sets and fuzzy logic aimed at the problems of uncertainty in oil prices on the world market and the volume of resources in the country.

Section 8 enlightens the issues of forecasting the development of national economy in oil exporting country (2016). In order to forecast development of national economy depended on oil and gas income we proposed fuzzy econometric models to define optimal production structure of GDP in Azerbaijan.

In section 9, by the method of intuitionistic fuzzy logic, the information economy development level is defined on the basis of the data of Global Innovation Index. Also, the influence of human resources to the information economy on value added was analysed.

Section 10 is devoted to assessment of development resources in new sector of the national economy (2018). By the application of intuitionistic fuzzy logic instruments and DEMATEL methods, we analysed impact level of indicators' sub-indices to the development level of information economy.

The issues of Assessment level of humanism in national sustainable development (2018) were described in section 11. In order to define quality of humanism in national sustainable development, quality of life, human capital, and ecocivilization indices were evaluated.

Section 12 was devoted to the problems of Fuzzy estimation of the Export Sophistication level of the country (2019) By using intuitionistic fuzzy linguistic theory aggregated index of export sophistication level was estimated.

Models for the assessment of the factors of emigration (2019) was proposed in section 13. To investigate emigration process in Azerbaijan in this paper we took into account results of our previous investigations in which we applied intuitionistic linguistic fuzzy instruments.

Section 14 illuminates the quality estimation level of country's development problems. Taking into account the fourth industrial revolution results, in this section an index determining the level of development of a country was proposed, criteria of which are the levels of macrostability, social and human capital and research, skills, knowledge and technology, and ecological civilization. In order to calculate this index, an intuitionistic fuzzy linguistic algorithm is proposed.

In section 15, the analytical approach to the ecological civilization level index assessment of the country (2022) was proposed. With this purpose, we set out an evaluation method for ecological civilization level index (ECLI) that has become an agenda of the new decade. This concept covers economic, social, and environmental indicators and addresses global ecological civilization and sustainable development.

The influence of world military-political situations to sustainable development of the country was investigated in section 16. The results of analysis of military and political events in the world show that wars, sanctions, the coronavirus epidemic have a strong impact on the sustainable development of the world economy and some countries.

In section 17, Interval-valued intuitionistic fuzzy model for simulation of Azerbaijan National Cyber Security Index was investigated and obtained results over actual data reflect NCSI level in the country and outcomes over simulated scenarios can be used for the improvement of the NCSI index over the certain indicators.

Problem of estimation of the social consequences of countries economic development was analyzed in section 18. Here the proposed approach to define social consequences of economic development of the country by using social sustainability and social quality indices give us possibility for wide analysis of socio-economic system functioning.

The fuzzy analysis of global uncertainty factors affecting the Azerbaijani economy highlighting the significant challenges posed by events such as the COVID-19 pandemic, the Ukrainian-Russian war, and climate change was provided in section 19.

In Chapter 20, the Global Economic Diversification Index for Azerbaijan was computed using indicators of output, trade, and tax revenues with the application of agent-based models and fuzzy algorithms.

I am grateful to the member of Royal Spanish Academy of Economics and Finance, Prof. Anna Maria Gil-Lafuente for recommendation to print my book.

I also express my gratitude to my assistant Asif Aliev for help in preparation of this book.

Dr. G. Imanov

Corresponding Member of Azerbaijan National Academy of Sciences, Foreign Academician of RACEF

CONTENTS

1. FUZZY MODELS FOR THE ASSESSMENT OF SUSTAINABLE DEVELOPMENT

1.1. Introduction

In 1992, in Rio de Janeiro under the aegis of the UNO, a conference took place during which the concept of sustainable development was accepted as the basic principle for human society's development in the 21st century. The reasons for accepting this concept were the social, economic, and ecological problems of the world's society.

The term "sustainable development" can be defined as development that satisfies human needs in the present time without sacrificing the ability of future generations to satisfy their own needs. Sustainable development considers two key interrelated concepts:

- The concept of necessities, including priority-driven necessities that are essential for the subsistence of the poorest population groups.

- The concept of limits, which are imposed by technological development and social structure, as well as the ability of the natural environment to fulfill present and future human needs.

The term "sustainable development" implies the improvement of human life quality without exceeding the present limits of the supporting ecosystem. A "sustainable economy" is the result of sustainable development and maintains its natural resources base. A sustainable economy can be achieved only with improvements in knowledge, structure, and technological efficiency.

To assess the sustainability of society's development, the UNO recommends considering 134 indicators. One of the co-authors of the sustainable development concept, academician V.A. Kaptyuk, has mentioned several criteria for assessing a country's sustainable development. By applying these indicators, we can determine whether a country's economy is developing, slightly decreasing, or being ruined. Countries that exceed the limits of the defined criteria (which are results of two centuries of experience and observations by economists and sociologists) are at risk of collapsing. Here are some of the criteria:

1. Gross Domestic Product (GDP) decrease rate. A decrease of 30-40% is catastrophic and makes it impossible for the country to recover.

2. Proportion of imported food products in consumption. It is necessary to avoid more than 30% of food product imports, as this can lead to possible instability in food supplies.

3. The portion of advanced technology products in exports should not be less than 10-15%.

4. Social sphere. The proportion of the richest 10% and the poorest 10% of the population. The acceptable level for social stability in the country is 10:1.

5. Demographic situation. The critical indicator for the death-rate/birth-rate ratio is 1.

6. Alcohol consumption. The international critical indicator of alcohol consumption is 8 liters annually per person.

In the present paper, we study fuzzy models of society development sustainability assessment and the forecasting of poverty rates.

1.2. Fuzzy Model for Assessment of Sustainable Development Level of Society

The sustainability of society development is defined by three factors: economic, social, and environmental. These parameters for Azerbaijan are shown in Table 1.1.

Table 1.1. Parameters of Economic, Social, and Environmental Development Sustainability for the Azerbaijan Republic (2000-2006)

No	Parameters	Limits	2000	2001	2002	2003	2004	2005	2006
1.	Growth rate	30-40%	11,1	9,9	10,6	11,2	10,2	26,4	34,5
2.	Portion of imported food in consumption:	30%							
	- Meat and meat products,		24	18	17	18	19	20	14
	- milk and dairy products,		13	14	19	16	13	13	12,5
	- eggs,		14	9	5	1	1	2	3,0
	- sugar,		100	100	100	100	100	100	32,9
	- vegetable oils,		68	46	49	41	69	64	-
	- fish and fish products,		14	14	13	17	25	32	36
	- potato,		13	13	17	3	6	6	7
	- vegetables		1	1	2	2	1	2	3,0
	- fruits,		2	2	2	2	6	7	9,0
	- grain and grain products.		38	27	27	32	40	33	34,9
3.	Portion of advanced technology products in export	10-15%	4,0	2,3	2,0	2,0	5,0	7,0	2,0
4.	Correlation of incomes of the rich and the poor (decile)	10:1	9,80	-	6,08	7,46	2,9	2,8	3,2
5.	Death – rate and birth-rate ratio	1	0,399	0,410	0,420	0,432	0,377	0,366	0,351
6.	Poverty level		68,1	49,0	46,7	44,7	40,2	29,3	20,8
7.	C O2 and particulate emission damages (% of GDP)	5	5,3	6,3	6,2	6,0	4,1	3,9	3,5
8.	Main capital investments purposeful for environment protection and rational utiliza- tion of natural resources (% of GDP)	5	0,04	0,02	0,04	0,04	0,02	0,02	0,05

GDP growth rate, portion of imported products in consumption, and portion of advanced technology products in export are indicators of economic factors. Decile, poverty rate, and demographic situation are indicators of social factors. CO_2 and particulate emission damages, and main capital investments for environmental protection and rational utilization of natural resources (% of GDP) are ecological factors. As seen from Table 1.1, only one economic indicator—growth rate—satisfied sustainable development criteria, while the portion of imported food in consumption and advanced technology products in export did not meet these criteria. Among the social indicators, the poverty level was high. Due to a shortage of ecological information, we analyzed CO_2 and particulate emission damage (% of GDP) indicators. If we took into account damages to water and land from pollution, these indicators could increase. In our case (see Table 1.1.), main capital investments for environmental protection and rational utilization of resources (% of GDP) are the lowest compared with the sustainable limit.

The sustainable development level of society and the factors that define it have a qualitative nature, making the modeling of these factors by means of classical mathematical methods impossible. Thus, our aim is to develop a fuzzy model for assessing the level of society's sustainable development.

According to the phases of the fuzzy modeling process, we begin by introducing linguistic variables corresponding to societal, economic, and environmentally sustainable development levels. The values of these linguistic variables are terms such as "sustainable," "close to sustainable," "weakly sustainable," and "non-sustainable," which we will formalize as fuzzy term-sets.

Interval estimations of the chosen terms for each of the linguistic variables are displayed in Table 1.2. To define these intervals, we used not only Azerbaijan's economic, social, and ecological indicators but also global indicators. Term-sets of sustainable development, economic and social sustainability indexes were defined within the interval [0, 1]. The ecological sustainability index was defined within the interval [0,100].

According to the statistical data for Azerbaijan in 2006 (Table 1.1), we evaluate point estimates from the sustainability point of view, using the available 8 criteria (Table 1.3). By applying the fuzzy inference mechanism (Fuzzy Inferences System), we obtain the following point estimations:

- For economic sustainability – 0.285

- For social sustainability – 0.250
- For ecological sustainability – 0.216

Assuming these parameters to be exogenous for the model developed on the basis of synthesized logic rules in the Fuzzy Inferences System program, we obtain a point estimate of the society's development sustainability level: 0.256, which, according to the accepted ranking system, corresponds to the term "weakly sustainable."

Table 1.2. Linguistic variables term-sets intervals

Parameters	**Definition**	**Sustainability level:**			
		«Sustainable»	**«Close to sustainable»**	**«Weakly sustainable»**	**«Non-sustainable»**
Economical	**EC**	1-0.75	0.75-0.5	0.5-0.25	0.25-0
GDP Growth rate	GR	>10	10-5	5- (-15)	<-15
Portion of imported products in consumption	[кP	0 - 10	10 - 20	20 - 30	>30
Portion of advanced tech nology products in export	TE	>10	10 - 5	5 - 2.5	2.5 – 0
Social	**SO**	1-0.75	0.75-0.5	0.5-0.25	0.25-0
Decile	DE	0 - 6	6 - 10	10 - 14	> 14
Poverty level	PO	0 - 7	7 - 11	11 - 15	>15
Demographic situation	DS	>1.1	1.1 - 1	1 – 0.9	0.9 – 0
Ecological	**EC**	>50	50 - 33	33 – 16.5	16.5 – 0
CO_2 and particulate emission damages (% of GDP)	ED	>5	5 – 3.3	3.3 – 1.65	1.65 – 0
Main capital investment s purposeful for environment protection and rational utilization of natural resources (% of GDP)	EI	>5	5 – 3.3	3.3 – 1.65	1.65 – 0
Sustainable development level	**SD**	1 – 0.75	0.75 – 0.5	0.5 – 0.25	0.25 – 0

Table 1.3. Point values of term-sets for Azerbaijan (2006)

	Sustainability assessment criteria	Point values
1.	GDP growth rate	26
2.	Portion of imported products in consumption:	34.9
3.	Portion of advanced technology products in export	2
4.	Decile	3.2
5.	Poverty level	20.8
6.	Demographic situation	0.35
7.	C O2 and particulate emission damages (% of GDP)	3.5
8.	Main capital investments purposeful for environment protection and rational utilization of natural resources (% of GDP)	0.05

1.3. Fuzzy forecasting model of poverty level

The problem of poverty is one of the key concepts of sustainability in social development. Poverty levels depend on population income, unemployment rate, inflation rate, and living wage. In Azerbaijan, these factors and their forecasts are analyzed in the current section.

Despite the fact that the regression equation is considered suitable according to certain criteria, it does not possess equal accuracy compared to modern fuzzy methods. This can be demonstrated with data over several years. Yearly data taken from statistics are averaged and cannot be considered exact numbers. Figures used in fuzzy models are inherently fuzzy and consist of completely determined intervals, taking into account errors at each α level. Moreover, in classic regression, all operations are implemented on real numbers, so the results are also displayed in real numbers. As initial parameters may not reflect reality accurately due to averaging, the results may not be precise. Since numbers are not specific in fuzzy estimations, the result obtained is also a fuzzy number. Generally, this ensures that the obtained results will fall within reliable intervals by α levels, considering errors.

To describe the whole problem, let us record the following variables conditionally marking the aforementioned indicators:

- Poverty rate (% of entire population) – PR
- Population income (mln. AZN) – PI

- Unemployment rate (% of able-bodied citizens) – UR
- Inflation rate (%) – IR
- Living wage (AZN) – LW

Table 1.4. is compiled based on these five indexes for Azerbaijan between 2000-2006.

Table 1.4. Five indices for Azerbaijan between 2000-2006 years

Years	Poverty rate (% of entire population) PR	Population income (mln. AZN) PI	Unemployment rate (% of able-bodied citizens) UR	Inflation rate (%) iR	Living wage (AZN) LW
2000	68,1	3511,4	1,17	101,8	23,2
2001	49,0	3802,0	1,29	101,5	24,0
2002	46,7	4244,1	1,35	102,8	35,0
2003	44,7	4978,9	1,43	102,2	35,8
2004	40,2	6135,3	1,45	106,7	38,8
2005	29,3	7792,3	1,44	109,6	42,6
2006	20,8	9949,8	1,35	108,3	58,0

The main problem is to provide accurate forecasts for economic indexes for the next three years based on available statistical data for 2000-2006. One of the well-known methods among forecasting rules is the linear regression equation. To formulate the problem in the form of linear regression, let us define each of the five economic indicators in compliance with the problem set: in this case, we get variables such as PR (dependent variable), and PI, UR, IR, LW (independent variables). The linear regression equation for this problem solution will be as follows:

$$PR(PI, UR, IR, LW) = a_0 + a_1 \cdot PI + a_2 \cdot UR + a_3 \cdot IR + a_4 \cdot LW \qquad (1.1)$$

Where the identification of a_0, a_1, a_2, a_3, a_4 coefficients is carried out by the application of the least-squares method in accordance with statistical principles. Thus, the calculation of function values for the coming years was carried out. The obtained classic model of multiple regression is shown below:

$$PR(PI, UR, IR, LW) = 35.5324 - 0.00661 * PI - 56.4371 * UR + 1.13111 * IR + 0.09011 * LW \quad (1.2)$$

$$R^2 = 0.931535, DW = 2.001001$$

So, in both classical regression and fuzzy regression models, it is necessary to evaluate the dependent function. First, let us present the dependent function in a generic form:

$$\widetilde{PR} = \tilde{f}(\widetilde{PI}, \widetilde{UR}, \widetilde{IR}, \widetilde{LW}) \quad (1.3)$$

The dependence here could be linear or non-linear. As is visible from formula (1.3), all the five indicators included in the problem are fuzzy numbers. Similar to the classical solution of the linear regression, the fuzzy problem also consists of evaluating the arbitrary term and coefficients:

$$\widetilde{PR} = \tilde{f}(\widetilde{PI}, \widetilde{UR}, \widetilde{IR}, \widetilde{LW}) = \tilde{A}_n + \tilde{A}_1 * \widetilde{PI} + \tilde{A}_2 * \widetilde{UR} + \tilde{A}_3 * \widetilde{IR} + \tilde{A}_4 * \widetilde{IM} \quad (1.4)$$

In this equation indicators *PR, PI, UR, IR, LW*, A_0 A_1 A_2 $A_3 A_4$ are fuzzy numbers.

We calculate the indicators: PR, PI, UR, IR, and LW using the isosceles triangle rule as shown below:

$$\widetilde{PR} = (PR_c, PR_w), \widetilde{PI} = (PI_c, PI_w), \widetilde{UR} = (UR_c, UR_w), \widetilde{IR} = (IR_c, IR_w), \widetilde{LW} = (LW_c, LW_w) \quad (1.5)$$

Let us express each of , A_0 A_1 A_2 A_3 A_4 coefficients in isosceles triangle form:

$$A_0 = (a_{0c}, a_{0w}), A_1 = (a_{1c}, a_{1w}), A_2 = (a_{2c}, a_{2w}), A_3 = (a_{3c}, a_{3w}), A_4 = (a_{4c}, a_{4w}) \quad (1.6)$$

The arcwise-interval form of the fuzzy linear regression equation for each α level is as follows:

$$PR^{\alpha}(PI^{\alpha}, UR^{\alpha}, IR^{\alpha}, LW^{\alpha}) = A_0^{\alpha} + A_1^{\alpha} \cdot PI^{\alpha} + A_2^{\alpha} \cdot UR^{\alpha} A_3^{\alpha} \cdot IR^{\alpha} + A_4^{\alpha} \cdot LW^{\alpha} \quad (1.7)$$

i.e.

$$PR^{\alpha}(PI^{\alpha}, UR^{\alpha}, IR^{\alpha}, LW^{\alpha})$$
$$= (PR_c^{\alpha}(PI^{\alpha}, UR^{\alpha}, IR^{\alpha}, LW^{\alpha}), PR_w^{\alpha}(PI^{\alpha}, UR^{\alpha}, IR^{\alpha}, LW^{\alpha}),)$$

$$PI^{\alpha} = (PI_c^{\alpha}, PI_w^{\alpha}), UR^{\alpha} = (UR_c^{\alpha}, UR_w^{\alpha}), IR^{\alpha} = (IR_c^{\alpha}, IR_w^{\alpha}), LW^{\alpha} = (LW_c^{\alpha}, LW_w^{\alpha})$$

$$A_0^{\alpha} = (A_{0c}^{\alpha}, A_{0w}^{\alpha}), A_1^{\alpha} = (A_{1c}^{\alpha}, A_{1w}^{\alpha}), A_2^{\alpha} = (A_{2c}^{\alpha}, A_{2w}^{\alpha}), A_3^{\alpha} = (A_{3c}^{\alpha}, A_{3w}^{\alpha}), A_4^{\alpha} = (A_{4c}^{\alpha}, A_{4w}^{\alpha})$$

Extending abovementioned formulas, we can use following forms:

$$PR_c(PI, UR, IR, LW) = a_{0c} + a_{1c} \cdot PI_c + a_{2c} \cdot UR_c + a_{3c} \cdot IR_c + a_{4c} \cdot LW_c \quad (1.8)$$

$$PR_w(PI, UR, IR, LW) = a_{0w} + a_{1c} \cdot PR_w + a_{1w} \cdot PR_c + a_{2c} \cdot UR_w + a_{2w} \cdot UR_c + a_{3c} \cdot IR_w + a_{3w} \cdot IR_c + a_{4c} \cdot LW_w + a_{4w} \cdot LW_c \quad (1.9)$$

It is possible to apply similar equations in the same order for all α levels. Minimizing the fuzzy regression equation for each α level requires solving the following linear programming problem:

Objective function:

$$\sum PR_w = n \cdot a_{0w} + \left(\sum_{i=1}^{T} PI_{w_i}\right) a_{1c} + \left(\sum_{i=1}^{T} PI_{c_i}\right) a_{1w} + \left(\sum_{i=1}^{T} UR_{w_i}\right) a_{2c} + \left(\sum_{i=1}^{T} UR_{c_i}\right) a_{2w} + \left(\sum_{i=1}^{T} IR_{w_i}\right) a_{3c} + \left(\sum_{i=1}^{T} IR_{c_i}\right) a_{3w} + \left(\sum_{i=1}^{T} LW_{w_i}\right) a_{4c} + \left(\sum_{i=1}^{T} LW_{c_i}\right) a_{4w} \to min$$

Constraints:

$$a_{0c} - a_{0w} + \left(PI_{c_i} - PI_{w_i}\right) \cdot a_{1c} - PI_{c_1} \cdot a_{1w} + \left(UR_{c_i} - UR_{w_i}\right) \cdot a_{2c} - UR_{c_i} \cdot a_{2w} + \left(IR_{c_i} - IR_{w_i}\right) \cdot a_{3c} - IR_{c_i} \cdot a_{3w} + \left(LW_{c_i} - LW_{w_i}\right) \cdot a_{4c} - LW_{c_i} \cdot a_{4w} \le PR_{c_i} - PR_{w_i},$$
$$(i = \overline{1,7})$$

$$-a_{0c} - a_{0w} - \left(PI_{c_i} - PI_{w_i}\right) \cdot a_{1c} - PI_{c_1} \cdot a_{1w} - \left(UR_{c_i} - UR_{w_i}\right) \cdot a_{2c} - UR_{c_i} \cdot a_{2w}$$
$$- \left(IR_{c_i} - IR_{w_i}\right) \cdot a_{3c} - IR_{c_i} \cdot a_{3w} - \left(LW_{c_i} - LW_{w_i}\right) \cdot a_{4c} - LW_{c_i} \cdot a_{4w}$$
$$\leq -PR_{c_i} - PR_{w_i}, \qquad (i = \overline{1,7})$$
$$a_{0w}, a_{1w}, a_{2w}, a_{3w}, a_{4w} \geq 0$$

Having solved this problem, we obtain , A_0, A_1 A_2 A_3 A_4 coefficients analyzed by each α level, which are shown in Table 1.5. The coefficients obtained at α levels as a result of fuzzy linear regression equation calculations are given in Table 1.5. With this purpose, the PR (poverty rate) forecast for 2007-2009 in average, best, and worst variants were applied. The average case forecast method is one of the most commonly used among all forecasting methods and allows us to obtain reliable results on sustainable development. The best-case forecast method provides accurate results in terms of such development when growth rates are rapidly changing; the method of the worst forecast in terms of development is efficient when the decreasing rate rapidly changes.

- **Average** – calculating the square roots of the sum of squares of growth rates, we add them to the 2006-year results and obtain the forecasted indices for the following years.
- **Best** – having calculated the maximum difference between growth rate indices in Table 1.4, we add it to the 2006-year results and obtain the forecasted indices for the following years.
- **Worst** – having determined the minimum difference between growth rates in Table 1.4, we add it to the 2006-year results and obtain the forecasted indices for the following years.

Table 1.5. Regression coefficients at α-levels

Coefficients		α-levels					
		0.0	0.2	0.4	0.6	0.8	1.0
A_0	a_{0c}	59.9747	59.3790	58.7834	58.1417	56.9517	5.7616
	a_{0w}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
A_1	a_{1c}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	a_{1w}	0.0040	0.0040	0.0039	0.0039	0.0037	0.0035

Cont…

Coefficients		α-levels					
		0.0	0.2	0.4	0.6	0.8	1.0
A_2	a_{2c}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	a_{2w}	0.0000	0.0000	0.1000	0.0000	0.0000	0.0000
A_3	a_{3c}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	a_{3w}	0.0370	0.0243	0.0117	0.0000	0.0000	0.0000
A_4	a_{4c}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	a_{4w}	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Table 1.6. Root-mean-square values, evaluated by indicators

Var.	Years	PR_C	PR_W	PI_C	PI_W	UR_C	UR_W	IR_C	IR_W	LW_C	LW_W
Average	2007	17,07	3,71	11836	1507	1,38	0,042	109,4	0,83	67,6	12,6
	2008	14,01	3,24	14080	2104	1,41	0,041	110,6	1,06	78,7	20,6
	2009	11,50	2,83	16749	2939	1,45	0,039	111,7	1,35	91,7	33,8
Best	2007	14,77	0,51	10773	1079	1,26	0,015	107,0	0,29	59,3	7,7
	2008	10,48	0,06	11665	1079	1,18	0,005	105,7	0,13	60,7	7,7
	2009	7,44	0,01	12630	1079	1,11	0,017	104,5	0,06	62,1	7,7
Worst	2007	19,91	6,56	12705	1793	1,48	0,405	113,1	3,14	84,6	31,2
	2008	19,06	2,52	16222	2980	1,64	0,364	118,0	5,2	123,4	12,6
	2009	18,24	4,41	20713	4952	1,81	0,328	123,2	7,34	179,9	51,3

Then we determine forecast function values using the obtained input values for 2007-2009 (Table 1.6). To implement this, we plug the input values into formulas 1.8 and 1.9 for each α level and carry out the calculations. Calculations are implemented separately for each version: average, best, and worst.

In accordance with the triangle rule, let us call the center and extensions obtained by α levels the base center, left, and right sides of the isosceles triangle. As a result, we obtain central, left, and right values of poverty rate, population income, unemployment rate, inflation rate, and living wage for 2007-2009, which are indicated in Table 1.7.

Table 1.7. Forecast results of the indicators

Var.	Years	PR	PR_L	PR_R	PI	PI_L	PI_R	UR	UR_L	UR_R	IR	IR_L	IR_R	LW	LW_L	LW_R
Average	2007	17,07	13,36	20,78	11836	10329	13343	1,38	1,338	1,422	109,4	108,57	110,23	67,6	55,0	80,2
	2008	14,01	10,77	17,25	14080	11976	16184	1,41	1,369	1,451	110,6	109,54	111,66	78,7	58,1	99,3
	2009	11,50	8,67	14,33	16749	13810	19688	1,45	1,411	1,489	111,7	110,35	113,05	91,7	57,9	125,5
Best	2007	14,77	14,26	15,28	10773	9694	11852	1,26	1,245	1,275	107,0	106,71	107,29	59,3	58,6	67,0
	2008	10,48	10,42	10,54	11665	10586	12744	1,18	1,175	1,185	105,7	105,57	105,83	60,7	53,0	68,4
	2009	7,44	7,43	7,45	12630	11551	13709	1,11	1,093	1,127	104,5	104,44	104,56	62,1	54,4	69,8
Worst	2007	19,91	12,35	27,47	12705	10912	14498	1,48	1,075	1,885	113,1	113,10	116,24	84,6	53,4	115,8
	2008	19,06	16,54	21,58	16222	13242	19202	1,64	1,276	2,004	118,0	112,80	123,20	123,4	110,8	136,0
	2009	18,24	13,83	22,65	20713	15761	25665	1,81	1,482	2,138	123,2	115,86	130,54	179,9	128,6	231,2

Three versions of the forecast values shown in Table 1.7 reflect central, left, and right sides. As required, the obtained fuzzy results can be converted into real numbers, a process known as defuzzification, which can be implemented using various methods. One such method is (5), calculated as the correlation of the sum of products of fuzzy function values evaluated at corresponding α levels with the sum of the same α levels.

$$PR^* = \frac{\sum_{i=1}^{R} PR_i \alpha_i}{\sum_{i=1}^{R} \alpha_i} \tag{1.10}$$

Thus, after carrying out the calculations, we obtain the results shown in Table 1.8.

Table 1.8. Results converted into real numbers with defuzzification

Variants	Indicators	Poverty rate		
	Years	2007	2008	2009
	Average	17,1	14,0	11,5
	Best	14,8	10,5	7,4
	Worst	19,9	19,1	18,2

1.4. Conclusions

The following conclusion remarks can be cited:

- It was proved that the fuzzy inference method is suitable for the evaluation of the sustainable development level.

- Estimations carried out by applying the fuzzy inference method indicated that Azerbaijan's development according to the analyzed criteria is low-sustainable.

- To increase the sustainable development level, the implementation of a complex program for improvement in economic, social, and particularly ecological development blocks is necessary.

- These models could be applied to investigate the problem of sustainability in Spain and other Mediterranean countries.

References

1. World Commission on Environment and Development. (1991). *Report of the World Commission on Environment and Development: Our Common Future - A/42/427 Annex - UN Documents: Gathering a body of global agreements.* http://www.un-documents.net/wced-ocf.htm

2. *Report of the United Nations Conference on Environment and Development, Rio de Janeiro, 3-14 June 1992. Volume 1, Resolutions adopted by the Conference.* (1993). United Nations Digital Library System. https://digitallibrary.un.org/record/160453?ln=es&v=pdf

3. Bourgeois society searching for stability. (1991, p. 3-6).

4. Parsons, T. (1969). The Concept of Society: The Components and Their Interrelations. *Collier-Macmillan Ltd.,* p. 5-33.

5. Raymers, N.F. (1992). Hopes for mankind survival. *Conceptual ecology*, p. 141-145.

6. Kaptyuk, V.A. (2001). *Is elaboration of strategy of Russia sustainable development pos- sible presently? Chemistry in the interests of sustainable development*, 9(1), p. 145-155.

7. Bourguignon, P., & Fields, G.S. (1990). Poverty Measures and Anti-poverty Policy. *Reserches Economiques de Louvain*, 56.

8. Sen, A.K. (1985). Sociological Approach to Measurement of Poverty: A reply to Professor Peter Townsend. *Oxford Economic Papers*, 37.

9. *Fuzzy Sets, Neural Networks, and Soft Computing*: Yager, Ronald R., Zadeh, L. A. (1994). Van Nostrand Reinhold, p. 440.

10. Zadeh, L. (1976). The concept of a linguistic variable and its application to approximate reasoning.

11. Ishibuchi, H. (1992). Fuzzy regression analysis. *Japanese journal of Fuzzy Theory and Systems*, Number 1, p. 137.

12. Gil-Aluja, J. (2003). Introduction to the uncertainty theory in enterprises management. *Ed.Springer.*

13. Swanson, E. (2007). *World development indicators 2007*. World Bank.

14. *The little green data book 2007*. (2007). World Bank.

2. UNCERTAINTY PROBLEMS AND FUZZY MODELING OF THE SOCIOECONOMIC SYSTEM

2.1. Introduction

A socioeconomic system (SES) is considered an aggregate of the economic system and the social environment. While the economic system covers the production, distribution, exchange, and consumption of gross products, the social environment encompasses society, and the material and spiritual conditions of human existence. SES represents a hierarchical information system, and the majority of its parameters have a non-numerical nature. The final product of SES, as an information system, is the integrated population's life quality parameter of the state, formed based on the following five integrated characteristics: population quality, well-being of the population, quality of social security, quality of the ecological niche, and natural-climatic conditions. As it is not difficult to notice, parameters of these characteristics can be qualitative indices formed, for example, by gradational scaling.

The information environment forming the population's life quality parameter is actually the economic system and the social environment of the state, which determines economic behavior in production, distribution, exchange, and consumption. This information environment differs by numerous factors of uncertainty, with the majority of its parameters being qualitative and, as a rule, immeasurable. Therefore, to overcome the complexities related to the recording and processing of immeasurable data, we propose using the mathematical tools of fuzzy set theory in the present work. In particular, for modeling the level problems of SES, we propose representing qualitative indicators by linguistic variables accepting values as fuzzy term-sets [9]. In this case, to define the population's life quality integrated parameter, fully reflecting the level of SES development; it is possible to take advantage of fuzzy logic inference, particularly the fuzzy model based on linguistic rules. To achieve isomorphism of this model, the number of preconditions and consequences of fuzzy linguistic rules are selected based on the requirements of the fuzzy environment, while its parameters, such as membership functions of linguistic variables, should be appropriately optimized.

Models at all levels of the economic system (micro, meso, macro, and meta) and models of economic behavior corresponding to its social environment are used as a source of information for such modeling. To study the social environment and the consequences of its influence on global parameters of SES, we propose applying fuzzy models for economic behavior in the production, distribution, and consumption of the gross product. Here, fuzzy curves of consumer indifference and fuzzy utility functions from consumption sets are used as tools for modeling.

Below, the existing factors of uncertainty in SES are investigated, and proceeding from this, alternative fuzzy models for solving the economic system level problems are presented.

2.2. The factors of uncertainty in SES

The SES is an open, dynamic, and ill-structured system [1] functioning under conditions of complete uncertainty. Additionally, there are no effective methods to overcome this uncertainty. Moreover, these uncertainties have an uncertain or fuzzy nature. Therefore, it is quite justified that further research on SES should focus on studying the nature of this present uncertainty. Uncertainty is a concept reflecting the absence of unambiguity. There are two types of uncertainty: true uncertainty, stipulated by the internal properties of investigated objects, and uncertainty related to the incompleteness of information about these objects. As many studies have shown, both types of uncertainty exist in SES.

The first researcher to study the phenomenon of uncertainty in SES was the American economist F. Knight [2], who noted that to define a reasonable way of behavior; the economic subject should determine causal relations between decisions and their consequences. However, due to the increased uncertainty of the economic environment, they can only resort to defining probabilities of event occurrences. However, the closer we get to the innovative field, the more we face unique events for which the mathematical calculation of probabilities is simply impossible. In this respect, F. Knight proposed naming the first type of uncertainty (when there is some information about processes) as risk, while the second type he defined as *uncertainty* itself. The problem of uncertainty was also investigated broadly by J. Gil Aluja [3, 4] with a focus on its fuzzy nature.

It is known that the basic sources of uncertainty in the economy, as well as in other areas, are the incompleteness or inadequacy of human knowledge about processes occurring in the environment and contingency, which in similar conditions occurs unequally and cannot be foreseen. In this case, the research of uncertainty in all its appearances on the SES scale is being conducted through the application of alternative approaches.

Each SES is a complex, self-organizing object developing under the influence of many changing certain and uncertain factors, both internal and external. Among the factors forming a principle of uncertainty in the SES, it is possible to distinguish *economic, political, socio-psychological, technological*, and *natural* components of uncertainty. Departing from the general structure of level problems in the functioning environment of the SES, it is possible to consider the appropriate factors of uncertainty. Among *political factors* of uncertainty, we distinguish internal and external factors. Internal political factors include: 1) the legislative system of the state; 2) the economic policy of the government; 3) the social policy of the government; 4) the activity of opposition forces; 5) the ethno-political situation. External political factors of uncertainty include a set of conditions incorporated in general diplomatic, military-political, and politico-economic groups.

Social-psychological factors of uncertainty are considered in the aspects of economic and human behavior. The classical types of economic behavior are realized in various phases of the reproduction cycle. In general, economic behavior is not an independent factor in the development of economic life. It depends on a number of deeper factors such as the formation of economic culture and economic thinking, and the features of existing systems of economic and social relations. In the field of human relations, one might distinguish a whole group of uncertainty factors defined by value-normative space, cultural features, and the state of society. These factors reflect human, public, and cultural measurements of economic phenomena and, therefore, are uncertain.

The *technological factors* of uncertainty in SES are caused by the functioning of existing and the appearance of new engineering, as well as the development of new technologies. The general direction of the development of science and technology, especially in the near future, can be predicted with known accuracy. However, complete definition of specific consequences of various scientific findings and technical inventions is almost impossible. Technical progress is not achievable without risk and uncertainty.

Uncertainty in *natural environments* arises from the spontaneity of natural phenomena, particularly those resulting in various natural disasters, which can have a strong negative influence on economic processes and may become a source of unforeseen costs. Furthermore, ecological problems play a special role in the modern world, as they are the consequence of unsystematic human activity, which is destructive to nature.

Thus, we see that under the influence of political, socio-psychological, technological, and natural factors of uncertainty at various levels of SES (micro, meso, macro, and meta), there are different categories of uncertainty.

2.3. Some fuzzy models for SES

At the micro level of SES, the task of positioning the consumer market is considered, where in the specific market segment, the rational choice of a competitive food commodity is carried out using a method of fuzzy logic inference. To realize this task, qualitative criteria for evaluating interchangeable food products are used. Their fuzzification, the subsequent formation of preference relations, and a subset of undominated alternatives are carried out using the mathematical tool of fuzzy set theory. Furthermore, using the example of the Azerbaijan consumer market, a model of consumer behavior is developed based on the application of the fuzzy logic inference mechanism. In this model, fuzzy sets are chosen as curves of indifference, and the utility from each chosen set of goods and services (the value of the utility function) is determined using point estimations of these fuzzy sets. In particular, suppose we deal with a segment of food commodities in the consumer market, where the space of possible sets of goods is a closed, convex, and continuous m-dimensional hyperspace $C = \{X = (x_1, x_2, \dots, x_m)^T \mid x_j, j = \overline{1,m}\}$, in which x_j denotes the quantity of j-th commodity acquired by the consumer. Let's break all consumers in q linguistic categories by levels of interval incomes, $r_k (k = \overline{1,q})$, part of which they are ready or capable to spend for the purchase of food commodities from the given segment. Then, taking into account "degraded" values of the prices p_j of the goods from a set X, the proposed fuzzy model in a general can be expessed as:

$$If\ I = \tilde{r}_k\ and\ P_1 = \tilde{p}_1\ and\ P_2 = \tilde{p}_2\ \ and \dots and\ P_m = \tilde{p}_m, then\ IC = \tilde{l}_i \qquad (2.1)$$

Where, $r_k (k = \overline{1,q})$ is k-th fuzzy level of consumers' incomes; $p_j (j = \overline{1,q})$ is the fuzzy level of price of j-th commodity from a set X. $l_i (i = \overline{1,s})$ i-th fuzzy level of indifference curve IC. Each of submitted in (2.1) levels has a non-numerical nature and can be expressed by terms such as, for example, "low", "average", "high", "lower than average", etc.

The choice of this approach is justified by the following reasons. During the optimization of their choice, each consumer can use a so-called map of indifference curves, each of which in classical interpretation represents a geometric place of points (sets of commodities) in space, whose dimension is defined by the number of consumed goods. It is obvious that due to income limitations, only one of these indifference curves will have a point (set) where the consumer reaches maximum utility from consuming the appropriate set of goods. In a multivariate case, this is a point of tangency of the appropriate indifference curve with a hyperplane of consumer incomes in the space of commodity prices. As it is known, each indifference curve corresponds to a certain utility level, estimated in conventional units (utiles). However, we recognize that the concept of "utility" is rather a qualitative category than a quantitative one. Therefore, as a criterion of utility, we propose using a linguistic variable whose values would be fuzzy term-sets. This, in turn, allows each indifference curve to be considered a fuzzy set. Among components of a basic vector of this set, only one, where the curve of indifference touches the appropriate hyperplane of consumer income, will have a membership function equal to 1. In the proposed fuzzy model of consumption, the linguistic variable "utility" can be regarded as an endogenous value. As exogenous values of the considered model, consumer income and retail prices for goods or services are chosen. These values are never strictly fixed. Each of them varies within the limits of the appropriate interval, and consequently, their average value must be used. Finally, this results in errors that sometimes do not provide the required adequacy of the model to consumer behavior. Therefore, we shall also interpret these values as linguistic variables with "degraded" values from the appropriate intervals. As a result, using the acquired model, it was possible to construct a family of fuzzy indifference curves, whose defuzzified values of levels became conditional alternatives to utiles.

A key parameter describing the meso-economic level of SES is the level of regional development (RD). It is determined through indexes of RD, being, in essence, endogenous values of the meso-economic model. In this case, values such as levels of supply of the regional population with crop areas, production capacities, social objects, workplaces, natural resources, and the level of production volume per capita are exogenous. It is obvious that this is not the full list of values that finally form the level of RD. There are many factors of aesthetic, psychological, and social character, which cannot be measured or balanced and do not have expression in any units. The relative importance of such factors in regional space is determined by instinctive sympathies and antipathies, developed as a result of nurture, education, and the social environment of local population representatives. Therefore, the exact definition of the level of RD generally represents the most complex problem of measurement and comparison of many diverse (incommensurable) variables that form parameters of the meso-economic model. As a result, the estimation data of RD obtained in practice cannot be considered absolute since the desired result cannot be determined without taking into account the above factors, over which it is impossible to perform usual arithmetic operations. Moreover, even the exogenous values of meso models listed above are not absolute; they always change within certain limits. Therefore, to achieve greater adequacy, it is more expedient to estimate parameters and variables of meso models through intervals with their subsequent fuzzification.

For the meso level of SES, the fuzzy productive model for defining the level of regional development RD can look as follows:

$$If\ P_1 = \tilde{p}_1^{k_1}\ and\ P_2 = \tilde{p}_2^{k_2}\ and \dots and\ P_{13} = \tilde{p}_{13}^{k_{13}}, then\ RD = \tilde{l}_i \qquad (2.2)$$

Where, $r_k(k = \overline{1,q})$, are linguistic variables describing the basic social and economic indicators of regions; $\tilde{p}_i^{k_i}$ is the fuzzy term-set corresponding to k_i-th value of linguistic variable. $P_i; \tilde{l}_i(j = 1,2\dots)$ is the fuzzy j-th level of regional development. Number of rules and number of term-sets for each linguistic variable P_i are chosen on the basis of accessible heuristic knowledge. Based on this model and expert socioeconomic information on eleven regions of Azerbaijan, the ranking of the appropriate regional levels of development is carried out.

At the macro level, we propose the fuzzy analogue for the econometric model of defining gross domestic product (GDP), whose level in generalized form depends on investment volume, inflation rate, and the oil price in the world market. In classical interpretation, the parameter of GDP and the designated factors influencing its value are averaged. These values vary within certain limits, which establish corresponding levels for them. Therefore, to increase the degree of adequacy of the model for defining GDP, it is reasonable to use the mathematical tool of fuzzy sets through the fuzzification of elements and parameters of the model. In this case, the fuzzy analogue model of defining GDP can be presented as the following linear relationship:

$$G\tilde{D}P = \tilde{A}_0 + \tilde{A}_1 \cdot I\tilde{N}V + \tilde{A}_2 \cdot I\tilde{N}F + \tilde{A}_3 \cdot \tilde{P}_{oil} \qquad (2.3)$$

Where, is a required fuzzy parameter of $G\tilde{D}P$; $I\tilde{N}V$ is a fuzzy volume of investment contributions; $I\tilde{N}F$ is a fuzzy inflation rate; $\tilde{P}_{0il}$ is a fuzzy price level of one barrel of petroleum in the world market; $\tilde{A}_k$ $(k = \overline{0,3})$ are fuzzy parameters.

For definition of fuzzy level of investment contributions, it is possible to take advantage of a fuzzy recurrent parity:

$$I\tilde{N}V = \tilde{B}_0 + \tilde{B}_1 \cdot \tilde{S}(t-1) + \tilde{B}_2 \cdot \tilde{S}(t-2) + \tilde{B}_3 \cdot \tilde{S}(t-1) \quad (2.4)$$

Where, $\tilde{S}(t-1), \tilde{S}(t-2), \tilde{S}(t-1)$ are fuzzy volumes of savings relative to the t-th year relative to years, (t-1), (t-2) and $(t–3)$; $\tilde{B}_k$ $(k = \overline{0,3})$ are fuzzy parameters.

To determine fuzzy analogue of inflation rate it is possible to apply the following fuzzy linear model:

$$I\tilde{N}F = \tilde{C}_0 + \tilde{C}_1 \cdot \tilde{M} \quad (2.5)$$

Where, $\tilde{M}$ is a fuzzy volume of money available in circulation; $\tilde{C}_0$ and $\tilde{C}_1$ are unknown fuzzy parameters.

Finally, for definition of the current fuzzy price level of one barrel of oil in the world market it is possible to take advantage of a fuzzy recurrent parity:

$$\tilde{P}_{oil}(t) = F\left(P_{oil}(t-1), \tilde{P}_{oil}(t-2), \tilde{P}_{oil}(t-3)\right) \quad (2.6)$$

Where, $P_{oil}(t-1), \tilde{P}_{oil}(t-2), \tilde{P}_{oil}(t-3)$ are the fuzzy price levels of one oil relative to the current t-th year accordingly in years $(t–1)$, $(t–2)$ and $(t–3)$.

The next important problem at the macro level of SES is the development of the balance reflecting inter-branch proportions. The exact formulation of the purpose of this problem of input-output balance (IOB) and criteria for its achievement (criterion function) generally represents the most complex problem of measurement and comparison of many diverse (incommensurable) variables of which parameters of its model develop. By virtue of these circumstances, it is possible to replace the classical model of IOB with a fuzzy analogue, i.e., a system of algebraic equations with fuzzy variables and fuzzy parameters:

$$\tilde{X} = \tilde{A} \cdot \tilde{X} + \tilde{Y} \tag{2.7}$$

Where, $\tilde{Y} = (\tilde{y}_1, \tilde{y}_1, .., \tilde{y}_n)$ is a vector of the final products, expressed as fuzzy levels of volumes; $\tilde{X} = (\tilde{x}_1, \tilde{x}_1, .., \tilde{x}_n)$ is a set of fuzzy levels of volumes of production possible at the present resources; $\tilde{A} = (\tilde{a}_{ij})_{n \times n}$ is a matrix of fuzzy factors of direct expenses, which show fuzzy levels of production volumes of i-th branch necessary for production of one unit of production of j-th branch. The fuzzy problem of IOB (7) can be simulated and solved using a fuzzy neural network [10]. For this purpose, we shall present this system in a well-justified, equivalent aspect:

$$\tilde{B} \cdot \tilde{X}^* = \tilde{Y} \tag{2.7'}$$

Where $\tilde{X} = (\tilde{x}_1, \tilde{x}_1, .., \tilde{x}_n)$ is the required vector with fuzzy components; $\tilde{B} = \left[\tilde{b}_{ik}\right]_{i,k=1}^{n}$ is a fuzzy matrix with fuzzy elements $\tilde{b}_{ik} = \begin{cases} \tilde{a}_{ik}, & i \neq k \\ 1 - \tilde{a}_{ik}, & i = k \end{cases}$ $\tilde{Y}^T = (\tilde{y}_1, \tilde{y}_1, .., \tilde{y}_n)^T$ is a fuzzy vector-column. As a fuzzy neural network we shall choose a two-layer network, whose weights of internal connections will be required fuzzy numbers $\tilde{x}_k = (k = \overline{1,n})$. For their finding, for example, it is possible to choose "error backpropagation" learning algorithm and to realize it under the circuit of the neuro-identifier (Figure 2.1). In its output, the fuzzy neural network induces a signal $\tilde{z}_i = \sum_{k=1}^{n} \tilde{a}_{ik} \tilde{x}_k (i = \overline{1,n})$. Here with, as criterion of its comparison with a desirable target it is possible to use a fuzzy measure of comparison $E(\tilde{z}_i, \tilde{y}_i)$ [10]. Assuming that the optimum fuzzy output of a neural network finally should satisfy the condition, $E(\tilde{z}_i, \tilde{y}_i)$=1 though "error backpropagation" learning algorithm it is possible to adjust fuzzy parameters $\tilde{x}_k = (k = \overline{1,n})$ so that this condition on the certain steps oftraining is accomplished. For realization of the arithmetic operations stipulated by these algorithm it is possible to use, for example [10] in which the techniques of operations on fuzzy sets is considered. The proposed fuzzy model of IOB was confirmed on data of four branches of Azerbaijan economy.

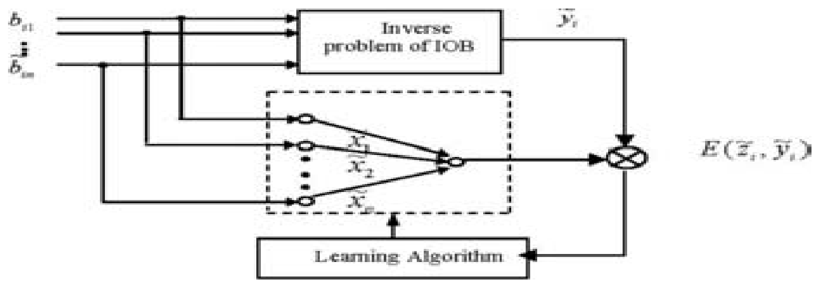


Figure 2.1. Neural identification of fuzzy solutions of IOB problems

Other approach to the decision of the fuzzy problem of IOB is based on finding of an inverse matrix. In this case, decision of the fuzzy problem (2.7) relative of *X* in the matrix form is expressed as:

$$\tilde{X} = (E - \tilde{A})^{-1}\tilde{Y} \qquad (2.8)$$

or in the extended expression as:

$$\tilde{x}_{ik} = \sum_{j=1}^{n} \beta_{ij} y_{jk}; i, k = \overline{1, n} \qquad (2.8')$$

Where, β_{ij} are the fuzzy numbers of the inverse matrix $(E - \tilde{A})^{-1}$. As known, the scheme of construction of the inverse matrix including calculation of the matrix determinant $|\, E - \tilde{A} \,|$ and algebraic adjuncts of the transposed elements , is realized by formula:

$$\beta_{ij} = \frac{\tilde{\beta}_{ji}}{\det{(E - A)}}; i, j = \overline{1, n} \qquad (2.9)$$

To find β_{ij} it is possible to take advantage of the construction of "linearized history" of the fuzzy number and its corresponding algebra.

For the meta level of SES, an alternative approach for estimating the global level of state development based on fuzzy logic inferences is considered. Using the proposed fuzzy model and research conducted within the framework of the United Nations Development Program, the estimation of the global level of development of Azerbaijan is carried out. The endogenous value of the given model is the quality indicator "global level of development" (GD) of SES, and the exogenous values are linguistic variables: "index of human development" (HDI) and "index of technological achievements" (TAI), accepting values in fuzzy term-sets determined by gradational scales. Based on these variables and the chosen dominant judgments, fuzzy linguistic rules for the estimation of GD are formed as follows:

$$\text{If HDI} = \tilde{A}_i \text{ and TAI} = \tilde{B}_i\text{, then GD} = \tilde{C}_i \tag{2.10}$$

Where, $\tilde{A}$ $(i = 1, 2, ...)$ is the fuzzy term-set corresponding to i-th value of linguistic variable HDI; $\tilde{B}_i$ $(j = 1, 2, ...)$ is the fuzzy term-set corresponding to j-th value of linguistic variable TAI; $\tilde{C}_i$ $(k = 1, 2, ...)$ is the fuzzy term-set corresponding to k-th value of linguistic variable GD.

2.4. The population quality of life index

The basis of each society is its socioeconomic system (SES). By the socioeconomic system, we understand a set of economic systems and the social environment. Usually, in the literature, the output of the socioeconomic system is the gross domestic product (GDP) per capita. However, since this parameter is an economic parameter, it does not completely reflect the social condition of the population. In human life, along with the economic level, social, moral, and psychological levels of the person also play an important role. Therefore, GDP cannot completely describe the results of the functioning of the social and economic system.

In other words, in developing a model, it is necessary to take into account the factors influencing the level of development of life quality. In the given part, the model of the quality of life of the population of the state is considered. Using various methods of estimation of an index of life quality [6, 7, 8] and the technology of fuzzy logic inferences, it is necessary to estimate LQI on the basis of a fuzzy model. It is important to note that the parameter LQI, like many economic parameters, has an uncertain character. The mathematical instruments for solving problems of uncertainty in economic processes at the present stage of the development of science is the theory of fuzzy sets.

The target parameter of the model is the integrated parameter of the activity of the social and economic system, an *index of the quality of life of the population* (LQI), and the input parameters are the following linguistic variables:

- Index of quality of the population (PQI)
- Index of well-being of the population (WPI)
- Index of quality of the social sphere (SSI)
- Index of quality of the ecological niche (EQI)
- Index of natural-climatic conditions of the country (NCI)

Each of the above-mentioned parameters is a target parameter of the block expressing quantitative and qualitative indicators:

Block 1. The Quality Index of Population

1.1. Death rate per 1000 persons

1.2. Birth rate per 1000 persons

1.3. Expected life expectancy at birth, years

1.4. Children's death rate per 1000 born alive

1.5. Parent death rate per 100000 live births

1.6. State expenditure on education as a % of GDP

1.7. Gross domestic product per capita on PPP, in US dollars

Block 2. The Well-Being Index (Standard of Living) of the Population

This block accumulates individual properties describing the degree of satisfaction of material and spiritual needs of the population:

2.1. Real incomes and expenditures of the population

2.2. Supply of population with housing and other property

2.3. Supply of population with capacities in public health services, education, culture (including science), rest, and infrastructure (power resources, communication means, including modern information technologies, etc.)

Block 3. Index of Quality of Social Sphere (Social Security)

The basic components of the category "social security" are the following:

3.1. Quality of working conditions and level of social protection (quality of motivation, level of industrial accidents and occupational diseases, characteristics of labor employment, etc.)

3.2. Level of physical and property safety of members of society (the characteristics of crime, organized crime, etc.)

3.3. Quality of sociopolitical health of society

Block 4. Index of Quality of Ecological Niche

4.1. Air pollution (determined by the weight of harmful substances emitted into the atmosphere per square meter of the area, per capita, per million dollars of GDP)

4.2. Water pollution (determined by the volume of polluted waters dumped into surface reservoirs per square meter of the area; by the ratio of the volume of sewage dumped into surface reservoirs to the volume of fresh water taken from water sources)

4.3. Condition of soil

Block 5. Index of Natural-Climatic Conditions

5.1. Volume and structure of natural resources and raw materials

5.2. Climate

5.3. Frequency and specificity of force majeure situations

In the model, all parameters of each block are presented with the help of linguistic variables and using methods of fuzzy logic inferences.

Using the program package MATLAB 7.0/Fuzzy Toolbox/Fuzzy Inference System, the solution of this problem for each block (by passing the above-mentioned stages for each block) for the year 2004 for Azerbaijan produced the following precise values:

1. Quality of the population (PQI) - 0.852
2. Well-being of the population (WPI) - 0.500

3. Quality of the social sphere (SSI) - 0.330

4. Quality of the ecological niche (EQI) - 0.500

5. Natural-climatic conditions (NCI) - 0.330

For the first block, PQI, the estimation for Azerbaijan is 0.852, indicating that the quality of the population in the country is high. This is confirmed by individual criteria comprising this category: a low death rate of 6 (for comparison, the lowest death rate is in Kuwait and the highest is in Malawi at 24); an average birth rate of 15 (for example, in France it is 13, in Russia it is 9); high expected life expectancy at birth of 72 years (the highest value of this criterion is in Japan and Sweden); and low levels of parent and children's death rates. Despite rather low values of state expenditure on education as a percentage of GDP and gross national income per capita on PPP, their densities do not have a significant influence on the parameter "Quality of the Population."

For the second block, WPI for Azerbaijan is 0.5. It indicates that the well-being of the population of the republic is estimated as average. The high growth rate of GDP, average value of the Gini coefficient, and low–average values for the number of telephone lines, mobile phones per 1000 persons, and number of Internet users create this picture.

The third block, SSI, in Azerbaijan is about 0.33. This value is lower than average. Analyzing the parameters making up this category, we see that although the unemployment rate in the country is low, expenditures on the pension system as a percentage of GDP are low, payments for social protection as a percentage of total state expenditure are below average, and expenditures on health as a percentage of all expenditures are average.

The value of the fourth block, EQI, is 0.5, indicating an average level. Composing parameters, such as water pollution with organic substances and CO2 emissions in the atmosphere, are low. However, parameters for the amount of sources of clean water per capita and the general area of reserves are also low, leading to an average quality of the ecological niche.

For the fifth block, NCI, the estimated value is 0.33. This takes into account the stocks of petroleum and gas in Azerbaijan.

Using these results as exogenous variables, the following fuzzy model rules for the integrated parameter of quality of life (LQI) are constructed:

***Rule 1*: If *PQI* ="Low" both *SLI* ="Low" and *SSI* ="Low" and *EQI* ="Low" and *ECI* ="Low", then *LQI* = "Low";**
***Rule 2*: If *PQI* ="Low Average" and *SLI* ="Low Average" and *SSI* ="Low Average" and *EQI* ="Low Average" and *ECI* ="Low Average", then *LQI* ="Low Average";**

***Rule 3*: If *PQI* ="Average" both *SLI* ="Average" and *SSI* ="Average" both *EQI* ="Average" and *ECI* = "Average", then *LQI* ="Average";**

***Rule 4*: If *PQI* ="High" *SLI* both ="High" and *SSI* ="High" both ="High" and *ECI* ="High", then *LQI* ="High";**

***Rule 5*: If *PQI* ="High" both *SLI* ="Average" and *SSI* ="Low Average" both *EQI* ="Average" and *ECI* ="Low Average", then *LQI* ="Average";**

***Rule 6*: If *PQI* ="High" and *SLI* ="Low Average" and *SSI* ="Low Average" and *EQI* ="Low Average" and *ECI* ="Low Average", then *LQI* ="Low Average";**

***Rule 7*: If *PQI* ="Average" both *SLI* ="High" and *SSI* ="Average" both *EQI* ="Average" and *ECI* = "Low Average", then *LQI* ="Average";**

***Rule 8*: If *PQI* ="Low" both *SLI* ="Low" and *SSI* ="Average" and *EQI* ="Low Average" and *ECI* ="Average", then *LQI* ="Low";**

Thus, on the basis of constructed 20 rules and as a result of the performed estimations quality of life of the population of Azerbaijan - LQI=0.5, i.e. is *"Average"*.

2.5. Conclusion

On the basis of the performed research of uncertainty factors influencing the socioeconomic system, we propose fuzzy models for solving various problems of the economic system at micro, meso, macro, and meta levels, as well as for socioeconomic behavior. The method of fuzzy inferences calculates the integrated index of quality of life of the population, which covers not only quantitative but also qualitative parameters not subject to measurement. The research carried out does not claim to be exhaustive. For a comprehensive study, it is necessary to develop an integrated system of models for the economic system and the social environment.

References

1. Simon, H. A. (1973). The structure of ill structured problems. *Artificial Intelligence*, 4(3–4), 181–201.

2. Knight, F. H. (1921). *Risk, uncertainty and profit*.

3. Gil-Aluja, J. (1999). Elements for a theory of decision in uncertainty. *Applied optimization*. https://doi.org/10.1007/978-1-4757-3011-1

4. Gil-Aluja, J. (2003). *Introduction to the uncertainty theory in enterprices management*. Ed. Springer.

5. Sogradov, A. A. (1995). *The theory and methods of study of quality of a life of the population*.

6. Aivazian, S. Ä. (2003). Towards a methodology of measuring of the population, life quality synthesized categories, Economy and mathematical methods.

7. Bourguignon, P., & Fields, G. S. (1990). Poverty Measures and Anti-poverty Policy. *Reserches Economiques de Louvain*, 56.

8. Sen, A. K. (1985). Sociological Approach to Measurement of Poverty: A reply to Professor Peter Townsend. *Oxford Economic Papers*, 37, 1985.

9. Zadeh, L. (1973). The concept of a linguistic variable and its application to approximate reasoning. *American Eksevier Publishing Company*.

10. *Fuzzy Sets, Neural Networks, and Soft Computing*: Yager, Ronald R., Zadeh, L. A. (1994). Van Nostrand Reinhold, p. 440.

11. Aliev, R. A., Fazlollahi, B., & Aliev, R. R. (2004). Soft Computing and its Applications in Business and Economics. In *Studies in fuzziness and soft computing*.

12. Imanov, Q. C. (2004). Soft Computing in Models of Socioeconomic Systems Management. *ICCI*.

3. FUZZY COMPUTATION OF THE ENVIRONMENTAL SUSTAINABILITY INDEX

3.1. Introduction

Ecology is the main subject of concern nowadays. The poisoning of the environment is the fastest-spreading disease of civilization. Overpopulation and pollution have created such problems as massive deforestation, the destruction of animal habitats, the greenhouse effect, and global warming.

During the UNO Millennium Summit held in September 2000 [1], the Millennium Declaration was accepted. It is an intensive action plan that outlines 8 specific goals with precise time limits, 18 objectives, and 48 indicators. The assurance of environmental sustainability is the seventh goal of the Declaration.

Recent research carried out at Yale and Columbia Universities in the USA [2] and by Russian scientists [4] identified environmental sustainability indices for different countries.

3.2. A new structure of environmental sustainability index

The Environmental Sustainability Index (ESI), proposed by researchers at Yale and Columbia Universities, initially utilizes 76 indicators classified into 21 sub-systems. Based on these sub-systems, the following 5 groups are formed:

1. Environmental systems
2. Reducing environmental stresses
3. Reducing human vulnerability
4. Social and institutional capacity
5. Global stewardship

Integrating the calculation results of the 5 groups mentioned above, the Environmental Sustainability Index is estimated.

Researchers from Yale and Columbia Universities also proposed the Environmental Performance Index (EPI) [4]. For the 25 indicators at the first stage, 6 political strategies are defined. These 6 categories are then integrated into 2 objects (ecosystem vitality and environmental health), based on which the Environmental Performance Index is estimated.

Russian researchers have proposed the Ecological Sphere Development Index (ESDI), with sub-indices including:

Ecological System:

1. Atmosphere quality
2. Water quality
3. Amount of available water
4. Biodiversity
5. Land

Reduction of Ecological Stress:

1. Reduction in atmospheric emissions
2. Reduction of ecosystem stress
3. Reduction of stress on the population
4. Reduction of emissions and wastes
5. Reduction of stress on water resources
6. Management of natural resources

Each sub-index consists of certain indicators. In total, for the estimation of the 2 proposed components (sub-indices), 38 parameters are utilized. ESI was calculated for 146 countries, EPI for 149 countries, and ESDI for 94 countries. Indices for some Mediterranean and Caspian countries are demonstrated in Tables 3.1-3.4.

Table 3.1. Environmental Sustainability Index by countries

Rank Nº	Countries	ESI 2005
36	France	55.2
67	Greece	50.1
69	Italy	50.1
76	Spain	48.8
91	Turkey	46.6
96	Algeria	46.0
105	Morocco	44.8
115	Egypt	44.0
117	Syria	43.8

Table 3.2. Environmental Performance Index by countries

Rank Nº	Countries	EPI 2008
10	France	87.8
24	Italy	84.2
30	Spain	83.1
44	Greece	80.2
66	Algeria	77.0
71	Egypt	76.3
72	Turkey	75.9
82	Morocco	72.1
99	Syria	68.2

ESI and EPI for Caspian Countries were as following:

Table 3.3. ESI

Rank Nº	Countries	ESI 2005
33.	Russia	56.1
78.	Kazakhstan	48.6
99.	Azerbaijan	45.4
132.	Iran	39.8
144.	Turkmenistan	33.1

Table 3.4. EPI

Rank Nº	Countries	EPI 2008
28.	Russia	83.9
67.	Iran	76.9
80.	Azerbaijan	72.2
85.	Turkmenistan	71.3
107.	Kazakhstan	65.0

The first ten leader countries by ESI and EPI are follows:

Table 3.5.ESI for ten countries

Rank Nº	Countries	ESI 2005
1.	Finland	75.1
2.	Norway	73.4
3.	Uruguay	71.8
4.	Sweden	71.7
5.	Iceland	70.8
6.	Canada	64.4
7.	Switzerland	63.7
8.	Guyana	62.9
9.	Argentina	62.7
10.	Austria	62.7

Table 3.6. EPI for ten countries

Rank Nº	Countries	EPI 2008
1.	Switzerland	95.5
2.	Sweden	93.1
3.	Norway	93.1
4.	Finland	91.4
5.	Costa-Rica	90.5
6.	Austria	89.4
7.	New Zealand	88.9
8.	Latvia	88.8
9.	Columbia	88.3
10.	France	87.8

Table 3.7. The last ten countries by ESI and EPI are follows

Rank Nº	Countries	ESI 2005	Rank Nº	Countries	EPI 2008
137.	Yemen	37.3	140.	Guinea-Bissau	49.7
138.	Kuwait	36.6	141.	Yemen	49.7
139.	Trinidad & Tobago	36.3	142.	Dem. Rep. Congo	47.3
140.	Sudan	35.9	143.	Chad	45.9
141.	Haiti	34.8	144.	Burkina Faso	44.3
142.	Uzbekistan	34.4	145.	Mali	44.3
143.	Iraq	33.6	146.	Mauritania	44.2
144.	Turkmenistan	33.1	147.	Sierra Leone	40.0
145.	Taiwan	32.7	148.	Angola	39.5
146.	North Korea	29.2	149.	Niger	39.1

For the calculation of the above-mentioned environmental indices, methods of mathematical statistics were applied.

In the present paper, we propose a fuzzy logic method for the estimation of the Ecological Sustainability Index. Therefore, based on 14 parameters, we defined 6 strategic categories.

3.3. Problem Definition

Utilizing fuzzy logical inference techniques, we need to determine the Ecological Sustainability Index (ESI*) based on a fuzzy model set. The output parameter of the model will be ESI*.

Input Parameters:

- Air Quality Index (AQI)
- Water Quality Index (WQI)
- Land Quality Index (LQI)
- Biodiversity Index (BDI)
- Environmental Damage Index (EDI)
- Environmental Protection Investments Index (EPII)

Each strategic category is represented by the following parameters:

Category 1: Air Quality Index: 1.1 Annual average SO_2 concentrations (micrograms per cubic meter)

1.2 Annual average NO_2 concentrations (micrograms per cubic meter)

1.3 Annual average TSP concentrations (micrograms per cubic meter)

Category 2: Water Quality Index: 2.1 Dissolved oxygen concentrations (milligrams of dissolved oxygen per liter of water)

2.2 Freshwater availability (thousands of cubic meters per capita)

2.3 Percentage of national territory where the consumption of fresh water is more than 40% of available water (%)

Category 3: Land Quality Index: 3.1 Percentage of total land area (including inland waters) having very low anthropogenic impact

3.2 Percentage of total land area (including inland waters) having very high anthropogenic impact

3.3 Annual average forest cover change rate (% of total territories covered by forests)

Category 4: Environmental Biodiversity Index: 4.1 Territories under protection (% of total country territory)

4.2 Percentage of country territory in threatened ecoregions (% of total country territory)

4.3 National Biodiversity Index (0-1)

Category 5: Environmental Damage Index: 5.1 CO_2 and suspended particulates pollution (% of GDP)

Category 6: Environmental Protection Investments Index: 6.1 Capital investments for Environmental Protection Programs (% of GDP)
The functional structure of the model is shown in Figure 3.1:

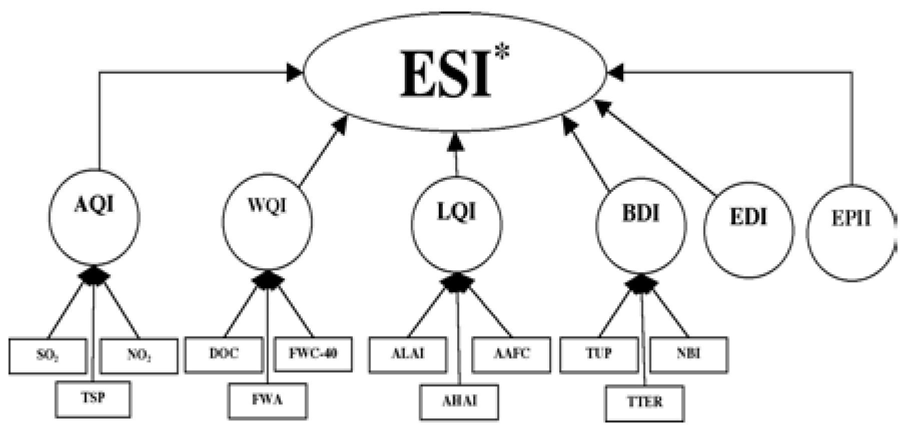


Figure 3.1. Functional structure of the model

3.4. Problem solution

All parameters of each block should be evaluated using linguistic variables, and then, utilizing the fuzzy logic inference method [5], we will estimate the Ecological Sustainability Index (ESI*).

To formalize parameters of the membership function, we utilize a triangular membership function:

$$\mu(x, a, b, c) = \max\left(\min\left(\frac{x-a}{b-a}, \frac{c-x}{c-b}\right), 0\right) \tag{3.1}$$

Where b is center, $[a, c]$ segment is the base of triangle.

Term sets and relevant intervals of input and output parameters are shown in table 3.8.

Table 3.8. Term sets and relevant intervals

Parameter	Definition	Terms And Its Values			
Air Quality Index (AQI)		Unsustainable	Weakly Sustainable	Close to Sustainable	Sustainable
		0 – 25	25 – 50	50 – 75	75 – 100
Annual Average SO2 (SO2)	µgr/m3	Critical	Excessive	Normal	Sustainable
		>40	30-45	15-30	0-20
Annual Average NO2	3	>60	50-60	30-50	20-40
Annual Average TSP (TSP)	µgr/m3	>50	25-50	15-30	10-20
Water Quality Index (WQI)		Unsustainable	Weakly Sustainable	Close to Sustainable	Sustainable
		0 – 25	25 – 50	50 – 75	75 – 100
		Critical	Excessive	Normal	Sustainable
Dissolved oxygen concentrations (milligrams of dissolved oxygen per liter of water) (DOC)	(mg/l)	>14	10-14	7-11	<7
		Critical	Deficient	Sufficient	Sustainable
Fresh water availability (per capita) (FWA)	Thousand m3/ person	<5	4-20	18-200	>200

3.5. Fuzzy logic-based evaluation of the environmental sustainability index

Table 3.9. Term-sets for output parameters

Percentage of national territory where consumption of fresh water is more than 40% of available water (FWC 40%)	%	70-100	30-70	30-20	20-0
Land Quality Index (LQI)		Unsustainable	Weakly Sustainable	Close to Sustainable	Sustainable
		0 – 25	25 – 50	50 – 75	75 – 100
		Critical	Unsustainable	Normal	Sustainable
Percentage of total land area (including inland waters) having very low anthropogenic impact (ALAI)	%	0-20	15-30	30-70	>70
Percentage of total land area (including inland waters) having very high anthropogenic impact (AHAI)	%	>30	15-30	5-15	<5
Annual average forest cover change rate (AAFC)	Rate	<-0.3	-0.3 – 0.2	0.1-2	>2
Environmental Biodiversity Index (EBI)		Unsustainable	Weakly Sustainable	Close to Sustainable	Sustainable
		0 – 25	25 – 50	50 – 75	75 – 100
		Critical	Deficient	Sufficient	Sustainable
Territories under protection (TUP)		<8	8-15	14-30	>30

Cont…

		Critical	Unsustainable	Normal	Sustainable
Percentage of country territory in threatened ecoregions (TTER)	%	>40	20-40	10-20	0-10
National Biodiversity Index (NBI)	0-1	<0.20	0.20-0.50	0.45-0.65	0.6-1
Environmental Damage In- dex (Environmental pollution index) (EDI): CO2 and parti- culate emissions damages	% of GDP	Critical	High	Moderate	Negligible
		>5	5-3.3	3.3-1.65	1.65-0
Environmental Protection Investments Index (EPII): Capital investments for envi- ronmental protection	% of GDP	Low	Deficient	Satisfactory	Sufficient
		0-1.65	1.65-3.3	3.3-5	>5
ESI		Unsustainable	Weakly Sustainable	Close to Sustainable	Sustainable
		0 – 25	25 – 50	50 – 75	75 – 100

As we can see from Table 3.9, term sets of output parameters—water quality index, land quality index, biodiversity index, and ecological sustainability index (output parameter)—are defined in a segment, and the following terms correspond to them: unsustainable, weakly sustainable, close to sustainable, and sustainable.

Intervals of 14 indicators of strategic categories, corresponding to separate terms, are defined based on maximum concentration limit (MCL) standards, maximum permissible emission (MPE), and ecological objectives of the Millennium Declaration.

In Table 3.8, the studied intervals cover all parameters of the current situation in relevant blocks of different countries around the world. Using term sets, fuzzy rules were evaluated. Rules for the ESI are given in Table 3.10:

Table 3.10. Rules for the ESI

Rules	Linguistic Variables	Terms		Linguistic Variables	Terms		Linguistic Variables	Terms		Linguistic Variables	Terms		Linguistic Variables	Terms		Linguistic Variables	Terms		Function	Terms
1IF	AQI	A1	AND	WQI	A1	AND	LQI	a1	AND	EBI	a1	AND	EDI	A4	AND	EPII	a1	THEN	ESI*	e1
2IF	AQI	A2	AND	WQI	A2	AND	LQI	a2	AND	EBI	a2	AND	EDI	A3	AND	EPII	a2	THEN	ESI*	e2
3IF	AQI	A3	AND	WQI	A3	AND	LQI	a3	AND	EBI	a3	AND	EDI	A2	AND	EPII	a3	THEN	ESI*	e3
4IF	AQI	A4	AND	WQI	A4	AND	LQI	a4	AND	EBI	a4	AND	EDI	A1	AND	EPII	a4	THEN	ESI*	e4
5IF	AQI	A1	AND	WQI	A2	AND	LQI	a3	AND	EBI	a4	AND	EDI	A3	AND	EPII	a2	THEN	ESI*	e2
6IF	AQI	A2	AND	WQI	A3	AND	LQI	a3	AND	EBI	a3	AND	EDI	A3	AND	EPII	a1	THEN	ESI*	e2
7IF	AQI	A3	AND	WQI	A4	AND	LQI	a2	AND	EBI	a3	AND	EDI	A3	AND	EPII	a3	THEN	ESI*	e3

Table 3.11. Matrix forms of satisfaction rules

Nº rules	AQI (a)	AQI (c)	AQI (b)	AQI (O)	WQI (a)	WQI (c)	WQI (b)	WQI (O)	LQI (a)	LQI (c)	LQI (b)	LQI (O)	EBI (a)	EBI (c)
6	12.5	37.5	62.5	1	37.5	62.5	87.5	1	37.5	62.5	87.5	0.646	37.5	62.5
16	12.5	37.5	62.5	1	37.5	62.5	87.5	1	12.5	37.5	62.5	0.354	37.5	62.5
17	12.5	37.5	62.5	1	37.5	62.5	87.5	1	37.5	62.5	87.5	0.646	37.5	62.5
18	12.5	37.5	62.5	1	37.5	62.5	87.5	1	12.5	37.5	62.5	0.354	37.5	62.5

Continued table 3.11

Nº rules	EBI (b)	EBI (O)	EDI (a)	EDI (c)	EDI (b)	EDI (O)	EPII (a)	EPII (c)	EPII (b)	EPII (O)	ESI* (a)	ESI* (c)	ESI* (b)	ESI* (O)
6	87.5	1	2.45	4.15	5.85	0.618	0	0.825	2.47	1	37.5	62.5	87.5	0.618
16	87.5	1	2.45	4.15	5.85	0.618	0	0.825	2.47	1	12.5	37.5	62.5	0.354
17	87.5	1	0.83	2.475	4.13	0.381	0	0.825	2.47	1	12.5	37.5	62.5	0.381
18	87.5	1	0.83	2.475	4.13	0.381	0	0.825	2.47	1	12.5	37.5	62.5	0.354

Table 3.12. Trapezes of satisfied rules

Nº rules	ESI*-a(x)	ESI*-a(y)	ESI*-c(x)	ESI*-c(y)	ESI*-d(x)	ESI*-d(y)	ESI*-b(x)	ESI*-b(y)
6	37.5	0	52.950	0.618	72.050	0.618	87.5	0
16	12.5	0	21.350	0.354	53.650	0.354	62.5	0
17	12.5	0	22.025	0.381	52.975	0.381	62.5	0
18	12.5	0	21.350	0.354	53.650	0.354	62.5	0

Using Azerbaijan ecosystem parameters for 2005-2007 (see table 3.13 below) punctual estimations of Ecological Sustainability Index (ESI*) have been carried out.

Table 3.13. Point values of the input parameters of the model

Parameters	SO2	NO2	TSP	DOC	FWA	FWC 40%	ALAI	AHAI	AAFC	TUP	TTER	NBI	EDI	EPII
Values	0.25	19.81	99.3	6.85	3.11	65.4	46.68	3.03	1.30	10.6	100	0.53	3.5	0.05

To estimate the value of the Environmental Sustainability Index (ESI), we calculated the values of the Air Quality Index, Water Quality Index, Land Quality Index, and Biodiversity Index by solving four problems using fuzzy logic inference. Values for the other two indicators—Environmental Damage Index and Environmental Protection Investments Index—were assigned as expert estimations based on statistical data. The evaluated results were applied as input parameters for the estimation of the Environmental Sustainability Index.

Then, according to the stages of fuzzy modeling, the composition of geometrical figures relevant to fuzzy rules was carried out as shown in Figure 3.2.

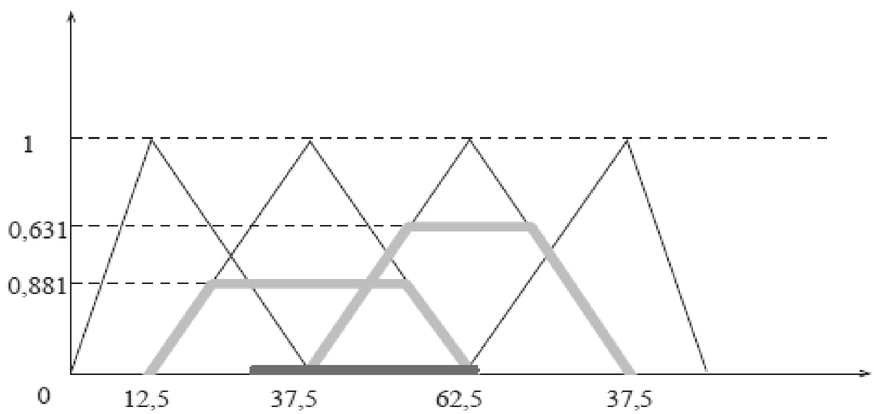


*Figure 3.2. Fuzzy number corresponding to ESI**

After defuzzification using the centroid method, the following values were obtained: Air Quality Index – 37.5 (weakly sustainable), Water Quality Index – 62.5 (close to sustainable), Land Quality Index – 53.65 (close to sustainable), Environmental Biodiversity Index – 62.5 (close to sustainable). The Environmental Damage Index and Investments in the Environmental Protection sector are defined as 3.5 (high) and 0.05 (unsustainable), respectively. The value of the Ecological Sustainability Index is 45.5992, which corresponds to the term "weakly sustainable." The value of the Ecological Sustainability Index obtained, termed "weakly sustainable," corresponds to the 25-50 interval.

Defuzzification of the fuzzy numbers obtained was also carried out using the WABL [6] method, and the results are displayed below:

Table 3.14. Obtained results defuzification by WABL methods

	DEFINITION	LEFT	CENTER	RIGHT
1	Air Quality Index	12.967	37.500	62.033
2	Water Quality Index	44.733	62.500	80.267
3	Land Quality Index	37.938	50.000	62.063
4	Biodiversity Index	42.292	62.500	82.708
5	Ecological Sustainability Index	25.863	43.750	61.638

As we can see from the results obtained, the ESI estimation via the application of the fuzzy logic inference method conforms to the estimations of ESI and EPI carried out at Yale and Columbia Universities (45.4 and 55.7 for Azerbaijan, respectively) and to the results obtained by Russian scientists (social sphere index – 55). These estimations correspond to the "weakly sustainable" term set. The main factor for the low value of the Environmental Sustainability Index estimated is the limited quantity of indicators and strategic categories.

We have chosen one thousand hypothetical point values of six input parameters (AQI, WQI, LQI, BDI, EDI, EPI) in corresponding term sets. By applying the fuzzy logic inference method, one thousand output parameters were calculated to forecast the Environmental Sustainability Index (ESI). The one thousand fuzzified values obtained, covering the segment 37.5 – 61.2, are shown in the picture.

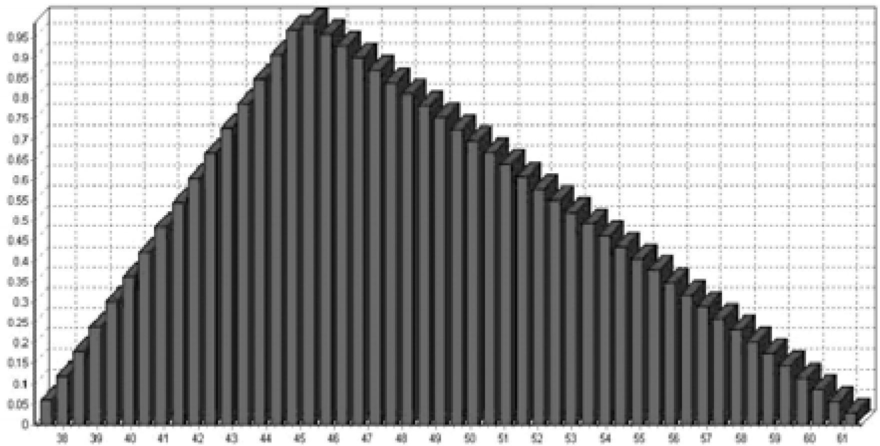


Figure 3.3. Fuzzy sets of obtained results

Applying mechanism of the "possibility theory" probabilities of events corresponding to 50 segments of the basis of fuzzy multitude were calculated. At the same time following conditions were applied:

$Pr(A) \leq Il(A)$ for any $A \subset P(X)$
so that:

$p_1 + p_2 + \dots + p_{50} = 1$
$p_2 + p_3 + \dots + p_{50} \leq \mu_2$
$p_3 + p_4 + \dots + p_{50} \leq \mu_3$
....
$p_{50} \leq \mu_{50}$

Where, $Pr(A)$ – probability of A event, $Il(A)$ – degree of possibility for A, and p_i – probability of the point in X set.

Table 3.15. Calculation results for event probabilities

$0.031 \leq p_1 \leq 1$	$0 \leq p_{26} \leq 0.493$
$0 \leq p_2 \leq 0.969$	$0 \leq p_{27} \leq 0.484$
$0 \leq p_3 \leq 0.957$	$0 \leq p_{28} \leq 0.464$
$0 \leq p_4 \leq 0.928$	$0 \leq p_{29} \leq 0.435$

Cont…

$0 \le p_5 \le 0.909$	$0 \le p_{30} \le 0.423$
$0 \le p_6 \le 0.899$	$0 \le p_{31} \le 0.406$
$0 \le p_7 \le 0.87$	$0 \le p_{32} \le 0.377$
$0 \le p_8 \le 0.848$	$0 \le p_{33} \le 0.363$
$0 \le p_9 \le 0.841$	$0 \le p_{34} \le 0.348$
$0 \le p_{10} \le 0.812$	$0 \le p_{35} \le 0.319$
$0 \le p_{11} \le 0.787$	$0 \le p_{36} \le 0.302$
$0 \le p_{12} \le 0.783$	$0 \le p_{37} \le 0.29$
$0 \le p_{13} \le 0.754$	$0 \le p_{38} \le 0.261$
$0 \le p_{14} \le 0.727$	$0 \le p_{39} \le 0.241$
$0 \le p_{15} \le 0.725$	$0 \le p_{40} \le 0.232$
$0 \le p_{16} \le 0.696$	$0 \le p_{41} \le 0.203$
$0 \le p_{17} \le 0.667$	$0 \le p_{42} \le 0.181$
$0 \le p_{18} \le 0.666$	$0 \le p_{43} \le 0.174$
$0 \le p_{19} \le 0.638$	$0 \le p_{44} \le 0.145$
$0 \le p_{20} \le 0.609$	$0 \le p_{45} \le 0.12$
$0 \le p_{21} \le 0.605$	$0 \le p_{46} \le 0.116$
$0 \le p_{22} \le 0.58$	$0 \le p_{47} \le 0.087$
$0 \le p_{23} \le 0.551$	$0 \le p_{48} \le 0.059$
$0 \le p_{24} \le 0.545$	$0 \le p_{49} \le 0.058$
$0 \le p_{25} \le 0.522$	$0 \le p_{50} \le 0.029$

As it is seen from the table 3.15 maximum probabilities correspond to [44, 49] segment.

3.6. Conclusions

The fuzzy inference method for estimating the Ecological Sustainability Index (ESI) using inputted term sets more adequately describes the formation process of this index. To enhance the accuracy of the results obtained, it is necessary to increase the number of indicators and strategic categories.

Our approach was to determine two aspects of uncertainty by applying fuzzy logic and probability theory methods. Using fuzzy logic, we defined crisp values of the fuzzy values, and then we used these fuzzy values to define probability valuations of the forecasting estimates. By means of clear logic, we have defined exact results based on the fuzzy information. By applying probability theory and possibility theory methods, the probability of selecting the relevant result was defined. As we can see from the results obtained, the ESI estimation via the application of the fuzzy logic inference method conforms to the estimations of ESI and EPI carried out at Yale and Columbia Universities (for Azerbaijan: 45.4 and 55.7, respectively) and to the results obtained by Russian scientists (social sphere index: 55), corresponding to the “weakly sustainable” term set. The main factor for the low value of the estimated environmental sustainability index is the limited quantity of indicators and strategic categories.

References

1. United Nations. (2000). *United Nations Millennium Development goals*.

2. (2005). *Environmental Sustainability Index, Benchmarking National Environmental Stewardship. Yale Center for Environmental Law and Policy Yale University, Center for International Earth Science Information Network Columbia University.* World Economic Forum, Geneva, Switzerland. Joint Research Centre, European Commission, Ispra, Italy.

3. Pilot (2006). *Environmental Performance Index, Benchmarking National Environ- mental Stewardship. Yale Center for Environmental Law and Policy Yale University, Center for International Earth Science Information Network Columbia University*. World Economic Forum, Geneva, Switzerland. Joint Research Centre, European Commission, Ispra, Italy.

4. Sadkov, V.G., & Grekov, I.E. Civilization’s highest values and society’s development estimation for different countries. Intellectual power of humanity and accordance of world development, 1-38. http//www.plproject.ru/planetary03.php.

5. Zadeh, L. (1973). The concept of a linguistic variable and its application to approximate reasoning. *American Elsevier Publishing Company*.

6. Nasibov, E., & Mert, A. (2005). *Determinig the WABL parameters for simulating certain support-based defuzzification methods*. Proceedings of ICSC-CW-2005, Antalya, Turkey, 159-167.

7. Imanov, G.C., Hasanli, Y.H., & Pur Riza, S.M. (2007). *The fuzzy model of ecological-economic development*. Proceedings, ICSCTE-2007, Baku, Azerbaijan, 93-99.

4. FUZZY PROBABILITY MODEL FOR EVALUATING OF FINANCIAL STABILITY INDEX

4.1. Introduction

For the sustainable socioeconomic development of the state, a very important problem for the government is the warning and control of financial crisis risks.

A financial crisis involves the reduction or increment of financial-credit indicators of the economic system from the required threshold, which creates social tension, political risks, and losses in the rate of economic growth.

Today, the problem of financial stability of states is a global issue. Since the 1990s, scientists have constructed several early warning systems, including notable works by G. Kaminsky, C. Reinhart, M. Goldstein, and D. Salvatore. Key publications in this field include "The Twin Crisis: The Causes of Banking and Balance of Payments Problem" [1], "Assessing Financial Vulnerability" [2], and "Forecasting Financial Crisis in Emerging Market Economies" [3].

In the paper [1], the links between banking and currency crises, the macroeconomic background of the crisis, the anatomy of crises, and indicators are analyzed. The book [2] presents a comprehensive battery of empirical tests on the performance of alternative early warning indicators for emerging-market economies, proving useful in constructing a more effective global warning system. The authors draw conclusions about which specific indicators have sent the most reliable early warning signals of currency and banking crises in emerging economies. They also test the out-of-sample performance of the model during the Asian crisis and find that it effectively identifies the most vulnerable economies. Additionally, they show how the early warning system can be used to construct a "composite" crisis indicator to weigh the importance of alternative channels of cross-country "contagion" of crises and generate information on the recovery path from crises. In the paper [3], annual data for six financial indicators were gathered and compared to the critical levels found.

In these works, statistical and probabilistic models were used to evaluate the composite financial stability index. However, as seen from these investigations, all analyzed indicators are fuzzy. In this paper, we attempt to construct a fuzzy model for forecasting the index of financial stability for Azerbaijan. For this solution, we mainly used information from the IMF, World Bank, Journal of Institutional Investor, and the Central Bank of Azerbaijan.

The process of modeling is enclosed in three stages:

- Selection of indicators and information processing
- Assessment of the composite financial stability index
- Forecasting the level of financial stability

4.2. Information processing and evaluation of the composite financial stability index

For fuzzy modeling of the financial crisis, we used indicators and thresholds proposed in [1]. They are given in Table 4.1.

Table 4.1. Indicators of the Early Warning System of the Financial Crisis – 1 Optimal thresholds (percentile)

1. M2 multiplier;	- MMV	89	90
2. Domestic credit / nominal GDP;	- DOC	88	90
3. Real interest rate on deposits;	- RIR	88	80
4. Ratio of lending rate to deposit rate	- LED	88	87
5. Excess real M1 balance	- EMB	89	88
6. M2 (in US dollars) / reserves (in US dollars)	- MRE	90	90
7. Bank deposits	- CBD	15	20
8. Exports (in US dollars)	- EXP	10	10
9. Imports (in US dollars)	- IMP	90	80
10. Credit rating	- CRA	11	11
11. Terms of trade	- TRA	10	19
12. Real exchange rate	- PRE	10	10
13. Reserves	- INR	10	20

Cont…

14. Domestic-foreign interest rate differential on deposits	– IRD	89	81
15. Output	- OUT	10	14
16. Stock prices (in US dollars)	- SMI	15	10
17. Overall budget balance / GDP	- BUD	10	14
18. Current account balance a share of GDP	- CAB	20	14
19. Current account balance a share of investment	- CAI	15	10
20. Short-term capital inflows	- SCI	85	89
21. Foreign direct investment (FDI)	- FDI	16	12
22. General government consumption / GDP	- GGC	90	88
23. Central bank credit to the public sector / GDP	- CBC	90	90
24. Net credit to the public sector / GDP	- NCR	88	80

In Table 4.1, for variables such as international reserves, exports, the terms of trade, deviations of the real exchange rate from the trend, commercial bank deposits, output, the stock market index, and credit rating, a decline in the indicator increases the probability of a crisis. The threshold is set below the mean of the indicators.

The indicators in Table 4.1 allow the construction of terms—stable, threshold, crisis—and intervals of the linguistic variable "financial state" of the country, which are illustrated in Table 4.2. The term values were determined using percentiles of the distribution, which were equal to the arithmetic mean of the values available from the research [1, 2].

Table 4.2. Terms of linguistic variables financial state and its intervals (in percentiles)

No	Indicators	Stable			Threshold			Crisis		
1	INR	100.00	57.50	15.00	20.00	15.00	10.00	15.00	8.00	1.00
2	EXP	100.00	55.00	10.00	12.50	10.00	7.50	10.00	5.50	1.00
3	TRA	100.00	57.25	14.50	19.00	14.50	10.00	14.50	7.75	1.00
4	DRE	100.00	55.00	10.00	12.50	10.00	7.50	10.00	5.50	1.00
5	CBD	100.00	58.75	17.50	20.00	17.50	15.00	17.50	9.25	1.00
6	OUT	100.00	56.00	12.00	14.00	12.00	10.00	12.00	6.50	1.00

Cont…

No	Indicators	Stable			Threshold			Crisis		
7	SMI	100.00	56.25	12.50	15.00	12.50	10.00	12.50	6.75	1.00
8	CBC	1.00	45.50	90.00	87.50	90.00	92.50	90.00	95.00	100.00
9	CRA	100.00	55.50	11.00	8.50	11.00	13.50	11.00	6.00	1.00
10	CAB	1.00	9.00	17.00	14.00	17.00	20.00	17.00	58.50	100.00
11	CAI	1.00	6.75	12.50	10.00	12.50	15.00	12.50	56.25	100.00
12	DOC	1.00	45.00	89.00	88.00	89.00	90.00	89.00	94.50	100.00
13	IRD	1.00	43.00	85.00	81.00	85.00	89.00	85.00	92.50	100.00
14	EMB	1.00	44.75	88.50	88.00	88.50	89.00	88.50	94.25	100.00
15	FDI	1.00	7.50	14.00	12.00	14.00	16.00	14.00	57.00	100.00
16	GGC	1.00	45.00	89.00	88.00	89.00	90.00	89.00	94.50	100.00
17	IMP	1.00	43.00	85.00	80.00	85.00	90.00	85.00	92.50	100.00
18	LED	1.00	44.25	87.50	87.00	87.50	88.00	87.50	93.75	100.00
19	MMV	1.00	45.25	89.50	89.00	89.50	90.00	89.50	94.75	100.00
20	MRE	1.00	45.50	90.00	87.50	90.00	92.50	90.00	95.00	100.00
21	NCR	1.00	42.50	84.00	80.00	84.00	88.00	84.00	92.00	100.00
22	BUD	1.00	6.50	12.00	10.00	12.00	14.00	12.00	56.00	100.00
23	RIR	1.00	42.50	84.00	80.00	84.00	88.00	84.00	92.00	100.00
24	SCI	1.00	44.00	87.00	85.00	87.00	89.00	87.00	93.50	100.00

Table 4.3. Azerbaijan financial and macroeconomical indicators for 2007.09 - 2008.08.

	1	2	3	4	5	6	7	8	9	10	11	12
INR	3135.7	3237.4	3370.4	4015.2	3929.8	4015.5	4256.9	4315.5	4323.4	5225.7	5223.7	5338.2
EXP	324	503.9	641.8	596.7	626.2	571.6	346.2	2313.4	11011.9	2619.7	17189.3	3025.2
TRA	-168.7	-9.9	63.3	-112.2	132.6	130.9	-71.7	1741.2	10473.9	1998.9	16372.3	2419.7
DRE	93.4	92.4	92.7	95.1	96.5	98	97.2	100.3	102.6	103	102.5	105
CBD	3403.8	3539.17	3612.43	3762.44	3697.74	4293.81	4293.88	4432.43	4667.35	5067.03	5010.77	5023.24
OUT	1211.16	2748.88	2126.87	3340.74	2392.76	2414.15	3559.3	3101.66	3946.76	3043.55	3979.33	2321.98
SMI	79.93	85.93	93.93	92.11	93.66	96.81	105.1	109.95	123.24	134.05	133.9	115.08

Cont...

	1	2	3	4	5	6	7	8	9	10	11	12
CBC	0	0	0	0	0	0	0	0	0	0	0	0
CRA	40	40	40	40	40	40	40	40	40	40	40	40
CAB	0.41	0.57	0.59	0.28	0.64	0.59	0.42	0.82	0.78	0.49	0.46	0.72
CAI	1.08	1.98	2.02	1.2	3.96	2.95	2.66	3.89	3.66	2.6	2.36	2.35
DOC	0.11	0.13	0.14	0.05	0.03	0.02	0.04	0.09	0.25	0.03	0.05	0.04
IRD	11.91	12.17	12.12	12.12	11.97	12.21	12.39	0	0	0	0	0
EMB	30.7	54.3	100	91.32	82.6	74.79	111.68	114.78	85.48	4.12	-13.03	0
FDI	0.16	0.09	0.09	0.06	0.09	0.08	0.05	0.07	0.06	0.04	0.05	0.09
GGC	10	10	10	10	10	10	10	10	10	10	10	10
IMP	492.7	513.8	578.5	708.9	493.6	440.7	417.9	572.2	538	620.8	817	605.5
LED	1.4	1.4	1.4	1.4	1.4	1.6	1.8	1.7	1.5	1.5	1.5	1.74
MMV	1.88	1.91	1.91	1.72	1.84	1.94	1.83	1.89	1.96	1.85	1.85	1.77
MRE	18.1	16.9	17	17.6	16.5	18.6	16.8	19.2	20.2	19.3	20.7	16
NCR	21	21	21	21	21	21	21	21	21	21	21	21
BUD	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
RIR	10.76	10.2	8.78	9.26	9.26	8.45	7.49	7.32	8.26	10.49	10.79	9.48
SCI	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

For the assessment of the composite financial stability index, we used fuzzy logic inference. We used Azerbaijan's financial and macroeconomic indicators for 2007.09 – 2008.08 (Table 4.3). Note that in Azerbaijan's financial statistics, the CBC indicator is absent. Therefore, we used 23 indicators.

In the next stage, we fuzzified the indicators and constructed membership functions. For this purpose, we defined three terms for linguistic variables (stable, threshold, crisis) and, in the fuzzification process; we used the Gaussian function of normal distribution (Figure 4.1). Then, rules determining the financial state index (FSI) were constructed. Using the method of composition, we received the aggregated fuzzy set, which is the area of values for the fuzzy variable – FSI (Figure 4.2). By the centroid method, we carried out the procedure of defuzzification and found the FSI value to be 25.48, which corresponds to a stable state. From Figure 4.2, we can see that 66.6% of the support of the fuzzy set is in the stable state and 33.4% in the threshold state.

Table 4.4. Azerbaijan financial and macroeconomical indicators for 2007.09 – 2008.08. (in percentiles)

	1	2	3	4	5	6	7	8	9	10	11	12
INR	26.61	28.85	31.78	45.96	44.08	45.97	50.42	50.85	50.91	57.53	57.51	58.35
EXP	40.59	41.15	41.59	41.44	41.54	41.37	40.66	46.85	58.08	47.81	64.56	49.09
TRA	40.7	41.2	41.44	40.88	41.66	41.65	41	46.79	58.22	47.61	64.49	48.95
DRE	31.68	27.89	29.02	38.14	43.45	49.15	46.11	52.63	55.54	56.04	55.41	58.57
CBD	27.68	31.32	33.29	37.32	35.58	50.54	50.54	51.78	53.89	57.47	56.97	57.08
OUT	16.33	47.94	35.15	53.37	40.62	41.06	54.87	51.73	57.53	51.33	57.75	39.16
SMI	26.66	32.18	39.54	37.86	39.29	42.19	49.81	51.42	55.5	58.81	58.76	53
CBC	0	0	0	0	0	0	0	0	0	0	0	0
CRA	40	40	40	40	40	40	40	40	40	40	40	40
CAB	34.04	50.2	50.89	20.58	52.62	50.89	35.07	58.83	57.45	42.32	39.22	55.38
CAI	23.95	39.8	40.51	26.07	58.22	52.29	50.59	57.81	56.46	50.24	46.49	46.32
DOC	52.34	54	54.83	42.14	37.17	34.69	39.65	50.69	63.93	37.17	42.14	39.65
IRD	54.3	54.53	54.49	54.49	54.35	54.57	54.73	31.12	31.12	31.12	31.12	31.12
EMB	38.7	47.39	54.74	53.67	52.6	51.64	56.17	56.55	52.95	28.92	22.61	27.4
FDI	64.48	52.19	52.19	40.79	52.19	50.44	35.52	46.05	40.79	30.26	35.52	52.19
GGC	10	10	10	10	10	10	10	10	10	10	10	10
IMP	39.07	42.19	50.58	57.01	39.21	31.39	28.02	50.27	45.77	52.67	62.33	51.91
LED	35.46	35.46	35.46	35.46	35.46	52.71	60.26	56.48	46.79	46.79	46.79	57.99
MMV	51.42	53.84	53.84	15.47	44.54	56.27	42.11	52.23	57.89	46.96	46.96	27.54
MRE	50.09	37.17	38.26	44.81	32.8	51.91	36.08	54.1	57.74	54.46	59.56	27.34
NCR	21	21	21	21	21	21	21	21	21	21	21	21
BUD	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
RIR	57.18	54.58	44	50.22	50.22	39.4	26.05	23.69	36.76	55.93	57.32	51.24
SCI	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5	1.5

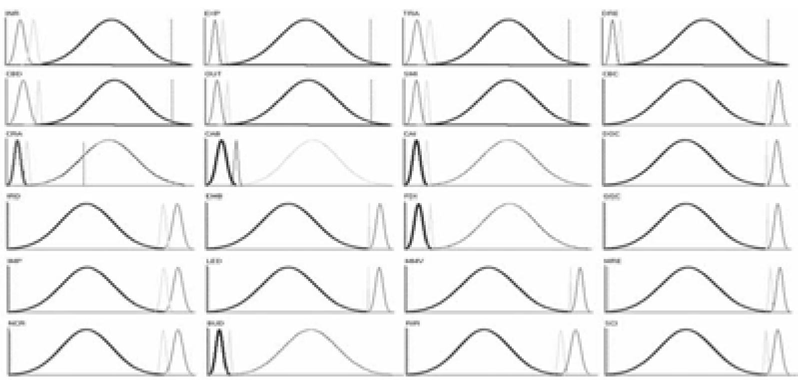


Figure 4.1 Fuzzy sets of the input indicators of the model

Table 4.5. Meaning of input indicators of the model for September 2007 year (in percentiles)

Indicators		Month 1	Term
International reserves	- INR	26.61	E1
Exports	- EXP	40.59	E1
The terms of trade	- TRA	40.7	E1
Real exchange rate	- DRE	31.68	E1
Commercial bank deposits	- CBD	27.68	E1
Output	- OUT	16.33	E1
Stock prices	- SMI	26.66	E1
Central Bank credit to the public sector / GDP	- CBC	0	E1
Credit rating	- CRA	40	E1
Current account balance / GDP	- CAB	34.04	E3
Current account balance / Investment	- CAI	23.95	E3
Domestic credit / GDP	-DOC	52.34	E1
Domestic-foreign interest rate differential on deposits	– IRD	54.3	E1
Excess real M1 balance	- EMB	38.7	E1
Foreign direct investment / GDP	- FDI	64.48	E3
General government consumption / GDP	- GGC	10	E1
Import	- IMP	39.07	E1
=Ratio of lending rate to deposit rate	- LED	35.46	E1
M2 multiplier	- MMV	51.42	E1
M2 / reserves	- MRE	50.09	E1
Net credit to the public sector / GDP	- NCR	21	E1
Overall budget balance / GDP	- BUD	0.02	E1
Real interest rate on deposits	- RIR	57.18	E1
Short-term capital inflows / GDP	- SCI	1.5	E1

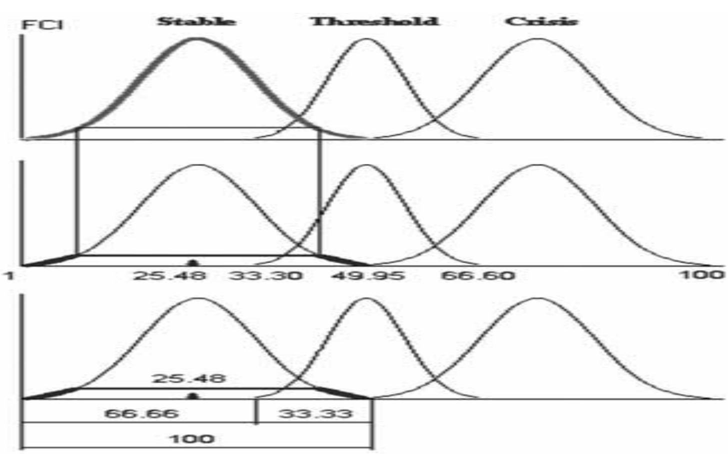


Figure 4.2. Fuzzy sets of the FSI

The problems were solved for 12 months of 2007-2008, and as a result, the indicators CAB, CAI, and FDI were in a crisis state for all periods.

4.3. Fuzzy Markov model-based forecasting of the composite financial stability index

Fuzzy Markov model is expressed by the following equation:

$$U_x^{(n)} = U_x^{(0)} \circ M^n \tag{4.1}$$

Where, $U_x^{(0)}$ - initial state vector describing the probability of the state composite financial stability index;

$U_x^{(n)}$ - probability vector of the state composite financial stability index in the n periods,

M^n- transition matrix, elements which represents grade of membership of the transition going from one state to another.

For solution equation (4.1), we used idea, which described in [4] and [5].

In our case, the initial vector of the probability of the state is evaluated with the composite financial stability index, which we obtained by applying fuzzy logic inference. It is necessary to underline that we assign equal importance to each indicator.

As seen from Table 4.3, out of 23 input indicators, only 3 indicators are allocated in a crisis state. If the probability of each indicator being in a crisis state is equivalent, then the probability of the financial system being in a crisis situation is 0.13 (3/23). Naturally, the probability in the threshold state will be 0.87.

The distribution of the probability comprises 3 events - S1 (stable), S2 (threshold), S3 (crisis), defined by Table 4.6:

Table 4.6.Probability indicators

Number of indicators	Probability of the indicators at the crisis state
1 – 3	0 – 0,13
4 – 6	0,17 – 0,26
7 – 12	0,30 – 0,52
13 – 23	0,57 – 1

This table gives us the possibility to define the distribution of the probability of the following 4 states of the Financial Stability Index:

Table 4.7. Probability of arise

Very high stability	(VH)	1-0.87
High stability	(H)	0.87-0.74
Law stability	(L)	0.74-0.48
Very law stability	(VH)	0.48-0

Conformable membership function for (VH), (H), (L) and (VL) are as follows:

μ_{VH} = 0/0.87+0.154/0.88+0.308/0.89+0.462/0.9+0.615/0.91+0.769/0.92+0.923/0.93+**1/0.935**+0.923/0.94+0.769/0.95+0.615/0.96+0.462/0.97+0.308/0.98+0.154/0.99+0/1

μ_{H} = 0/0.74+0.154/0.75+0.308/0.76+0.462/0.77+0.615/0.78+0.769/0.79+0.923/0.8+**1/0.805**+0.923/0.81+0.769/0.82+0.308/0.85+0.615/0.83+0.462/0.84+0.308/0.85+0.154/0.86+0/0.87

μ_{L} = 0/0.48+0.077/0.49+0.154/0.5+0.231/0.51+0.308/0.52+0.385/0.53+0.462/0.54+0.538/0.55+0.615/0.56+0.692/0.57+0.769/0.58+0.846/0.59+0.923/0.6+**1/0.61**+0.923/0.62+0.846/0.63+0.769/0.64+0.692/0.65+0.615/0.66+0.538/0.67+0.462/0.68+0.385/0.69+0.308/0.7+0.231/0.71+0.154/0.72+0.077/0.73+0/0.74

μ_{VL} = 0/0+0.0417/0.01+0.0833/0.02+0.125/0.03+0.167/0.04+0.208/0.05+0.25/0.06+0.292/0.07+0.333/0.08+0.375/0.09+0.417/0.1+0.458/0.11+0.5/0.12+0.542/0.13+0.583/0.14+0.625/0.15+0.6

67/0.16+0.708/0.17+0.75/0.18+0.792/0.19+0.833/0.2+0.875/0.21+0.917/0.22+0.958/0.23+**1/0.24**+0.958/0.25+0.917/0.26+0.875/0.27+0.833/0.28+0.792/0.29+0.75/0.3+0.708/0.31+0.667/0.32+0.625/0.33+0.583/0.34+0.542/0.35+0.5/0.36+0.458/0.37+0.417/0.38+0.375/0.39+0.333/0.4+0.292/0.41+0.25/0.42+0.208/0.43+0.167/0.44+0.125/0.45+0.0833/0.46+0.0417/0.47+0/0.48

Using above designation of probability were constructed the next transition matrix of probability:

$$M^{(1)} = \begin{pmatrix} VL & VH & VH \\ H & VL & H \\ L & L & VH \end{pmatrix} \tag{4.2}$$

Mainly this matrix constructed by experts, depend from financial situation of the state.

Initial state vector $U_x^{(0)}$ is defined by using financial stability index, which is evaluated by using of the fuzzy logic inference. As since in our case financial stability index include 3 indicators, which are in crisis state, that is the reason of probability remaining at the threshold state, that equal 0,87 and at the threshold and crisis state respectively equal 0,07 and 0,06. To take into account this fuzzy initial state vector $U_x^{(0)} = (VH,VL,VL)=(0.87,0.07,0.06)$.

Using meaning of $U_x^{(0)}$ and M^1 we calculate the meaning of $U_x^{(1)} = U_x^{(0)} \circ M^1$ for the next period:

$$U_x^1 = (VH,VL,VL)^{\circ} \begin{pmatrix} VL & VH & VH \\ H & VL & H \\ L & L & VH \end{pmatrix} \tag{4.3}$$

Respectively to logical multiplication:

$$(VH \wedge VL) \vee (VL \wedge H) \vee (VL \wedge L) = VL \vee VL \vee VL = VL$$

$$(VH \wedge VH) \vee (VL \wedge VL) \vee (VL \wedge L) = VH \vee VL \vee VL = VH$$

$$(VH \wedge VH) \vee (VL \wedge H) \vee (VL \wedge VH) = VH \vee VL \vee VL = VH$$

If the matrix M^1 change in (1.4) by the matrix $\overline{M^1}$, then

$$U_x^1 = (VH, VL, VL)^\circ \begin{pmatrix} VH & VL & VL \\ H & H & L \\ L & L & VH \end{pmatrix} \tag{4.4}$$

Respectively to logical multiplication:

$(VH \wedge VH) \vee (VL \wedge H) \vee (VL \wedge L) = VH \vee VL \vee VL = VH$

$(VH \wedge VL) \vee (VL \wedge H) \vee (VL \wedge L) = VL \vee VL \vee VL = VL$

$(VL \wedge VL) \vee (VL \wedge L) \vee (VL \wedge VH) = VL \vee VL \vee VL = VL$

The crisp values of the logical variables are defined through the calculations given above, by means of the choice of probability, which corresponds to the maximum value of the membership degree:

$U_x^1 = (VH, VL, VL) = (0.93, 0.24, 0.24)$

$U_x^1 = (VH, VL, VL) = (0.24, 0.93, 0.93)$

The Fuzzy-Markov forecasting model is better suited for long-term forecasts than short-term ones [6]. We believe that, in both cases, the transition matrix must be constructed with the participation of highly qualified experts, as the result of the forecasting depends on the transition matrix.

4.4. Inferences

In this paper, we used a fuzzy logic inference system to evaluate the composite financial stability index of the state. A fuzzy Markov model was utilized to predict the possible value of the FSI for the following month. As we underlined, in our case, the importance degree of the indicators was accepted as equivalent. It is very important that in the future we define the importance degree for each indicator.

References

1. Goldstein, M., Kaminsky, G. L., & Reinhart, C. M. (2000). *Assessing Financial Vulnerability: An Early Warning System for Emerging Markets*. http://ci.nii.ac.jp/ncid/BA47870677

2. Reinhart, C., & Kaminsky, G. (2000). The twin crises: Te causes of banking and balance of payments problems. *MPRA Paper*. http://ideas.repec.org/p/pra/mprapa/13842.html

3. Reagle, D., & Salvatore, D. (2000). Forecasting Financial Crises in Emerging Market Economies. *Open Economies Review*, 11(3), 247-259. https://doi.org/10.1023/a:1008374807370

4. Zadeh, L.A. (1975). Linquistic Approach and its Application in Decision Analysis. *Directions in Large-Scale Systems*. Plenum Press, 339-357.

5. Cheong, N. C. W., Way, N. C. C., & Ramachandran, V. (2002). Web server workload forecasting in fuzzy environment - linguistic approach. *IJCIM*. https://doi.org/10.1109/tencon.2000.893690

6. Jiang, X., Xu, Z., Deng, Y., & Liu, X. (2006). *Application of Fuzzy-Markov Method in China Fire Forecasting by 55-year.* Proceeding of the 2006 International Symposium of Safety Science and Technology, Changsha, China, 952-956.

5. FUZZY ESTIMATION OF THE SOCIOECONOMIC SYSTEM'S QUALITY

5.1. Introduction

The economic, social, and political events occurring in the world require a revision of the evolution model of the problems within the socioeconomic system. The functioning of every socioeconomic system should reflect concrete social consequences. Existing models of the socioeconomic system are not able to describe these effects.

Recent research on this system, particularly by J. Stiglitz, A. Sen, and J-P. Fitoussi [1], offers methodological approaches to the measurement of economic performance and social progress. I believe the theory of fuzzy sets and fuzzy logic could solve this problem.

In order to estimate the quality of the socioeconomic system, we have studied the following aggregated systems and processes:

- Social system
- Economic system
- Social mobility
- Conditional factors of social quality

To define the quality of social and macroeconomic systems, fuzzy weighted rules algorithms are proposed; the fuzzy time series concept was applied for the analysis and forecasting of social mobility; and a fuzzy approach was used for the calculation of indices of conditional factors of social quality.

5.2. Estimation of the Quality of Social System

There are various approaches to studying the theory of social systems; however, the most comprehensive and accomplished manner is presented in T.

Parson's works [2, 3]. He attempted to create a logic-deductive theoretical model of society, covering human reality in all its integrity and variety. According to him, a social system is understood as an ordered, hierarchical set of individuals, social groups, and a community of organizations united by stable connections and relations, interacting with the environment as a single unit. Each social system should satisfy the material, social, and spiritual needs of its members.

For modeling societal systems, we have studied the economic (EE), social (SE), political (PE), spiritual (SPE), and natural environments (NE) of a person's environment. These environments are interconnected, and the result of their functioning defines the quality of social development in a society (SSQ). The components of the social system are as follows:

1. **Economic Environment**: Characterized by the rates of increase of gross national product (ΔGDP), gross national product per capita (GDP/P), rate of inflation (CPI), share of import products in consumption (FIM), share of high-tech production in export (TEX), financial stability (FIS), and business environment index (BEN). The output parameter of this subsystem is the Economic Environment Quality Index (EEQI).

2. **Social Environment**: Includes indicators such as life expectancy of the population (LEP), decile (a parity between the income of 10% of the richest population and the income of 10% of the poorest population) (DEC), rate of unemployment (UNE), the relation of the number of deaths to the number of births (RDB), expenditures on education (EXE), public health services (EXH), culture (EXC), science (EXS), monthly average salary (WAG), and state pension expenses (PEN). The output of this subsystem is the Social Environment Quality Index (SEQI).

3. **Political Environment**: Components include the risk of military conflict (RAC), risk of social explosion (RSE), constitutional mechanisms of delegation of power (CMP), the relation between the state and opposition (GSO), threat of politically motivated violence (TPV), international disputes and tensions (IDT), government policy towards business (GPB), effectiveness of the political system in policy formulation and execution (EPS), quality of the bureaucracy (QUB), transparency and fairness of the legal system (TLS), efficiency of the legal system (ELS), corruption (COR), and impact of crime (CRI). The output of this subsystem is the Political Environment Quality Index (PEQI).

4. **Spiritual Environment**: Includes the level of religiousness of society (LOR), tolerance level (LOT), level of impact of religious institutions on the development of society (LOI), quality of culture of the society (QCS), level of information support (LIS), quality of science (QIS), and quality of healthcare (QHC). The output of this subsystem is the Spiritual Environment Quality Index (SpEQI).

5. **Natural Environment**: Characterized by air quality (AQI), water quality (WQI), land quality (LQI), biodiversity (EBI), environmental protection investments (EPI), and environmental damage (NED). The output of this subsystem is the Natural Environment Quality Index (NEQI).

The system of indicators for various environments is multidimensional, meaning that most indicators have both quantitative and qualitative measurements.

At the initial stage of gathering necessary information on subsystem indicators and societal systems, we considered reports from the United Nations Organization, the World Bank [4], the International Monetary Fund [5], and other international organizations [6], as well as expert opinions from various profiles. Indicators of the political environment are entirely borrowed from [7]. The information collected allowed us to define linguistic variables and their corresponding intervals.

Based on the indices EEQI, SERI, PEQI, SpEQI, and NEQI, we calculated the composite Social System Quality Index (SSQI). The algorithm of fuzzy weighted rules was used to solve this problem. This algorithm is necessary when solving problems with linguistic variables and determining the weights of input and output characteristics. It can significantly reduce the number of admissible rules and improve the accuracy of the results.

During the formation of the algorithm of weighted rules, ideas from the fuzzy inference method and the batch least squares algorithm of groups [8] were used. To demonstrate the steps of the algorithm, we applied the information from the economic environment model (Table 5.1).

In Table 5.1, the indicators GDP/P (GDP per capita in thousand USD), ΔGDP (GDP growth rate in percent), CPI (level of inflation), FIM (portion of imported food in consumption), TEX (portion of advanced technology products in export), FIS (financial stability index), and BEN (business environment score) are inputs, and EEQI (Economic Environment Quality Index) is the output variable. First, fuzzification using Gaussian functions is carried out. Next, based on the quantity of terms, initial fuzzy rules (in our case, terms 5, quantity of initial rules is equal to five) are defined. By using the n-factorial base on inputs and outputs and considering terms, all possible rules are generated in the program.

Table 5.1. Parameters of the economical environment model

Variables			Terms and supports			Azerbaijan
1 GDP/P	Very low 0.320- 17	Low 16.5 – 33	Moderate 32.5 – 50	High 49.5 – 67	Very high 66.5 – 84	Very low 4.0
2 Δ GDP	Very low -∞ - 1	Low 0.8 - 3	Moderate 2.8 – 5	High 4.5 - 8	Very high 7.5 - ∞	Moderate 5
3 CPI	Very low 0.1 – 3	Low 2.5 – 5.0	Moderate 4.5 – 8	High 7.5 - 10	Very high 9 - ∞	Moderate 5.8
4 FIM	Very high 0 – 4	High 6 – 12	Moderate 10 – 20	Low 18 – 30	Very low 25 - 100	Low 30
5 TEX	Very high 10 – 7.5	High 8 – 5.5	Moderate 6 – 3.5	Low 4 – 1.5	Very low 2 – 0	Very low 2
6 FIS	Crises 100 – 79	Nearly crises 80 – 59	Weak stability 60 – 39	Stability 40 – 19	Very stability 20 – 1	Stability 40
7 BEN	Very bad 0 – 2	Bad 1.9 – 4	Moderate 3.9 – 6	Good 5.9 – 8	Very good 7.9 – 10	Moderate 5.3
EEQI	Very bad 0 – 2	Bad 1.5 - 4	Moderate 3.5 - 6	Good 5.5 – 8	Very good 7.5 - 10	Moderate 4.7

Further, the mean point- c_j^i of each basis of unimodal fuzzy number corresponding to i terms of the j linguistic variable of the fuzzy number are defined. On the basis of c_j^i matrix C = (c_j^i) were constructed. Initial rules are expressed on the basis of c_j^i.

In this case, matrix C may be defined as follows:

$$C = \begin{pmatrix} C1 & C2 & C3 & C4 & C5 & C6 & C7 \\ 8.66 & -1.50 & 1.55 & 2.00 & 8.75 & 89.50 & 1.00 \\ 24.75 & 1.90 & 3.75 & 9.00 & 6.75 & 69.50 & 2.75 \\ 41.25 & 3.90 & 6.25 & 15.00 & 4.75 & 49.50 & 4.75 \\ 58.25 & 6.25 & 8.75 & 24.00 & 2.75 & 29.50 & 6.75 \\ 75.25 & 10.25 & 14.50 & 62.50 & 1.00 & 10.50 & 8.75 \end{pmatrix}$$

Further, by means of the below given formula (5.1), degree of membership for every point of support part, fuzzy number corresponding to linguistic variables is defined:

$$\mu_i(x) = \prod_{j=1}^{n} exp\left[-\frac{1}{2}((x_j^i - c_j^i)/\sigma_j^i)^2\right] \tag{5.1}$$

Where n is the number of input variables; x_j^i – value of support points of the fuzzy number of the terms;

i – an index of the term; c_j^i- a mean point of corresponding terms i; σ_j^i- average square deviation of an interval of the corresponding term.
In this case meaning of σ_j^i is calculated as follows:

Table 5.2. Calculation results for σ_j^i

	VERYLOW	LOW	MODERATE	HIGH	VERY HIGH
GDP/P	4.8208	4.8499	5.0517	5.0517	5.0808
ΔGDR	0.3317	0.6364	0.6708	1.0400	0.7517
CPI	0.8367	0.7517	1.0400	0.7517	0.9000
FIM	2.3402	1.7635	2.8870	3.4643	21.6797
TEX	0.7517	0.7517	0.7517	0.7211	0.5788
FIS	6.0918	6.0918	6.0623	6.0623	5.4850
BEN	0.5788	0.6055	0.6364	0.6364	0.6519

Using value of σ_j^i we define value of $\mu_i(x)$ for all terms:

Table 5.3. $\mu_i(x)$ for all terms

	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
GDP/P	0.000000	0.000000	0.000000	0.000000	0.000000
ΔGDP	0.004087	0.000017	0.000010	0.000000	0.000002
CPI	0.000001	0.000002	0.000000	0.000002	0.000000
FIM	0.000000	0.000000	0.000000	0.000000	0.000000
TEX	0.000002	0.000002	0.000002	0.000004	0.000045
FIS	0.000000	0.000000	0.000000	0.000000	0.000000
BEN	0.000045	0.000028	0.000017	0.000017	0.000017

After that weights antecedent to initial rules are defined:

$$w_i^a = \mu_i(x) \Big/ \sum_{i=1}^{R} \mu_i(x)$$
$$\sum_{i=1}^{n} w_i^a = 1 \tag{5.2}$$

Where w_i is- weight antecedent of initiated rules, $\mu_i(x)$ - degree of fuzzy variables entered in the antecedent part of rules.

Substituting value of the formula (5.1) in the formula (5.2), we obtain the following:

$$w_i^a = \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x_j^i - c_j^i)}{\sigma_j^i}\right)\right] \Big/ \sum_{i=1}^{R} \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x_j^i - c_j^i)}{\sigma_j^i}\right)\right] \tag{5.3}$$

w_i^a - weights of terms of the antecedent part look like:

Table 5.4. Weights of terms of the antecedent parts

	VERY LOW	LOW	MODERATE	HIGH	VERY HIGH
GDP/P	0.0000	0.0000	0.0000	0.0000	0.0000
ΔGDP	0.9884	0.3425	0.3480	0.0007	0.0350
CPI	0.0001	0.0464	0.0005	0.0996	0.0029
FIM	0.0000	0.0000	0.0000	0.0000	0.0000
TEX	0.0005	0.0464	0.0777	0.1641	0.7034
FIS	0.0000	0.0000	0.0000	0.0000	0.0000
BEN	0.0110	0.5647	0.5738	0.7356	0.2588
$\sum_{i=1}^{n} w_i^a$	1.00	1.00	1.00	1.00	1.00

On the next stage, by means of the equation below (5.4), w_i^c- defines weighted values for consequence part of rules:

$$w_i^c = \sum_{i=1}^{R} b_i \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x_j^i - c_j^i)}{\sigma_j^i}\right)\right] \Big/ \sum_{i=1}^{R} \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x_j^i - c_j^i)}{\sigma_j^i}\right)\right] \quad (5.4)$$

b_i- mean point of corresponding terms of the consequence part of the rules.

Further, using the maximum values w_i^c, w_i^a we define new system of rules:

R1: If GDP/P=Moderate – 41.3 (w_1^a =0.000) and ΔGDP= Very Low – 0.5 (w_2^a= 0.9884) and CPI=High - 8.8 (w_3^a=0.0996) and FIM=Very Low – 4 (w_4^a=0.000) and TEX=Very High - 1 (w_5^a=0.7034) and FIS=Very High – 10.5 (w_6^a=0.000) and BEN=Moderate 5 (w_7^a=0.5738) then EEQI =Moderate – 4.8

R2: If GDP/P = Very Low -4.0 (w_1^a=0.000) and ΔGDP = Moderate -5 (w_2^a=0.9884) and CPI= Moderate -5.8 (w_3^a=0.0001) and FIM= Low-30 (w_4^a=0.0005) and TEX=Very Low-2.0 (w_5^a=0.7034) and FIS=Stable-40 (w_6^a=0.000) and BEN= Moderate -5.3 (w_7^a=0.0110) then EEQI=?

In the new system R1-is rule, which we find and R2- is rule, which corresponds to the fixed meaning of input variables (last column table 5.1). By using composition operation, corresponding fuzzy number is defined.

At the last stage, using Centroid methods defuzzification of fuzzy numbers is carried out.

As result, we find both crisp and linguistic meaning of EEQI =Moderate-4.763.

Using this algorithm we define – SEQI = (moderate – 0.5); PEQI = (moderate – 2.95); SpEQI = (moderate – 4.75); NEQI = (bad – 2.95).

Based on the defined indices—EEQI, SEQI, PEQI, SpEQI, and NEQI—the Social System Quality Index (SSQI) has been defined and is equal to moderate, at 4.7. The SSQI of Azerbaijan is primarily affected by moderate qualities of the economic, political, social, and spiritual environments, and a low level of the natural environment.

The average inflation rate (5.8%), the high share of imported products (30%) in consumption, and the low share of high-tech products (2%) in export have affected the quality of the economic environment. The quality of the social environment is characterized by a very low monthly average salary (401 USD), low expenses on public health services (3.7%), low pension expenses (3.7%), low education expenses (1.9%), and a very low level of spending on the development of science (0.241%). The quality of the political environment is mainly affected by poor mutual relations between the government and the opposition, a low degree of transparency and fairness in the political system, the efficiency of the legal system, and a high level of corruption. The quality of the spiritual environment is defined by a very low level of influence of religious organizations on improving the standard of living of the population, and a low degree of quality in public health services and education. The quality of the natural environment is negatively impacted by very poor air quality, poor water quality, a low index of natural biodiversity, and a very low level of capital investments in environmental protection.

5.3. Estimation of the Quality of Economic System

The quality of the social system mainly depends on the quality of the functioning of the economic system. For fuzzy modeling, the following indicators of financial and monetary policy have been used:

1. Rate of increase of gross national product - ΔGDP;
2. The rate of refinancing of the Central Bank - RCB;
3. Consumer price index - CPI;
4. External government debts - EGD;
5. Budget deficit - BD;
6. Tax revenue - TR;
7. Parity of purchasing capacity of national currency – PPP;
8. Currency reserves - CR.

Table 5.5. Parameters of the model of macroeconomic system

Terms / Variables	Very low	Low	Moderate	High	Very high	Azerbajjan
1. Δ GDP	Very low <1	Low 0.8 – 3	Moderate 2.8 – 5	High 4.5 - 8	Very high > 7.5	Moderate 5
2. RCB - %	<1	0.75 – 2	1.75 – 3	2.75 - 5	> 4.75	High 5

Cont…

Terms / Variables	Very low	Low	Moderate	High	Very high	Azerbajjan
3. CPI - %	<4.5	5 – 9	8-10	9.5 - 12	> 11.5	Low 5.8
4. EGD - % GDP	0 – 19	18 – 26	25-30	28 – 35	> 34	Very low 6
5. BD - % GDP	0 – 0.6	0.7-1.5	1.4-3	2.8 – 6	> 5.5	Low 0.9
6. TR - % GDP	1 - 10	9 - 20	19 – 30	29 - 40	> 39 - 70	Low 17.8
7. PPP	<2	2.85 - 1.85	2.2 - 1.9	2 - 1	> 0.94	Very low 2
8. CR – in days	<30	29 – 60	59 – 370	360 - 730	> 720	Moderate 219
Economic system quality index – ESQI	Very bad 0 – 0.2	Very bad 0.15 – 0.4	Moderate 0.35 – 0.6	Good 0.55 – 0.8	Very good 0.75 - 1	Moderate 0,5

To solve this problem, the algorithm of weighted rules has been applied again. The Economic System Quality Index equals an average of 0.5. The value of the Economic System Quality Index was mainly affected by the low level of tax revenue. It is necessary to note that in Azerbaijan, in addition to currency reserves, there are also reserves in the oil fund, which could be used as social investments that would undoubtedly improve the quality of the social system.

The constructed approach for defining social and economic systems quality indices allows decision-makers at the macro level to control and regulate development parameters of the socioeconomic systems. At the following stage, the quality of social mobility and conditional factors of social quality were defined.

5.4. Estimation of the Social Mobility

According to the definition proposed by the well-known American sociologist P. Sorokin, social mobility is represented as “any transition of an individual or social object or value, anything that has been created or modified by human activity, from one social position to another” [1]. Vertical and horizontal mobility are the primary types of social mobility. The determinant factors of social mobility in society include the historical type of social stratification, the condition and development index of the economy, the social atmosphere in the country, ideology, traditions, religion, education, family, place of residence, and individual characteristics of a person.

Social mobility is measured by means of two basic indicators:

1. Speed of mobility, i.e., the number of steps that individuals were able to ascend or had to descend

2. Intensity of mobility, i.e., the number of individuals that moved along the social ladder in the vertical direction during a certain time span

Concepts of fuzzy time series and Markov's fuzzy linguistic chain have been applied in the current paper to analyze and forecast social mobility.

To analyze social mobility, we have developed Table 5.6, which shows the distribution of the population across economic strata in 2005-2010, based on information on the value of the poverty line (PL) in Azerbaijan [21] and the grouping scale of the population according to income proposed in [10]. As shown in Table 5.6, the population is divided into 5 economic strata according to the income grouping scale:

Absolutely poor – S_1; Relatively poor – S_2; Low-income – S_3; Moderate incomed – S_4; Better off – S_5.

Table 5.6. Distribution of population across economic strata

Economic strata	2005		2008		2010	
	PL=42,6	Proportion of population	PL=78,6	Proportion of population	PL=98,7	Proportion of population
Absolutely poor – up to 0,5 PL	up to 21,6	0,001	up to 39,3	0	up to 49,35	0
Relatively poor 0,5 – 1 PL	21,6 – 42,6	0,270	39,3 – 78,6	0,15	49,35– 98,7	0,101
Low–income 1,0 – 2,0 PL	42,6 – 85,2	0,696	78,6 – 157,2	0,773	98,7– 197,4	0,789
Moderate incomed 2,0 – 3,0 PL	85,2– 127,8	0,027	157,2– 165,8	0,050	197,4– 296,1	0,089
Better off– more than 3,00 PL	127– greater	0,006	165,8– greater	0,027	296,15– greater	0,021

Analysis of 2005–2010 data on the mobility scale indicates that the portion of the "absolutely poor" population group has decreased to 0, the portion of the "relatively poor" population has decreased by 16.9 points, and the portions of the "low income" and "moderate income" populations have increased by 9.3 and 6.2 points, respectively. At the same time, while the portion of the "better off" population increased by 2.1 points during 2005–2008, it decreased by 0.6 points during 2008–2010.

To analyze the speed of mobility, let us consult the graph provided in Figure 5.1.

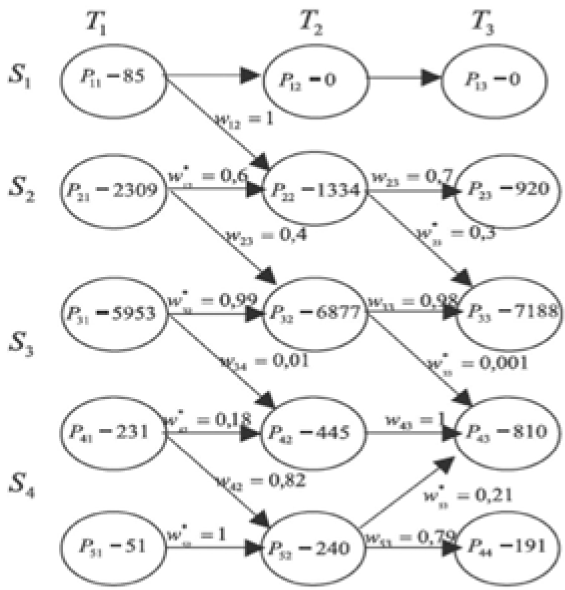


Figure 5.1. Social mobility speed graph

In the graph S_i (i = 1,…, 5) economic strata of population is denoted, T_j (j = 1,…, 3) – years of analysis, P_j (i = 1,…, 5; j = 1,…, 3) – number of population in the economic strata in the corresponding year, W_{ij} and W_{ij}^*– portion of population moving to different strata and staying in the same strata correspondingly.

As it is shown in the graph, number of steps for which it was possible to ascend from S_1 to S_2, from S_2 to S_3, from S_3 to S_4 – is only one; in the meantime there is a case when portion of "better off" population S_5 descended to a lower strata S_4.

To forecast the value of the poverty line, the concept of fuzzy time series, initially proposed by Q. Song and B. S. Chissom [11,12], and further developed by a number of authors, has been applied. However, the greatest contribution to the development of this concept was made by S. M. Chen [13]. To forecast the value of the poverty line (PL) according to Azerbaijan data, we used time series reflecting this indicator for 2001–2010 (Table 5.7):

Table 5.7. Value of poverty line

Years	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
PL in AZN	24	35	35,8	38,8	42,6	58	64	78,6	89,5	98,7

Calculated forecasted value (102.56 AZN) of the poverty line and the grouping scale of population allows us to evaluate parameters of the economic strata for 2011.

Absolutely poor: 51.28; Relatively poor: 51.28÷102.56; Low–income: 102.56÷205.12;

Moderate incomed: 205.12÷307.68; Better off – more than 307.68.

Zadeh's linguistic approach [14] and Markov's linguistic chains [15], [16] were applied in order to forecast social mobility.

For this purpose, first of all, we fuzzificated specific share of population in different economic strata as linguistic variables: low L (0–0.3), average M (0.29–0.66), high (H) 0.65–1.

Vector of the current (2010) condition of economic stratas:, corresponds to the linguistic vector (L, L, H, L, L).

Discrete mobility matrix of conditions of economic strata to according the analysis (Figure 5.1) can be represented as follows:

$$T_{2011} = \begin{array}{c} \\ S_2 \\ S_3 \\ S_4 \\ S_5 \end{array} \begin{array}{c} \begin{array}{ccccc} S_1 & S_2 & S_3 & S_4 & S_5 \end{array} \\ \begin{vmatrix} 0 & 1 & 0 & 0 & 0 \\ 0 & 0.8 & 0.2 & 0 & 0 \\ 0 & 0 & 0.8 & 0.2 & 0 \\ 0 & 0 & 0 & 0.8 & 0.2 \\ 0 & 0 & 0 & 0.2 & 0.8 \end{vmatrix} \end{array}$$

Discrete matrix of mobility can be represented by means of linguistic variables as follows:

$$T_{2011} = \begin{Vmatrix} L & H & L & L & L \\ L & H & L & L & L \\ L & L & H & L & L \\ L & L & L & H & L \\ L & L & L & L & H \end{Vmatrix}$$

For forecasting of conditions of the economic strata in 2011 Markov's fuzzy linguistic chain has been applied: $S_{2011} = S_{2010} \circ T_{2011}$ where element S_i, is calculated via the following equation:

$$S_i = \cup_n (S_i \cap t_j) \tag{5.5}$$

Fuzzy linguistic vector is forecasted by means of equation S_i (5):

$$S_{2011} = (L,L,H,L,L),$$

As it is obvious from the results obtained, vector of conditions of economic strata repeats conditions of year 2010. This is mainly, connected to the fact that the mobility matrix covers situation for 2005–2010.

Let us assume that individuals, who make decisions in the field of social policy, have decided to improve its conditions. In this case, mobility matrix will take following shape:

$$T_{2011}^{opt.} = \begin{Vmatrix} L & H & L & L & L \\ L & M & M & L & L \\ L & L & M & M & L \\ L & L & L & M & H \\ L & L & L & L & H \end{Vmatrix}$$

And the state vector: $S_{2011}^{opt} = (L, L, M, M, M)$

5.5. Analysis of the conditional factors of social quality

The theory of social quality has been offered by U. Beck, V. Maesen, L. Thomese, and A. Walker [17, 18, 19]. Social quality represents the degree of participation of citizens in the social and economic life of a society, enhancing their well-being and individual potential development.

Conditional factors of social quality are defined as "the extent to which people are able to participate in the social and economic life of their communities under conditions which enhance their well-being and individual potential" [18].

As one of the four conditional factors of social quality, socio-economic security refers to the materials and other resources required for "the enhancement of the interactions of individual people as social beings" [20]. Hence, socio-economic security encompasses issues such as risk related to existential security, basic security of daily life, freedom, safety, justice, and life changes dependent on institutions, norms, and regimes. Whether from employment, social security, health care, or other sources, socio-economic security protects people from poverty and other forms of material or immaterial deprivation. Thus, we define its subject matter as the degree to which people have command over material and immaterial resources over time in the context of social relations.

Socio-economic security indicators:

- Number of square meters per household member (NSM)
- Proportion of population living in houses with a lack of basic amenities (PPL)
- Proportion of people covered by compulsory/voluntary health insurance (PHI)
- Number of medical doctors per 10,000 inhabitants (MED)
- Length of notice before termination of labor contract (LNT)
- Proportion of employed workforce with temporary, non-permanent job contracts (PET)
- Proportion of workforce that is illegal (PWI)
- Number of fatal cases (NFC)
- Number of nonfatal cases (NNC)

- Number of hours a full-time employee typically works a week (NHE)
- Proportion of pupils leaving education without finishing compulsory education (PLE)
- Study fees in school as a proportion of the national mean net wage (SFS)
- Study fees in high school as a proportion of the national mean net wage (SFH)
- Proportion of students who, within a year of leaving school, are able to find employment (PSE)
- People affected by criminal offenses per 10,000 inhabitants (CRI)
- Ecocivilization index (ECC)

The index of quality of socio-economic security (SESI) is the output indicator.

Social cohesion is the second factor, referring to the nature of outcomes of processes of integration and disintegration. Cohesion is influenced and changed by processes of social, economic, and cultural differentiation in societies. To measure cohesion, the emphasis should be on the positions, ideas, and feelings of social beings in concrete circumstances. Cohesion is a relational concept that expresses the strength or weakness of social relations at the societal, community, and local levels.

Social cohesion indicators:

- Extent to which most people can be trusted (TRU)
- Trust in authorities (TRA)
- Trust in religion (TRR)
- Number of cases referred to the European Court of Law (ECO)
- Respect for parents (IFA)
- Blood donation (%) (BLO)
- Multiculturalism (tolerance) (TOL)
- Willingness to pay more taxes if it would improve the situation of the poor (WMT)
- Help for elders (VOL)

- Membership (active or inactive) of political, voluntary, charitable organizations, or sports clubs (MVO)
- Frequency of contact with friends and colleagues (CWF)
- Sense of national pride (NAP)

The quality of social cohesion (SCOI) index is the output indicator.

Social inclusion is the third factor of social quality and is the degree to which people are and feel integrated into social relationships, organizations, subsystems, and structures. More specifically, it is the degree to which people have access to a wide range of social relations that constitute everyday life. Social inclusion is concerned with dynamic processes, is comprehensive in terms of the processes and subsystems it refers to, is multi-layered in that it may cover exclusion from personal relationships, neighborhoods, organizations, or supranational blocks, and has both an objective and subjective side.

Social inclusion indicators:

- Proportion having the right to vote in local elections (POV) and proportions exercising it (PPV)
- Proportion with the right to a public pension (PEN)
- Proportion of ethnic minority groups elected or appointed to parliament, boards of private companies, and foundations (ETH)
- Proportion of women elected or appointed to parliament, boards of private companies, and foundations (WPA)
- Long-term unemployment (12+ months) (LTU)
- Proportion of the population with entitlement to and using public primary health care (PPH)
- Proportion of homeless, sleeping rough (HLP)
- Average waiting time for social housing (WAI)
- School participation rates and higher education participation rates (HED)
- Proportion of people in need receiving care services (PPN)
- Density of public transport system and road density (TRD)
- Number of public sports facilities per 10,000 inhabitants (NPS)

- Number of public and private civic and cultural facilities (e.g., cinema, theater, concerts) per 10,000 inhabitants (NPC)
- Duration of contact with relatives (cohabitating and non-cohabitating) (PRC)

The index of quality of social inclusion (SIQI) is the output indicator.

Social empowerment is the fourth factor and is concerned with the means and processes necessary for people to be capable of actively participating in social relations and actively influencing the immediate and more distant social and physical environment. It is a process concerned with the individual or a social group, where the status of being empowered is inherent in the individual rather than being linked to external factors. We cannot directly measure empowerment, but we can analyze it from different perspectives, considering its three dimensions: access, participation, and control.

Social empowerment indicators:

- Extent to which social mobility is knowledge-based (SOM)
- Percentage of the population that is literate and numerate (PLN)
- Availability of free media (FME)
- Percentage of the labor force that is a member of a trade union (TRU)
- Percentage of the labor force covered by a collective agreement (LCA)
- Percentage of the employed labor force receiving work-based training (TRA)
- Index of democracy (DEM)
- Percentage of organizations/institutions with work councils (WCC)
- Percentage of the national and local public budget reserved for voluntary, non-profit citizenship initiatives (CIL)
- Proportion of the national budget allocated to all cultural activities (CUL)
- Percent expenses of national and local budgets devoted to disabled people (DIL)

The quality of social empowerment (SEQI) index is the output indicator.

Indicators of conditional factors of social quality were adopted from [20].

For the calculation of indices of conditional factors of social quality, the following method is proposed:

1. Development of a table describing the parameters of the model based on information from international organizations and experts.

2. Definition of membership degrees of input parameters presented in the form of relevant terms.

3. Determination of the minimum degree of membership to the corresponding term of input parameters, i.e. $\min_j \mu_{ij}$;

4. Determination of the maximum of the minimum values of the degrees of membership to the corresponding term, i.e. $\min_j (\min_j \mu_{ij})$;

The value obtained will reflect the quality of the social factor.

The proposed methodology is tested based on the information on the quality parameters of the model of socio-economic security (Table 5.8). The source materials are from international socio-economic organizations and expert opinions. Using the information on the socio-economic security of Azerbaijan in 2010, given in the last column of Table 5.8, we have estimated the index of socio-economic security by applying the methodology described above.

Table 5.8. Parameters of socio-economic security model

Input variable	Terms and its intervals				Azerbaijan
1.NSM	Low 0 - 15	Moderate 14 - 20	High 18 - 30	Very high 28 - 70	12,6
2.PPL	Very low 0,5 – 0,25	Low 0,24–0,16	Moderate 0,15 – 0,1	High 0,09 - 0	15 %
3. PHI	Very low 0 - 10	Low 9 - 21	Moderate 20 - 60	High 59 - 100	0,2 %
4.MED	Very low 0 - 300	Low 299 - 350	Moderate 300 - 400	High 370 - 600	36,8 %
5.LNT	Very bad 1 - 31	Below normal 30 - 51	Normal 51 - 30	Good 31 - 1	60 days
6. PET	Very high 100 - 50	High 49 - 20	Moderate 19 - 10	Low 9 - 1	68 %

Cont…

Input variable	Terms and its intervals				Azerbaijan
7. PWI	High 0,5 – 0,2	Moderate 0,19–0,14	High 0,13–0,09	Very low 0,18 – 0	0,002 % (10 тыс.)
8. NFC	High 10 – 8	Moderate 7 - 5	Low 4 - 2	Very low 1 - 0	Fat – 0.00128
9. NNC	High 10 – 8	Moderate 7 - 5	Low 4 - 2	Very low 1 - 0	Non Fat – 0.00172
10. NHE	Very high 50 - 44	Normal 43 - 39	Below normal 38 - 36	Very low 35 - 20	42
11. PLE	Very high 50 - 20	High 18 - 9	Moderate 8 - 7	Low 6 - 0	10 %
12. SFS	Very high 6 - 3	High 2,9 - 2	Low 1 – 0,5	Very low 0,4 - 0	2,8
13. SFH	Very high 7 - 3	High 2,9 - 2	Low 1 – 0,5	Very low 0,4 - 0	6
14. PSE	Very bad 0 - 5	Bad 4 - 10	Satis-factory 9 - 20	High 19 - 100	30 %
15. CRI	High 180 – 80	Moderate 79 - 50	Low 49 - 20	Very low 19 - 0	13,5
16. ECC	Low 0 - 0.2	Moderate 0,19 – 0,5	Above moderate 0,49 – 0,7	High 0,7 - 1	Above moderate 0,632
Output - SESI	Low 0 - 0.25	Moderate 0,2 – 0,5	High 0,4 – 0,75	Very high 0,07 - 1	0,12

To estimate the quality of the social factor, the following terms were applied: low (L), medium (M), high (H), and very high (VH), scaled in the interval [0, 1].

In the second stage, we determined the degree of membership of national indicators of socio-economic security to the appropriate term. To determine the degrees of membership, we used triangular membership functions.

In the last stage, the calculated membership degrees of the 16 indicators for the terms are as follows:

Table 5.9. Membership terms

Low (L)	Mean (M)	High (H)	Very high (VH)
$\mu_{HSM} = 0.32$ $\mu_{PHI} = 0.4$ $\mu_{PET} = 0.72$ $\mu_{SFH} = 0.5$	$\mu_{PPL} = 0.25$ $\mu_{MED} = 0.64$ $\mu_{LNT} = 0.18$ $\mu_{NHE} = 0.66$ $\mu_{PLE} = 0.22$ $\mu_{ECC} = 0.65$	0	$\mu_{PWI} = 0.05$ $\mu_{NFC} = 0.003$ $\mu_{NNC} = 0.003$ $\mu_{PSE} = 0.27$ $\mu_{CRI} = 0.58$
min: 0.32	min: 0.18	0	min: 0.003

Among the minimum values, we determined the maximum, which is equal to 0.32. This value corresponds to the term "low." Thus, the quality index of socio-economic security is defined as SESI = low. Likewise, the indices of the quality of social inclusion, social empowerment, and social cohesion are as follows: SIQI = 0.86 (high), SEQI = 1 (high), and SCQI = 1 (moderate), respectively.

5.6. Conclusions

Results of the fuzzy analysis of the socioeconomic system quality show that the following indicators strongly influence the development of this system:

- A1: Level of corruption
- A2: Level of tax revenue
- A3: Level of the natural environment
- A4: Productivity of the economy
- A5: Index of democracy

These indicators have a lowering effect on the following indicators:

- B1: Quality of Education
- B2: Quality of Science
- B3: Quality of Healthcare
- B4: Quality of Housing

- B5: Average Wages
- B6: Level of Poverty
- B7: Level of Unemployment
- B8: Social Mobility
- B9: Level of Employment of the Youth

To estimate the degree of influence of factors Ai on indicators of the social system Bj, we used the method of forgotten effects offered by professors A. Kaufmann and J. Gil Aluja [21]. The idea of this method is as follows. The scale of influence in the range of [0, 1] is defined:

- The matrix of [M] – direct impact of the elements Ai on Bj is defined;
- The matrix [And], describing extent of influence between the elements Ai is defined;
- The matrix [B] describing extent of influence between the elements B_j is defined;
- By max-min composition, $[M^*]=[A] \circ [M] \circ [B]$ is defined;
- At the last stage, composition of three matrixes [M *], results of the forgotten effects is defined by $[O]= [M^*]\ (-)\ [M]$.

We used the following fuzzy linguistic indicators to define the degree of influence:

- Very low - VL (0 – 0.2)
- Low - L (0.18 - 0.4)
- Medium - M (0.38 – 0.6)
- High - H (0.58 – 0.8)
- Very high - VH (0.78 – 1)

To define the [O] matrix of forgotten effects, we used the vertex method to calculate the distance between two triangular fuzzy numbers [22], which consists of the following steps:

$$d(\hat{a},\hat{b}) = \sqrt{\tfrac{1}{3}\left\{(a_1 - b_1)^2 + (a_2 - b_2)^2 + (a_3 - b_3)^2\right\}},$$

where $\widehat{a} = (a_1, a_2, a_3)$ and $\widehat{b} = (b_1, b_2, b_3)$ are two triangular fuzzy numbers.

Elements [A], [M], [B] matrixes, were define by expert opinion and results of some investigation, which are given in tables 5.10-5.14

Table 5.10. Matrix of Effects

B	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
B_1	VH	VH	VH	VH	M	M	H	H	H
B_2	VH	VH	VH	L	M	VL	L	H	H
B_3	H	H	H	VL	M	VL	H	L	VL
B_4	M	M	M	VH	VL	VL	VL	L	VL
B_5	VH	VH	VH	VH	VH	VH	H	VH	H
B_6	VH	VH	VH	VH	VH	VH	VH	VH	VH
B_7	VL	VL	VL	VL	VL	VH	VH	H	VH
B_8	M	M	M	H	M	H	L	VH	M
B_9	L	L	L	VL	L	H	VH	H	VH

Table 5.11. Matrix of Causes

A	A_1	A_2	A_3	A_4	A_5
A_1	VH	VH	VH	VH	M
A_2	L	VH	VH	H	VL
A_3	L	M	VH	H	VL
A_4	L	VH	VH	VH	VL
A_5	M	M	M	M	VH

Table 5.12. Matrix of Direct Incidents

M	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
A_1	VH	VH	VH	VH	H	H	H	VH	H
A_2	VH	VH	VH	H	VH	VH	VH	VH	H
A_3	VL	VL	VL	VL	VL	M	VL	VL	VL
A_4	VH	VH	VH	VH	VH	VH	VH	VH	VH
A_5	M	M	M	M	M	M	M	M	M

Table 5.13. Matrix of Cumulated Effect

M*	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
A_1	VH	VH	VH	VH	VH	VH	VH	VH	VH
A_2	VH	VH	VH	VH	VH	VH	VH	VH	VH
A_3	H	H	H	H	H	H	H	H	H
A_4	VH	VH	VH	VH	VH	VH	VH	VH	VH
A_5	M	M	M	M	M	M	M	M	M

Table 5.14. Matrix of Forgotten Effects

O	B_1	B_2	B_3	B_4	B_5	B_6	B_7	B_8	B_9
A_1	0	0	0	0	0,2	0,2	0,2	0	0.2
A_2	0	0	0	0.2	0	0	0	0	0.2
A_3	0.69	0.69	0.69	0.69	0.69	0.2	0.69	0.69	0.69
A_4	0	0	0	0	0	0	0	0	0
A_5	0	0	0	0	0	0	0	0	0

Tables 5.11 is constructed by composition of matrices A, M, B. Table 5.12 demonstrates forgotten effects between studied indicators.

The proposed paper was not intended to contain full research of this problem. In the future, it is necessary to construct the subsystem of «decision making», which will allow coordination of the results of decisions of other subsystems studied in the paper. Also, it is necessary to apply other methods of fuzzy sets and fuzzy logic to define parameters of the socioeconomic system.

References

1. Stiglitz, J., Sen, A., & Fituossi, J.P. (2009). *Report of the Commission on the Measurement of Economic Performance and Social Progress*, 291.

2. Parsons, T. (1966). *Societies evolutionary and comparative perspectives*. Prentice Hall.

3. Parsons, T. (1971). *System of modern societies*. Prentice Hall.

4. *World Development Report 2010*. (2009). https://doi.org/10.1596/978-0-8213-7987-5

5. Dept, N. I. S. (2008). International Financial Statistics. In *International financial statistics yearbook (International Monetary Fund)*. https://doi.org/10.5089/9781451964097.041

6. Transparency International. (2019). *Transparency International Annual Report 2009 - publications*. Transparency.org, 68. https://www.transparency.org/en/publications/transparency-internationals-annual-report-2009

7. *World investment prospects to 2011*. (2011). Foreign direct investment and the challenge of political risk. Columbia Program on International Investment, 250.

8. Ross, T. J. (2010). *Fuzzy Logic with Engineering Applications*. Wiley, 629.

9. *Social And Cultural Mobility : Pitirim A.sorokin : Free Download, Borrow, and Streaming : Internet Archive*. (2017). Internet Archive. https://archive.org/details/in.ernet.dli.2015.275737

10. Bogomolova, T. (2011) Economic mobility in Russia in the space of poverty-nonpoverty: the trajectory of transitions in the 1990s and 2000s. Social policy: expertise, recommendations, overviews (SPERO) Series 14:41–56.

11. Song, Q., & Chissorn, B.S. (1993). Forecasting enrollments with fuzzy time series – part I. *Fuzzy Sets and Systems* 54, 1–9.

12. Song, Q., & Chissorn, B.S. (1994). Forecasting enrollments with fuzzy time series – part II. *Fuzzy Sets and Systems* 62, 1–8.

13. Chen, S.M. (1996). Forecasting enrollments based on fuzzy time series. *Fuzzy Sets and Systems* 81, 331–339

14. Zadeh, L.A. (1975). Linguistic Approach and its Application in Decision Analysis, *Directions in Large–Scale Systems*. Plenum Press, 339–357.

15. Cheong, N. C. W., Way, N. C. C., & Ramachandran, V. (2002). Web server workload forecasting in fuzzy environment - linguistic approach. *IJCIM*. https://doi.org/10.1109/tencon.2000.893690

16. Jiang, X., Xu, Z., Deng, Y., & Liu, X. (2006). *Application of Fuzzy-Markov Method in China Fire Forecasting by 55-year.* Proceeding of the 2006 International Symposium of Safety Science and Technology, Changsha, China, 952-956.

17. Beck, W., van der Maesen, L., & Walker, A. (1997). Social quality: from issue to concept. *The Social Quality of Europe*. Springer.

18. Beck, W., van der Maesen, L., & Walker, A. (1997). Introduction: who and what is the European Union for?. *The Social Quality of Europe*. Springer.

19. Beck, W., van der Maesen, L., Thomese, F. & Walker, A. (2001). *Social Quality: a Vision for Europe.* Kluwer Law.

20. van der Maesen, L., Walker, A., & Keizer, M. (2005). European Network Indicators of Social Quality - ENIQ - , *Social Quality: the final report*. European Foundation on Social Quality, 105.

21. Kaufmann, A., & Gil-Aluja, J. (1989). *Modelos para la investigacion de effectos olvidados*. Milladoiro.

22. Chen, C.T. (2000). Extension of TOPSIS for Group Decision-making under Fuzzy Environment. *Fuzzy Sets and Systems* 114, 1-9.

23. *Independent Azerbaijan 20 year, State Statistical Committee of the Azerbaijan Republic*. (2011).

6. MEASURING THE DEVELOPMENT OF THE NATIONAL GREEN ECONOMY

6.1. Introduction

In order to achieve this we have primarily applied data available from Azerbaijan and international organizations (UNEP, OECD). In order to solve problem of the National Green Economy Index (NGEI) we have used fuzzy set and fuzzy logic theory.

Green Economy is one of the important criteria for the sustainable development of a country. UNEP defines the green economy as “one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities. It is low carbon, resource efficient and socially inclusive” [1].

The concept of a green economy has to replace the brown economy as world economic development progresses. Decades of creating new wealth through a ‘brown economy’ model based on fossil fuels have not substantially addressed social marginalization, environmental degradation, and resource depletion. In addition, the world is still far from delivering on the Millennium Development Goals by 2015 [1].

To investigate the Green Economy problem, it is necessary to use all conceptions about evolution, revolution, and involution in social systems.

The United Nations Department of Economic and Social Affairs [2], having analyzed over 80 publications on the green economy and green growth concepts, offers economic, social, and ecological indicators to measure the level of green economy development. It is also suggested to use the Global Green Economy Index [2] (GGEI) and the NASDAQ OMX Green Economy Benchmark Index (QGREEN) to estimate the level of the Green Economy. GGEI is estimated using indicators such as **clean energy technology,**

sustainable forms of tourism, and improved domestic environmental quality. QGREEN includes indicators such as **energy efficiency, clean fuels, renewable energy generation, natural resources, water, pollution mitigation, and advanced materials**.

The green economy will emerge in different forms and in different regions, depending on the local economic strengths and weaknesses.

This paper focuses on the National Green Economy Index (NGEI) to define the development level of the green economy in Azerbaijan. To meet this objective, we follow twelve indicators:

- Ecological quality (ECQ)
- Renewable energy (REE)
- Protection of land (PRL)
- Green tourism (TOR)
- Quality of life (QOL)
- Green GDP (EPP)
- Energy intensity (ENI)
- Organic agriculture (ORA)
- Worldwide governance index (WGI)
- International Innovation Index (III)
- Transport greenhouse gas emissions per capita (GHG)

To achieve this, we have primarily applied data available from Azerbaijan and international organizations (UNEP, OECD). To solve the problem of the National Green Economy Index (NGEI), we have used fuzzy set and fuzzy logic theory.

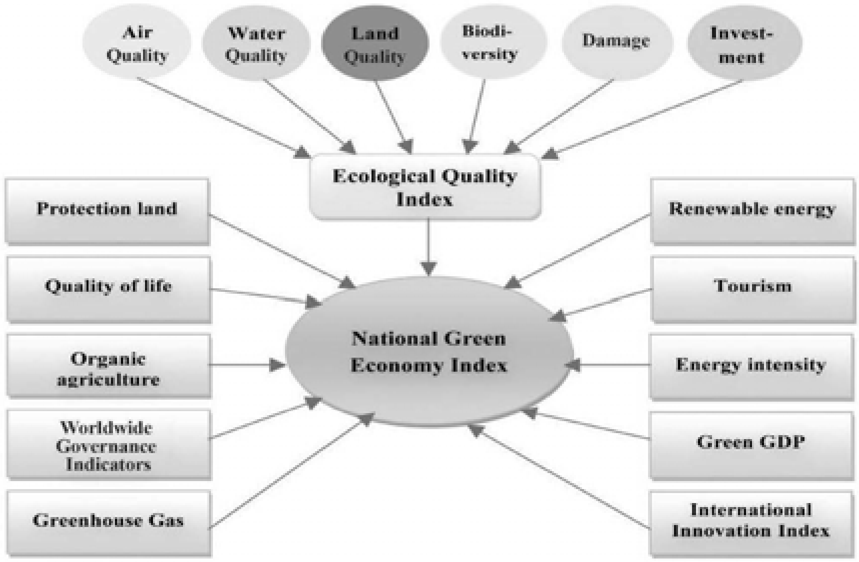


Figure 6.1. Structure of the elements Green Economy Quality

6.2. Indicators of Green Economy

1. **Ecological Quality Index** – This main indicator describes the level of development of the national green economy and is characterized by the quality of air, water, land, biodiversity, environmental protection investments, and environmental damage.

2. **Renewable Energy** – Derived from natural processes that are replenished constantly, it includes energy generated from solar, wind, biomass, geothermal, hydropower, ocean resources, and biofuels and hydrogen derived from renewable resources [3]. The IEA estimates that about 11% of world marketed energy consumption is from renewable energy sources, with a projection of 15% by 2040 [4].

3. **Protected Area** – Defined as “land and/or sea especially dedicated to the protection and maintenance of biological diversity, and of natural and associated cultural resources, and managed through legal or other effective means” [5].

4. **Tourism in Green Economy** – Refers to tourism activities that can be maintained or sustained indefinitely in their social, economic, cultural, and environmental contexts, known as “sustainable tourism.” Sustainable tourism takes full account of current and future economic, social, and environmental impacts, addressing the needs of visitors, the industry, the environment, and host communities. It is not a special form of tourism; rather, all forms of tourism may strive to be more sustainable [6].

5. **Quality of Life Index** – Includes the following subindexes [7]:

- Health
- Education
- Wealth
- Democracy
- Peace
- Environment

6. **Green GDP Index** = (GDP – EPE) / GDP, where GDP is the gross domestic product, and EPE is environmental protection expenditure.

7. **Energy Intensities** – Expressed as total primary energy supply in tons of oil equivalent (TPES) per unit of GDP and per capita. TPES equals production plus imports minus exports minus international bunkers plus or minus stock changes [8]. In our investigation, we use the energy intensity indicator, which expresses the proportion of TPES/GDP.

8. **Organic Agriculture** – Defined as “an ecological production management system that promotes and enhances biodiversity, biological cycles, and soil biological activity. It is based on minimal off-farm inputs and on management practices that restore, maintain, or enhance ecological harmony. The primary goal of organic agriculture is to optimize the health and productivity of interdependent communities of soil life, plants, animals, and people” [9], [10].

9. **World Governance Index (WGI)** – Includes the following aspects [11]:

- Peace and Security
- Rule of Law
- Human Rights and Participation

- Sustainable Development
- Human Development

10. International Innovation Index – Proposed by the Boston Consulting Group, it takes into account two types of innovation output:

- *Tangible Outcomes:* New products, knowledge, formulas, designs, and expertise that are easily quantified and can be legally protected through patents or other intellectual-property vehicles.
- *Intangible Outcomes:* New processes or ways of doing business that lead to a competitive advantage, such as a new company-wide production process that results in higher quality and greater productivity. Intangible outcomes are not easily quantified but can have a major impact on quantifiable results, such as overall business performance. They generally cannot be legally protected [12].

11. Transport Greenhouse Gas Emissions per capita (GHG) – Transport-sector CO2 emissions represent 23% globally and 30% within the OECD of overall CO2 emissions from fossil fuel combustion. The sector accounts for approximately 15% of overall greenhouse gas emissions. Global CO2 emissions from transport have grown by 45% from 1990 to 2007, led by emissions from the road sector in terms of volume, and by shipping and aviation in terms of highest growth rates [13].

6.3. Model for Estimation of the Ecological Quality Index

To construct a fuzzy model for the estimation of the ecological quality index, we used ecological information from international organizations and Azerbaijan.

Table 6.1. Ecological data in linguistic terms

Parameter	Definition	Terms and its values					Azerbaijan
I Air Quality Index (AQI)		Very bad	Bad	Moderate	Good	Very Good	
		0 - 20	19 40	39 - 60	59 – 80	79-100	
1.Annual Average SO2 (SO2)	mgr/m3	Very high > 40	High 30-45	Moderate 20-35	Low 10-25	Very low 0-15	Low 15
2.Annual Average NO2 (NO2)	mgr/m3	Very high > 60	High 50-60	Moderate 40-50	Low 30-45	Very low 20-35	High 50

Cont…

Parameter	**Definition**	**Terms and its values**					**Azerbaijan**
3.Annual Average TSP (TSP)	mgr/m3	Very high > 50	High 35-50	Moderate 30-40	Low 15-30	Very low 10-20	Very high 300
II Water Quality Index (WQI)		Very bad 0-20	Bad 20-40	Moderate 40-60	Good 60-80	Very good 80-100	Bad 21.8
4. Dissolved oxygen concentrations (milliliters of dissolved oxygen per liter of water) (DOC)	(ml/l)	Very bad > 14	Bad 11-14	Moderate 9-12	Good 7-10	Very good < 7	Good 8.27
5. Fresh water resources (FWR)	m3/per capital	Very bad < 3500	Bad 3000-6000	Moderate 5500-9000	Good 8500-12000	Very good 11500-15000	Very bad 948
6. Fresh water withdrawal 40 % of available water (FWW)	% of internal resources	Very low > 79	Low 80-59	Moderate 60-39	High 40-19	Very high 20-0	Very low 150
III Land Quality Index (LQI)		Very bad 0-20	Bad 19.5-40	Moderate 39.5-60	Good 59.5-80	Very good 79.5-100	Moderate 49.5
7. Percentage of agricultural land (AGL)	% of land area	Very low 0-15	Low 14.5-25	Moderate 24.5-50	High 49.5-70	Very high > 69.5	High 58
8. Annual average forest area (AAF)	% of land area	Very bad 0 - 10	Bad 9-20	Moderate 19-30	Good 29-40	Very good 39-50	Bad 11.3
IV Environ-mental Biodi-versity Index (EBI)		Very bad 0 - 20	Bad 19 - 40	Moderate 39 60	Good 59 – 80	Very good 79-100	Bad 29.5
9. Territories under protec-tion (TUP)		Very bad <8	Bad 7-15	Moderate 14-22	Good 21-30	Very good > 29	Bad 10.1
10. Percentage of the country territory in the threatened ecoregions (TTER)	%	Very bad > 40	Bad 0-40	Moderate 20-30	Good 10-20	Very good 0-10	40

Cont…

Parameter	Definition	Terms and its values					Azerbaijan
11. National Biodiversity Index (NBI)	0-1	Very bad < 0.20	Bad 0.19-0.40	Moderate 0.30-0.50	Good 0.45-0.65	Very good 0.6-1	Good 0.534
V 12. CO2 and particulate emissions damage	MT per capita	Very high > 4.5	High 3.5-5	Moderate 2.3-3.6	Low 1.1-2.4	Very low 0-1.2	High 4.4 (2009)
VI 13. Capital investments for environmental protection programs	% of GDP	Very low 0-1.2	Low 1.1-2.3	Moderate 2.2-3.5	High 3.4-5	Very high > 4.9	Very low 0.5 (2009)
QNE		0-20	19-40	39-60	59-80	70-100	

To solve the stated problem, which corresponds to the model, the algorithm of weighted rules [14] has been used. The steps of the algorithm are as follows:

Fuzzification: This is carried out as the first step, using a Gaussian function. *Definition of Initial Fuzzy Rules:* Based on the number of terms, initial fuzzy rules are defined (for example, if the number of terms is 3, the number of initial rules is also three).

Definition of Possible Rules: In the following step, other possible rules are defined by the Cartesian product of terms in the initial rules.

Peak Point Calculation: The peak point of each corresponding interval is defined on the basis of the matrix $C = (c_{ij})$**,** where i is the corrected index and j is the index of terms. Initial rules are expressed based on c_{ij}.

Calculation of Degree of Membership: After that, the product of the degree of membership of linguistic variables that enter into the antecedent of each rule is calculated using the following formula:

$$\mu(x) = \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x^i - c_j^i)}{\sigma_j^i}\right)^2\right] \tag{6.1}$$

Where n - number of input variables; x – terms; i – an index of term; c_j^i - a peak point of corresponding terms i; s_j average quadratic deviation of an interval of a corresponding term.

Exact Values of Target Variable: The exact values of the target variable rules are defined using the formula mentioned below:

$$f\left(x \mid \left[c_j, \sigma_j, b_i\right]\right) = \frac{\sum_{i=1}^{R} b_i \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x^i - c_j^i)}{\sigma_j^i}\right)^2\right]}{\sum_{i=1}^{R} \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x^i - c_j^i)}{\sigma_j^i}\right)^2\right]} \qquad (6.2)$$

$$\theta = [c_i, \sigma_i, b_i]$$

Where, x (x_j^i) vector-line x ($x_1^i, \ldots x_7^i$) of corresponding terms, - the θ is vector, which elements are calculated by using c_i,σ_i, b_i and - exact values of target rules. After that weighted anticident of initial rules are defined:

$$w_i = \frac{\mu_i(x)}{\sum_{i=1}^{n} \mu_i(x)} \qquad (6.3)$$

$$\sum_{i=1}^{n} \mu_i = 1$$

Where, w_i - weighted anticident of initialed rules, μ_i - degree of indistinct variables entered in the anticident a part of rules. Substituting value of the formula (6.1) in the formula (6.3), we will receive:

$$w_i = \frac{\prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x^i - c_j^i)}{\sigma_j^i}\right)^2\right]}{\sum_{i=1}^{R} \prod_{j=1}^{n} exp\left[-\frac{1}{2}\left(\frac{(x^i - c_j^i)}{\sigma_j^i}\right)^2\right]} \qquad (6.4)$$

Then, w_i is calculated to construct a matrix Φ:

$$\Phi = \begin{pmatrix} w^T(x^1) \\ w^T(x^2) \\ w^T(x^3) \\ w^T(x^4) \\ w^T(x^5) \end{pmatrix} \qquad (6.5)$$

At the subsequent stage $\Phi = (\Phi^T \Phi)^{-1} \Phi^T Y$ is calculated, where the Φ^T transposed form Φ, Y - a vector of the target variables expressed in values and, using equality $f\left(x/_{\theta}\right) = \theta^T * w(x)$ weight of rules are defined.

Then, using the fixed values of input variables and weights of rules, a set of the selected rules is defined. Based on these rules, a composition operation is undertaken, allowing the definition of the corresponding fuzzy figure. Finally, defuzzification of fuzzy numbers is carried out using the Centroid method.

6.4. Model for Green Economy

To model the quality of the Green Economy, the following terms are used: Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH), which are scaled in the interval [0, 1]. In the modeling process, we also used the terms Very Bad (VB), Bad (B), Moderate (M), Good (G), and Very Good (VG).

To estimate indices of the level of development of the Green Economy, we proposed a method based on L. Zadeh's composite rules of inference [15], which consists of the following steps:

I. *Development of a Table:* Describing the parameters of the model based on information obtained from international organizations and experts. The first column of the table shows the input parameters of the model, and the following columns show terms and their intervals. The last column specifies the crisp meaning of input parameters for a fixed period.

Table 6.2. Table Model of Green Economy

№	Categories	Source Indicators	Development level					
			World Indicators					
			Very low	Low	Medium	High	Very high	Azerbaijan
1	Ecological quality – ECQ	2010	0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	L 0,25
2	Renewable energy - REE		0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	VL 0.013
3	Protection land - PRL	2012	0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	VL 0,102

Cont...

№	Categories	Source Indicators	Development level					
			World Indicators					
			Very low	Low	Medium	High	Very high	Azerbaijan
4	Green tourism - TOR		0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	VL 0,012
5	Quality of life – QOL	2011	0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	M 0,548
6	Green GDP		0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	VL 0,008
7	Energy intensity- ENI	2010	VB 0,56 – 0,45	B 0,44– 0,33	M 0,32- 0,21	G 0,2 – 0,09	VG 0,08 →0	G 0,1
8	Organic agriculture - ORA		0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	M 0,5
9	Worldwide governance index - WGI	2008	0 - 0,2	0,18 - 0,4	0,38 - 0,6	0,58 - 0,8	0,78 - 1	M 0,578
10	International Innovation Index - III		VB (-2) – (-1,1)	B (-1,2) – (-0,3)	M (-0,4) – 0,5	G 0,4 – 1,3	VG 1,2 - 2	B -0,54
11	Transport greenhouse gas emissions per capital -GHG		20 - 10	9,5 - 3	2,9 - 1	0,9 – 0,5	0,4 - 0	H 0,55

II. *Definition of membership degrees of the crisp meaning of the input parameters to the relevant terms.* For this aim we used Gaussian membership function:

$$\mu_A(x, c_i, \sigma_i) = e^{-(x-c_i)^2/2\sigma_i^2}$$

Where c_i is the center of the ith fuzzy set and σ_i is the width of one of the ith fuzzy sets.

1. Determination of the minimum degree of membership to the corresponding term of input parameters, i.e $\min\limits_j \mu_{ij}$.

2. Determination of the maximum of the minimum values of the degrees of membership to the corresponding term, i.e. $\max_{i} \min_{j} \mu_{ij}$;

The obtained value will reflect the quality of the National Green Economy.

The proposed methodology is tested based on information on quality parameters of the model of the Green Economy (Table 6.2). The source materials are obtained from international organizations and the Azerbaijan Republic [16], [17]. Information on the Green Economy indicators of Azerbaijan is given in the last column of Table 6.2.

In the second stage, we determined the degree of membership of national indicators of the green economy to the appropriate term.

Very Low (VL)	**Low (L)**	**Medium (M)**	**High (H)**	**Very High (VH)**
μ_{REE}= 0.03	μ_{ECQ} = 0.55	μ_{QOL} = 0.29	μ_{ENI} = 0.05	0
μ_{PRL} = 1	μ_{III} = 0.38		μ_{GHG} = 0.08	
μ_{TOR} = 0.03		μ_{ORA} = 0.96		
μ_{EEP}= 0.02		μ_{WGI} = 0.06		
min: 0.02	<u>min: 0.38</u>	min: 0.06	min: 0.05	min: 0

Among the minimum values, the maximum value is determined, which is equal to 0.38. This value corresponds to the term - “low”, thus defining index of level of development of Green Economy.

6.5. Conclusion

Research undertaken using fuzzy logic methods on the National Green Economy Development Index for Azerbaijan shows that the very low value of this index is primarily influenced by the very low level of renewable energy use, low levels of protected land, green tourism, and ecological quality in Azerbaijan. The problem of investment distribution between sectors of the Green Economy needs to be researched to improve this situation in the future.

References

1. *Towards a Green Economy Pathways to Sustainable Development and Poverty Eradication*. (2011). UNEP - UN Environment Programme. https://www.unep.org/resources/report/towards-green-economy-pathways-sustainable-development-and-poverty-eradication-10

2. *A Guidebook to the Green Economy Issue 1: Green Economy, Green Growth, and Low-Carbon Development - history, definitions and a guide to recent publications | Department of Economic and Social Affairs*. (2012). https://sdgs.un.org/publications/guidebook-green-economy-issue-1-green-economy-green-growth-and-low-carbon-development

3. Renewables Information 2008. (2008). In *Renewables information*. https://doi.org/10.1787/renew-2008-en

4. *World Energy Outlook 2013 – Analysis - IEA*. (2013). IEA. https://www.iea.org/reports/world-energy-outlook-2013

5. *United Nations List of Protected Areas (2003)*. (2003). UNEP - UN Environment Programme. https://www.unep.org/resources/report/united-nations-list-protected-areas-2003

6. *Making tourism more sustainable: a guide for policy makers*. (2005). UNEP - UN Environment Programme. https://www.unep.org/resources/report/making-tourism-more-sustainable-guide-policy-makers.

7. *2011 Quality of Life Index*. (2011). Nation Ranking. http://nationranking.wordpress.com/2011/03/06/2011-qli/

8. *Environment at a Glance 2013*. (2013). In The nvironment at a glance. https://doi.org/10.1787/9789264185715-en

9. *National Organic Program | Agricultural Marketing Service*. (n.d.). http://www.ams.usda.gov/nop/

10. Research Institute of Organic Agriculture FiBL. (2014). *organic-world.net - 2014 edition of «The World of Organic Agriculture»*. https://www.organic-world.net/yearbook/yearbook-2014.html

11. Forum for a new World Governance (Ed.). (2011). *WGI. World Governance Index. 2011 Report* (Version 2.0.). https://www.kosmosjournal.org/wp-content/article-pdfs/world-governance-index.pdf

12. Desk, A. D. R. (2009). *The Innovation Imperative in Manufacturing: How the United States Can Restore Its Edge | NAM - Area Development*. Area Development. https://www.areadevelopment.com/studiesresearchpapers/3-9-2009/innovation-leadership-manufacturing-nam.shtml

13. Wilson, S. (2020). *Reducing Transport Greenhouse Gas Emissions: Trends and Data 2010*. ITF. https://www.itf-oecd.org/reducing-transport-greenhouse-gas-emissions-trends-and-data-2010

14. Ross, T. J. (2004). *Fuzzy Logic with Engineering Applications, 2nd Edition*. Wiley.com. https://www.wiley.com/en-ca/Fuzzy+Logic+with+Engineering+Applications%2C+2nd+Edition-p-9780470860748

15. Zadeh, L. A. (1973). Outline of a New Approach to the Analysis of Complex Systems and Decision Processes. *IEEE Transactions On Systems Man And Cybernetics, SMC*-3(1), 28-44. https://doi.org/10.1109/tsmc.1973.5408575

16. *Report of Ministry of Ecology and Natural Resources of Azerbaijan Republic, Part I*. (2013). Baku-2013, 96.

17. *Report of Ministry of Ecology and Natural Resources of Azerbaijan Republic, Part II*. (2013). Baku-2013, 235.

7. OIL PRICES AND THE ECONOMIC DIVERSIFICATION CHALLENGE IN AZERBAIJAN

7.1. Introduction

The period from 2005 to 2015 was a flourishing time for the oil and gas industry boom in Azerbaijan. Reduced prices in the world oil market strongly influence the development of the national economy of oil and gas-extracting countries, including Azerbaijan. During this period, the share of this sector in the structure of the country's GDP was 0.42-0.54, in the volume of investments - 0.25-0.65, in exports - 0.77-0.95, and the structure of budget revenue was about 0.25-0.34. The average export price of Azerbaijani oil in the first half of 2015 was 50 USD, compared to 104 USD for the average annual export price in 2014.

Today, not only does the decrease in oil prices in world markets affect Azerbaijan's economy, but a decline in oil production due to the reduction of reserves also greatly impacts the normal functioning of the economy. For instance, while the volume of oil extraction in 2008 was 50.8 million tons, it amounted to 45.6 million tons in 2011 and 43.84 million tons in 2014. The forecast for 2016 is 40.62 million tons. In these conditions, the diversification of the economic structure of Azerbaijan is part of the strategic development of the country. Liquidity reserves allow Azerbaijan to pursue the diversification of the national economy structure, as this indicator was 50 billion dollars at the beginning of 2015.

In this paper, we analyzed the structure of the current economic diversification during 2005-2015 and recommend appropriate directions for diversification. To cope with this objective, fuzzy sets theory and fuzzy logic instruments were applied. The application of fuzzy sets and fuzzy logic is based on the problems of uncertainty in oil prices on the world market and the volume of resources in the country.

7.2. Analysis of economic diversification level

Diversification of the economic structure is one of the significant steps in achieving sustainable development. A normally diversified economy provides optimal growth and a balanced relationship among industries within the national economy. There are various methods for determining the level of economic diversification. In literature, notable methods include the Ogive Index [1], the Entropy Index [2], and the Herfindahl-Hirschman Index [3]. Simultaneously, the level of diversification can be determined using W. Leontief's input-output model [4], [5], [6].

In this work, a fuzzy entropy composite index and a fuzzy version of the input-output model are proposed to estimate the level of diversification. The calculations are based on the data of the Azerbaijan Republic [http://stat.gov.az].

7.3. Fuzzy entropy composite index

To calculate the fuzzy entropy composite index of the diversification level of Azerbaijan's economy, we used structural indicators of GDP for 2013. Using the formula for equiproportional distribution (1 / N = 1/13 = 0.077, where N is the number of sectors), intervals and corresponding terms are determined:

- **Lowest norm (VLN)**: (0.010, 0.030, 0.050)
- **Below the norm (LON)**: (0.040, 0.053, 0.065)
- **Norm (NOR)**: (0.060, 0.080, 0.100)
- **Above the norm (HAN)**: (0.090, 0.295, 0.500)

Next, the membership degree of structural parameters to corresponding terms is defined. Based on this information, the fuzzy entropy of economic sectors -, and parameters of the model are computed.

The obtained results of parameter calculations are shown in Table 7.1.

Table 7.1. Parameters of the entropy models

Economic sectors	2013	$\mu_A(x)$	Terms	$E_i(A_i)$
Agriculture	0.057	0.667	**LON**	**0.7395**
Mining industry	0.420	0.39	**HAN**	**0.4535**
Manufacturing	0.045	0.25	**VLN**	**0.2698**
Construction	0.124	0.166	**HAN**	**0.1756**
Trade	0.076	0.8	**NOR**	**0.8627**
Transport and communication	0.066	0.3	**NOR**	**0.3208**
Tourism	0.020	0.5	**VLN**	**0.5833**
Real estate	0.022	0.6	**VLN**	**0.6964**
State governance and social insurance	0.027	0.85	**VLN**	**0.8779**
Education	0.050	0.769	**LON**	**0.8188**
Health care	0.019	0.45	**VLN**	**0.5094**
Finance, insurance	0.062	0.25	**LON**	**0.2679**
Other services	0.012	0.1	**VLN**	**0.0995**

On the basis of the following equation of Fuzzy *Entropy Composite Index* of diversification- $E(A)$ is defined:

$$E(A) = \sum_{i=1}^{n} E_i(A_i)_i = \sum_{i=1}^{n} \frac{|A_i \cap A_i^C|}{|A_i \cup A_i^C|} = \frac{1.9+4.226+5.1+2.988}{19.1+15.774+15.9+17.012} = 0.209689, i = 1, \ldots, 13.$$

The obtained results of the Fuzzy Entropy Composite Index calculations demonstrate a low level of diversification in the Azerbaijani economy in 2013.

Investigations [5], [6] of economic diversification levels using methods of equiproportional distribution do not provide a complete assessment of economic diversification. To achieve a comprehensive assessment, the use of the input-output balance model is recommended.

7.4. Input-output model-based analysis of economic diversification

P.B. Siegel [7], J.E. Wagner, and S.C. Deller [5] suggest the analysis of regional economic diversification based on V. Leontief's input-output model. Following this idea, we considered a fuzzy approach to analyze input-output balance. For this purpose, the input-output balance of Azerbaijan for the year 2006 is fuzzified in the following manner. The minimum and maximum values for the coefficients are identified in the direct relation matrix. The interval of minimum and maximum values is divided into appropriate linguistic terms, as demonstrated below:

Table 7.2. Direct relation matrix of input-output balance in 2006

Code		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Agriculture	0.204269	0.003035	0.000001	0.084648	0.000001	0.002291	0.000763	0.000506	0.000003	0.000000	0.000246	0.001681	0.000000	0.000357	0.000764
2	Fishing	0.000000	0.189500	0.000000	0.000054	0.000000	0.000000	0.000000	0.000786	0.000000	0.000000	0.000000	0.000000	0.000000	0.000008	0.000000
3	Mining industry	0.001415	0.004435	0.014485	0.221853	0.526327	0.060578	0.000215	0.000067	0.002764	0.000000	0.001746	0.000095	0.000024	0.000026	0.001358
4	Manufacturing	0.038532	0.058219	0.032094	0.291153	0.099320	0.134819	0.169255	0.040592	0.088213	0.049674	0.070987	0.095654	0.256503	0.064769	0.129991
5	Electricity, gas and water	0.018128	0.057058	0.005949	0.030128	0.090972	0.004440	0.004781	0.012823	0.007426	0.002043	0.017129	0.012629	0.014314	0.017298	0.007215
6	Construction	0.019910	0.000000	0.009124	0.026276	0.037204	0.303251	0.063960	0.077207	0.015718	0.002830	0.067204	0.038156	0.014581	0.224881	0.088182
7	Trade	0.072712	0.000103	0.007313	0.033896	0.016781	0.000193	0.042780	0.002240	0.004837	0.015993	0.008761	0.000678	0.003900	0.002501	0.000892
8	Tourism	0.000301	0.001419	0.000279	0.000522	0.000558	0.002499	0.009662	0.141207	0.002847	0.002758	0.007699	0.004848	0.000506	0.006517	0.007620
9	Transport, storage and communication	0.018382	0.053113	0.018334	0.026855	0.015597	0.028151	0.021167	0.035524	0.263558	0.055142	0.083494	0.015965	0.014565	0.029849	0.033603
10	Finance, insurance	0.000550	0.001830	0.000258	0.003223	0.001666	0.001988	0.001692	0.003063	0.006351	0.043175	0.002439	0.002679	0.000847	0.006385	0.003528
11	Real estate	0.001841	0.000582	0.005590	0.016417	0.002520	0.027050	0.017117	0.014041	0.029639	0.105612	0.152905	0.008587	0.005131	0.018405	0.009638
12	Education services	0.000000	0.000000	0.000006	0.000301	0.000027	0.000690	0.000046	0.000000	0.000573	0.000935	0.001445	0.019255	0.000000	0.000662	0.000031

Cont…

13	Health care and social services	0.000027	0.001364	0.000073	0.000358	0.000072	0.000081	0.000004	0.000106	0.000097	0.000003	0.000332	0.008220	0.001914	0.000657	0.000255
14	Public administration and social insurance	0.000000	0.000000	0.001883	0.000086	0.001571	0.018739	0.026356	0.004295	0.022167	0.001177	0.018313	0.001859	0.000487	0.017934	0.000185
15	Public utilities	0.000418	0.000261	0.000567	0.004718	0.000778	0.002041	0.001347	0.004169	0.004531	0.001701	0.002610	0.012704	0.004135	0.005157	0.103799

Table 7.3. Interval terms

Term Code	Terms	A	C	B
R1	Very Weak	0	0.01	0.02
R2	Weak	0.015	0.03	0.045
R3	Average	0.04	0.055	0.07
R4	Below average	0.065	0.1075	0.15
R5	Strong	0.1	0.25	0.4
R6	Very strong	0.35	0.5	0.65

Linguistic matrix formulated on the basis of linguistic terms has been described in Table 7.4.

Table 7.4. Linguistic matrix of intersectoral relations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	R5	R1	R1	R4	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
2	R1	R5	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
3	R1	R1	R1	R5	R6	R3	R1	R1	R1	R1	R1	R1	R1	R1	R1
4	R2	R3	R2	R5	R4	R4	R5	R2	R4	R3	R4	R4	R5	R3	R4
5	R1	R3	R1	R2	R4	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1

Cont...

6	R1	R1	R1	R2	R2	R5	R3	R4	R1	R1	R3	R2	R1	R5	R4
7	R4	R1	R1	R2	R1	R1	R2	R1	R1	R1	R1	R1	R1	R1	R1
8	R1	R1	R1	R1	R1	R1	R1	R4	R1	R1	R1	R1	R1	R1	R1
9	R1	R3	R1	R2	R1	R2	R2	R2	R5	R3	R4	R1	R1	R2	R2
10	R1	R1	R1	R1	R1	R1	R1	R1	R1	R2	R1	R1	R1	R1	R1
11	R1	R1	R1	R1	R1	R2	R1	R1	R2	R4	R5	R1	R1	R1	R1
12	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
13	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1
14	R1	R1	R1	R1	R1	R1	R2	R1	R2	R1	R1	R1	R1	R1	R1
15	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R4

As it is seen from Table 7.3, the number of all intersectoral relations is 225, of which 170 (75.5%) - are very weak, 20 (9%) - weak, 9 (4%) - average, 15 (6.7%) - below average, 10 (4.4%) - strong and 1 (0.4%) - very strong.

In order to analyze intersectoral relations and identify the leading industries affecting the overall development of the economy, we use fuzzy DEMATEL method proposed by C.L. Lin and W.W. Wu [8].

For this purpose we constructed a matrix of fuzzy triangular numbers (Table 7.5.), corresponding to the linguistic matrix (Table 7.4).

Then, fuzzy number S is calculated on the basis of elements demonstrated in the table 7.5 and the following equation:

$$S = \frac{1}{\max 1 \le i \le n \sum_{j=1}^{n}(l_{ij}, m_{ij}, u_{ij})} = \frac{1}{(0.76, 1.40, 2.04)} = (0.49, 0.71, 1.32) \qquad (7.1)$$

Table 7. 5. Fuzzy numbers matrix of intersectoral relations

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	(0.1,0.25,0.4)	(0,0.01,0.02)	(0,0.01,0.02)	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
2	(0,0.01,0.02)	(0.1,0.25,0.4)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
3	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.1,0.25,0.4)	(0.35,0.5,0.65)	(0.04,0.055,0.07)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
4	(0.015,0.03,0.045)	(0.04,0.055,0.07)	(0.015,0.03,0.045)	(0.1,0.25,0.4)	(0.065,0.108,0.15)	(0.065,0.108,0.15)	(0.1,0.25,0.4)	(0.015,0.03,0.045)	(0.065,0.108,0.15)	(0.04,0.055,0.07)	(0.065,0.108,0.15)	(0.065,0.108,0.15)	(0.1,0.25,0.4)	(0.04,0.055,0.07)	(0.065,0.108,0.15)
5	(0,0.01,0.02)	(0.04,0.055,0.07)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
6	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0.015,0.03,0.045)	(0.1,0.25,0.4)	(0.04,0.055,0.07)	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0.04,0.055,0.07)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0.1,0.25,0.4)	(0.065,0.108,0.15)
7	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
8	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
9	(0,0.01,0.02)	(0.04,0.055,0.07)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0.015,0.03,0.045)	(0.015,0.03,0.045)	(0.1,0.25,0.4)	(0.04,0.055,0.07)	(0.065,0.108,0.15)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0.015,0.03,0.045)
10	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
11	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0.065,0.108,0.15)	(0.1,0.25,0.4)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
12	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
13	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
14	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0.015,0.03,0.045)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)
15	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0,0.01,0.02)	(0.065,0.108,0.15)

Table 7.6. The normalized matrix of the intersectoral relations - T

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.07,0.11,0.15	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
2	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
3	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.10,0.25,0.40	0.35,0.50,0.65	0.04,0.06,0.07	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
4	0.01,0.03,0.04	0.04,0.06,0.07	0.01,0.03,0.04	0.00,0.00,0.00	0.07,0.11,0.15	0.07,0.11,0.15	0.10,0.25,0.40	0.01,0.03,0.04	0.07,0.11,0.15	0.04,0.06,0.07	0.07,0.11,0.15	0.07,0.11,0.15	0.10,0.25,0.40	0.04,0.06,0.07	0.07,0.11,0.15
5	0.00,0.01,0.02	0.04,0.06,0.07	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
6	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.01,0.03,0.04	0.00,0.00,0.00	0.04,0.06,0.07	0.07,0.11,0.15	0.00,0.01,0.02	0.00,0.01,0.02	0.04,0.06,0.07	0.01,0.03,0.04	0.00,0.01,0.02	0.10,0.25,0.40	0.07,0.11,0.15
7	0.07,0.11,0.15	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
8	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
9	0.00,0.01,0.02	0.04,0.06,0.07	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.01,0.02	0.01,0.03,0.04	0.01,0.03,0.04	0.01,0.03,0.04	0.00,0.00,0.00	0.04,0.06,0.07	0.07,0.11,0.15	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.01,0.03,0.04
10	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
11	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.07,0.11,0.15	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
12	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02
13	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02	0.00,0.01,0.02
14	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.01,0.02	0.01,0.03,0.04	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00	0.00,0.01,0.02
15	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.01,0.02	0.00,0.00,0.00

Table 7.7. Total intersectoral relations matrix - F

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	0.00,0.00,0.01	0.00,0.00,0.03	0.00,0.00,0.02	0.02,0.04,0.11	0.00,0.01,0.04	0.00,0.01,0.03	0.00,0.01,0.05	0.00,0.00,0.02	0.00,0.01,0.03	0.00,0.00,0.03	0.00,0.01,0.03	0.00,0.01,0.03	0.00,0.01,0.05	0.00,0.00,0.03	0.00,0.01,0.03
2	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02
3	0.00,0.01,0.05	0.00,0.01,0.06	0.00,0.00,0.03	0.02,0.09,0.30	0.08,0.18,0.47	0.01,0.02,0.09	0.00,0.01,0.11	0.00,0.01,0.05	0.00,0.01,0.06	0.00,0.01,0.05	0.00,0.01,0.07	0.00,0.01,0.06	0.00,0.01,0.11	0.00,0.01,0.07	0.00,0.01,0.07
4	0.00,0.02,0.08	0.01,0.02,0.08	0.00,0.01,0.05	0.00,0.00,0.06	0.02,0.04,0.15	0.02,0.04,0.13	0.02,0.09,0.30	0.00,0.01,0.07	0.02,0.04,0.13	0.01,0.02,0.09	0.02,0.04,0.14	0.02,0.04,0.13	0.02,0.09,0.29	0.01,0.02,0.11	0.02,0.04,0.14
5	0.00,0.00,0.02	0.01,0.02,0.05	0.00,0.00,0.02	0.00,0.01,0.04	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02
6	0.00,0.01,0.03	0.00,0.00,0.03	0.00,0.00,0.03	0.00,0.01,0.05	0.00,0.01,0.06	0.00,0.00,0.02	0.01,0.02,0.08	0.02,0.04,0.11	0.00,0.01,0.04	0.00,0.01,0.03	0.01,0.02,0.07	0.00,0.01,0.05	0.00,0.01,0.04	0.02,0.09,0.28	0.02,0.04,0.12
7	0.02,0.04,0.10	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.01,0.05	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.03	0.00,0.00,0.03
8	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02
9	0.00,0.00,0.03	0.01,0.02,0.06	0.00,0.00,0.02	0.00,0.01,0.05	0.00,0.01,0.03	0.00,0.01,0.04	0.00,0.01,0.05	0.00,0.01,0.04	0.00,0.00,0.02	0.01,0.02,0.06	0.02,0.04,0.11	0.00,0.00,0.03	0.00,0.01,0.03	0.00,0.01,0.05	0.00,0.01,0.05
10	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02
11	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.03	0.00,0.01,0.04	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.01,0.04	0.02,0.04,0.10	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.03	0.00,0.00,0.02
12	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02
13	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02	0.00,0.00,0.02
14	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.01,0.04	0.00,0.00,0.02	0.00,0.01,0.04	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01	0.00,0.00,0.02
15	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.03	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.02	0.00,0.00,0.01

Here l_{ij}, m_{ij}, u_{ij} are respectively the left, middle and right elements of a triangular fuzzy numbers.

Further, normalized matrix T (Table 7.6) is determined on the basis of the following equation:

$$T = S * A \tag{7.2}$$

As the next stage in calculations, the total intersectoral relations matrix F (Table 7.7) is constructed with the following equation:

$$F = T(I - T)^{-1} \tag{7.3}$$

where I- is the identity matrix.

In the last stage, the sum of elements of rows and columns shown in the table 7.8 are found by using the following equations:

$$R_i = \sum_{j=1}^{n} (l_{ij}, m_{ij}, u_{ij}), \qquad (\mathrm{i} = 1,2,..,\mathrm{n}) \tag{7.4}$$

$$D_j = \sum_{j=1}^{n} (l_{ij}, m_{ij}, u_{ij}), \qquad (\mathrm{j}=1,2,..,\mathrm{n}) \tag{7.5}$$

Table 7.8. The results of solution I-O matrix in 2006

Number of Economic sectors	Dl	Dm	Du	Rl	Rm	Ru	Dl+Rl	Dm+Rm	Du+Ru	Dl-Rl	Dm-Rm	Du-Ru
1	0.019	0.108	0.541	0.020	0.105	0.480	0.039	0.213	1.021	-0.461	0.003	0.521
2	0.000	0.056	0.297	0.031	0.113	0.469	0.031	0.169	0.766	-0.469	-0.057	0.266
3	0.124	0.388	1.633	0.004	0.065	0.327	0.128	0.453	1.960	-0.203	0.323	1.629
4	0.185	0.539	1.941	0.055	0.215	0.852	0.240	0.754	2.793	-0.667	0.324	1.886
5	0.014	0.083	0.386	0.105	0.286	1.010	0.119	0.369	1.396	-0.996	-0.203	0.281
6	0.087	0.277	1.023	0.034	0.130	0.543	0.121	0.407	1.566	-0.456	0.147	0.989

Cont...

Number of Economic sectors	Dl	Dm	Du	Rl	Rm	Ru	Dl+Rl	Dm+Rm	Du+Ru	Dl-Rl	Dm-Rm	Du-Ru
7	0.020	0.104	0.472	0.043	0.191	0.848	0.063	0.295	1.320	-0.828	-0.087	0.429
8	0.000	0.056	0.297	0.024	0.111	0.479	0.024	0.167	0.776	-0.479	-0.055	0.273
9	0.058	0.176	0.667	0.024	0.113	0.505	0.082	0.289	1.172	-0.447	0.063	0.643
10	0.000	0.056	0.297	0.036	0.131	0.539	0.036	0.187	0.836	-0.539	-0.075	0.261
11	0.023	0.109	0.464	0.042	0.153	0.625	0.065	0.262	1.089	-0.602	-0.044	0.422
12	0.000	0.056	0.297	0.020	0.105	0.476	0.020	0.161	0.773	-0.476	-0.049	0.277
13	0.000	0.056	0.297	0.025	0.157	0.747	0.025	0.213	1.044	-0.747	-0.101	0.272
14	0.007	0.072	0.347	0.039	0.177	0.755	0.046	0.249	1.102	-0.748	-0.105	0.308
15	0.000	0.056	0.297	0.036	0.143	0.603	0.036	0.199	0.900	-0.603	-0.087	0.261

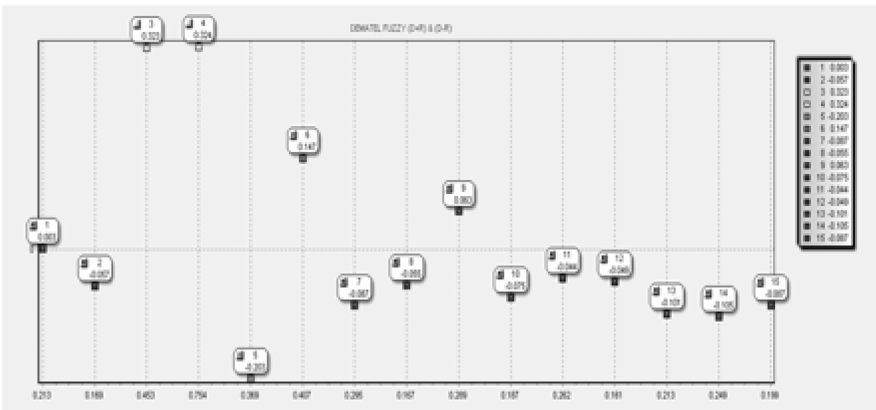


Figure 7.1. Diagram results of solution I-O matrix 2006

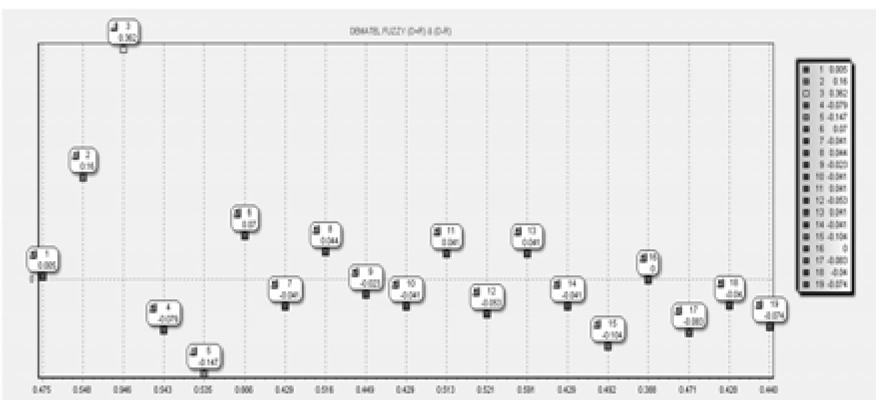


Figure 7.2. Diagram results of solution I-O matrix 2011

The results of calculation with I-O matrix 2006 given in the Figure 7.1 shows mining industry 1, manufacturing- 4, construction-6, transportation-9, agriculture-1, as the leading sectors of Azerbaijan economy. The remaining sectors of national economy are underdeveloped.

Based on the input-output balance of Azerbaijan in 2011, covering 19 industries, also major industry sectors affecting the growth of the economy are found using fuzzy method DEMATEL. The results of solving the problem are given in the Table. 7.8 and Figure 7.3.

As seen from the figure 7.2, which shows the results of calculation for I-O matrix 2011 with 19 sectors of economy, leading branches are manufacturing- 3, mining- 2, construction- 6, transportation- 8, finance and insurance- 11, agriculture- 1

Table 7.9.The results of solution I-O matrix in 2011

Code	Economic sectors	Dl	Dm	Du	Rl	Rm	Ru	Dl+Rl	Dm+Rm	Du+Ru	Dl-Rl	Dm-Rm	Du-Ru
1	Agriculture	0.027	0.24	1.117	0.024	0.235	1.096	0.051	0.475	2.213	-1.069	0.005	1.093
2	Mining industry	0.093	0.354	1.432	0	0.194	0.989	0.093	0.548	2.421	-0.896	0.16	1.432
3	Manufacturing industry	0.278	0.654	2.187	0.059	0.292	1.24	0.337	0.946	3.427	-0.962	0.362	2.128
4	Energy	0.023	0.232	1.087	0.071	0.311	1.289	0.094	0.543	2.376	-1.266	-0.079	1.016
5	Water supply	0	0.194	0.989	0.087	0.341	1.38	0.087	0.535	2.369	-1.38	-0.147	0.902
6	Construction	0.106	0.368	1.434	0.062	0.298	1.264	0.168	0.666	2.698	-1.158	0.07	1.372
7	Trade	0	0.194	0.989	0.025	0.235	1.099	0.025	0.429	2.088	-1.099	-0.041	0.964
8	Transport	0.051	0.28	1.223	0.025	0.236	1.1	0.076	0.516	2.323	-1.049	0.044	1.198
9	Tourism	0.012	0.213	1.038	0.025	0.236	1.1	0.037	0.449	2.138	-1.088	-0.023	1.013
10	Information technology	0	0.194	0.989	0.025	0.235	1.098	0.025	0.429	2.087	-1.098	-0.041	0.964
11	Finance and insurance	0.05	0.277	1.209	0.025	0.236	1.099	0.075	0.513	2.308	-1.049	0.041	1.184
12	Real estate	0.024	0.234	1.093	0.062	0.287	1.211	0.086	0.521	2.304	-1.187	-0.053	1.031
13	Professional activities	0.073	0.316	1.308	0.049	0.275	1.2	0.122	0.591	2.508	-1.127	0.041	1.259
14	Administration	0	0.194	0.989	0.025	0.235	1.099	0.025	0.429	2.088	-1.099	-0.041	0.964
15	Public administration and social security	0	0.194	0.989	0.062	0.298	1.264	0.062	0.492	2.253	-1.264	-0.104	0.927
16	Education	0	0.194	0.989	0	0.194	0.989	0	0.388	1.978	-0.989	0	0.989
17	Health care	0	0.194	0.989	0.05	0.277	1.211	0.05	0.471	2.2	-1.211	-0.083	0.939
18	Recreation	0	0.194	0.989	0.024	0.234	1.093	0.024	0.428	2.082	-1.093	-0.04	0.965
19	Other services	0	0.183	0.937	0.037	0.257	1.156	0.037	0.44	2.093	-1.156	-0.074	0.9
		0.737	4.903	21.977	0.737	4.906	21.977	1.474	9.809	43.954	-21.24	-0.003	21.24

The results of research on the analysis of the development of the Azerbaijani economy carried out by international economic organizations such as UNDP [9], The World Bank in 2005 [10], and Chemonics International in 2009 [11] show a high potential for the development of agriculture, agro-industry, and service sectors.

7.5. Conclusion

The results of the investigation show that the diversification of the Azerbaijani economy is not fully comprehensive. To thoroughly investigate this problem, there is a need to study other subsystems of the economy, such as employment, investment, exports, and imports. The results should be integrated into one indicator of the diversification level of the national economy. The process of diversification of the national economy should be conducted regularly.

References

1. Tress, R. C. (1938). Unemployment and the Diversification of Industry1. *Manchester School*, 9(2), 140-152. https://doi.org/10.1111/j.1467-9957.1938.tb01420.x

2. Berry, C. H., & Jacquemin, A. P. (1979). Entropy Measure of Diversification and Corporate Growth. *The Journal Of Industrial Economics*, 27(4), 359-369.
https://doi.org/10.2307/2097958https://www.jstor.org/stable/2097958

3. Hirschman A.O. [1964] The Paternity of an index, American Economic Review, September, 1964,pp.761-762.

4. Smith, S. M., &. Gibson. C. M. (1988). Industrial diversification in nonmetropolitan counties and its effect on economic stability. *ideas.repec.org*. https://ideas.repec.org/a/ags/wjagec/32109.html

5. Wagner, J., & Deller, S. (1996). *A Measure of Economic Diversity : An Input-Output Approach*. https://www.semanticscholar.org/paper/A-Measure-of-Economic-Diversity-%3A-An-Input-Output-Wagner-Deller/b055c0b4a52b599c3bba36a69e87235e3b2b3757

6. Wagner, J. E. (2000). Regional Economic Diversity: Action, Concept, or State of Confusion. *ideas.repec.org*. https://ideas.repec.org/a/ags/jrapmc/132170.html

7. Siegel, P. B., Johnson, T. G., & Alwang, J. (1995). Regional Economic Diversity and Diversification. *Growth And Change*, 26(2), 261-284. https://doi.org/10.1111/j.1468-2257.1995.tb00171.x

8. Lin, C. L., & Wu, W. (2004). *A Fuzzy Extension Of The Dematel Method For Group Decision Making*. https://www.semanticscholar.org/paper/A-FUZZY-EXTENSION-OF-THE-DEMATEL-METHOD-FOR-GROUP-Lin-Wu/4ef7816a9ee2abf343bb5f8ce63ababc9ffe1762

9. Almas, L. K. &. Nazim. U. H. (2013). Azerbaijan's Current and Potential Comparative Advantage: An Exploratory Study. *ideas.repec.org*. https://ideas.repec.org/p/ekd/004912/5501.html

10. *Azerbaijan - Agricultural markets study: realizing Azerbaijan's comparative advantages in Agriculture*. (2005). World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/198631468207847565/azerbaijan-agricultural-markets-study-realizing-azerbaijans-comparative-advantages-in-agriculture

11. Stryker, J. D. (2009). Domestic Resource Cost Analysis of Azerbaijan. Final Report. In *USAID*. https://pdf.usaid.gov/pdf_docs/Pnadt149.pdf

8. FORECASTING NATIONAL ECONOMIC DEVELOPMENT IN AN OIL-EXPORTING COUNTRY

8.1. Introduction

Like all oil-exporting countries, the development of the national economy of Azerbaijan depends on the oil price in the world market. Recently, the oil price in the global market fell by almost half. This rapid decline strongly influenced the economic, social, and financial state of countries reliant on their oil exports. Accordingly, new economic conditions emerged in the second half of 2014, which continued to negatively impact the economic dynamics of Azerbaijan, where 90% of exports were dependent on oil.

The economic management system, which was based on large-scale oil revenues over the last decade, lost its regulating capacity. To prevent the rapid depletion of reserves, the government decided to devalue its currency by 25.1% on February 21, 2015. The national currency experienced its second sharp devaluation at the end of the year on December 21, 2015. In 2015, GDP created in the economy increased by 1.1%, reaching 54.4 billion AZN. However, as a result of the 98.7% devaluation of the national currency during the reporting year, the GDP in terms of USD experienced a 27.7% reduction compared to the previous year (75.2 billion USD in 2014, World Bank). Thus, during 2015, GDP was 54.35 billion USD.

In the current situation, short-term forecasting of the development and diversification structure of the national economy is especially important. To forecast the development of a national economy dependent on oil and gas income, we propose econometric models for forecasting the development of the national economy and defining the optimal structure of GDP production in Azerbaijan. Statistical information from 1990-2015 has been used for analyzing and forecasting the development of the national economy [1].

8.2. Econometric model for forecasting of GDP volume

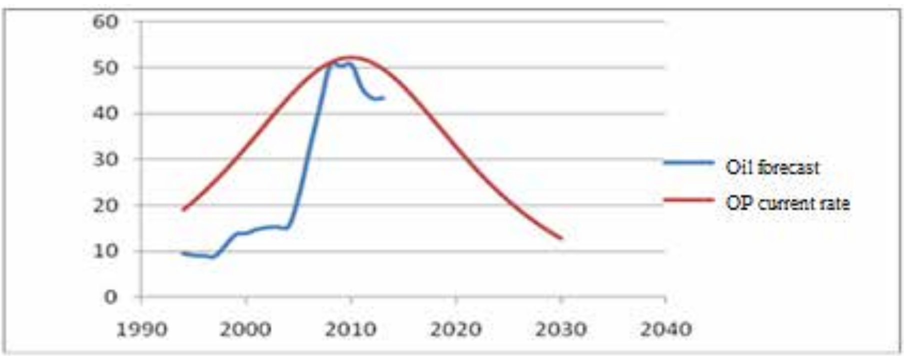
The econometric model for forecasting the development of the national economy consists of four equations – Hubbert's curve [2], Oil income, Gas income, and GDP production function.

Firstly, to forecast the volume of oil and gas production, geological models of M. Hubbert are used, which are described by the following logistic equation [2]:

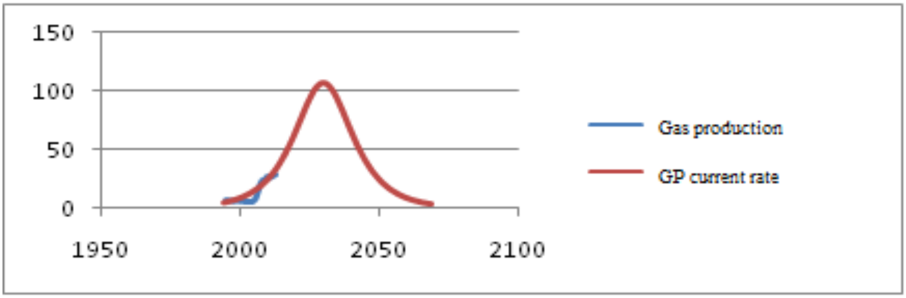
$$N_p = \frac{N_R}{1 + e^{-b(t-t_m)}} \tag{8.1}$$

Where, N_p - is the volume of production, N_R - is the ultimate recoverable resources (URR), b – is the parameter of the curve slope and t_m- is the time, corresponding to the production peak. Oil (OP) and gas (GP) production in Hubbert's curve for Azerbaijan are shown in Figures 8.1 and 8.2, respectively. Maximum oil reserves are estimated at 1 billion tons, and maximum gas reserves are estimated at 2 trillion cubic meters.

Maximum oil reserves are estimated as 1 billion tones and maximum gas reserves as 2 trillion cubic meters.



Graph 8.1. Oil production Hubbert's curve: b=0.1, T(max)=201 0, OP=50.8 mln. tons



Graph 8.2. Gas production in Hubbert's curve: b=0.1, T(max)=2030, GP=107 bln. cubic meters

According to the equation (8.1) oil and gas production are calculated (for oil until 2030 and for gas until 2075).

As we can see from the graph above, gas production will reach its peak point in 2030 and then gradually decline until 2075. We would like to note that this result has been obtained under conditions of growth equal to 0.107244531296 (10.7%). It is widely known that in 2013, Azerbaijan signed an agreement with two international companies for gas exploration. This agreement considered the significant inflow of foreign investments into Azerbaijan. Consequently, gas production will be sufficiently increased during this period.

Table 8.1 demonstrates the results of forecasted oil and gas production for the years 2016-2020 according to Figures 8.1 and 8.2.

Table 8.1. Volume of oil and gas production according to Hubbert's curves

Years	Oil production (mln. tons)	Gas production (bln. cubic meters)
2016	29.47	39
2017	27.86	44
2018	26.11	48
2019	24.25	53
2020	22.30	57

The second equation expresses the dependence of oil income on oil export and oil price:

$$\text{LOG(OIL\_INCOME)} = 2.9 + 0.77^{*}\text{LOG(OIL\_EXPORT)} + 1.003^{*}\text{LOG(OIL\_PRICE)} \quad (8.2)$$

Results of the calculation of the coefficients of regression equations (8.2) for oil income show that a 1 percent growth in oil export increases oil income by 0.77 percent, and a 1 percent growth in oil price increases oil income by 1 percent.

The forecasted value of oil export for the years 2016-2020 is defined by the weight of oil export in oil production (0.8), which was formed during the period of 2000-2015. In this case, the volume of oil export in 2016-2020 is respectively 23.58, 23.29, 20.89, 19.4, and 17.84 million tons. To define the world oil price, we used the World Bank forecast [3] for 2016-2020, which equals 41, 50, 53.3, 56.7, and 60.4 US dollars, respectively. Using the second equation, based on the given information on oil export and price, we computed the forecasted values of income, which equaled 10.8, 11.3, 11.3, 11.4, and 11.5 billion USD for the corresponding years 2016-2020.

The following equation demonstrates the trend of gas income:

$$\mathrm{LOG(GAS\_INCOME)} = 8.86 + 0.04{*}@\mathrm{TREND} \qquad (8.3)$$

As seen from equation (8.3), the average annual growth of gas income is equal to about 4 percent. The forecasted volumes of gas income are given in Table 8.2.

Table 8.2. Forecasted volume of gas income

Years	GAS_INCOME
2016	7.5
2017	7.8
2018	8.1
2019	8.4
2020	8.8

The fourth equation expresses the volume of GDP dependent on oil-gas income and investment in the oil-gas sector.

By using the results of oil and gas income forecasting and a hypothetical value of investment in the oil-gas sector (4 billion USD), the forecasted values of GDP for the years 2016-2020 were defined.

$$\begin{gathered}\mathrm{LOG(GDP)} = -5.84 + 0.23{*}\mathrm{LOG(OIL\_INCOM)} + \\ +0.59{*}\mathrm{LOG(GAS\_INCOM)} + 0.26{*}\mathrm{LOG(INV)}\end{gathered} \qquad (8.4)$$

As you see from the equation, a 1 percent growth in oil income increases GDP by 0.23 percent, a 1 percent growth in gas income increases GDP by 0.59 percent, and a 1 percent increase in investment raises the volume of GDP by 0.26 percent.

As a result, by using equation (8.4), the forecasted GDP for the years 2016-2020 is 41.8, 43.3, 44.2, 45.3, and 46.6 billion AZN, respectively.

The forecasted GDP shows that the volume of GDP in the years 2016-2020 will decrease by 1.61 to 1.8 times compared to 2014 (75.2 billion USD). To improve this situation, diversification of the structure of the national economy is necessary.

8.3. Fuzzy optimization model for the national economy structure

In order to optimize industrial structure of economy, we consider fuzzy analogue of M. Conroy's model [8] in interpretation of X. Huang [9]:

$$\max M[s_1\tilde{d}_1 + s_2\tilde{d}_2 + \ldots + s_n\tilde{d}_n\ ]; \tag{8.5}$$

$$\begin{cases} V[s_1\tilde{d}_1 + s_2\tilde{d}_2 + \ldots + s_n\tilde{d}_n\ ] \le \alpha; \\ -\sum_{i=1}^{n} s_i \cdot ln(s_i) \ge E; \\ \sum_{i=1}^{n} s_i \ = 1;\ s_i \ge 0, \end{cases} \tag{8.6}$$

Where s_i denotes the share of i-th sector in GDP; d_i is a fuzzy volume equivalent of expected return in i-th sector of economy; α - the level of the expected risk associated with the formation of a new economic structure; E- entropy in new economic structure; M [·] and V[·] – are the matrix and vector operations respectively, expected value and variations of fuzzy variable from expected return across sectors, taking into account the computational uncertainty measurement [11], which is used in selection of unimodal triangular membership functions in order to describe fuzzy set d_i:

$$\mu_{\widetilde{d}_i}(u) = \begin{cases} \dfrac{u-a_i}{b_i-a_i}, 0 \le u \le b_i; \\ \dfrac{c_i-u}{c_i-b_i}, b_i < u \le c_i, \end{cases} \tag{8.7}$$

Accordingly calculated as:

$$\begin{aligned} M[s_1\widetilde{d}_1 + s_2\widetilde{d}_2 + \ldots + s_n\widetilde{d}_n] &= \sum_{i=1}^{n} b_i s_i; \\ V[s_1\widetilde{d}_1 + s_2\widetilde{d}_2 + \ldots + s_n\widetilde{d}_n] &= \sum_{i=1}^{n} \frac{(c_i-a_i)^2}{24} s_i^2 \end{aligned} \tag{8.8}$$

The following sectors have been chosen in the model (8.5) - (8.6) for solving the problem of determining the optimal structure of Azerbaijan's economy: 1) Agriculture; 2) Mining; 3) Manufacturing; 4) Construction; 5) Service; 6) Others.

Tables 8.3 and 8.4 show macro indicators of Azerbaijan's economy, which represent input data for the implementation of the model (8.5) - (8.6).

Table 8.3. Sectorial structure of GDP in Azerbaijan (mln. manats, at current prices)

Years / Sectors	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	1,137.9	1,329.4	1,901.0	2,246.0	2,179.5	2,344.6	2,643.5	2,813.7	3,122.2
2	5,283.9	9,534.0	15,219.2	21,164.5	15,090.4	19,482.2	24,980.0	23,570.1	2,2790.2
3	812.4	1,082.2	1,413.5	1,888.7	1,967.3	2,011.9	2,077.2	2,321.8	2,452.8
4	1,126.8	1,445.5	1,825.4	2,800.3	2,554.3	3,439.7	4,141.0	5,507.9	6,753.7
5	1,985.8	2,666.0	3,692.0	5,824.6	12,399.6	1,2071.4	8,688.8	9,565.3	10,459.2
6	1,300.9	1,856.6	2,497.8	4,105.2	4,628.2	4,866.9	7,954.2	7,572.9	8,726.0

Source: www.stat.gov.az [11]

Table 8.4. Share of sectors in GDP of Azerbaijan

Years / Sectors	2006	2007	2008	2009	2010	2011	2012	2013
1	0.074211	0.071604	0.05906	0.056145	0.053025	0.052193	0.054793	0.057495
2	0.532218	0.573252	0.556531	0.388734	0.440607	0.494892	0.458994	0.419677
3	0.060412	0.053241	0.049664	0.050678	0.045501	0.041152	0.045214	0.045168
4	0.080692	0.068756	0.073635	0.0658	0.077792	0.082039	0.107258	0.124368
5	0.148825	0.139064	0.153161	0.319418	0.273005	0.172138	0.18627	0.192604
6	0.103641	0.094083	0.107948	0.119224	0.110069	0.157585	0.147471	0.160688

Based on the data given in Table 8.3, the nominal volume of expected return in sectors of the economy is obtained according to the equation:

$$d_i = \frac{x_{it} - x_{it-1}}{x_{it-1}}, \quad i=1 \div 6 \tag{8.9}$$

Where, x_{it} is the GDP volume of i-th sector in the year t, x_{it-1} - GDP volume of i-th sector in the year $t-1$. The obtained data on return volumes across economic sectors are organized in the form of Table 8.3.

Table 8.5. Expected return in six sectors of Azerbaijan's economy

Years / Sectors	2006	2007	2008	2009	2010	2011	2012	2013
1	0.168	0.43	0.181	-0.056	0.106	0.127	0.064	0.11
2	0.804	0.596	0.391	-0.287	0.291	0.282	-0.056	-0.033
3	0.332	0.306	0.336	0.042	0.023	0.032	0.118	0.056
4	0.284	0.263	0.534	-0.137	0.424	0.204	0.33	0.226
5	0.342	0.385	0.578	1.129	-0.026	-0.28	0.101	0.093
6	0.427	0.345	0.643	0.127	0.052	0.634	-0.048	0.152

By using the methods described in [6, 7], we applied fuzzification procedure to obtained data on volumes of expected return by economic sectors. This procedure consists of sequential implementation of the following steps:

Step 1. *Determination of the minimum and maximum values of return.* As an example, we choose the data on the volume of expected return in the second sector (u_2) of Azerbaijan's economy. According to the data given in the Table 8.3, the minimum and maximum values are respectively: $d_{\min}$= -0.287 and $d_{\max}$=0.804.

Step 2. *Construction of a universal set.* According to [6], the universal set, as the basis for construction of fuzzy equivalents for the volume of expected return by economy sectors, in general form appears as:

$$U = \left[d_{\min} - t_{\alpha}(n) \cdot \frac{s}{\sqrt{n}} ; d_{\max} + t_{\alpha}(n) \cdot \frac{s}{\sqrt{n}} \right] \qquad (8.10)$$

Where, $t_{\alpha}(n)$ is a table value of Student's t-test at significance level 0,05 for a selection composed of 8 elements, s- standard deviation of u_2.

According to [6] and assuming a = 0.05, we have $t_{0.05}[4]$ = 2.3048; s = 0.361. Further, on the basis of (8.7), we get interval U = [- 0.581; 1.098] as a universal set.

Step 3. *Partition of universum into equal intervals.* Required number of intervals of partition of the universum U is defined from the following ratio:

$$m = \frac{1.098 - (-0.581)}{(\sum |u_{t2} - u_{t1}|)/7} = \frac{1.68}{0.291} \approx 6.$$

Then, dividing interval U into 6 equal parts, we get partial intervals of the same length:

$$l = \frac{1.098 + 0.581}{6} = 0.28.$$

Below, Table 8.6 shows the number of obtained data on the volume of expected return across economic sectors included in each of the constituent intervals of the universum U.

Table 8.6. Number of obtained data on the volume of expected return by the second sector of economy included in partial intervals

Interval name	Partial interval	Number of obtained data on the volume of expected returns
u_1	[-0,581; -0,301]	0
u_2	[-0,301; -0,021]	3
u_3	[-0.021; 0.259]	0
u_4	[0.259; 0.539]	3
u_5	[0.539; 0.819]	2
u_6	[0.819; 1.099]	0

Step 4. *Defining fuzzy analogues*. According to the rule described in [7], we defined the values of the left-hand side and the right hand side parameters of unimodal triangular membership functions of fuzzy sets, which describe the historical data of corresponding return for the second sector of Azerbaijan's economy:

$$\frac{3\cdot(-0.301)+3\cdot 0.259+2\cdot 0.539}{8}=0.119,$$

$$\frac{3\cdot(-0.021)+3\cdot 0.539+2\cdot 0.189}{8}=0.399.$$

Thus, the fuzzy set describing the expected return by the second sector is reconstructed as unimodal triangular membership function with identified parameters a = 0.119, b = 0.259, c = 0.399, i.e. as the function of the following form:

$$\mu_{\tilde{d}_2}(u)=\begin{cases}\dfrac{u-0.119}{0.259-0.119}, 0\le u\le 0.259;\\ \dfrac{0.399-u}{0.399-0.259}, 0.259<u\le 0.399,\end{cases}$$

or

$$\mu_{\tilde{d}_2}(u)=\begin{cases}\dfrac{50}{7}u-\dfrac{119}{140},\ 0\le u\le 0.259;\\ -\dfrac{50}{7}u+\dfrac{399}{140},\ 0.259<u\le 0.399.\end{cases}$$

By applying this fuzzification procedure to all "crisp" data on the expected return (Table 8.7) and to the share of sectors (Table 8.6), we, thereby, have identified parameters of the corresponding membership functions that are arranged in the table 8.7.

Table 8.7. Parameters of unimodal membership functions of fuzzy analogues of expected return and share of sectors in Azerbaijan's economy

Sectors	Fuzzy analogue of return level	Parameters of membership functions			
		a_i	b_i	c_i	s_i[1]
1	$\tilde{d}_1$	0.0636	0.1362	0.2058	0.601
2	$\tilde{d}_2$	0.119	0.259	0.399	0.705
3	$\tilde{d}_3$	0.11	0.15	0.19	0.056
4	$\tilde{d}_4$	0.168	0.292	0.416	0.096
5	$\tilde{d}_5$	0.00275	0.198	0.393	0.226
6	$\tilde{d}_6$	0.11	0.2915	0.483	0.143

The models (8.5) - (8.6), which are considered to maximize the profitability of sectors in Azerbaijan's economy, are implemented as a linear optimization problem. In our case, in a numerical expression, the model has the following form:

$$0.1362 \cdot s_1 + 0.259 \cdot s_2 + 0.15 \cdot s_3 + 0.292 \cdot s_4 + 0.198 \cdot s_5 + 0.2915 \cdot s_6 \to \max,$$

$$\begin{cases} 0.1422 \cdot s_1 + 0.28 \cdot s_2 + 0.08 \cdot s_3 + 0.248 \cdot s_4 + 0.39 \cdot s_5 + 0.373 \cdot s_6 \leq \sqrt{24r} = 0.833; \\ -s_1 \cdot \ln s_1 - s_2 \cdot \ln s_2 - s_3 \cdot \ln s_3 - s_4 \cdot \ln s_4 - s_5 \cdot \ln s_5 - s_6 \cdot \ln s_6 \geq E; \\ \sum_{i=1}^{6} s_i = 1; \\ 0 \leq s_i \leq 1. \end{cases}$$

As a result, desired results are obtained by using the Simplex method for different scenarios of entropy. Namely, the optimal values of share across six indicated sectors in general structure of Azerbaijan's economy are obtained. Table 8.8 demonstrates these results.

1 Similarly computed means of values fuzzy numbers of sectors' share.

Table 8.8. The optimal values of share of sectors in GDP

Entropy level (E)	**1.4**	**1.5**	**1.6**	**1.7**
Share of economic sectors	**Calculated values**			
s_1	0.0943	0.0968	0.1374	0.1976
s_2	0.0836	0.0877	0.1032	0.1287
s_3	0.0582	0.0877	0.0917	0.1074
s_4	0.0812	0.0877	0.0917	0.1074
s_5	0.1418	0.1484	0.1541	0.1429
s_6	0.5451	0.5	0.4297	0.3197
Functional value	0.2541	0.2498	0.2418	0.2292

8.4. Conclusion

As a result of solving the problem, which corresponds to the models (8.5) - (8.6), values for the specific share of each sector in the general structure of Azerbaijan's economy have been obtained. According to this, the emerging trend is that the specific share of agriculture should be increased by two times. It is necessary to reduce the share of production in the mining industries, increase the weight of the manufacturing industry, slightly reduce the weight of the construction sector, and increase the weight of the "other" and "services" sectors.

References

1. Anar Samadov (www.anarsamadov.net). (n. d.). *Azərbaycan Respublikasının Dövlət Statistika Komitəsi*. Azərbaycan Respublikasının Dövlət Statistika Komitəsi. https://stat.gov.az/

2. Hubbert, M. K. (1982). Techniques of Prediction as Applied to Production of Oil and Gas. *US Department of Commerce, NBS Special Publication* 631. https://www.scirp.org/reference/referencespapers?referenceid=982611

3. World Bank Group (Ed.). (2016). Commodity Markets Outlook. In *worldbank.org*. https://pubdocs.worldbank.org/en/143081476804664222/CMO-October-2016-Full-Report.pdf

4. Conroy, M. E. (1975). The Concept and Measurement of Regional Industrial Diversification. *Southern Economic Journal*, 41(3), 492-505. https://doi.org/10.2307/1056160https://www.jstor.org/stable/1056160

5. Xiaoxia, & Huang. (2012). *An Entropy Method for Diversified Fuzzy Portfolio Selection*. https://www.semanticscholar.org/paper/An-Entropy-Meth-

od-for-Diversified-Fuzzy-Portfolio-Xiaoxia-Huang/1967e43070369c3eb-16522f726b6195c64854440

6. Manikandan, M., Senthamarai, K., & Deneshkumar, V. (2013). Computational Method Based on Distribution in Fuzzy Time Series Forecasting. *Journal of Scientific Research*, 2. https://www.worldwidejournals.com/international-journal-of-scientific-research-(IJSR)/article/computational-method-based-on-distribution-in-fuzzy-time-series-forecasting/MTYxNw==/

7. Guo, H., Sun, B., Karimi, H. R., Ge, Y., & Jin, W. (2012). Fuzzy Investment Portfolio Selection Models Based on Interval Analysis Approach. *Mathematical Problems In Engineering*, 1. https://doi.org/10.1155/2012/628295

9. ASSESSMENT THE DEVELOPMENT LEVEL OF THE INFORMATION SECTOR IN THE NATIONAL ECONOMY

9.1. Introduction

In the 21st century, the information sector of the economy is developing at a high rate, providing a significant contribution to the development of national economies. The concept of the "information economy" was proposed in 1976 by the American economist Marc Porat [1], who built on F. Machlup's "Knowledge Industries" theory [2]. Since then, the term "information economy" has been widely used in both scientific and practical areas. With the development of digital networks and ICT, the information economy is increasingly transforming into the digital (electronic) economy, which is currently its leading sector. The information economy is closely connected with the development of science and technology; it creates new products and values from the "human brain" by using technical and software instruments. The resources of the information economy create possibilities to produce high-quality products and services, increase labor productivity, and drive the growth of national economies as a whole.

The main productive factors of the information economy are human capital, information resources, and information and communication technologies (ICT).

Information resources include scientific knowledge, production technologies, culture, experience, and skills (mentality, traditions) accumulated by humanity. These information resources shape human capital. According to the definition by experts from the Organization for Economic Cooperation and Development (OECD), human capital is productive wealth embodied in labor, skills, and knowledge [3].

ICT encompasses the tools and areas of work and training, including technologies such as desktop and laptop computers, software, peripherals, and

Internet connections that are designed to store, process, and transfer information.

Knowledge is a historical characteristic of matter, expressing the nature and degree of orderliness of its reflection in individual or social awareness. The material content of the production process, expressed by the sequence of production operations, forms the system that transforms the object of labor into its product, and this system is called production technology, or simply, technology. The important point is that technology allows the achievement of predetermined results, which is the product of labor, anticipating and ensuring the required outputs of the ongoing production processes.

Since 2002, the North American Industry Classification System (NAICS) classifies the information industry into six categories [4]:

1. **Publishing industry** - newspapers, periodicals, book publishers, publishers of catalogs and mailings, software publishers (except the Internet);
2. **Cinema and sound recording industry**;
3. **TV and radio broadcasting** (except Internet);
4. **Telecommunications** - wired and wireless telecommunication operators, satellite and other telecommunications;
5. **Data processing, hosting, and related services**;
6. **Other information services** - news syndicates, libraries and archives, internet publishing and broadcasting, web portals, and other information services.

In the People's Republic of China, the information economy is divided into the following three sectors [5]:

1. **The production of information technology equipment**, which includes microelectronics, electronics, computers, communications, and the production of network equipment, as well as the creation of information technology infrastructures;
2. **The information commercialization sector**, consisting of the information production subsectors, the commercialization of information, and information services;

3. **Department of semi-official information** (branch of the information department in the non-information industry).

To measure the volume of the information economy product, M. Porat proposes the value added calculated using the Leontief input-output model [6]. Alongside this, World Bank experts propose the knowledge economy index [7], which is calculated based on:

- Economic and institutional regime;
- Education and skills;
- Information and communication infrastructure;
- Innovation system.

In this paper, using the method of intuitionistic fuzzy logic, the information economy development level is defined based on the data of the Global Innovation Index. Additionally, the influence of human resources on the information economy's value added, created in the information sector of the national economy, is analyzed using the Cobb-Douglas function.

9.2. Models for the estimation of information economy development level

In the first approach, instruments of the intuitionistic linguistic fuzzy set were used for modeling. To formulate the fuzzy model, the following production resources of the information economy were considered:

– **Human Capital and Research (HCR);**
– **Information and Communication Technologies (ICT);**
– **Knowledge and Technology (KNT).**

Information for these subsystems was taken from the "Global Innovation Index" report [8]. According to the method of determining the Global Innovation Index, the "Human Capital and Research" sub-index is defined using the state's expenditure on education, tertiary education, and research and development. The "Information and Communication Technologies" sub-index is formed using indicators of ICT instruments, ICT use, the government's online services, and online e-participation. The "Knowledge and Technological Outputs" sub-index is calculated based on knowledge creation indicators (patents, articles, links), knowledge impact (expenditure on computer software development), ISO 9001 certification, high-tech production, and knowledge diffusion (high-tech and ICT services foreign direct export).

Since the sub-index indicators have different units of measurement, they are normalized in the interval [0 ... 100] using the known minimax method. The information taken from [8] on sub-indices for the years 2010-2016 is given in Table 9.1.

Table 9.1. The values of sub-indices

Sub-indices	*Years*						
	2010	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
HCR	30.4	30.0	25.5	20.9	21.9	22.9	17.9
ICT	22.8	27.0	29.1	34.7	47.8	48.6	65.2
KNT	24.4	20.5	13.7	19.1	19	17.6	15.4

As underlined, in order to estimate the index of information economy development level, the instruments of linguistic fuzzy sets were used.

An intuitionistic fuzzy set, which is a generalization of L. Zadeh's fuzzy set, was developed by K. Atanassov. [9] In 2009, Wang and Li proposed the linguistic intuitionistic fuzzy set [10]:

$$A = \{\langle x, [S_{\theta(x)}, \mu_A(x), \nu_A(x)]\rangle x \in X\} \tag{9.1}$$

Where, $S_\theta(x) \in S, \mu_A : X \to [0,1]$ and $\nu_A : X \to [0,1]$ satisfying the condition $\mu_A(x) + \nu_A(x) \leq 1$, $\mu_A(x)$ and $\nu_A(x)]$ are respectively membership and non-membership degree of the elements x to the linguistic value $S_{\theta(x)}$.

For each linguistic intuitionistic fuzzy set $A = \{\langle x, [S_{\theta(x)}, \mu_A(x), \nu_A(x)]\rangle x \in X\}$, there is $\pi_A(x) = 1 - \mu_A(\mathrm{x}) - \nu_A(x)$, which is called the fuzzy intuitionistic index of x element of the linguistic variable $S_{\theta(x)}$.

For the linguistic intuitionistic fuzzy set $A = \{\langle x, [S_\theta(x), \mu_A(x), \nu_A(x)]\rangle x \in X\}$, $(S_{\theta(x)}, (\mu_A(x), \nu_A(x))$ triple is called a linguistic intuitionistic fuzzy number.

In the first stage of estimation the index of development level of information economy, the information in Table 9.1 is *fuzzificated*, membership (μ), non-membership degrees (ν) are calculated by the known method [9], and the following intervals of linguistic terms (LT) are de fined:

– Low (L) = (0, 11.25, 22.5);

– Lower than medium (LM) = (20, 31.25, 42.5);

– Medium (M) = (40, 51.25, 62.5);

– Higher than medium (HM) = (60, 71.25, 82.5);

– High (H) = (80, 91.25, 102.5).

The following scaling for terms were established to evaluation of indices:

L= (-2), LM= (-1), M= 0, HM=1, H=2.

The calculated values of parameters of the fuzzy model are given in Table 9.2.

Table 9.2. The calculated values of indices based on the fuzzy model

Sub-indices	**2010**			**2011**			**2012**		
	LT	**μ**	**υ**	**LT**	**μ**	**υ**	**LT**	**μ**	**υ**
HCR	LM	0.92	0.08	LM	0.89	0.11	LM	0.49	0.51
ICT	LM	0.25	0.75	LM	0.62	0.38	LM	0.81	0.19
KNT	LM	0.39	0.61	L	0.18	0.82	L	0.78	0.22

Continued

Sub-indices	**2013**			**2014**			**2015**			**2016**		
	LT	**μ**	**υ**	**LT**	**μ**	**υ**	**LT**	**μ**	**υ**	**LT**	**μ**	**υ**
HCR	L	0.14	0.86	LM	0.17	0.83	LM	0.26	0.74	L	0.41	0.59
ICT	LM	0.69	0.31	M	0.69	0.31	M	0.76	0.24	HM	0.46	0.54
KNT	L	0.30	0.70	L	0.31	0.69	L	0.44	0.56	L	0.63	0.37

The index of information economy development level of Azerbaijan for 2010-2016, is estimated based on the indices. For this purpose, the following equation is proposed:

$$IEDI_t = w_{1,t} * HCR_{1,t} + w_{2,t} * ICT_{2,t} + w_{3,t} * KNT_{3,t} \qquad (9.2)$$

Where, w_{it} is the weight and $HCR_{1,t}$, $ICT_{2,t}$ $KNT_{3,t}$ are the indices of the terms of i sub-index in *t-th* year.

In order to define the weights were used the following equation:

$$w_{it} = \frac{1-e_{it}}{n-\sum_{i=1}^{n} e_{it}}, \quad i=1,...,4, \quad t=2010,...,2015 \qquad (9.3)$$

Where, e_{it} is the entropy of an intuitionistic fuzzy number, which is defined by the following equation proposed in [11].

$$e_{it} = \frac{1-(w_{it}-\nu_{it})^2}{1-3*(w_{it}-\nu_{it})^2}, \quad i=1,...,4, \quad t=2010,...,2015 \qquad (9.4)$$

$e_{HC1,10} = 0.09$, $e_{ICT\ 2,10} = 0.42$, $e_{KNT\ 3,10} = 0.83$

$w_{1,10} = 0.55$, $w_{2,10} = 0.35$,$w_{3,10} = 0.10$

$e_{HC\ 1,11} = 0.14$, $e_{ICT\ 2,11} = 0.80$, $e_{KNT\ 3,11} = 0.27$

$w_{1,11} = 0.48$, $w_{2,11} = 0.11$,$w_{3,11} = 0.41$

$e_{HC\ 1,12} = 1.00$, $e_{ICT\ 2,12} = 0.89$, $e_{KNT\ 3,12} = 0.35$

$w_{1,12} = 0$, $w_{2,12} = 0.14$,$w_{3,12} = 0.86$

$e_{HC\ 1,13} = 0.19$, e_{ICT} 2,13 = 0.60, $e_{KNT\ 3,13} = 0.57$

$w_{1,13} = 0.50$, $w_{2,13} = 0.24$, $w_{3,13} = 0.26$

The calculation results are presented below:

$e_{HC\ 1,14} = 0.25$, $e_{ICT\ 2,14} = 0.60$, $e_{KNT\ 3,14} = 0.60$

$w^{1,14} = 0.48$, $w_{2,14} = 0.26$, $w_{3,14} = 0.26$

$e_{HC\,1,15} = 0.46$, $e_{ICT\,2,15} = 0.40$, $e_{KNT\,3,15} = 0.95$

$w_{1,15} = 0.46$, $w_{2,15} = 0.20$, $w_{3,15} = 0.04$

$e_{HC\,1,16} = 0.88$, $e_{ICT\,2,16} = 0.96$, $e_{KNT\,3,16} = 0.78$

$w_{1,16} = 0.32$, $w_{2,16} = 0.10$, $w_{3,16} = 0.58$

Using the values of weights and sub-indices, the index of information economy development level of Azerbaijan during 2010-2016 years, are calculated:

IEDI (2010) = 0.55*(-1) + 0.35*(-1) + 0.1*(-1) = -1.00 (LM)

IEDI (2011) = 0.48*(-1) + 0.11*(-1) + 0.41*(-2) = -1.41 (close to L)

IEDI (2012) = 0*(-1) + 0.14*(-1) + 0.86*(-2) = -1.86 (L)

IEDI (2013) = 0.50*(-2) + 0.24*(-1) + 0.26*(-2) = -1.76 (L)

IEDI (2014) = 0.48*(-1) + 0.26*0 + 0.26*(-2) = -1.00 (LM)

IEDI (2015) = 0.46*(-1) + 0.50*0 + 0.04*(-2) = -0.54 (between LM and M)

IEDI (2016) = 0.32*(-2) + 0.1*1+0.58*(-2) = -1.70 (close to L)

The results of estimation show that information economy development levels in 2011, 2012, 2013 and 2016 years were low, in 2010, 2014 - lower than medium, and 2015 - between lower than medium and medium. According to the World Bank, the index of the knowledge economy of Azerbaijan among 146 countries in the world for 2012 is 4.56, and this equals to 79th place, which corresponds to our calculations.

In order to define the impact of production factors on the total out put of the information economy, we use the Cobb-Douglas production function [12]:

$$ADP = A_0 * Inv^{\alpha_1} * Emp^{\alpha_2}$$
$$\alpha_1 + \alpha_2 = 1 \tag{9.5}$$

Where **ADP** is the created value added, **Inv**- investment, **Emp**- the number of employees involved in information economy, α_1, α_2- param eters of the function.

Table 9.3 presents the information [13] for calculating the parameters of the production function.

Table 9.3. The values of the indicators of production function

Parameters	2005	2006	2007	2008	2009	2010
Emp (thsd)	32,30	32,70	33,20	33,50	34,00	55,80
Inv (mln USD)	150,10	155,00	161,80	153,40	129,80	204,00
ADP (mln USD)	320,50	352,60	507,30	643,80	686,80	715,80

Continued Table 9.3.

Parameters	2011	2012	2013	2014	2015	2016
Emp (thsd)	58,00	58,70	58,10	59,20	60,30	61,20
Inv (mln USD)	408,70	307,30	192,40	147,20	338,40	198,20
ADP (mln USD)	786,70	869,40	920,10	963,30	970,70	918,00

The results of calculation are obtained in the following production function of the information economy of Azerbaijan:

$$ADP = 74.01 * Inv^{0.16} * Emp^{0.84}$$

As seen from the production function, the main factor affecting the growth of value added was human resources with an elasticity factor of 0.84.

9.3. Conclusion

The proposed approach to defining the development level of the information economy provides an opportunity to assess the levels of resources such as human capital, information and communication technologies, and technological progress in the country. It also offers the possibility to optimize the structure of investments in the information sector of the economy.

References

1. Porat, M. (1998). The Information Economy: Definition and Measurement. In *Elsevier eBooks* (pp. 101-131). https://doi.org/10.1016/b978-0-7506-7058-6.50012-0

2. Fishlar, A., & Machlup, F. (1964). The Production and Distribution of Knowledge in the United States. *Southern Economic Journal*, 30(4), 372. https://doi.org/10.2307/1055322

3. Organisation for Economic Cooperation and Development. (n. d.). *OECD Data Explorer*. https://data-explorer.oecd.org/

4 US Census Bureau. (2017). *Data releases*. Census.gov. https://www.census.gov/programs-surveys/acs/news/data-releases.2017.html#list-tab-1133175109

5. Si, Y. (2001). *Information industry*. Chongqing Publishing Company.

6. Leontief, W. W. (1966). *Input-output economics*. http://documents.irevues.inist.fr/bitstream/2042/29465/1/CNE-CNAM_consultation.pdf

7. World Bank. (n. d.). *World Bank Group - International Development, Poverty and Sustainability*. https://www.worldbank.org/kam

8.WIPO, Cornell University, INSEAD. (2015). Global Innovation Index 2015. *www.wipo.int*. https://doi.org/10.34667/tind.28212

9.Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 20(1), 87-96. https://doi.org/10.1016/s0165-0114(86)80034-3

10. Wang, J. Q., & Li, J. J. (2009). The multi-criteria group decision making method based on multi-granularity intuitionistic two semantics. *Science And Technology Information*, 33, 8-9.

11. Li, L. (2016). A new entropy-based intuitionistic fuzzy multi-attribute decision making method. *American Journal Of Applied Mathematics*, 4(6), 277. https://doi.org/10.11648/j.ajam.20160406.13

12. Sun, C., Jiao, H., & Ren, Y. (2014). Regional Informatization and Economic Growth in Japan: An Empirical Study Based on Spatial Econometric Analysis. *Sustainability*, 6(10), 7121-7141. https://doi.org/10.3390/su6107121

13. *The State Statistical Committee of the Republic of Azerbaijan*. (n. d.). https://www.stat.gov.az/?lang=en

10. ASSESSMENT OF DEVELOPMENT RESOURCES IN NEW SECTOR OF THE NATIONAL ECONOMY

10.1. Introduction

Today, the information economy is one of the most important sectors of the world economy. The famous Spanish sociologist, Professor Manuel Castells, notes that "A new economy emerged in the last quarter of the twentieth century on a worldwide scale. I call it informational, global, and networked to identify its fundamental distinctive features and to emphasize their intertwining. It is informational because the productivity and competitiveness of units or agents in this economy (be it firms, regions, or nations) fundamentally depend upon their capacity to generate, process, and apply efficiently knowledge-based information." [1]

The OECD defines two categories of products and services in the information economy [3]:

- **ICT Products and Services:** (Computers and peripheral equipment, communication equipment, consumer electronic equipment, miscellaneous ICT components and goods, manufacturing services for ICT equipment, business and productivity software and licensing services, information technology consultancy and services, telecommunication services, leasing or rental services for ICT equipment, and other ICT services).

- **Content and Media Products and Services:** (Printed and other text-based content on physical media and related services, motion picture, video, television, and radio content and related services, music content and related services, games software, online content and related services, and other content and related services).

The value added of the global ICT share in GDP in 2015 was 4.3% [2].

The main development resources of the information economy are human capital, knowledge, and technology.

Human capital is one of the main factors driving the development of the socio-economic system. The fundamental concept of human capital theory was proposed by American economists and Nobel Prize laureates Schultz [4] and Becker [5]. According to a definition from experts of the Organization for Economic Cooperation and Development (OECD), human capital is regarded as "the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social, and economic well-being" [6].

Cornell University, INSEAD, and the World Intellectual Property Organization have proposed indicators for measuring human capital, knowledge, and technology [7]. According to these measures, human capital is expressed by the levels of education, tertiary education, and research and development:

1.1. Education (ED) encompasses the following indicators:

- 1.1.1. Government Expenditure on Education (% of GDP) - EED;
- 1.1.2. Government Expenditure on Education per person, secondary (% of GDP per capita) – GEE;
- 1.1.3. School-life expectancy, primary to tertiary education (years) – SLE;
- 1.1.4. Assessment in reading, mathematics, and science – RMS;
- 1.1.5. Pupil-teacher ratio, secondary – PTS;

1.2. Tertiary Education (TE) includes the following indicators:

- 1.2.1. School enrollment, tertiary (% of GDP) - TEN;
- 1.2.2. Tertiary graduates in science, engineering, manufacturing, and construction (% of total tertiary graduates) - GSE;
- 1.2.3. Tertiary inbound mobility ratio (%) - TIM;

1.3. Research and Development (R&D) includes the following indicators:

- 1.3.1. Researchers, full-time equivalence (FTE) (per million population) – RES;
- 1.3.2. Gross expenditure on R&D (% of GDP) – ERD;
- 1.3.3. Average expenditure of the top 3 global companies on R&D, mln. USD – RDC;

1.3.4. Average score of the top 3 universities in the QS (world university ranking) world university ranking – URT.

Knowledge is a major resource of technological innovation. The standard R&D-related measures do not necessarily reflect successful implementation or the amount and quality of outputs. Nevertheless, these input and flow indicators form the starting point for measuring knowledge outputs and for gauging social and private rates of return on knowledge investments. Rough indicators have been developed to translate certain knowledge inputs into knowledge outputs, which describe and compare the economic performance of countries. These measures tend to categorize industrial sectors or parts of the workforce as more or less intensive in R&D, knowledge, or information. The measures are based on the assumption that certain knowledge-intensive sectors play a key role in the long-run performance of countries by producing spill-over benefits, providing high-skill and high-wage employment, and generating higher returns to capital and labor [8].

Knowledge and technology outputs are expressed by the following indicators and sub-indices:

2.1. Knowledge Creation (KNC):

2.1.1. Patent applications by origin - PAO;

2.1.2. PCT international applications by origin - PCT;

2.1.3. Utility model applications by origin - MAO;

2.1.4. Scientific and technical publications - STP;

2.1.5. Citable documents H-index - CDH;

2.2. Knowledge Impact (KNI):

2.2.1. Growth rate of GDP per person engaged - GRR;

2.2.2. New business density - NBD;

2.2.3. Total computer software spending - SOF;

2.2.4. ISO 9001 quality certificates - ISO;

2.2.5. High-tech and medium-high-tech output - HTO;

2.3. Knowledge Diffusion (KND):

2.3.1. Intellectual property receipts - IPR;

2.3.2. High-tech exports - HTE;

2.3.3. ICT services exports - ICE;

2.3.4. Foreign direct investment net outflows – FDI;

To measure the volume of information economy products, M. Porat proposes the value added calculated by means of the Leontief input-output model [9]. Along with this, World Bank experts have proposed the Knowledge Economy Index [10], which is calculated based on the economic and institutional regime, education and skills, information and communication infrastructure, and innovation system.

In this part, using intuitionistic fuzzy logic instruments and DEMATEL methods, we analyzed the impact level of indicators' sub-indices on the development level of the information economy.

10.2. Database processing

In order to find out the impact level of resources to development of information sector, by applying the instruments of intuitionis tic fuzzy logic and DEMATEL methods, the indicators of sub-indices "human capital" and "knowledge and technology" were studied in the report [7] which are chosen as database in the current work. In that report, indicators, indices and sub-indices were developed for 127 countries of the world. In order to fuzzify these indicators, instruments of intuitionistic fuzzy logic are used. Every indicator of each country is divided into three triangle fuzzy number: low (L), medium (M), high (H). For example, for sub-index of "researches and development" index it will be equal to L = [12.29; 2815.19], M = [2704.8; 5617.8], and H = [5397.5; 8255]. On the base of crisp meaning "Researches per million of population", which equal to 1605, membership degree is defined as [11]:

The triangular curve is a function of vector x, and depends on three scalar parameters a, b, and c, as given by:

$$\mu' = \frac{c-x}{c-b} = \frac{2815.19 - 1605}{2815.19 - 1414.01} = 0.86 \qquad (10.1)$$

On the base of the meaning and degree of consistency proposed by Hersh [12], the hesitancy was defined by the coefficient π. In our case, π = 0.1. Then, by using the following equation [11] intuitionistic fuzzy membership (μ) and non-membership degree (ν) were defined:

$$\mu = \mu' * (1 - \pi) = 0.86 * (1 - 0.1) = 0.77$$
$$\nu = 1 - \mu - \pi = 1 - 0.77 - 0.1 = 0.13 \tag{10.2}$$

Thus, intuitionistic fuzzy number corresponding to indicator "Researches per million of population" of ED sub-index equals to (0.77, 0.13, 0.1). The values as intuitionistic fuzzy numbers of other indicators of sub-indices are defined by the same procedure and demonstrated in table 10.1. Then calculating processes were carried out by using DEMATEL method [13].

Table 10.1. Intuitionistic fuzzy number values of indicators

Indices	Sub-indices	Indicators	L	M	H	Azerbaijan (IFS)
HC&R (Human capital and research)	ED	EED	[1.1;6.76]	[6.5;12.41]	[11.92;17.7]	2.46 (0.03;0.17;0.8)
		GEE	[5.1;27.64]	[26.6;49.5]	[48.1;71.1]	20.1 (0.47;0.23;0.3)
		SLE	[5.32;10.57]	[10.15;15.7]	[15.09;20.43]	12.64 (0.97; 0.03; 0)
		RMS	[336;427.9]	[411.1;512.5]	[492.45;587.5]	340 (0.01;0.09;0.9)
		PTS	[7.25;28.9]	[27.7;50.4]	[48.4;70.4]	9 (0.03;0.17;0.8)
	TE	TEN	[0.8;38.0]	[36.27;75.18]	[72.23;110.16]	23.16 (0.16;0.64;0.2)
		GSE	[2.64;18.35]	[17.63;34.0]	[32.67;48.69]	22.02 (0.264;0.236;0.5)
		TIM	[0.03;13.81]	[13.27;27.59]	[26.51;40.56]	2.25 (0.1;0.2;0.7)
	R&D	RES	[12.29;2815.19]	[2704.8;5617.9]	[5593.5;8255.4]	1605 (0.77;0.13;0.1)
		ERD	[0.04;1.49]	[1.43;2.93]	[2.81;4.29]	0.21 (0.05;0.15;0.8)
		RDC	[0;2483.6]	[2386.2;4967.2]	[4772.4;7304.7]	0.00 (0;0;1)
		URT	[0;33.7]	[32.37;67.38]	[64.74;99.19]	18.63 (0.81;0.09;0.1)
Knowledge and technology outputs	Know. Creation	PAO	[0.02;15.08]	[14.48;30.13]	[28.95;44.3]	1.24 (0.03;0.17;0.8)
		PCT	[0.01;3.11]	[2.99;6.21]	[5.97;9.13]	0.01 (0;0;1)
		MAO	[0.02;16.14]	[15.5;32.25]	[30.99;47.6]	0.14 (0;0;1)
		STP	[0.62;22.47]	[21.59;44.31]	[42.57;64.85]	2.63 (0.04;0.16;0.8)
		CDH	[23;360.77]	[346.63;698.1]	[670.7;1015.1]	58 (0.044;0.155;0.8)
	Know. Impact	GRR	[-8.08;-2.72]	[-2.84;2.57]	[2.47;7.81]	1.33 (0.79;0.11;0.1)
		NBD	[0.03;10.66]	[10.24;21.29]	[20.45;31.3]	0.99 (0.144;0.656;0.2)
		SOF	[0.11;0.44]	[0.42;0.77]	[0.74;1.07]	0.06 (0;0;1)
		ISO	[0.17;27.02]	[25.96;53.87]	[51.75;79.12]	1.47 (0.01;0.09;0.9)
		HTO	[0.87;24.13]	[23.19;47.38]	[45.52;69.25]	10.36 (0.65;0.15;0.2)
	Know. diffusion	IPR	[0.0;1.07]	[1.03;2.14]	[2.06;3.16]	0.00 (0;0;1)
		HTE	[0.04;9.56]	[9.8;19.07]	[18.33;28.02]	0.13 (0;0;1)
		ICE	[0.04;3.54]	[3.4;7.04]	[6.76;10.33]	0.49 (0.077,0.223,0.7)
		FDI	[-5.91;14.15]	[13.59;34.32]	[32.98;53.43]	2.64 (0.09;0.211,0.7)

According to stages of computing by methods of DEMATEL, the matrix of factor relation was constructed.

For this purpose, intuitionistic fuzzy Hamming distance equation was applied [14]:

$$d_{ij} = \frac{1}{2}\left(\left|\mu_i - \mu_j\right| + \left|\nu_i - \nu_j\right| + \left|\pi_i - \pi_j\right|\right) \tag{10.3}$$

Then, factor relation matrix L was constructed by using formula

$$L = \begin{pmatrix} 0.00 & 0.47 & 0.90 & 0.04 \\ 0.47 & 0.00 & 0.20 & 0.76 \\ 0.90 & 0.20 & 0.00 & 0.90 \\ 0.04 & 0.76 & 0.90 & 0.00 \end{pmatrix} \tag{10.4}$$

For the normalization of the factor relation matrix L, coefficient of normalization λ was defined:

$$\lambda = \frac{1}{max\left[\left(\sum_i d_{ij}\right), \left(\sum_j d_{ji}\right)\right]} = \frac{1}{max[(1.41,1.43,2.00,1.70)(1.41,1.43,2.00,1.70)]} = \frac{1}{2} = 0.5 \tag{10.5}$$

By means of the value λ total influence matrix D was defined:

$$D = \lambda * L = \begin{pmatrix} 0.000 & 0.235 & 0.450 & 0.020 \\ 0.235 & 0.000 & 0.100 & 0.380 \\ 0.450 & 0.100 & 0.000 & 0.450 \\ 0.020 & 0.380 & 0.450 & 0.000 \end{pmatrix} \tag{10.6}$$

On the base of matrix D, complex influence matrix T was defined:

$$T = D(I - D)^{-1} = \begin{pmatrix} 0.900 & 0.990 & 1.430 & 1.060 \\ 0.992 & 0.827 & 1.190 & 1.249 \\ 1.430 & 1.190 & 1.482 & 1.596 \\ 1.060 & 1.250 & 1.587 & 1.216 \end{pmatrix} \tag{10.7}$$

In the next stage, sums of rows and columns of matrix T were obtained:

$$R_i = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} \quad (i = 1, \dots, n) \tag{10.8}$$

$$C_i = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \quad (j = 1, \dots, n) \tag{10.9}$$

The value R_i indicates the total given both directly and indirectly effects, that factor i has on the other factors. The value of C_j shows the total received both directly and indirectly effects, that all other factors j. If $j = i$, the value of $(R_i + C_j)$ represent the total effects both given and received by factor i. In contrast, the value of $(R_i - C_j)$ shows net contribution by factor i on the system. Moreover, when $(R_i - C_j)$ is positive, factor i is a net cause. When $(R_i - C_j)$ is negative, factor i becomes a net receiver.

Obtained results of total relation for indicators of sub-indices "researches and development" were given in table 10.2. For other sub-indices, the results were indicated in Tables 10.3, 10.4.

For corresponding sub-indices, cause and effect relationship diagram is built and demonstrated in diagrams 10.1, 10.2, 10.3.

The cause-and-effect diagram is constructed by mapping all coordinate sets of $(R_i + C_j, R_i - C_j)$ to visualize the complex interrelationship and provide information to judge which are the most important factors and how influence affected factors. The factors that t_{ij} is greater than (α), are selected in cause-and-effect diagram.

10.3. Analysis of cause-effect relationship

In order to define impact level of internal factors, a threshold value (α) is calculated. The threshold value (α) was computed by the average of the elements in matrix T, as given in:

$$\alpha = \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} t_{ij}}{N} \tag{10.10}$$

Where, N is total number of the elements in matrix T.

This calculation aimed to eliminate some minor effects elements in matrix T. (Yang et al., 2008) α (R&D)=1.22, α (KNC)=0.59,

α (TED)=1.51, α (KNI)=1.29,

α (EDU)=0.38, α (KND)=8.19,

The numbers above the threshold value in tables are indicated by (*).

Table 10.2. Total relation indicators of researches and development

	RES	ERD	RDC	URT	R_i	C_J	$R_i + C_J$	$R_i - C_J$
RES	0.9	0.99	1.43	1.06	4.38	4.382	8.762	-0.002
ERD	0.992	0.827	1.19	1.249	4.258	4.257	8.515	0.001
RDC	1.43	1.19	1.482	1.596	5.698	5.699	11.397	0.001
URT	1.06	1.25	1.597	1.216	5.123	5.121	10.244	0.002

In Table 10.2, maximum value is $R_i + C_j$ = 11.397and minimum is -8.515. Therefore, the results of priority indicators of these sub-indices are: *RDC > URT > RES > ERD*

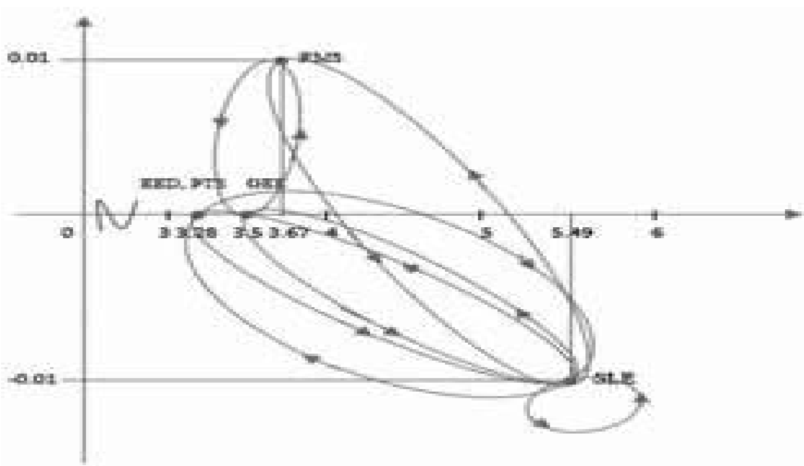


Figure 10.1. Diagram of indicators ED

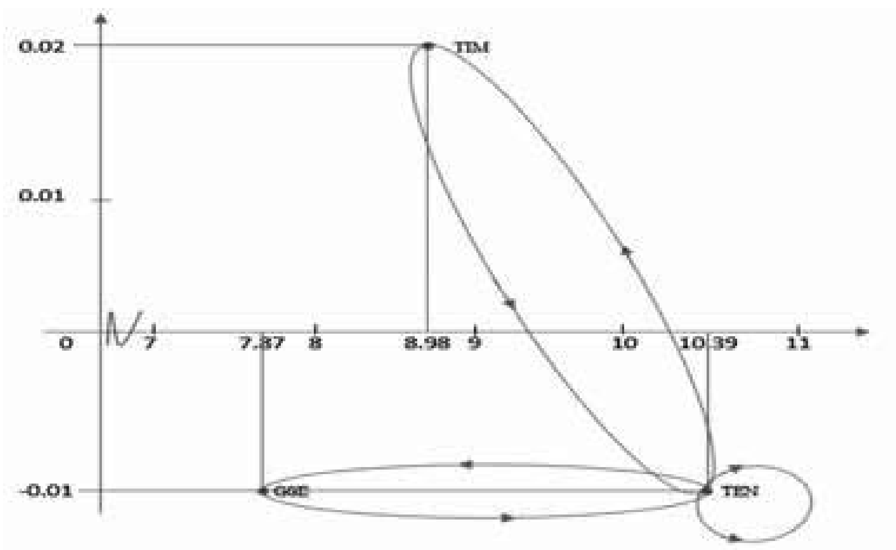
As it is seen from Figure 10.1, the cause group criteria consist of Assessment in Reading Mathematics and Science (RMS), Government Expenditure on Education (EED), Pupil-teacher ratio (PTS), Government Expenditure on Education per people, secondary (GEE). The effect group criteria are School-life expectancy, primary to tertiary education (SLE). The cause group criteria refer to the implication of the influencing criteria, while the effect group criteria refer to the implication of the influenced criteria. Considering the interdependence among factors, much attention should be paid to the cause group criteria related to their influence on the effect group criteria.

Table 10.3. Total relation indicators of tertiary education

	TEN	GSE	TIM	R_i	C_J	$R_i + C_J$	$R_i - C_J$
TEN	1.73	1.61	1.85	5.19	5.2	10.39	-0.01
GSE	1.61	1	1.32	3.93	3.94	7.87	-0.01
TIM	1.86	1.33	1.31	4.5	4.48	8.96	0.02

In Table 10.3 maximum Tertiary Enrollment (TEN) Tertiary inbound mobilitygraduates in science and engineering (GSE).

Figure 10.2 shows that cause group criteria are Tertiary Inbound Mobility ratio (TIM), and the effect group criteria consist of Tertiary graduates in Science, Engineering, manufacturing and construction (GSE) and Tertiary School Enrollment (TEN).



SLE > RMS > GEE > EED, PTS

Figure 10.2. Diagram of indicators TE

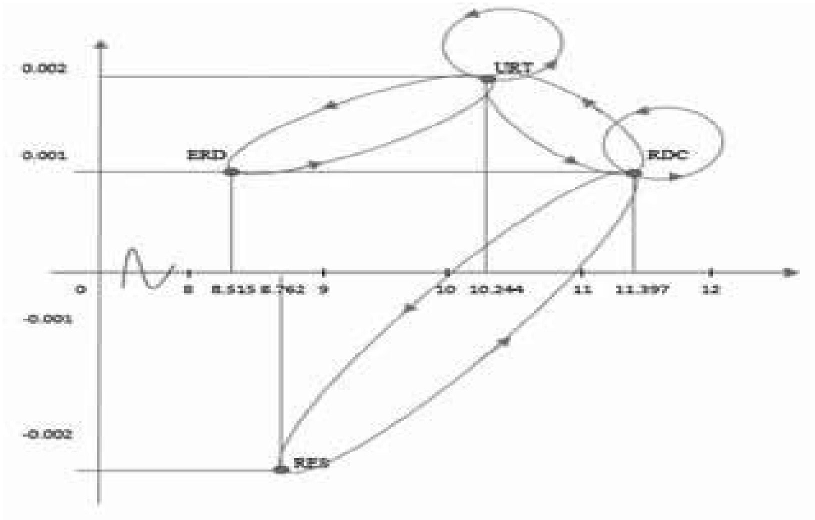


Figure 10.3. Diagram of indicators R&D

The results shows that School Life Expectancy (SLE) is greater than Assessment in Reading, Mathematics and Science (RMS), RMS is greater than Government Expenditure on Education per Pupil, secondary (GEE), and GEE is greater than Expenditure on Education (EED), and Pupil-Teacher Ratio, secondary (PTS), respectively.

Table 10.4. Total relation indicators of education

	EED	GEE	SLE	RMS	PTS	R_i	C_j	$R_i + C_j$	$R_i - C_j$
EED	0.23	0.34	0.56	0.28	0.23	1.64	1.64	3.28	0
GEE	0.34	0.23	0.45	0.39	0.34	1.75	1.75	3.5	0
SLE	0.56	0.45	0.57	0.6	0.56	2.74	2.75	5.49	-0.01
RMS	0.28	0.39	0.61	0.28	0.28	1.84	1.83	3.67	0.01
PTS	0.23	0.34	0.56	0.28	0.23	1.64	1.64	3.28	0

Figure 10.3 demonstrates that the cause group criteria include Average score of the top 3 universities at the QS (URT), Gross Expenditure on R&D (ERD), Average Expenditure of the top 3 global companies by R&D (RDS), and effect group criteria - Researches, full-time equivalence (RES).

Table 10.4. Total relation indicators of knowledge diffusion

	IRP	HTE	ICE	FDI	R_i	C_j	$R_i + C_j$	$R_i - C_j$
IRP	7.8	7.8	8.32	8.32	32.24	32.2	64.44	0.04
HTE	7.8	7.8	8.32	8.32	32.24	32.2	64.44	0.04
ICE	8.3	8.3	8.31	8.36	33.27	33.31	66.58	-0.04
FDI	8.3	8.3	8.36	8.31	33.27	33.31	66.58	-0.04

ICT service exports, foreign direct investment net outflows is greater than intellectual property receipts and high-tech exports.

Figure 10.3 shows that cause group criteria are Intellectual Property Receipts (IRP), High-Tech Exports (HTE), second effect group criteria- ICT Service Exports (ICE), Foreign Direct Investment net outflows (FDI).

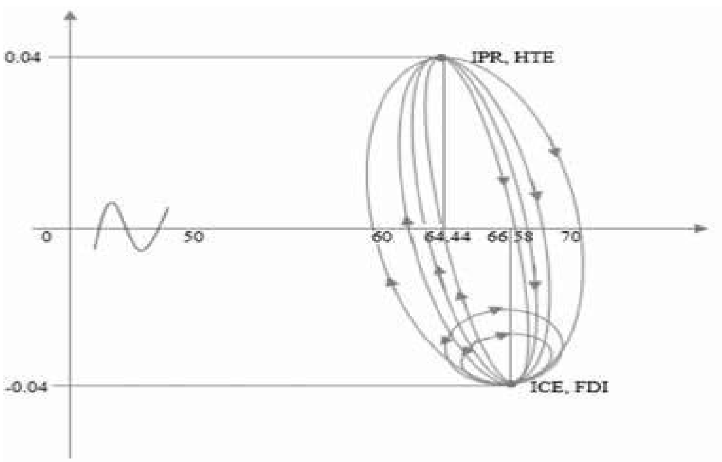


Figure 10.4. Diagram of indicators

10.4. Conclusion

The application of intuitionistic fuzzy instruments and DEMATEL methods for assessing the impact level of indicators' sub-indices, which formulate "human capital" and "knowledge and technology" as development resources of the information economy, provides a clear framework for determining the optimal direction of investments towards specific subsectors. This approach enables a more targeted allocation of resources, ensuring that investments are channeled into areas that will most effectively enhance the growth and development of the information economy. By understanding the interrelationships and influence levels among these sub-indices, decision-makers can prioritize investment strategies that maximize the overall impact on the economy's informational and technological advancements.

References

1. Castells, M. (2009). *The Rise of the Network Society*. https://doi.org/10.1002/9781444319514

2. Information Economy Report 2017. (2017). *UN Trade And Development (UNCTAD)*, 111. https://unctad.org/publication/information-economy-report-2017

3. Information Economy Product Definitions Based on the Central Product Classification (version 2). (2009). *OECD Digital Economy Papers*. https://doi.org/10.1787/222222056845

4. Schultz, T. W. (1961). Investment in Human Capital. *The American Economic Review*, 51(1), 1-17. https://www.jstor.org/stable/1818907.

5. Becker, G. S. (1962). Investment in Human Capital: A Theoretical Analysis. *Journal Of Political Economy*, 70(5, Part 2), 9-49. https://doi.org/10.1086/258724

6. OECD. (2001). *The Well-being of Nations: The Role of Human and Social Capital*. OECD Publishing, Paris, https://doi.org/10.1787/9789264189515-en.

7. Cornell University, INSEAD, & WIPO. (2017). *The Global Innovation Index 2017: Innovation Feeding the World, Ithaca, Fontainebleau, and Geneva*. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2017.pdf

8. OECD. (1996). The knowledge-based economy. Paris OECD. *Scientific Research Publishing*, 46. https://www.scirp.org/reference/referencespapers?referenceid=951528

11. ASSESSMENT HUMANISM IN NATIONAL SUSTAINABLE DEVELOPMENT

11.1. Introduction

Humanism is a progressive philosophy of life that, without supernaturalism, affirms our ability and responsibility to lead ethical lives of personal fulfillment that aspire to the greater good of humanity. The life stance of Humanism—guided by reason, inspired by compassion, and informed by experience—encourages us to live life well and fully. It evolved through the ages and continues to develop through the efforts of thoughtful people who recognize that values and ideals, however carefully wrought, are subject to change as our knowledge and understanding advance [1].

In September 2015, the General Assembly of the United Nations (UN) adopted the 2030 Agenda for Sustainable Development, including 17 Sustainable Development Goals (SDG, 2015). The distinctive feature of the Sustainable Development Goals is their comprehensive, universal, and deeply humanistic character. Let us conditionally classify the 17 Goals into the following groups. Please see SDG (2015) or the text later below for full wording of the Goals: Primary needs of humans (2. Food, 3. Health, 6. Water, and 7. Energy); Equality between humans (1. No poverty, 4. Education, 5. Gender equality, and 10. Reduced inequalities); Efficient, sustainable production (8. Economic growth, 9. Innovative industry, 12. Responsible consumption and production, 13. Climate action); Landscapes in danger (11. Cities, 14. Life in water, and 15. Life on land); Worldwide cooperation (16. Peace and justice and 17. Partnerships). "Through the adoption of the SDGs, the world is trying to create a new humanism [2]. A new humanism is a universal vision open to the whole human community and encompassing every contingent in order to give a new impetus to solidarity, to unite people, and to awaken their conscience."

In order to define the quality of humanism in national sustainable development, indices for quality of life, human capital, and ecocivilization were proposed.

11.2. Quality of life index

The Economist Intelligence Unit has developed a Quality of Life Index (QLI) based on a unique methodology that links the results of subjective life-satisfaction surveys [3]. The Quality of Life Index is described by the following nine factors:

1. **Material Wellbeing**
   GDP per person, at PPP in $.
2. **Health**
   Life expectancy at birth, in years.
3. **Political Stability and Security**
   Political stability and security ratings.
4. **Family Life**
   Divorce rate (per 1,000 population), converted into an index from 1 (lowest divorce rates) to 5 (highest).
5. **Community Life**
   Dummy variable taking the value of 1 if a country has either a high rate of church attendance or trade union membership; zero otherwise.
6. **Climate and Geography**
   Latitude, to distinguish between warmer and colder climates.
7. **Job Security**
   Unemployment rate, in %.
8. **Political Freedom**
   Average of indices of political and civil liberties. Scale of 1 (completely free) to 7 (unfree).
9. **Gender Equality**
   Ratio of average male and female earnings, based on the latest available data.

Using statistical information from international organizations and statistical indicators of Azerbaijan for the years 2010-2016, Table 11.1 was constructed.

Table 11.1. Quality of life factors data for Azerbaijan

	2010	2011	2012	2013	2014	2015	2016
Material wellbeing	4753.0	5752.9	5966.1	6258.3	6268.0	5706.6	6266.3
Health	73.6	73.8	73.9	74.2	74.2	75.2	75.2
Political stability and security	-0.24	-0.53	-0.72	-0.41	-0.56	-0.73	-0.87
Family life	1.0	1.2	1.2	1.3	1.3	1.3	1.4
Community life	1.0	1.0	1.0	1.0	1.0	1.0	0.99
Climate and geography	22.9	25.4	26.1	22.1	25.6	22.1	22.3
Job security	5.6	5.4	5.2	5.0	4.9	5.0	5.0
Political freedom	5.5	5.5	5.5	5.5	6.0	6.0	6.5
Gender equality	0,89	2,09	2,14	2,13	1.95	1,96	2,13

In order to define the Quality of Life Index, instruments of intuitionistic fuzzy linguistic sets were used. For this purpose, in the first stage, the data provided in Table 11.1 were normalized using the following formula:

$$Y = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{11.1}$$

Results are given in table 11.2:

Table 11.2. Normalized data

	2010	2011	2012	2013	2014	2015	2016
Material wellbeing	0	0,66	0,8007	0,9936	1	0,6294	0,9989
Health	0	0,125	0,1875	0,375	0,375	1	1

Cont…

Political stability and security	1	0,5397	0,2381	0,7302	0,4921	0,2222	0
Family life	0	0,5	0,5	0,75	0,75	0,75	1
Community life	1	1	1	1	1	1	0
Climate and geography	0,2	0,825	1	0	0,875	0	0,05
Job security	1	0,7143	0,4286	0,1429	0	0,1429	0,1429
Political freedom	0	0	0	0	0,5	0,5	1
Gender equality	0	0,96	1	0,992	0,848	0,856	0,992

In second stage were defined linguistic terms, which demonstrated in Table 11.3.

Table 11.3. Linguistic terms

	L	M	H
Material wellbeing	0-0.34	0.327-0.68	0.647-1
Health	0-0.34	0.327-0.68	0.647-1
Political stability and security	0-0.34	0.327-0.68	0.647-1
Family life	0-0.34	0.327-0.68	0.647-1
Community life	0-0.34	0.327-0.68	0.647-1
Climate and geography	0-0.34	0.327-0.68	0.647-1
Job security	0-0.34	0.327-0.68	0.647-1
Political freedom	0-0.34	0.327-0.68	0.647-1

On the base of information given in Table 11.2 and we calculated parameters of intuitionistic linguistic fuzzy numbers, which demonstrated in table 11.4.

Table 11.4. Intuitionistic linguistic fuzzy numbers

	2010	2011	2012	2013	2014	2015	2016
Material wellbeing	(0,1,0)L	(0.09, 0.898, 0.011) M	(0.904,0.022,0.074)H	(0.027,0.96,0.003)H	(0,1,0)H	(0.23,0.714,0.055)M	(0,1,0)H
Health	(0,1,0)L	(0.588, 0.27, 0.1414) L	(0.718,0.191,0.09)L	(0.232,0.75,0.013)M	(0.232,0.75,0.013)M	(0,1,0)H	(0,1,0)H
Political stability and security	(0,1,0)H	(0.633, 0.288, 0.08)M	(0.48,0.46,0.06)L	(0.377,0.575,0.047)H	(0.75,0.156,0.094)M	(0.555,0.375,0.07) L	(0,1,0)L
Family life	(0,1,0)L	(0.786,0.115,0.099)M	(0.786,0.115,0.099)M	(0.468,0.473,0.059)H	(0.468,0.473,0.059)H	(0.468,0.473,0.059)H	(0,1,0)H
Community life	(0,1,0)H	(0,1,0)H	(0,1,0)H	(0,1,0)H	(0,1,0)H	(0,1,0)H	(0,1,0)H
Climate and geography	(0.69,0.259,0.08)L	(0.791,0.11,0.099)H	(0,1,0)H	(0,1,0)L	(0.565,0.364,0.07)H	(0,1,0)L	(0.235,0.735,0.03)L
Job security	(0,1,0)H	(0.305,0.657,0.038)H	(0.459,0.483,0.058)M	(0.573,0.243,0.084)L	(0,1,0)L	(0.573,0.243,0.084)L	(0.573,0.243,0.084)L
Political freedom	(0,1,0)L	(0,1,0)L	(0,1,0)L	(0,1,0)L	(0.786,0.115,0.099)M	(0.786,0.115,0.099)M	(0,1,0)H
Gender equality	(0,1,0)L	(0.181,0.797,0.02)H	(0,1,0)H	(0.036,0.959,0.005)H	(0.687,0.227,0.086)H	(0.651,0.268,0.08)H	(0.036,0.959,0.005)H

Then, the weights of k-th quality of life indicators in t-years were obtained by applying following formula [4]:

$$\lambda_k = \frac{(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right))}{\sum_{k=1}^{l}(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right)} \qquad (11.2)$$

$$\sum_{k=1}^{l}\lambda_k = 1$$

Table 11.5. Weights of indicators

	2010	2011	2012	2013	2014	2015	2016
Material wellbeing	0 (L)	0,017 (M)	0,525 (H)	0,014 (H)	0 (H)	0,055 (M)	0 (H)
Health	0 (L)	0,170 (L)	0,141 (L)	0,118 (M)	0,047 (M)	0 (H)	0 (H)
Political stability and security	0(H)	0,154 (M)	0,072 (L)	0,203 (H)	0,238 (M)	0,146 (L)	0 (L)
Family life	0 (L)	0,278 (M)	0,195 (M)	0,263 (H)	0,104 (H)	0,117 (H)	0 (H)
Community life	0(H)	0(H)	0(H)	0(H)	0(H)	0(H)	0(H)
Climate and geography	1 (L)	0,285 (H)	0 (H)	0 (L)	0,134 (H)	0 (L)	0,233 (L)
Job security	0 (H)	0,061 (H)	0,068 (M)	0,385 (L)	0 (L)	0,171 (L)	0,733 (L)
Political freedom	0 (L)	0 (L)	0 (L)	0 (L)	0,290 (M)	0,324 (M)	0 (H)
Gender equality	0 (L)	0,035 (H)	0 (H)	0,018 (H)	0,188 (H)	0,187 (H)	0,034 (H)
$\sum \lambda_i$	1	1	1	1	1	1	1

In order to calculate Aggregated Quality of Life Index for each year, intuitionistic linguistic weighted average operator developed by J. Wang and H. Li [5] was used:

$$\boldsymbol{AQLI} = \langle S_{\sum_{k=1}^{t} \lambda_k \theta\left(a_{ij}^{k}\right),} (1 - \prod_{k=1}^{t} (1 - \mu\left(a_{ij}^{k}\right))^{\lambda_k,} \prod_{k=1}^{t} (\nu\left(a_{ij}^{k}\right))^{\lambda_k} \rangle \qquad (11.3)$$

As results of computing of Aggregated Quality of Life Index, we got:

AQLI (2010) =low;	**AQLI (2014)=high;**
AQLI (2011) =middle:	**AQLI (2015)=middle;**
AQLI (2012) =low;	**AQLI (2016)=low;**
AQLI (2013) =middle;	

11.3. Human Capital

One of the main factors of the sustainable development of a country is national human capital. Cornell University, INSEAD, and the World Intellectual Property Organization have proposed indicators for measuring Human Capital, knowledge, and technology [6]. According to these measures, Human Capital is expressed by the level of Education, Tertiary education, and Research and Development:

Education (ED) encompasses the following indicators:

1.1.1 Government Expenditure on Education (% of GDP) - EED;

1.1.2 Government Expenditure on Education per person, secondary (% of GDP per capita) – GEE;

1.1.3 School-life expectancy, primary to tertiary education (years) – SLE;

1.1.4 Assessment in reading, mathematics, and science – RMS;

1.1.5 Pupil-teacher ratio, secondary – PTS;

Tertiary education (TE) includes the following indicators:

1.2.1 School enrollment, tertiary (% of GDP) - TEN;

1.2.2 Tertiary graduates in science, engineering, manufacturing, and construction (% of total tertiary graduates) - GSE;

1.2.3 Tertiary inbound mobility ratio (%) - TIM;

Research and development (R&D) includes the following indicators:

1.3.1 Researchers, full-time equivalence (FTE) (per million population) – RES;

1.3.2 Gross expenditure on R&D (% of GDP) – ERD;

1.3.3 Average expenditure of the top 3 global companies by R&D, mln. $ USD – RDC;

1.3.4 Average score of the top 3 universities at the QS (world university ranking) – URT.

To define the quality of national human capital, methods of intuitionistic linguistic sets were used, as described in the previous section of the paper. The results of the computation demonstrated the following:

National Human Capital Index:

NHCI (2012) = $\langle S_{1.09}\,(0.69{,}0.19)\rangle$; **NHCI (2015)** = $\langle S_{1.12}\,(0.61{,}0.31)\rangle$;

NHCI (2013) = $\langle S_{1.1}\,(0.65{,}0.24)\rangle$; **NHCI (2016)** = $\langle S_{1.22}\,(0.60{,}0.32)\rangle$;

NHCI (2014) = $\langle S_{1.12}\,(0.62{,}0.31)\rangle$; **NHCI (2017)** = $\langle S_{1.13}\,(0.52{,}0.42)\rangle$;

All values of the linguistic index for NHCI were slightly above one, i.e., between Low and Middle. The smallest value for the linguistic index was obtained for 2012, and the maximum value was reached in 2016. A comparative analysis showed that in 2012, the factors of TEN (university enrollment) and URT (3 universities) had the maximum weights in the formation of NHCI, while RES (researchers) and PTS (pupil/teacher ratio) had the minimum weights. In 2016, the largest weights were found in the indicators SLE (expected duration of education), URT (3 universities), and GEE (government expenditure on education). Notably, the value of the weight for URT remained stable at a high level throughout the period. However, RES (researchers) and PTS (pupil/teacher ratio), which had minimal weights during the study period, showed a noticeable effect with a small increase in their values, as their weights increased by 2.86 and 3.86 times, respectively, from 2012 to 2016.

11.4. Ecological Civilization Index

Sustainable development as a notion tacitly conceives the economy as something separate from nature that needs to be managed to avoid too much damage to the environment, allowing nature to continue being exploited.

The notion of ecological civilization views this orientation to nature, as something separate from humans, as the fundamental problem underlying ecological destruction. It calls for cultural and social transformation to overcome this way of thinking, now embodied in and reproduced by our dominant institutions. This transformation involves a fundamental rethinking of ethics, politics, and technoscience based on process metaphysics, articulated through the science of ecology. It requires such a fundamental change in how people think about these topics that it is necessary to invoke resources provided by transculturalism [7].

The Ecocivilization Index (ECI) can characterize the degree of readiness of a country or particular region for a transition to a new society where prosperity is achieved in harmony with the surrounding environment. In an ecocivilized society, humans are part of the biosphere, as provided by the concept of the UNESCO MaB Program [8]. The ECI is a multi-component indicator, and various indicators influence the level of this Index. With the support of this indicator, the readiness of various elements influencing the transition to ecocivilization can be assessed. This means that along with obtaining general information, the ECI can increase efficiency and accelerate the transition processes by influencing significant factors. Eight subsystems—(1) demographic indicators, (2) consumption patterns, (3) green economy, (4) biodynamic agriculture and organic food, (5) health, (6) education, science, new technologies, (7) poverty, and (8) legal environment—have been suggested for ECI calculation. The specified subsystems involve a number of parameters.

More detailed characteristics of the subsystems are given below:

1. *Demography*

As mentioned, the volumes of industrial and agricultural production, as well as the quantity and spectrum of delivered goods and services, depend primarily on the number of people for whom these goods and services are produced. Population growth, along with an increase in average life span, automatically increases production volumes in industry, agriculture, and services, resulting in increased pressure on the environment. Therefore, the indicators characterizing the dynamics of demographic processes are used to assess this subsystem. Indicators such as the level of fertility, annual population growth, population density, age structure, and others have been mobilized.

2. *Consumption*

Along with the population size and demographic structure of society, consumption levels significantly influence industrial and agricultural production volumes and the characteristics of provided services. Resource mobilization and environmental pressure are directly connected with consumption levels. Growth in extensive consumption, typical of consumer societies, leads to intensive resource mobilization and environmental contamination. The transition to an ecological civilization requires not only technological progress but also the formation of a new culture of consumption and a fundamentally new behavioral stereotype. Eliminating consumption inequality, which is currently observed in many societies, is also necessary for the transition to ecological civilization. Therefore, this subsystem is assessed based on parameters such as energy consumption per capita, GDP per unit, and the Gini Index, which assesses income distribution in society. A new parameter, "transition to green fashion," has been introduced by the authors of this paper. This indicator reflects the voluntary refusal of society members to engage in excessive consumption.

3. *Transition to an ecologized economy*

This subsystem requires the use of "green" technologies and manufacturing processes in industry and transport. A number of indicators are used to assess this component of the subsystem. These include GDP per unit of energy, the share of renewable energy in the overall energy balance, greenhouse gas emissions per capita and per GDP unit, biosphere reserves, national parks and other protected areas as a share of national territory, the number of vehicles per 1,000 population, the share of public transportation, and others.

4. *Ecologized agriculture, food and forage processing*

For assessment of this subsystem, indicators such as the share of biodynamic and organic agriculture and the share of organic food in the market have been mobilized.

5. *Health*

It is known that average life span has increased considerably during the last decades. Several indicators are used to assess this subsystem, including life expectancy, expenditures on public health services as a percent of GDP, and the consumption level of antimutagens, anticarcinogens, and geroprotectors.

6. ***Education, science and new technologies***

Indicators for this subsystem include research and development expenditures as a percent of GDP, expenditures on education as a percent of GDP, tertiary students in science, mathematics, and engineering as a percent of tertiary students, and the state of education on sustainable development at secondary and tertiary levels.

7. *Poverty*

This subsystem has been assessed using indicators such as the Human Poverty Index for a country or territory, access to improved water supply and sanitation systems (as a percent of the total population), and the proportion of the population below the poverty line. International statistics were used for this assessment.

8. *Legislative environment and management policy*

This subsystem has been assessed based on indicators such as ratification of environmental treaties, commitments to environmentally sustainable management, and state programs and projects on environmental and renewable resource management.

The Ecological Civilization Index (ECI) was estimated using the fuzzy inference method proposed by E.H. Mamdani [9]. The results of the calculations are as follows:

ECI= 0.632 (above an average)

Table 11.6. Eight key indicators

Subsystems	Indices
Energy consumption	0.815 – high
Organic agriculture	0.495 – average
Demography	0.655 – above average
Health	0.495 – average
Education, science, new technologies	0.655 – above average
Poverty	0.655 – above average
Legal environment	0.655 – above average
Green economy	0.334– low

11.5. Conclusion

The findings from this study provide a multifaceted understanding of the quality of life, human capital, and ecological civilization in Azerbaijan, all of which are essential components of sustainable development. The comprehensive assessment provided by these indices not only underscores the interconnectivity between human capital, quality of life, and ecological sustainability but also offers valuable insights for policymakers. By identifying the strengths and weaknesses within these domains, Azerbaijan can better strategize its development plans to ensure balanced and sustainable growth. The proposed methodology, with its emphasis on intuitionistic fuzzy linguistic sets and multi-dimensional analysis, provides a robust framework that can be adapted by other nations seeking to evaluate and enhance their sustainable development trajectories.

Overall, the continuous monitoring and enhancement of these indices are critical for fostering a more inclusive, innovative, and ecologically balanced society. As Azerbaijan continues to develop, integrating these insights into national policy-making will be key to achieving long-term sustainability and improving the overall quality of life for its citizens. The methodology and results presented in this study serve as a foundation for future research and policy initiatives aimed at fostering a more humanistic and sustainable development model.

References

1. *Humanism and Its Aspirations: Humanist Manifesto III, a Successor to the Humanist Manifesto of 1933 - American Humanist Association.* (2018). American Humanist Association. https://americanhumanist.org/what-is-humanism/manifesto3/

2. Mika, J. (2016). Challenges For Meteorology In The Sustainable Development Goals (2015-2030). *DOAJ (DOAJ: Directory Of Open Access Journals)*. https://doi.org/10.17378/awc2016_01

3. The Economist Intelligence Unit's quality-of-life index. (2005). In *https://www.economist.com*. The World. https://www.economist.com/media/pdf/quality_of_life.pdf

4. Boran, F. E., Genç, S., Kurt, M., & Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems With Applications*, 36(8), 11363-11368. https://doi.org/10.1016/j.eswa.2009.03.039

5. Wang, J.Q., & Li, H.B. (2010). Multi-criteria decision-making method based on aggregation operators for intuitionistic linguistic fuzzy numbers. *Control Decis*, 25, 1571-1574.

6. Cornell University, INSEAD, & WIPO. (2015). *The Global Innovation Index 2015: Effective Innovation Policies for Development*. https://www.wipo.int/edocs/pubdocs/en/wipo_pub_gii_2015.pdf

7. Gare, A. (2017). From 'Sustainable Development' to 'Ecological Civilization': Winning the War for Survival. *Cosmos and History: The Journal of Natural and Social Philosophy*, 13(3), 130–153. https://cosmosandhistory.org/index.php/journal/article/view/656

8. Alakbarov, U., & Imanov, G. (2011) Ecological civilization index: concept and first implementation. *Proceedings of the "Man and Biosphere" MaB, (UNESCO), Azerbaijan National Committee, Ecological civilization, sustainable development, environment, annual edition*, 7, 5-14.

9. Mamdani, N. (1977). Application of Fuzzy Logic to Approximate Reasoning Using Linguistic Synthesis. *IEEE Transactions On Computers*, 26(12), 1182-1191. https://doi.org/10.1109/tc.1977.1674779

10. Porat, M. (1977). *The information economy: definition and measurement*. Palo Alto: US Department of Commerce. https://eric.ed.gov/?id=ED142205

11. World Bank Institute (Ed.). (2008). *Measuring Knowledge in the World's Economies: Knowledge Assessment and Knowledge Economy Index. Knowledge for Development Program*. https://estadisticas.pr/files/BibliotecaVirtual/estadisticas/biblioteca/BM/BM_KAM_2008.pdf

12. Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 20(1), 87-96. https://doi.org/10.1016/s0165-0114(86)80034-3

13. Hersh, M. (2006). Mathematical Modelling for Sustainable Development. *Environmental engineering*. https://doi.org/10.1007/3-540-31224-2

14. Gan, J., & Luo, L. (2017). Using DEMATEL and Intuitionistic Fuzzy Sets to Identify Critical Factors Influencing the Recycling Rate of End-Of-Life Vehicles in China. *Sustainability*, 9(10), 1873. https://doi.org/10.3390/su9101873

15. Szmidt, E., & Kacprzyk, J. (2000). Distances between intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 114(3), 505-518. https://doi.org/10.1016/s0165-0114(98)00244-9

12. FUZZY ESTIMATION OF A COUNTRY'S EXPORT SOPHISTICATION LEVEL

12.1. Introduction

Economic complexity can be defined as the composition of a country's productive output and represents the structures that emerge to hold and combine knowledge [1]. **The sophistication (complexity)** level of the country's **exports** depends upon its own characteristics of **economic complexity.** Complexity economics is the study of economic systems as complex systems [2]. Analyses of socioeconomic development require taking into account the principles of economic complexity. In analyzing the structure of the export basket, it is necessary to investigate the level of export sophistication. A country's economic structural transformation achievement can be measured by its export sophistication [3]. Hausmann et al. [4] developed an indicator of a country's export sophistication that is measured by the associated income level of all products in this country's export basket. This is the so-called "EXPY." It differs from traditional predefined classifications of products' technology levels (e.g., manufactures are more sophisticated than agricultural products) because EXPY is an outcome-based indicator that classifies the technology level based on empirical calculation [5]. The underlying rationale is that a particular kind of product embodies a certain level of technology and human capital. Such embodied technology and human capital can be reflected by the income level of countries that export this product. Products mainly exported by rich countries tend to embody higher technology levels and more human capital, and specializing in such products leads to promising growth. Development can then be seen as a process of latching on to products associated with higher income levels, which is also a process of accumulating new production capabilities [6].

12.2. Estimation of EXPY and PRODY

The first step in calculating EXPY is to construct the weighted average income level associated with each product, which is known as PRODY:

$$PRODY_k = \sum_i \left\{ \frac{\left(\frac{x_i^k}{X_i}\right)}{\sum_i \left(\frac{x_i^k}{X_i}\right)} Y_i \right\} \tag{12.1}$$

Where, Y_i represents the GDP per capita of country i, x_i^k equals the export value of product k by country i, and X_i is equal to total export value of country i. The numerator is the share of product k in the country's total exports, and the denominator is the sum of this share across all countries exporting product k. The weight of GDP per capita is simply each country's revealed comparative advantage (RCA) in this product. Therefore, PRODY is the average GDP per capita of all exporting countries, weighted by each country's RCA. It is important to note that the RCA used as a weight in PRODY is different from the classical RCA by B. Balassa [7], because RCA in PRODY has been normalized to make the sum of the weights equal to one.
Then, the EXPY of country i is calculated as:

$$EXPY_i = \sum_k \frac{x_i^k}{X_i} PRODY_k \tag{12.2}$$

A country's EXPY is the average of PRODY values of all its exported products, weighted by the share of each product in this country's export basket. Importantly, each product's annual PRODY values during a given period are averaged to generate a single static PRODY for that product, and a country's annual EXPY is calculated based on these static PRODY values, giving each product a constant associated income level. The fixed value of PRODY implies that any change in EXPY is due to changes in the export structure of this country, rather than changes in GDP per capita of other exporting countries.

The construction of PRODY and EXPY requires data on countries' annual export values for each product category and their GDP per capita.

In this paper, using elements of intuitionistic fuzzy linguistic theory, we will attempt to construct an aggregation index for defining the export sophistication level. In the calculation process, we will use the export basket information of Azerbaijan for 2010-2017, as demonstrated in Table 12.1.

Table 12.1. Structure of the Export Basket: World vs. Azerbaijan

	Merchandise exports $ millions		Food % of total		Agricultural raw materials % of total		Fuels % of total		Ores and metals % of total		Manufactures % of total	
	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017	2010	2017
Azerbaijan	26.476	15.800	2.8	4.8	0.1	0.3	94.5	90.1	0.1	1.4	2.5	3.4
World	15.402.601	17.820.129	8.0	10.1	1.6	1.7	15.4	12.0	4.7	5.2	66.2	66.8

Source: World Development Indicators

12.3. Structure of merchandise exports

Firstly, to fuzzify export indicators, the Revealed Comparative Advantage (RCA) index is defined. The RCA is an index developed by B. Balassa in 1965 to measure comparative advantage in commodity exports. It is widely used by international organizations such as the World Bank. The RCA is calculated using Equation 12.3 below:

$$RCA_{ij} = \frac{x_{ij} / \sum_j x_{ij}}{\sum_j x_{ij} / \sum_j \sum^j \ x_{ij}} \qquad (12.3)$$

Where RCA_{ij} is the revealed comparative advantage of country i in commodity j; X_{ij} is the exports of commodity j from country i; $\Sigma_i X_{ij}$ is the total exports of country i; $\Sigma_j\, x_{ij}$ is the world exports of commodity j, and $\Sigma_j\, \Sigma^j X_{ij}$ is total world exports of commodities.

An RCA value greater than 1 indicates that a country has a comparative advantage in a product if its exports of that product are larger than what would be expected based on the size of the country's export economy and the product's global market.

Taking into account the RCA values of export products, as shown in Table 12.2., we divided linguistic terms into four variables within the interval [0.02; 10]:

Low (L) = (0.02; 0.51)

Middle (M) = (0.49; 1.02)

High (H) = (0.98; 5.1)

Very high (VH) = (4.9; 10)

Based on Table 12.1 and Attanasov's function [8], we defined the membership and non-membership functions for the export indicators:

$$\mu_{\tilde{x}}(x) = \begin{cases} \frac{u_{\tilde{x}}(x-\underline{t})}{t-\underline{t}} & if\ \underline{t} \le x < t \\ u_{\tilde{x}} & if\ x = t \\ \frac{u_{\tilde{x}}(\overline{t}-x)}{\overline{t}-t} & if t < x \le \overline{t} \\ 0 & if\ x < \underline{t}\ or\ x > \overline{t} \end{cases} \tag{12.4}$$

$$\nu_{\tilde{x}}(x) = \begin{cases} \frac{[t-x+w_{\tilde{x}}(x-\underline{t})]}{t-\underline{t}} & if\ \underline{t} \le x < t \\ w_{\tilde{x}} & if\ x = t \\ \frac{[x-t+w_{\tilde{x}}(\overline{t}-x)]}{\overline{t}-t} & if\ t < x \le \overline{t} \\ 1 & if\ x < \underline{t}\ or\ x > \overline{t} \end{cases} \tag{12.5}$$

For calculating membership - and non-membership - functions we used reduction coefficients which account for the accuracy of the statistical information. The results of the calculations for the membership, non-membership degree and linguistic indices are presented in table 12.2.

Table 12.2. RCA indicators

Products	RCA	
	2010	2017
Food	0.35	0.475
Agricultural	0.0625	0.176
Fuels	6.136	7.51
Ores metal	0.021	0.269
Manufacture	0.0378	0.051

Table 12.3. Intuitionistic fuzzy linguistic parameters

Products	2010				2017			
	S_{ϑ}	μ	ν	π	S_{ϑ}	μ	ν	π
Food	1	0,525	0,412	0,063	1	0,114	0,871	0,0146
Agricultural	1	0,139	0,844	0,017	1	0,509	0,427	0,65
Fuels	4	0,388	0,564	0,048	4	0,781	0,121	0,098
Ores metal	1	0,003	0,996	0,001	1	0,787	0,115	0,098
Manufacture	1	0,058	0,935	0,007	1	0,101	0,886	0,013

Next, we calculate the weights of the export indicators using the following equation. The weights for the k-th export indicator in year t is then obtained by applying the equation provided in [9]:

$$\lambda_k = \frac{(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right))}{\sum_{k=1}^{l}(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right)} \qquad (12.6)$$

$$\sum_{k=1}^{l} \lambda_k = 1$$

Table 12.4. Weights of export indicators

Products	2010	2017
	λ_k	λ_k
Food	0,492281996	0,032024687
Agricultural	0,115327734	0,332048556
Fuel	0,342422504	0,390544363
Ores	0,002442392	0,217067957
Manufacture	0,047525374	0,028314438
$\sum_{k=1}^{5} \lambda_k$	1	1

In order to calculate Aggregate Index of Export Sophistication (**AIES**) for 2010 and 2017 year, intuitionistic linguistic weighted average (**ILWA**) indicator developed by J. Wang and H. Li [10] is used:

$$\boldsymbol{ILWA} = \langle S_{\sum_{k=1}^{t}\lambda_k\theta\left(a_{ij}^{k}\right)}, (1-\prod_{k=1}^{t}(1-\mu\left(a_{ij}^{k}\right))^{\lambda_k}, \prod_{k=1}^{t}(\nu\left(a_{ij}^{k}\right))^{\lambda_k}\rangle \qquad (12.7)$$

AIES (2010) = $\langle S_{2.03};0.426,0.519\rangle$

AIES (2017) = $\langle S2.172;0.69,0.205\rangle$

The results of the computation indicate that the level of export sophistication for Azerbaijan in 2010 and 2017 was higher than the middle level, with an improvement in export sophistication observed in 2017 compared to 2010. However, this investigation is insufficient for a comprehensive analysis of export sophistication. For a thorough investigation, it is essential to analyze the diversification level of production.

Based on the input-output balance of Azerbaijan for 2011, covering 19 industries, and using the fuzzy DEMATEL method, key industry sectors affecting economic growth have been identified. The results of this analysis are detailed in paper [11]. As shown in paper [11], which presents the results of the Input-Output balance matrix for 2011 with 19 economic sectors, the leading sectors are manufacturing, mining, construction, transportation, finance and insurance, and agriculture.

12.4. Conclusions

The analysis of Azerbaijan's export sophistication reveals notable progress between 2010 and 2017. The data indicate an improvement in export sophistication levels, moving beyond the middle level in 2017. This upward trend suggests that Azerbaijan's export sector has become more competitive and sophisticated over time. However, this assessment alone does not provide a complete picture of the country's economic dynamics.

For a thorough evaluation of export sophistication, it is crucial to consider the diversification of production. The investigation, based on the input-output balance of Azerbaijan for 2011 and employing the fuzzy DEMATEL method, highlights key industry sectors that significantly influence economic growth. These sectors include manufacturing, mining, construction, transportation, finance and insurance, and agriculture. This analysis underscores the importance of a diversified economic base in enhancing export sophistication and overall economic development.

Further research, as indicated in previous studies by international economic organizations such as UNDP, the World Bank, and Chemonics International, underscores the potential for growth in agriculture, agro-industry, and the service sectors. These sectors present opportunities for diversification and should be strategically developed to support sustained economic advancement.

In conclusion, while Azerbaijan has made progress in export sophistication, a more comprehensive analysis that includes production diversification is essential. By focusing on key sectors and leveraging the identified potential areas for growth, Azerbaijan can further enhance its economic performance and export competitiveness. Future research should continue to explore these dimensions to provide a more holistic understanding of the country's economic landscape.

References

1. Erkan, B., & Yildirimci, E. (2015). Economic Complexity and Export Competitiveness: The Case of Turkey. *Procedia - Social And Behavioral Sciences*, 195, 524-533. https://doi.org/10.1016/j.sbspro.2015.06.262

2. Arthur, W. B. (1999). Complexity and the Economy. *Science*, 284(5411), 107-109. https://doi.org/10.1126/science.284.5411.107

3. Hausmann, R., & Klinger, B. (2006). Structural Transformation and Patterns of Comparative Advantage in the Product Space. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.939646

4. Hausmann, R., Hwang, J., & Rodrik, D. (2005). What you export matters. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.896243

5. Klinger, B. (2009). Is South-South Trade a Testing Ground for Structural Transformation? *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1457043

6. Andreoni, A. (2011). Productive Capabilities Indicators for Industrial Policy Design. *UNIDO Working Paper Series*. https://eprints.soas.ac.uk/19235/

7. Balassa, B. (1965). Trade Liberalisation and "Revealed" Comparative Advantage. *Manchester School*, 33(2), 99-123. https://doi.org/10.1111/j.1467-9957.1965.tb00050.x

8. Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 20(1), 87-96. https://doi.org/10.1016/s0165-0114(86)80034-3

9.Boran, F. E., Genç, S., Kurt, M., & Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems With Applications*, 36(8), 11363-11368. https://doi.org/10.1016/j.eswa.2009.03.039

10. Wang, J. Q., & Li, J. J. (2009). The multi-criteria group decision making method based on multi-granularity intuitionistic two semantics. *Science And Technology Information*, 33, 8-9.

11. Imanov, G. (2015). Oil prices and economic diversification problem of Azerbaijan. *Ciencia y realidades economicas: reto del mundo post-crisis a la actividad investigadora*, 57-72.

12. Hajiyev, N. U., &. Almas, L. (2013). Azerbaijan's Current and Potential Comparative Advantage: An Exploratory Study. ideas.repec.org. https://ideas.repec.org/p/ekd/004912/5501.html

13. *Azerbaijan - Agricultural markets study: realizing Azerbaijan's comparative advantages in Agriculture.* (2005). World Bank. https://documents.worldbank.org/en/publication/documents-reports/documentdetail/198631468207847565/azerbaijan-agricultural-markets-study-realizing-azerbaijans-comparative-advantages-in-agriculture

14. Stryker, J. D. (2009). Domestic Resource Cost Analysis of Azerbaijan. Final Report. In *USAID*. https://pdf.usaid.gov/pdf_docs/Pnadt149.pdf

13. MODELS FOR THE ASSESSMENT OF EMIGRATION FACTORS

13.1. Introduction

Due to the complexity of human life and rapidly changing socio-economic conditions, migration is becoming increasingly important every day. Migration is one of the most challenging issues for every country and society. It is the process of population displacement both within a country and across borders, with the aim of permanent or temporary residence. To distinguish migration from short-term movements, a one-year threshold has been established. Short-term visits like family visits, holidays, etc., are not considered migration. There is one exception to this rule: if a migrant has left their country of origin at least three months ago and is currently living abroad, they are considered a migrant since it is still unknown whether they will stay there for at least a year [1].

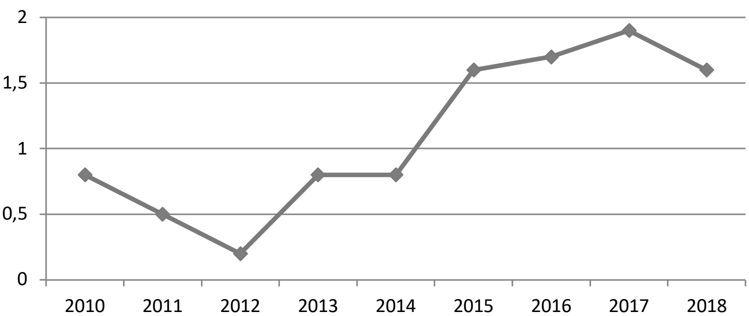
There are two types of migration: immigration and emigration. **Immigration**, one of the most commonly used terms, is defined as moving to a different country with the purpose of permanently living there. **Emigration**, on the other hand, refers to leaving one's home country to settle in another country. One of the major reasons people emigrate is to improve their quality of life or increase their employment opportunities. Emigration has both positive and negative impacts on the economies of the countries that people choose as their new permanent home.

13.2. Analysis of the problem

Different investigations have analyzed various factors influencing migration. For example, reference [2] examines political, economic, and social factors, while [3] investigates seven factors including GDP per capita, unemployment rate, demographic factors (total population and young male population), level of corruption, and enrollment in tertiary education. In study [4], the factors influencing transborder migration in Azerbaijan were determined. This study analyzed annual data of 11 explanatory variables, including economic, social, health, and educational factors, for the period from 1995 to 2015, using the Multivariate Adaptive Regression Splines (MARS) method.

This paper investigates the factors affecting the emigration process in Azerbaijan. To analyze emigration in Azerbaijan, we consider the results of three previous studies [5, 6, 7], which analyzed economic, social, and ecological factors using intuitionistic linguistic fuzzy numbers. Figure 13.1 shows the number of emigrants in Azerbaijan from 2010 to 2018.

Figure 13.1. Number of emigrants from Azerbaijan (thousand people).



Source: State Statistical Committee of Azerbaijan

As can be seen from Figure 13.1, the number of emigrants from Azerbaijan in 2017 increased by 8.44 times compared to 2012. This surge was primarily due to the economic and social situation in the country. The level of macroeconomic stability [5] in the republic declined from a stable level to low stability during this period. The inflation rate rose from 1% in 2012 to 12.9% in 2017. The main destinations for emigrants from Azerbaijan were Kazakhstan (474 people) and Russia (970 people). According to the UN High Commissioner for Refugees, there are currently 1,125 foreign migrants in Azerbaijan.

More than half of those with migrant status are 636 people with Afghan citizenship, followed by 388 Russian citizens of Chechen nationality. Additionally, there are 44 Iranian migrants in Azerbaijan, 15 from Pakistan and Syria each, 1 Turkish citizen, and 26 citizens from other countries.

In addition to individuals with migrant status, 886 people are registered with the mission claiming the need for international guardianship and trusteeship: Of these, 547 are citizens of Afghanistan, 135 from Pakistan, 37 from Turkey, 35 from Syria, 30 from Russia, 25 from Iran, and 77 citizens from other countries.

The economic factors considered [5] include: Gross Domestic Product (growth rate); Inflation %; Interest rate %; National debt relative to GDP %; Budget Deficit (% of GDP); Exchange rate; Current account balance (% of GDP); Unemployment rate %; and Foreign external investment (growth rate).

The social factors of emigration include: unemployment rate, life expectancy at birth, GINI coefficient, R&D expenditures, poverty level, and military expenditure.

The ecological factors of emigration include: air quality index, water quality index, land quality index, and expenditure on environmental protection.

To estimate the quality of macroeconomic, social, and ecological factors, the Intuitionistic Linguistic Weighted Average (ILWA) method was used:

$$\boldsymbol{ILWA} = \langle S_{\sum_{k=1}^{t}\lambda_k\theta\left(a_{ij}^k\right)}, (1-\prod_{k=1}^{t}(1-\mu\left(a_{ij}^k\right))^{\lambda_k}, \prod_{k=1}^{t}(\nu\left(a_{ij}^k\right))^{\lambda_k}\rangle \qquad (13.1)$$

And weight- of k-th macroeconomic indicators in t-years obtained by using following equation:

$$w_k = \frac{(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right))}{\sum_{k=1}^{l}(\mu_k + \pi_k\left(\frac{\mu_k}{\nu_k}\right)} \qquad (13.2)$$

$$\sum_{k=1}^{l} w_k = 1$$

As a result of the investigation in [5], the following findings were obtained:

Macroeconomic stability index:

AIMS (2010) = $\langle S_{2.1}$ (0.71,0.22)$\rangle$ – Stable;

AIMS (2011) = $\langle S_{2.4}$ (0.60,0.33)$\rangle$ – Stable;

AIMS (2012) = ⟨$S_{2.2}$ (0.74,0.19)⟩ – Stable;

AIMS (2013) = ⟨$S_{2.3}$ (0.76,0.14)⟩ – Stable;

AIMS (2014) = ⟨$S_{2.2}$ (0.74,0.13)⟩ – Stable;

AIMS (2015) = ⟨$S_{1.6}$ (0.75,0.15)⟩ – Low stable;

AIMS (2016) = ⟨$S_{1.3}$ (0.78,0.13)⟩ – Low stable;

As seen from the results of the calculation, macroeconomic stability was satisfactory from 2010 to 2014, but in 2015-2016, the level of macroeconomic stability was low.

Fluctuations and a decrease in the Growth Rate of Gross Domestic Product (GGD) from high stability (S_3)) in 2010 to an instability level (S_0) in 2016 can be largely attributed to changes in oil sector costs due to the global financial crisis. The change in oil prices in the world market impacted GDP growth, as the oil sector holds a significant share of Azerbaijan's GDP. Thus, the sharp decline in oil prices since the end of 2014 led to a decrease in the oil sector's contribution to GDP. The fact that the devaluation was not offset by a noticeable increase in the non-oil sector within a short time contributed to GDP instability.

High oil revenues in the country led to an increase in currency reserves, and fluctuations in inflation can be mainly linked to the monetary policy governed by the Central Bank. To ensure and diversify economic stability, a monetary policy regulating inflation rates was implemented. In 2013–2014, as a consequence of this policy, high stability in the inflation rate was achieved. However, in subsequent years, the financial crisis resulted in a decline in the national currency's value. As a result, continued economic stability could not be maintained through regulated monetary policy alone, leading to a transition to a floating exchange rate, which caused inflation rate fluctuations and instability.

During the oil boom that continued until 2015, the main factor driving economic growth was oil revenues. Loans were primarily focused on households (44% of credits in 2014), trade (15%), and construction (14%), sectors that are non-commercial and heavily dependent on oil revenues. The industrial sector accounted for only 10% of the credit portfolio of banks. Therefore, the role of the interest rate (INR) in economic growth during this period was minimal, and linking high economic growth to the interest rate is incorrect. The decline in the interest rate from S_3 to S_1 in 2015–2016 is associated with the reduced role of oil in this period.

The transition of the national debt to GDP ratio (NAD) from a low stability level () in 2010 to a high stability level in 2011 was due to increased oil production, foreign currency inflows, and a relative increase in the national currency (exchange rate - EXR). However, the decline to instability () from 2012 to 2016 was linked to a consistent decrease in oil production. The high stability level in 2016 can be attributed to a decrease in indebtedness and an increase in gas production.

The high stability level (S_3) of the budget deficit (DEF) was primarily due to transfers to the State Budget by the Oil Fund.

The macroeconomic stability level (S_2) of the exchange rate (EXR) in 2010–2014 was a major factor in keeping the national currency (manat) stable during this period. The transition to a low stability level (S_1) and instability level (S_0) can be explained by the sharp decline in oil prices in the world market and the subsequent depreciation of the manat.

The rise in the current account balance (CAB) from a medium stability level (S_2) in 2010 to a high stability level (S_2) in 2011 was related to an increase in the positive saldo of CAB from 15.0 billion U.S. dollars to 17.1 billion U.S. dollars. Due to the replacement of the positive saldo with a negative one in 2015–2016 (0.2 billion and 1.4 billion U.S. dollars, respectively) related to the significant decline in crude oil prices in the world market, its stability level decreased from high stability (S_3) in 2014 to medium stability (S_2) in 2015.

The unemployment rate (UNE) remained stable at around 5% and maintained a high stability level (S_3) during 2010–2016. State programs aimed at ensuring social-economic development in the regions, creating new workplaces, and developing the non-oil sector played a significant role in maintaining the high stability level observed in the unemployment rate.

The stability level of the foreign investment growth rate (FDI) remained stable at a medium stability level (S_2) during 2010–2016. This is associated with the high level and dynamic growth of foreign direct investments. These were 3.5 billion U.S. dollars in 2010, 4.4 billion U.S. dollars in 2011, 5.3 billion U.S. dollars in 2012, 6.3 billion U.S. dollars in 2013, 7.5 billion U.S. dollars in 2014, 7.5 billion U.S. dollars in 2015, and 7.4 billion U.S. dollars in 2016. During 2010–2016, the level of migration increased by 2.1 times.

The Fuzzy estimation of the Social Security Index (FASS) [6] yielded the following results:

***FASS(2007)*=** ⟨2.39;0.937;0.034;0.029⟩ – Green-Yellow

FASS (2008)= ⟨2.005;0.85;0.087;0.06⟩ – Yellow

FASS (2009)= ⟨2.138;0.72;0.21;0.06⟩ – Yellow

FASS (2014)= ⟨2.71;0.78;0.146;0.07⟩ – Yellow-Green

FASS (2015)= ⟨2.172;0.875;0.085;0.04⟩ – Yellow

FASS (2016)= ⟨1.98;0.4;0.49;0.1⟩ – Yellow-Orange

As shown by the results of the calculation, the level of social security in the second period improved and was higher than in the first period. The indicators of poverty level significantly influenced the situation. In the first period, the poverty level was in the red zone - S_r = 1,3, but in the second period, it improved to the yellow zone S_y = 3. The value of the Gini coefficient was in the orange zone - S_o = 2, during the first period, and it improved to the yellow zone - S_y = 3 in the second period. The level of Research & Development (R&D) expenditures decreased from green - S_g = 3 to red - S_r = 0. The level of unemployment remained unchanged in both periods, staying in the yellow zone - S_e = 2. Life expectancy at birth was in the green zone S_g in both periods. According to Figure 13.1, from 2014 to 2016, the level of emigration increased by more than two times. This indicates that a decrease in the level of social security influences the level of migration.

According to [7], to address the issue of defining the Ecological Security Index, the **Pressure-State-Response** (PSR) concept is used. **The Pressure subsystem** includes: population density (people per km² of land area), population growth rate, oil and gas production (thousand manats), and the number of cars. **The State subsystem** includes: carbon dioxide (CO_2) emissions (thousand tons), nitric oxide (N_2O) emissions (thousand tons), methane (CH_4) emissions (thousand tons), air-polluting emissions from transportation (thousand tons), soil erosion (hectares), pollutants released into the atmosphere (thousand tons), and the emission of polluted water through wastewater (million manats). **The Response subsystem** includes: national parks (km²), investment in ecological protection (thousand manats), investment in science (thousand manats), and the share of energy supply from renewable energy in the total amount of energy supply.

With this in mind, we have established and placed in Table 13.1 a system of indicators that describe the PSR concept for Azerbaijan during the period of 2010-2015. The values of sub-indices and aggregate indices of ecological security for the years 2010-2015 are provided in Table 13.1.

Table 13.1. Values of linguistic variables of the Ecological Security Index for 2010-2015 years

	2010	2011	2012	2013	2014	2015	2016
Pressure	VL	H	H	VH	H	H	H
State	H	H	H	H	H	L	H
Response	L	L	H	H	H	H	H
AESI	VL- L	L- H	H-VH	H-VH	H	L- H	H

Table 13.1. shows that in 2010 and 2011, the level of ecological security was low, and the number of emigrants was also low. In contrast, in 2014 and 2015, the ecological security index was very high, and the number of emigrants was also very high.

As shown in Figure 13.1, the number of emigrants from Azerbaijan during the period of 2014-2016 increased by more than two times. Using the migration data and the results of studies on macroeconomic stability, social security, and ecological security for the years 2014-2016, we attempt to determine the relationship between these indicators (Figure 13.2).

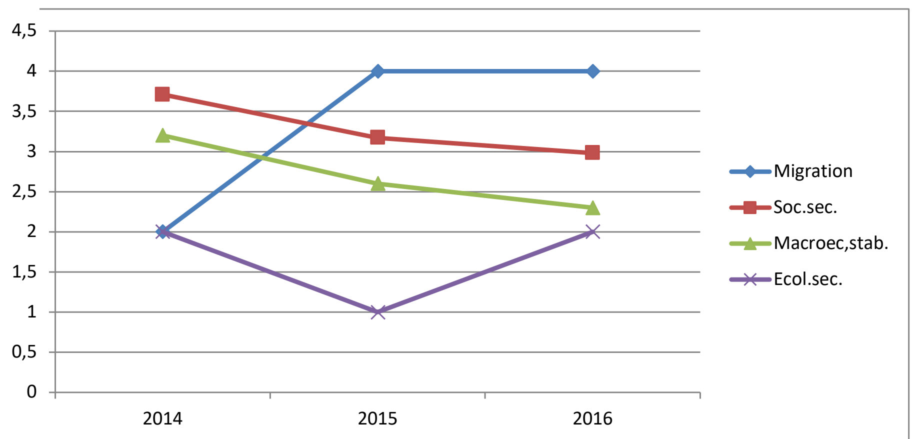


Figure 13.2. Graphic linguistic variables assigned to factors of migration

As shown in Figure 13.1., the number of emigrants from Azerbaijan began to increase in 2015 and reached its maximum level in 2017. The number of emigrants in 2017 amounted to 1,900 people, which is 9.5 times more than in 2012. This process was influenced by a decrease in macroeconomic stability in the country during 2015-2016. It is important to note that during this period, social indicators such as "Unemployment" were at the "Yellow Level," indicating an average level. The level of ecological security fluctuated between low and high during the analyzed period.

When categorizing the number of migrants into linguistic subsets, we use data for the entire period (2010-2018) in the following manner: the minimum amount is 0.2 thousand for 2012, and the maximum amount is 1.9 thousand people. Let us assume that within the interval [0.2; 2], we want to describe the migration indicators using four linguistic variables, which are defined in the intervals: [0.2; 0.65], [0.65; 1.1], [1.1; 1.55], and [1.55; 2]. These intervals, as they increase, have the following linguistic labels: Low – 1; Middle – 2; High – 3; Very High – 4.

We want to analyze the migration process during 2014-2018 by comparing the dynamics of this indicator with the previously analyzed dynamics of three macroeconomic indices: Social Security Index, Macroeconomic Stability, and Ecological Security for these years (Table 13.1). In order to compile a single table for comparing the indices of these indicators, it is necessary to standardize them to a uniform scale relative to boundary values. For example, the values of the Social Security Index in the period of 2014-2016 were 3.71, 3.172, and 2.98, respectively. These values fall into the linguistic sets VH (Very High), H (High), and H (High), respectively.

Table 13.2. Values of linguistic variables factors of emigration

	Migration	Social security	Macroeconomic stability	Ecological security
2014	2 (Middle-2)	3,71 (Very High-4)	3,2 (High-3)	2 (Middle-2)
2015	4 (Very High-4)	3,172(High-3)	2,6 (High-3)	1 (Low-1)
2016	4 (Very High-4)	2,98 (High-3)	2,3 (Middle-2)	2 (Middle-2)

For better understanding, let us build a chart where migration dynamics are shown alongside the other three variables.

Judging by the chart, the value of migration during these years increased from "High" (H) to "Very High" (VH) while the other two indexes (Social Security and Macroeconomic Stability) declined. During this period, Ecological Security indicators increased from "Low" to "Middle."

13.3. Conclusion

The findings of this study underscore the significant relationship between economic, social, and environmental factors and the level of emigration from Azerbaijan. Specifically, the analysis revealed that fluctuations in macroeconomic stability, social security, and ecological security have a direct impact on migration patterns. The interplay between these factors suggests that migration is a multifaceted phenomenon influenced by a combination of economic, social, and environmental conditions. As economic stability declined and social security weakened, the pressures on individuals to seek better opportunities abroad intensified. Even improvements in ecological security could not counterbalance the adverse effects of economic and social challenges.

Moreover, this study highlights the need for a comprehensive and integrated approach to migration management. By considering the interconnections between economic, social, and environmental factors, policymakers can develop more effective strategies to influence migration patterns and enhance the overall well-being of the population.

In conclusion, the relationship between economic, social, and environmental factors and emigration is complex and dynamic. Addressing these factors in a holistic manner is essential for creating a stable and prosperous society that retains its citizens and offers them opportunities for growth and development within the country.

References

1. European Commission: Eurostat. (2000). *Push and pull factors of international migration: A comparative report*. Publications Office.
2. Trpkova-Nestorovska, M. (2019). *Factors of emigration: analysis of countries from the European Union*. Repository Of UKIM. https://repository.ukim.mk/handle/20.500.12188/2937
3. Lanau, G. (2019). *Migration drivers: Why do people migrate?* Le Portail de Référence Pour L'espace de Liberté, Sécurité Et Justice. https://www.eu-logos.org/2019/05/31/migration-drivers-why-do-people-migrate/
4. Yüksel, S., Mukhtarov, S., Mahmudlu, C., Mikayilov, J., & Iskandarov, A. (2018). Measuring International Migration in Azerbaijan. *Sustainability*, 10(1), 132. https://doi.org/10.3390/su10010132

5. Imanov, G., Hasanli, Y., & Murtuzaeva, M. (2018). Fuzzy Analysis of Macroeconomic Stability. *Advances in intelligent systems and computing* (pp. 223-229). https://doi.org/10.1007/978-3-030-04164-9_31

6. Imanov, G., Murtuzaeva, M., & Hasanli, Y. (2019). Fuzzy Estimation of Level of Country's Social Security. *Advances in intelligent systems and computing* (pp. 190-196).

https://doi.org/10.1007/978-3-030-35249-3_24

7. Imanov, G., Murtuzaeva, M., & Pur Riza, S. (2017). *Model estimation ecological security aggregate index*. Comité Científico del XII Congreso Internacional de Gestion, Calidad, Derecho Y Competitividad Empresarial, celebrado en Morelia, Mexico, 12-13 octubre 2017.

14. ESTIMATING THE QUALITY OF NATIONAL DEVELOPMENT

14.1. Introduction

International organizations and scientists around the world have proposed different indices such as human development, quality of life, sustainable development criteria, inclusive development, and others to define the level of a country's development. The indicators used in these indices depend on the organization and the purpose of the scientists analyzing the level of development in a country. As the world enters the fourth industrial revolution, characterized by advancements in artificial intelligence, robotics, and the Internet, humanity faces the challenge of increasing knowledge and skills in these areas. In the context of the fourth industrial revolution, it is necessary to consider the level of knowledge and skills when determining the level of development.

In this paper, we propose an index for estimating the quality level of a country's development. Macroeconomic Stability, Social Capital, Level of Skills, Human Capital and Research, Knowledge and Technological Outputs, and Level of Ecocivilization indices were used for the estimation. In the computational process, an intuitionistic fuzzy linguistic set was applied.

14.2. Algorithm for estimation of sub-indices

The sub-index estimation algorithm consists of the following steps:

1. Step 1 - An intuitionistic linguistic number (***ILN)*** A in X is defined [1]. *As*

$$A = \{\langle x[h_{\theta(x)}, (\mu_A(x), v_A(x))]\rangle | x \in X\} \tag{14.1}$$

Here, $h_{\theta(x)} \in S$ and $\mu_A(x)$ and $v_A(x)$ represent the membership degree and non-membership degree of the element x related to linguistic index $h_{\theta(x)}$, respectively. $0 \le \mu_A(x) + v_A(x) \le 1$, for all $x \in X$. For each ***ILN*** *A* in *X*, if

$$\pi_A(x) = 1 - \mu_A(x) - \nu_A(x), \forall\ x \in X \tag{14.2}$$

Then, $\pi_A(x)$ is called the indeterminacy degree or hesitation degree of x of linguistic index $h_{\theta(x)}$.

2. Step 2 - For computational convenience, let $S = \{s_\alpha | \alpha = 0, 1, \ldots, l-1\}$ be a finite and totally ordered discrete term set, where l is the odd value and s_α represents a possible value for a linguistic variable. For example, when $l = 7$, the set S could be given as follows:

   $S = \{s_0, s_1, s_2, s_3, s_4, s_5, s_6\}$ = {*very poor*, *poor*, *slightly poor*, *fair*, *slightly good*, *good*, *very good*}

   In this paper, this set is given as $S = \{S_1$ – Low, S_2– *Middle*, S_3– *High*}.

3. Step 3 - Normalised indicators are converted into intuitionistic fuzzy numbers using the intuitionistic fuzzy triangular functions *iftrif* [2].

4. Step 4 - A definite intuitionistic fuzzy triangular membership and non-membership function of A takes the form:

$$\mu_A(x) = \begin{cases} 0 & ; \\ \left(\dfrac{x-a}{b-a}\right) - \epsilon & ; \\ \left(\dfrac{c-x}{c-b}\right) - \epsilon & ; \\ 0 & ; \end{cases} \qquad \nu_A(x) = \begin{cases} 1-\epsilon & ; & x \le a \\ 1 - \left(\dfrac{x-a}{b-a}\right) & ; & a < x \le b \\ 1 - \left(\dfrac{c-x}{c-b}\right) & ; & b \le x < c \\ 1-\epsilon & ; & x \ge c \end{cases} \tag{14.3}$$

5. Step 5 - Weights of indicators are estimated as the weights of decision makers as proposed by Boran et.al [3]. This concept is a more effective way to deal with vagueness of DMs, which may not be able to accurately express their satisfaction (or membership) degrees for alternatives, due to that (1) the decision-makers (DM) have not precise or sufficient information about the problem; (2) the DMs are unable to discriminate explicitly the superiority of an alternative to others [4].

Let $D_k = [\mu_k, \nu_k, \pi_k]$ be an intuitionistic fuzzy number for rating of k-th decision maker. Then the weight of k-th decision maker can be obtained as:

$$\lambda_k = \frac{(\mu_k + \pi_k(\frac{\mu_k}{\nu_k}))}{\sum_{k=1}^{l}(\mu_k + \pi_k(\frac{\mu_k}{\nu_k}))} \qquad (14.4)$$

$$\sum_{k=1}^{l} \lambda_k = 1$$

6. Step 6 - According to the following intuitionistic linguistic weighted average (ILWA) formula, the values of the sub-indices are calculated as following:

$$\boldsymbol{ILWA} = \langle S_{\sum_{k=1}^{t} \lambda_k \theta\left(a_{ij}^k\right)}, (1 - \prod_{k=1}^{t}(1 - \mu\left(a_{ij}^k\right))^{\lambda_k}, \prod_{k=1}^{t}(\nu\left(a_{ij}^k\right))^{\lambda_k}\rangle \qquad (14.5)$$

14.3. Macroeconomic stability Sub-index values

The European Union defined macroeconomic stability in the law [5] as consisting of four criteria and five indicators: low and stable inflation; low long-term interest rates; low national debt relative to GDP; low deficits; and currency stability.

In order to estimate sub-index of macroeconomic stability (**SIMS**) the following indicators are employed, which were proposed by International Monetary Fund (IMF):

- Real GDP growth (in percent) - **GDP**;
- Unemployment rate (in percent)- **UNE**;
- Consumer price index (period average) – **CPI;**
- Revenue (including grants, in percent of GDP) – **REV;**
- Expenditure (in percent of GDP) – **EXP;**
- General government gross debt (in percent of GDP) – **GGD;**
- Bank credit to the private sector (in percent of GDP) – **BCP;**
- Current account balance (in percent of GDP) – **CAB;**
- Foreign direct investment net inflows (in % GDP) – **FDI;**

- Gross international reserves (in months of non-oil imports) – **GIR;**
- Real Effective Exchange Rate (average, percentage change) - **REER.**

According to the steps of the algorithm and taking into account the indicators given in Table 14.3.1, as presented by the International Economic Organization, the parameters of linguistic variables were determined and are presented in Table 14.3.2.

Table 14.3.1. Macroeconomic Stability Indicators

Indicators	Periods		
	2016	2017	2018
GDP	-3.1	-0.3	1.4
UNE	5.0	5.1	5.0
CPI	12.4	12.8	2.3
REV	34.3	34.2	38.8
EXP	35.4	35.6	33.1
GGD	20.6	22.5	18.8
BCP	31	38	34
CAB	-3.6	4.1	12.9
FDI	7.6	11.9	7.0
GIR	4.2	5.1	4.7
REER	-27.0	3.3	5.6

Sources: IMF Executive Board Concludes 2019 Article IV Consultation with Republic of Azerbaijan, September 18, 2019, 6 p.[6]

Table 14.3.2. Linguistic values of macroeconomic indicators

Indicators	Periods		
	2016	2017	2018
	Low	Middle	High
GDP	[(-3)-(0.1)]	[0 – 2.6]	[2.5 – 5.0]
UNE	[0-10]	[9-5]	[4-0.5]
CPI	[6 – 4]	[4 – 2.1]	[2 – 0]
REV	[10-17]	[16-23]	[22-40]
EXP	[19-25]	[24-30]	[29-60]
GGD	[0-15]	[14-30]	[29-50]
BCP	[40-30]	[29-20]	[19-10]
CAB	[(-4)-0]	[(-1)-2]	[1-6]
FDI	[0-10]	[9.5-20]	19.5-100]
GIR	[0-2.9]	[2.8-3.0]	[3.0-7.0]
REER	[(-11)-(-4)]	[(-3)-4]	[1-10]

Then the fuzzy variables of macroeconomic stability were identified, which are shown in Table 14.3.3.

Table 14.3.3. Fuzzy Macroeconomic stability indicators

Indicators	Periods											
	2016				2017				2018			
	S_θ	μ	ν	π	S_θ	μ	ν	π	S_θ	μ	ν	π
RGG	1	0,1	0,01	0,89	1	0,2	0,78	0,02	2	0,79	0,12	0,09
UR	2	0,15	0,83	0,02	2	0,19	0,79	0,02	2	0,15	0,83	0,02
CPI	3	0,62	0,3	0,07	3	0,53	0,41	0,06	1	0,72	0,19	0,09
REV	3	0,54	0,4	0,06	3	0,03	0,39	0,58	3	0,11	0,87	0,01
EXP	3	0,35	0,61	0,04	3	0,42	0,53	0,05	3	0,22	0,75	0,03
GGGD	2	0,7	0,22	0,08	2	0,8	0,11	0,09	2	0,51	0,43	0,06
BCPS	3	0,17	0,81	0,02	3	0,34	0,62	0,04	3	0,68	0,24	0,08
CAB	1	0,1	0,89	0,01	3	0,51	0,43	0,06	3	0,51	0,43	0,06
FDI	1	0,41	0,54	0,05	2	0,39	0,56	0,05	1	0,51	0,43	0,06
GIR	3	0,51	0,43	0,06	3	0,81	0,1	0,09	3	0,72	0,19	0,09
REER	1	0,36	0,59	0,04	3	0,31	0,65	0,04	3	0,53	0,4	0,06

Result of computation are:

SMSI (2016) = $\langle S_{1.31}\ (0.23{,}0.16)\rangle$ – L – M

SMSI (2017) = $\langle S_{2.60}\ (0.65{,}0.24)\rangle$ – M – H

SMSI (2018) = $\langle S_{2.26}\ (0.65{,}0.86)\rangle$ – M – H

As can be seen from the results of calculating the sub-indices, the level of macroeconomic stability in Azerbaijan in 2016 was slightly above the low level.

In 2017, this indicator approached a high level, but in 2018, it slightly decreased compared to the previous year.

14.4. Social capital Sub-index values

Different definitions broadly define social capital as the institutions, relationships, attitudes, and values that govern interactions among people and contribute to economic and social development [7]. The OECD defines social capital as “networks together with shared norms, values, and understandings that facilitate cooperation within or among groups.” In this context, networks can be seen as real-world links between groups or individuals, such as networks of friends, family networks, or networks of former colleagues. Our shared norms, values, and understandings are less tangible than social networks. Sociologists often describe norms as society's unspoken and largely unquestioned rules, which become apparent when they are broken. Values may be more open to debate, as societies frequently question whether their values are changing. Nevertheless, values, such as respect for people's safety and security, are fundamental to every social group. Together, these networks and understandings foster trust, enabling people to work together effectively [8].

Solability, a joint venture between Swiss and Korean entities, defines the social capital of a nation as the sum of social stability and the well-being (perceived or real) of the entire population. Social capital generates social cohesion and a certain level of consensus, which in turn creates a stable environment for the economy and prevents the over-exploitation of natural resources. Social capital is not a tangible value, making it difficult to measure and evaluate in numerical terms [9]. Despite varying definitions, social capital generally refers to the networks of relationships among people who live and work in a particular society, who show trust in and solidarity with one another, and who enable that society to cooperate and function effectively.

To define the Social Capital sub-index (SISC), we used indicators proposed by the UN Basel Institute of Commons and Economics [10], with the addition of Healthcare and Corruption as indicators:

- **Social Climate (SC):** Typically defined as the perceptions of a social environment that are shared by a group of people [9].
- **Trust Among People (TR):** The belief that someone is good and honest and will not harm you, or that something is safe and reliable.
- **Willingness to Co-finance Public Goods by Austerity Measures (PG):** An indicator of how much a person values a good, measured by the maximum amount they would pay to acquire a unit of the good.
- **Willingness to Co-finance Public Goods by Taxes and Contributions (PT):** Financing local public goods, characterized by social enforcement and the involvement of public officials [10].
- **Willingness to Invest in the Local Economy, SMEs, and Cooperatives (IE):** Support by loans, tax concessions, and grants at sub-central, regional, and local levels of government for the local economy, SMEs (small and medium-sized enterprises), and cooperatives.

- **Helpfulness Among People (HE):** The quality of providing useful assistance and friendliness evidenced by a kindly and helpful disposition [11].
- **Friendliness Among People (FR):** The quality of being friendly and pleasant towards anyone.
- **Hospitality Among People (HO):** Friendly, welcoming behavior towards guests or strangers.
- **Healthcare (HL):** The total societal effort, whether organized or not, private or public, that attempts to guarantee, provide, finance, and promote health [11].
- **Corruption (CO):** A serious crime that undermines social and economic development and weakens the fabric of modern-day society [12].

By using expert opinions and following algorithmic steps, we defined the variables for social capital (Table 14.4.1).

In the computational process, terms with the following intervals were used: Low [1-3.3], Middle [3.0-6.6], and High [6.3-10]. The results—, indicate that the quality of social capital is high. This value of social capital quality will be applicable in future computational processes.

Table 14.4.1. Fuzzified indicators of Social Capital

Indicators		SC	TR	PG	PT	IE	HE	FR	HO	Hl	CO
Expert opinions		6	6	5	5	7	9	8	9	6	7.5
Parameters of Fuzzy numbers	μ	0,28	0,28	0,76	0,76	0,32	0,46	0,78	0,46	0,28	0,55
	ν	0,68	0,68	0,16	0,16	0,15	0,49	0,13	0,49	0,68	0,38
	π	0,03	0,03	0,09	0,09	0,53	0,05	0,09	0,05	0,03	0,07
Weights of criterias	λ	0.04	0,04	0,15	0,15	0,19	0,07	0,17	0,07	0,04	0,08

14.5. Human capital and research Sub-index values

One of the main factors contributing to a country's sustainable development is its national human capital. Human capital, as defined by the OECD, refers to "the knowledge, skills, competencies, and attributes embodied in individuals that facilitate the creation of personal, social, and economic well-being" [13].

Cornell University, INSEAD, and the World Intellectual Property Organization have estimated various indicators for Azerbaijan that measure human capital, knowledge, and technology [14]. These indicators are presented in Table 14.5.1.

Table 14.5.1. Human Capital & Research

Indicators	Periods				
	2015	2016	2017	2018	2019
ED	105	125	119	123	84
TE	83	84	73	74	82
RE	69	70	79	90	91

Source: [6]

To estimate the Human Capital and Research sub-index (SHCR), information from the Global Innovation Index was utilized. The sub-index considers three main components:

1. Education (ED):

- Government expenditure on education (% of GDP).
- Government funding per secondary student (% of GDP per capita).
- School life expectancy, primary to tertiary education, both sexes (years).
- PISA average scales in reading, mathematics, and science. The PISA (Programme for International Student Assessment) by OECD measures the ability of 15-year-olds to apply their knowledge in reading, mathematics, and science. PISA results reflect the quality and equity of learning outcomes worldwide. The 2018 PISA survey is the seventh round of this triennial assessment.
- The ratio of pupils enrolled in secondary school to the number of secondary school teachers.

2. Tertiary Education (TE):

- Tertiary enrolment (School enrolment, tertiary % gross).
- Graduates in science and engineering (percentage of total tertiary graduates in science, technology, engineering, and mathematics).
- Tertiary inbound mobility rate (%).

3. Research & Development (R&D):

– Researchers (full-time equivalent) per million population.

– Gross expenditure on R&D.

– Average expenditure by the top 3 global R&D companies.

– QS university ranking score of the top 3 universities.

To calculate the SHCR, a sub-index scoring algorithm was applied. This algorithm includes several steps, starting with defining linguistic variables for Human Capital and Research:

- **Low**: [1-45]
- **Middle**: [44-88]
- **High**: [87-131]

The results of the computations for the intuitionistic linguistic indicator and their corresponding weights are provided in Tables 14.5.2 and 14.5.3.

Table 14.5.2. Intuitionistic linguistic indicators Human capital and Research

Indicators	Periods															
	2015				2016				2017				2017			
	θ	μ	ν	π	θ	μ	ν	π	θ	μ	ν	π	θ	μ	ν	π
ED	1	0.69	0.22	0.09	1	0.23	0.74	0.04	1	0.23	0.48	0.29	1	0.31	0.65	0.046
TE	2	0.19	0.78	0.03	2	0.15	0.82	0.03	2	0.57	0.35	0.08	2	0.54	0.39	0.07
RE	2	0.73	0.18	0.1	2	0.69	0.22	0.09	2	0.34	0.6	0.05	1	0.12	0.86	0.03

Table 14.5.3. Weights of indicators

Indicators	Periods			
	2015	2016	2017	2018
ED	0.426	0.175	0.256	0.302
TE	0.088	0.115	0.486	0.588
RE	0.488	0.709	0.258	0.109

Results of computation of sub-indices

$\boldsymbol{SHCR}_{2015} = <S\_1.578, 0.683, 0.221>$ L-M

$\boldsymbol{SHCR}_{2016} = <S\_1.823, 0.59, 0.317>$ L-M

$\boldsymbol{SHCR}_{2017} = <S\_1.744, 0.446, 0.436>$ L-M

$\boldsymbol{SHCR}_{2018} = <S\_1.587, 0.44, 0.496>$ L-M

The results of the computation of the SHCR indicate that in 2015 and 2018, the index was slightly above the low range, while in 2016 and 2017 it approached the middle range.

14.6. Skills Sub-index values

A country's skills system enhances the capabilities of its population through various forms of education and training. This system encompasses formal and informal education, secondary, further, and higher education, as well as both academic and vocational education and training (**VET**). It also includes lifelong learning, on-the-job training, and the acquisition of competencies through years of professional experience. Moreover, the skills system is concerned with integrating various groups into the labor force to expand the economy's skills base. [15]

To estimate the sub-index for the level of skill (**SILS**), the following indices were chosen:

- **Skill Index (SKI)**: This index is described by various factors including mean years of schooling, extent of staff training, quality of vocational training, skillset of graduates, digital skills among the active population, ease of finding skilled employees, school life expectancy in years, critical thinking in teaching, and the pupil-to-teacher ratio in primary education. [16]

- **Human Development Index (HDI) - Change in Percent**: The Human Development Index (HDI) is a summary measure of achievements in three key dimensions of human development: a long and healthy life, access to knowledge, and a decent standard of living. [17]

- **Labor Productivity (LPR)**: This is measured as total production per employee, expressed in thousands of USD.

Based on statistical information and the steps of the algorithm, fuzzy parameters of the skill level were evaluated. These parameters are presented in Tables 14.6.1-14.6.4.

Table 14.6.1. Level of skills

Indicators	Periods			
	2015	2016	2017	2018
LPR	35.3	25.0	26.8	30.3
HDI	0.727	0.724	0.729	0.733
SKI	61.0	65.0	67.8	69.8

Table 14.6.2. Intervals and Linguistic level of skill

Indicators	Periods		
	2015	2016	2017
	Low	Middle	High
LPR	[1-67]	[66-134]	[133-200]
HDI	[0-0.33]	[0.32-0.67]	[0.66-1.00]
SKI	[0-34]	[33-67	[66-100]

Table 14.6.3. Fuzzy Level of skills

Indicators	Periods															
	2015				2016				2017				2018			
	S_θ	μ	v	π	S_θ	μ	v	π	S_θ	μ	v	π	S_θ	μ	v	π
LPTP	1	0,82	0,09	0.10	1	0,62	0,31	0.07	1	0,66	0,26	0.07	1	0,75	0,16	0.09
HDI	3	0,34	0,63	0.04	3	0,32	0,64	0.04	3	0,35	0,61	0.04	3	0,37	0,59	0.04
SI	2	0,30	0,66	0.04	2	0,10	0,89	0.01	3	0,09	0,90	0.01	3	0,19	0,79	0.02

Table 14.6.4. Weights

Indicators	Periods			
	2015	2016	2017	2018
LPTP	0,72	0,63	0,65	0,58
HDI	0,15	0,28	0,28	0,28
SI	0,13	0,08	0,07	0,15

SILS (2015)= $\langle S_{1.43}(0.73,0.15)\rangle$ – L – M

SILS (2016)= $\langle S_{1.65}(0.52,0.42)\rangle$ – L – M

SILS (2017)= $\langle S_{1.69}(0.57,0.36)\rangle$ – L – M

SILS (2018)= $\langle S_{1.85}(0.62,0.29)\rangle$ – L – M

The results of the computation for the SILS (Skill Index Level) from 2015 to 2017 indicate that the index was slightly above the low level. In 2018, the index approached the middle range.

14.7. Knowledge and technology outputs Sub-index values

To assess the sub-indices for Knowledge and Technology Outputs (KNTO), indicators from the Global Innovation Index [14] were used. These indicators include:

1. **Knowledge Creation (KC)**:
   - Number of resident patent applications filed at a national or regional patent office (per billion PPP$ GDP).
   - Number of Patent Cooperation Treaty (PCT) applications (per billion PPP$ GDP).
   - Number of resident utility model applications filed at the national patent office (per billion PPP$ GDP).
   - Number of scientific and technical journal articles (per billion PPP$ GDP).
   - H-index, which reflects the number of published articles (H) that have received at least H citations.

2. **Knowledge Impact (KI)**:
   - Growth rate of GDP per person engaged (%, three-year average).
   - New business density (new registrations per thousand population aged 15–64).
   - Total computer software spending (% of GDP).
   - ISO 9001 Quality Management Systems—Number of certificates issued (per billion PPP$ GDP).
   - High-tech and medium-high-tech manufacturing (% of total manufacturing output).

3. **Knowledge Diffusion (KD)**:

– Charges for the use of intellectual property, i.e., receipts (% of total trade, three-year average).

– High-tech net exports (% of total trade).

– Telecommunications, computers, and information services exports (% of total trade).

– Foreign direct investment (FDI) net outflows (% of GDP, three-year average).

As a result of computations based on statistical information and the applied algorithm, intuitionistic fuzzy linguistic numbers for KNTO were defined. The results are demonstrated in Tables 14.7.1-14.7.3.

Table 14.7.1. Knowledge & Technology outputs

Indicators	Periods		
	2016	2017	2018
KC	3	3.3	3.6
KI	28.2	16.7	19.8
KD	21.6	26.1	27.8

Table 14.7.2. Fuzzy parameters of the Knowledge and Technology Outputs

Indicators	Periods											
	2016				2017				2018			
	S_θ	μ	v	π	S_θ	μ	v	π	S_θ	μ	v	π
KC	1	0.8	0.09	0.11	1	0.80	0.09	0.11	1	0.84	0.84	0.84
KI	1	0.84	0.05	0.11	1	0.80	0.09	0.11	1	0.77	0.77	0.77
KD	1	0.77	0.14	0.10	3	0.31	0.65	0.04	2	0.27	0.27	0.27

Table 14.7.3. Weights

Indicators	Periods		
	2016	2017	2018
KC	0.299	0.454	0.624
KI	0.468	0.459	0.309
KD	0.232	0.087	0.066

Results of computation of sub-index ***KNTO*** for 2016-2018 are:

$$\boldsymbol{KNTO}(2016)= \langle S_{0.999}, 0.81, 0.08\rangle$$
$$\boldsymbol{KNTO}(2017)= \langle S_{1.17}, 0.80, 0.11\rangle$$
$$\boldsymbol{KNTO}(2018)= \langle S_{1.00}, 0.64, 0.26\rangle$$

The results of the computation show that during the period of 2016-2018, the Knowledge and Technology Outputs (KNTO) were low.

14.8. Ecological Civilization Sub-index values

R. Morrison [18] wrote: "An ecological civilization is based on diverse life ways sustaining linked natural and social ecologies. Such a civilization has two fundamental attributes. First, it looks at human life in terms of a dynamic and sustainable equilibrium with a flourishing living world: humanity is not at war with nature but exists within nature. Second, an ecological civilization means a basic change in the way we live: it depends on our ability to make new social choices. An ecological civilization is not a prescription for order but a description of the arrangement of disparate societies, of the exquisitely complex web of relationships with one another and with the biosphere.

An operational definition of an ecological civilization is to make economic growth mean ecological improvement. In an ecological economic and political order, an increase in finance capital means the protection and regeneration of natural capital.

An ecological order is all-encompassing. It means fundamental and transformative changes in energy and industrial production, in agriculture, forestry, fishing, aquaculture, water use, that must go hand in hand with the protection and restoration of habitat and ecosystems."

According to the above-mentioned definitions, to construct the Eco-civil sub-index (**ECSI**), the following indicators were taken into account:

- Renewable fresh water resources per 1,000 inhabitants (million m^3) – **RFW**;
- Expenses for the protection of the environment - % of GDP (thousand AZN) – **EPE**;
- Reforestation land in total forest area, in % – **RLF**; [19]

- Total protected areas as a share of national territory, in % – **TPA**;
- Share of total renewable energy supply in total energy consumption, in % – **SRE**;
- Environmental performance index – **EPI**; [20]
- Share of organic agricultural land – **OAL**; [21]

Using Azerbaijan Statistical and International Organization information [22], Eco-civil indicators for 2016-2018 were constructed, as demonstrated in Table 14.8.1.

Table 14.8.1. Eco-civil indicator

Indicators	Periods											
	2015			2016			2017			2018		
	S_θ	μ	v	S_θ	μ	v	S_θ	μ	v	S_θ	μ	v
RFWR	S_1	0,22	0,76	S_1	0,248	0,73	S_1	0,17001	0,81	S_1	0,23001	0,74
EPE	S_1	0,368	0,592	S_1	0,396	0,574	S_1	0,414	0,546	S_1	0,734	0,196
RLFA	S_1	0,054	0,956	S_1	0,054	0,956	S_1	0,054	0,956	S_1	0,054	0,956
TPA	S_1	0,796	0,124	S_1	0,798	0,122	S_1	0,796	0,124	S_1	0,796	0,124
SRESE	S_1	0,158	0,832	S_1	0,148	0,852	S_1	0,125	0,875	S_1	0,145	0,855
EPI	S_3	0,325	0,6535	S_3	0,507	0,443	S_3	0,505	0,445	S_3	0,54	0,405
SOAL	S_2	0,24	0,47	S_2	0,24	0,73	S_2	0,24	0,73	S_2	0,24	0,73

14.9. Eco-civilization fuzzy indicators

The parameters of linguistic variables, intuitionistic fuzzy set and indicator weights are shown in Tables 14.9.1- 14.9.3, respectively.

Table 14.9.1. Parameters linguistic variables Eco-civil index

Indicators	Low	Middle	High
RFW	[1-8]	[7-14]	[13-21]
EPE	[0.1-0.8]	[0.7-1.4]	[1.3-2.0]
RLF	[0-38]	[34-72]	[68-100]
TPA	[1-21]	[20-40]	[39-60]
SRE	[1-11]	[10-20]	[19-29]
EPI	[20-40]	[35-50]	[45-100]
OAL	[0.1-0.8]	[0.7-1.4]	[1.3-2.0]

Table 14.9.2. Fuzzy variables of Eco-civil index

Indicators	Periods		
	2016	2017	2018
RFW	2.0	1.7	1.96
EPE	0.26	0.27	0.40
RLF	0.98	0.98	0.98
TPA	10.3	10.3	10.3
SRE	1.8	1.7	1.8
EPI	83.78		62.33
OAL	0.8	0.8	0.8

Table 14.9.3. Weights of eco-civil indicators

Indicators	Periods			
	2015	2016	2017	2018
RFWR	0,081	0,083	0,058	0,063
EPE	0,140	0,137	0,149	0,281
RLFA	0,019	0,017	0,018	0,014
TPA	0,493	0,451	0,461	0,370
SRESE	0,057	0,048	0,042	0,039
EPI	0,120	0,184	0,189	0,166
SOAL	0,090	0,080	0,083	0,066

Results of computation of eco-civil sub-indices for 2015-2018 years are as follows

ECSI (2015) = $\langle S_{1.33}\,(0.61,0.29)\rangle$;

ECSI (2016) = $\langle S_{1.45}\,(0.62,0.29)\rangle$;

ECSI (2017) = $\langle S_{1.46}\,(0.63,0.29)\rangle$;

ECSI (2018) = $\langle S_{1.40}\,(0.68,0.24)\rangle$

As seen from results of computation of eco-civil sub - indices eco-civil situation in 2015-2018 were middle.

14.10. Aggregated index of country's development quality level

Using results of computation of sub-indices - **, SISC, SHCR, SILS, KNTO, ECSI** and intuitionistic linguistic weighted average equation (***ILWA),*** aggregated indices of country's development quality level for 2016-2018 were computed:

AIDQ (2016) = $\langle S_{1.55},(0.64,0.18)\rangle$ – above low

AIDQ (2017) = $\langle S_{1.85},(0.67,0.22)\rangle$ – above low

AIDQ(2018)= $\langle S_{1.82},(0.62,0.27)\rangle$ – near middle

As seen from the results quality level of country's development in three years was middle.

14.11. Conclusion

As seen from the approach to the problem of defining the level of a country's development in this paper, many indicators such as macroeconomic stability, social capital, human capital and research, levels of skills, and eco-civilization were investigated. This approach provides the ability to define the level of development by considering the processes that occur in the modern era of the Fourth Industrial Revolution. The proposed approach can enable decision-makers to estimate optimal parameters for managing the country's development quality level.

References

1.Wang, J. Q., & Li, H. B. (2010). Multi-criteria decision-making method based on aggregation operators for intuitionistic linguistic fuzzy numbers. *Control Decis*, 25, 1571–1574.

2.Radhika, C., & Parvathi, R. (2016). Intuitionistic fuzzification functions .*Global Journal of Pure and Applied Mathematics*, 12(6), 1211-1227.

3.Boran, F. E., Genç, S., Kurt, M., & Akay, D. (2009). A multi-criteria intuitionistic fuzzy group decision making for supplier selection with TOPSIS method. *Expert Systems With Applications*, 36(8), 11363-11368. https://doi.org/10.1016/j.eswa.2009.03.039

4.Herrera-Viedma, E., Chiclana, F., Herrera, F., & Alonso, S. (2007). Group Decision-Making Model With Incomplete Fuzzy Preference Relations Based on Additive Consistency. *IEEE Transactions On Systems Man And*

Cybernetics Part B (Cybernetics), 37(1), 176-189. https://doi.org/10.1109/tsmcb.2006.875872

5. *Art. 17.4-5. Maastricht Treaty*. (2002). Maastricht Treaty. https://www.europarl.europa.eu/about-parliament/en/in-the-past/the-parliament-and-the-treaties/maastricht-treaty

6. *IMF Executive Board Concludes 2019 Article IV Consultation with the Republic of Azerbaijan*. (2019). IMF. https://www.imf.org/en/News/Articles/2019/09/18/pr19341-azerbaijan-imf-executive-board-concludes-2019-article-iv-consultation

7. Grootaert, C., & van Bastelaert, T. (Ed.). (2002). *Understanding and measuring Social Capital: A Multidisciplinary Tool for Practitioners.* The World Bank. https://openknowledge.worldbank.org/entities/publication/8f069a0b-b4a4-5c05-bee7-d52c5b583716

8. OECD. (2001). *The Well-being of Nations: The Role of Human and Social Capital*. OECD Publishing, Paris, https://doi.org/10.1787/9789264189515-en

9. *The Global Sustainable Competitiveness Report 2019.* (2020). Issuu. https://issuu.com/solability/docs/the_global_sustainable_competitiveness_index_2019

10. Verbeek, J., & Dill, A. (2024). The forgotten dimension of the SDG indicators – Social Capital. *World Bank Blogs*. https://blogs.worldbank.org/en/voices/forgotten-dimension-sdg-indicators-social-capital

11. Donev, D., Kovacic, L., & Laaser, U. (2013). The Role And Organization Of Health Systems. *Health: Systems – Lifestyles – Policies*, I.

12. Jain, A.K. (2001). Corruption: A Review. *Journal of Economic Surveys*, 15, 71-121. http://dx.doi.org/10.1111/1467-6419.00133

13. Keeley, B. (2007). Human Capital: How what you know shapes your life. In *https://www.oecd.org/*. OECD Insights. https://www.oecd.org/content/dam/oecd/en/publications/reports/2007/02/human-capital_g1gh7c78/9789264029095-en.pdf

14. Cornell University, INSEAD, & WIPO. (2015). *The Global Innovation Index 2015: Effective Innovation Policies for Development.*

15. European Centre for the Development of Vocational Training [CEDEFOP] (Ed.). (2020). *2020 European Skills Index: Technical report.* https://www.cedefop.europa.eu/files/esi_-_technical_report_2020.pdf

16. *The Global Competitiveness Report 2017-2018*. (2024). World Economic Forum. https://www.weforum.org/publications/the-global-competitiveness-report-2017-2018/

17. United Nations. (2019). *Human Development Report 2019*. Human Development Reports. https://hdr.undp.org/content/human-development-report-2019

18. Morrison, R. (1995). *Ecological democracy*. South End Press.

19. *FRA 2015 | Global Forest Resources Assessments | Food and Agriculture Organization of the United Nations*. (2015). https://www.fao.org/forest-resources-assessment/past-assessments/fra-2015/en/

20. Wending, Z., Emerson, J.W., de Sherbinin, A., & Esty, D.C. (2020). *2020 Environmental Performance Index (EPI)*. https://earthdata.nasa.gov/data/catalog/sedac-ciesin-sedac-epi-2020-2020.00

21. Willer, H., & Lernoud, J. (2018). *Organic Eprints - The World of Organic Agriculture. Statistics and Emerging Trends 2018*. https://orgprints.org/id/eprint/34669/

22. *The State Statistical Committee of the Republic of Azerbaijan*. (n. d.). https://www.stat.gov.az/?lang=en

15. AN ANALYTICAL APPROACH TO ASSESSING A COUNTRY'S ECOLOGICAL CIVILIZATION INDEX

15.1. Introduction

The Ecocivilization concept is a paradigm of sustainable development. The phrase "Ecological civilization" first appeared in 1995 in R. Morrison's work [1]. Morrison wrote that an ecological civilization is based on diverse lifestyles that sustain interconnected natural and social ecologies. Such a civilization has two fundamental attributes. First, it views human life in terms of a dynamic and sustainable equilibrium with a flourishing living world. Humanity is not in conflict with nature but exists in harmony with it. Second, an ecological civilization involves fundamental changes in the way we live, depending on our ability to make new social choices. It is not a rigid prescription for order but rather a description of the arrangement of diverse societies within the complex web of relationships among themselves and the biosphere.

In 2007, the Chinese government adopted "ecological civilization" as a central policy objective. Recently, Chinese scientists have proposed methods for defining the level of ecological civilization at the national, provincial, and city levels. Notable works in this area include X. Wang and X. Chen's "An evaluation index system of China's development level of ecological civilization" [2], F. Dong et al.'s "How to evaluate provincial ecological civilization? The case of Jiangsu province, China" [3], and L. Mi et al.'s "Evaluating the effectiveness of regional ecological civilization policy: evidence from Jiangsu province, China" [4].

In Azerbaijan, the ecological civilization concept was introduced by U. Alakbarov [5]. In our earlier work [6], we estimated the Ecocivilization Index (ECLI) of the country by incorporating sub-indices such as Green Economy and Transport, Organic Agriculture, Legal Environment, Education, Health, Poverty, Demography, and Consumption.

In this paper, we evaluate the ECLI for Azerbaijan by selecting specific indicators related to Green Economy Quality, Social Quality, and Ecological Quality sub-indices, which are believed to be the major factors affecting the ECLI. Intuitionistic fuzzy linguistic theory applications are used as analytical tools for computing the ECLI.

15.2. Statement of the problem

To define the Ecological Civilization Index (ECLI) at the country level, the Green Economy Quality, Social Quality, and Environmental Quality sub-indices are incorporated. These sub-indices encompass a range of indicators that collectively provide a comprehensive assessment of the ecological civilization. The broad explanation of the indicators and their acronyms are presented below.

Green Economy Quality sub-index indicators

1	Green GDP (mln. USD) [7] - **GGP - Green GDP index** = (GDP – RME – EPD).
2	Share organic agriculture in agricultural land – **OAG.**
3	Share of total renewable energy in total energy supply – **REE - Renewable energy.**
4	Share of tourism industries in GDP (% of GDP) – **TIN**
5	Amount of organic fertilizer per 1 hectare of sown area (kg / ha) - **ORF**
6	The share of electro and Hybrid mobiles (in % of total) - **EHM**
7	Production waste per capita (kq) - **PWC**
8	Length of using ways of urban electric transport, km **- ETR**
9	Innovation index – **INI - International innovation index.**
10	Investment to natural resources and protection environment (thousand AZN) - **INR**

Social Quality sub-index indicators

1	The total area of residential premises per inhabitant (sq.m) – **ARP**
2	Sanitation - **SAN**
3	Water’s access (mln m^3) - **WAT**
4	Health care expenditures (% of GDP) - **HEE**
5	Poverty level in % - **POL**
6	Life expectancy - **LEX**
7	Death from diseases of the respiratory system (person) - **DDR**

Environmental Quality sub-index indicators

1	Air Quality - **AIQ**
2	Domestic and drinking purposed water (mln m^3) – **DPW.**
3	Agricultural lands-total (thsd. ha) – **AGL.**
4	Environmental protection expenditures (thousand AZN) – **EPE.**
5	Auto gas (share of related pollution to total) % - **AUG.**
6	Forest area (% of land area) WB – **FOA.**
7	Total protected areas as share of national territory, in percent – **PAT.**
8	TSP (thsd. ton) – total suspended particulates.

The data from 2018 to 2020 on ECLI indicators measured in different units are given in Table 15.1 below. The first column identifies the groups of indicators belonging to sub-indices.

Table 15.1. Ecological civilization level index indicators of Azerbaijan

E C L I					
		Years	**2018**	**2019**	**2020**
Green economy Quality	1	**GGP** (mln. USD)	46788.5	47900.2	42303.8
	2	**OAG**	0.8	0.8	0.8
	3	**REE**	7.85	6.87	4.66
	4	**TIN** (% of GDP)	4.3	4.5	1.9
	5	**ORF** (kg / ha)	666.0	669.0	700.0
	6	**EHM** (in % of total)	1	1.5	2
	7	**PWC** per capita(kq)	291.4	326.9	345.4
	8	**ETR** , km	36.6	36.6	36.6
	9	**INI**	30.2	30.2	27.2
	10	**INR** (thousand AZN)	247912.2	309855.6	170208.7
Social Quality	1	**ARP** (sq.m)	18.1	19.4	20.0
	2	SAN	67.1	75.5	77.8
	3	**WAT** (mln m^3)	9205	9472	9693
	4	**HEE** (% of GDP)	0.9	1.1	2.3
	5	**POL** (Goal 1) in %	5.1	4.8	6.2
	6	LEX	75.8	76.4	73.2
	7	**DDR** (person)	1826	1854	3149

Cont…

E C L I					
		Years	**2018**	**2019**	**2020**
Ecological Quality	1	**AIQ**	47.44	30.5	24.9
	2	**DPW** (mln m3)	306	312	319
	3	**AGL** (thsd. ha)	4779.5	4779.7	4780.1
	4	**EPE** (thousand AZN)	319256.1	387680.4	239764.5
	5	**AUG** (share of related pollution to total) %	85	84	82
	6	**FOA** (% of land area) WB	13.41	13.55	13.69
	7	**PAT** , in percent	10,3	10,3	10,3
	8	**TSP** (thsd. ton)	6.5	7.4	3.8

15.3. An algorithm for computation of ECLI

With the purpose to evaluate the ecological civilization index (ECLI) of the country, intuitionistic fuzzy logic instruments such as obtaining priority weights through intuitionistic fuzzy preference relation and aggregated weighted average operator are employed. The algorithm for computation of ECLI index consists of the following 7 steps that are introduced below:

***Step 1*. Normalization of crisp data.**

In order to convert crisp data into intuitionistic fuzzy numbers (IFNs), first the data have to be normalized. For this purpose, max-min normalization method can be utilized. The formula for the positive affecting indicators is:

$$Y = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{15.1}$$

The formula for negative affecting indicators is:

$$Y = \frac{x_{max} - x}{x_{max} - x_{min}} \tag{15.2}$$

The maximum and minimum values for normalization of indicators global best and worst case data have been used [8].

***Step 2.* Fuzzification of the normalized data.**

In this stage, normalized indicators are converted into IFNs by the application of the intuitionistic fuzzy triangular function.

The formula for intuitionistic fuzzy triangular membership and non-membership functions were established as following [9]:

$$\mu_A(x) = \begin{cases} 0 \quad ; \\ \left(\frac{x-a}{b-a}\right) - \epsilon; \\ \left(\frac{c-x}{c-b}\right) - \epsilon; \\ 0 \quad ; \end{cases} \quad \nu_A(x) = \begin{cases} 1-\epsilon \quad ; \; x \le a \\ 1 - \left(\frac{x-a}{b-a}\right); a < x \le b \\ 1 - \left(\frac{c-x}{c-b}\right); b \le x < c \\ 1-\epsilon \quad ; \; x \ge c \end{cases} \tag{15.3}$$

***Step 3.* Construction of Intuitionistic Fuzzy Preference Relation (IFPR) matrix.**

Based on fuzzy intervals between 0.1- 0.9, the linguistic terms with their IFNs counterparts have been developed [10] for construction of intuitionistic fuzzy preference relation (IFPR) matrix that classified in table 15.2.

Table 15.2. Linguistic terms for rating the criteria (indicators) preferences

Linguistic terms	IFNs for criteria preferences
Exactly equal (EE)	(0.50, 0.50)
Slightly preferred (SP)	(0.60, 0.30)
Definitely preferred (DP)	(0.70, 0.20)
Strongly preferred (STP)	(0.80, 0.10)
Extremely preferred (EP)	(0.90, 0.10)
Other midterms	*(0.55,0.35),(0.65, 0.25),(0.75, 0.15)*

***Step 4.* Checking the consistency of IFPR matrix.**

For this purpose, the following rules must be followed [11]:

Rule 1. For k > i + 1, let $\bar{r}_{ik} = (\bar{\mu}_{ik}, \bar{\mu}_{ik})$, where

$$\bar{\mu}_{ik} = \frac{\sqrt[k-i-1]{\prod_{t=i+1}^{k-1} \mu_{it}\mu_{tk}}}{\sqrt[k-i-1]{\prod_{t=i+1}^{k-1} \mu_{it}\mu_{tk} + \sqrt[k-i-1]{\prod_{t=i+1}^{k-1}(1-\mu_{it})(1-\mu_{tk})}}} \qquad (15.4)$$

$$\bar{\nu}_{ik} = \frac{\sqrt[k-i-1]{\prod_{t=i+1}^{k-1} \nu_{it}\nu_{tk}}}{\sqrt[k-i-1]{\prod_{t=i+1}^{k-1} \nu_{it}\nu_{tk} + \sqrt[k-i-1]{\prod_{t=i+1}^{k-1}(1-\nu_{it})(1-\nu_{tk})}}} \qquad (15.5)$$

Rule 2. For $k = i + 1$, let $\bar{r}_{ik} = r_{ik}$.

Rule 3. For $k > i + 1$, let , $\bar{r}_{ik} = (\bar{\nu}_{ki}, \bar{\mu}_k)$.

Rule 4. R is considered as an IPR, if

$$d(R, \bar{R}) < \tau \qquad (15.6)$$

Where $d(R, \bar{R})$ is the distance measure between the initial IPR R and its multiplicative consistent IPR $\bar{R}$, which can be obtained as:

$$d(R, \bar{R}) = \frac{1}{2(n-1)(n-2)} \sum_{i=1}^{n} \sum_{k=1}^{n} \left(\left| \bar{\mu}_{ik} - \mu_{ik}^{(p)} \right| + \left| \bar{\nu}_{ik} - \nu_{ik}^{(p)} \right| + \left| \bar{\pi}_{ik} - \pi_{ik}^{(p)} \right| \right) \qquad (15.7)$$

Here, π is the consistency threshold, and p is the number of iterations.

Rule 5. If τ *< 0.1, and i,k=1,2,…,n* a final IPR can be constructed as follows:

$$\tilde{\mu}_{ik}^{(p)} = \frac{(\mu_{ik}^{(p)})^{1-\sigma}(\bar{\mu}_{ik})^{\sigma}}{(\mu_{ik}^{(p)})^{1-\sigma}(\bar{\mu}_{ik})^{\sigma} + (1-\mu_{ik}^{(p)})^{1-\sigma}(1-\bar{\mu}_{ik})^{\sigma}} \qquad (15.8)$$

$$\tilde{\nu}_{ik}^{(p)} = \frac{(\nu_{ik}^{(p)})^{1-\sigma}(\bar{\nu}_{ik})^{\sigma}}{(\nu_{ik}^{(p)})^{1-\sigma}(\bar{\nu}_{ik})^{\sigma} + (1-\nu_{ik}^{(p)})^{1-\sigma}(1-\bar{\nu}_{ik})^{\sigma}} \; i, k = 1,2, \dots, n \qquad (15.9)$$

where σ is a controlling parameter that is established by the decision maker. The multiplicative consistent IPR can be adjusted automatically by following these steps.

***Step 5*. Obtaining the criteria weights.**

Then, the priority vector of criteria can be obtained as following [12]:

$$\omega_j = [\omega_j^L, \omega_j^U] = \left(\frac{1}{\sum_{j=1}^{n} \left(\frac{(1-\tilde{\mu}_{ij}^*)}{\tilde{\mu}_{ij}^*} \right)}, \frac{1}{\sum_{=1}^{n} \left(\frac{\tilde{\nu}_{ij}^*}{(1-\tilde{\nu}_{ij}^*)} \right)} \right) \tag{15.10}$$

Applying the method proposed in works [13] in the next stage, criteria weights vector ω* = (ω*, ω*, …, ω*) can be obtained so that all closeness coefficients of criteria could be as big as possible. With this objective, the following single-objective optimization model is applied:

Maximize

$$\sum_{j=1}^{n} \sum_{i=1}^{m} \omega_j \frac{d(r_{ij}, \alpha_j^-)}{d(r_{ij}, \alpha_j^+) + d(r_{ij}, \alpha_j^-)} \tag{15.11}$$

Subject to

$$\omega_1^L \leq \omega_1 \leq \omega_1^U$$
$$\omega_2^L \leq \omega_2 \leq \omega_2^U$$
$$\vdots$$
$$\omega_n^L \leq \omega_n \leq \omega_n^U$$
$$\sum_{j=1}^{n} \omega_j = 1$$
$$\omega_j \geq 0 \text{ for j} = 1, 2, 3, \ldots, n$$

In order to apply formula (15.10), the following operations on IFSs and IFNs will be used [14]:

Hamming distance between IFSs A and B is given as follows:

$$d(A,B) = \frac{1}{2}[|\mu_A(x) - \mu_B(x)| + |\nu_A(x) - \nu_B(x)| + |\pi_A(x) - \pi_B(x)|] \qquad (15.12)$$

Let α_i^+ =(1,0,0) (i = 1,2,3,…m) be m largest IFNs, then

$$A^+ = (\alpha_1^+, \alpha_2^+, \dots, \alpha_m^+) \qquad (15.13)$$

Is called as intuitionistic fuzzy positive ideal solution ($IFIS^+$). Let α_i^- = (0,1,0) (i=1,2,3,…m) be m smallest IFNs, then

$$A^- = (\alpha_1^-, \alpha_2^-, \dots, \alpha_m^-) \qquad (15.14)$$

Is called as intuitionistic fuzzy positive ideal solution ($IFIS^-$)

***Step 6.* Aggregation of IFNs.**

In this step, fused intuitionistic fuzzy values (IFVs) of Green Economy Quality, Social Quality and Environmental Quality sub-indices are computed through aggregation of indicators and taking into account priority weights of criteria. Consequently, aggregated intuitionistic fuzzy value (IFV) of the ECLI index is obtained via aggregation of IFVs of sub-indices with the application of the following intuitionistic fuzzy weighted average (IFWA) formulae [15.15]:

$$IFWA = \left(1 - \prod_{j=1}^{n} (1 - \mu_j)^{w_j}, \prod_{j=1}^{n} v_j^{w_j}\right) \qquad (15.15)$$

***Step 7.* Assessment of the ECLI index.**

The obtained aggregated intuitionistic value for ECLI index is difficult to comprehend and present a reasonable interpretation. In this context, modified linguistic term matches for intuitionistic fuzzy intervals that could communicate humanistic perception for rating the ECLI index has been developed referring to [16].

Table 15.3. Linguistic terms and their matching intuitionistic fuzzy scale

Linguistic terms	IFNs membership and non-membership function value intervals (μ,v)
Absolutely high (AH)	([0.85, 0.90], [0.00, 0.10])
Very high (VH)	([0.75, 0.85], [0.10, 0.15])
High (H)	([0.65, 0.75], [0.15, 0.25])
Medium high (MH)	([0.55, 0.65], [0.25, 0.35])
Medium (M)	([0.45, 0.55], [0.35, 0.45])
Medium low (ML)	([0.35, 0.45], [0.45, 0.55])
Low (L)	([0.25, 0.35], [0.55, 0.65])
Very low (VL)	([0.15, 0.25], [0.65, 0.75])
Absolutely low (AL)	([0.10, 0.15], [0.75, 0.85])

15.4. Estimation Results

In this section estimation output are presented. Following step 3 and 4 as provision for performing intuitionistic fuzzy aggregation, priority weights of sub indices are estimated consistent IFPR matrices. Computed following step 5, weights vectors for Green Economy Quality (ω^1), Social Quality (ω^2), and Environmental Quality (ω^3), sub-indices have been computed and are given below, respectively:

$\omega^1 = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5, \omega_6, \omega_7, \omega_8, \omega_9, \omega_{10}) = (0.1587, 0.1197, 0.1196, 0.1258, 0.0897, 0.0937, 0.0918, 0.0719, 0.0718, 0.0573)$

$\omega^2 = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5, \omega_6, \omega_7) = (0.1975, 0.1554, 0.1464, 0.1425, 0.1425, 0.1079, 0.1078)$

$\omega^3 = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5, \omega_6, \omega_7, \omega_8)$ (0.1816, 0.1356, 0.1356, 0.1361, 0.1264, 0.1020, 0.1019, 0.0808)

According to step 6, IFWA values are estimated for sub-indices before computation the overall index-ECLI that are illustrated in Table 15. 4.

Table 15.4. IFWA results as IFVs and their linguistic analogues

№	Sub-indices and overall index	IFWA and its linguistic matches			Weights of sub-indices
		2018	2019	2020	
1	Green Economy Quality sub-index	(0.29,0.66) L	(0.30,0.64) L	(0.30,0.65) L	0.4020
2	Social Quality sub-index	(0.31,0.63) L	(0.27,0.68) L	(0.33,0.62) L	0.3289
3	Environmental Quality sub-index	(0.58,0.28) MH	(0.43,0.49) M	(0.31,0.64) L	0.2691
Ecological Civilization Level Index		**(0.39,0.52) ML**	**(0.33,0.61) L**	**(0.31,0.64) L**	---

The analysis of the aggregated IFVs in Table 15.4. reveals that there were not significant changes in the level of Green Economy Quality and Social Quality sub-indices. However, there was a considerable downfall in the level of Environmental Quality sub-index, which is the main cause in deterioration of Ecological Civilization Level Index.

IFVs of IFWA results, corresponding to intuitionistic fuzzy scale given in table 15.6 are converted into linguistic terms, which represent ECLI for the analyzed years:

ECLI(2018) = **ML**

ECLI(2019) = **L**

ECLI(2020) = **L**

15.5. Conclusion

In this study, we proposed a new approach for assessing the Ecological Civilization Index (ECLI), which could serve as an empirical reference. Since evaluating the ECLI index is a relatively new area in the study of sustainable development, the main challenges associated with sustainable development have been considered. The key difference between this study and previous literature lies in the application of intuitionistic fuzzy set theory for the assessment of ECLI, which integrates important tools within the generated algorithm.

First, the crisp data on indicators were normalized, taking into account their global low and high levels. The normalized data were then fuzzified. Next, the priority weights of indicators were estimated after constructing Intuitionistic Fuzzy Preference Relation (IFPR) matrices. In the final stage, the ECLI was computed as an aggregated intuitionistic fuzzy value and converted into a linguistic value to make it comprehensible and expressive.

In future investigations, it should be noted that the proposed methodology provides more accurate results as the range of the time series increases.

References

1. Morrison, R. (1995). *Ecological democracy*. South End Press.
2. Wang, X., & Chen, X. (2019). An Evaluation Index System of China's Development Level of Ecological Civilization. *Sustainability*, 11(8), 2270. https://doi.org/10.3390/su11082270
3. Dong, F., Pan, Y., Zhang, X., & Sun, Z. (2020). How to Evaluate Provincial Ecological Civilization Construction? The Case of Jiangsu Province, China. *International Journal Of Environmental Research And Public Health*, 17(15), 5334.
   https://doi.org/10.3390/ijerph17155334
4. Mi, L., Jia, T., Yang, Y., Jiang, L., Wang, B., Lv, T., Li, L., & Cao, J. (2021). Evaluating the Effectiveness of Regional Ecological Civilization Policy: Evidence from Jiangsu Province, China. *International Journal Of Environmental Research And Public Health*, 19(1), 388. https://doi.org/10.3390/ijerph19010388
5. Alakbarov, U.K. (1998) Ecologization of Human Activity. *Energy, Ecology, Economy*, 141-143.
6. Alakbarov, U. K., Imanov, G., & MaB, UNESCO. (2011). *Ecological Civilization Index: Concept and first Implementation.: Proceeding of the "Man and Biosphere"* (Annual edition, Vol. 7). Azerbaijan National Committee, Ecological civilization, Sustainable development, Environment, 5-14.
7. Stiglitz, J., Sen, A., & Fituossi, J.P. (2009). *Report of the Commission on the Measurement of Economic Performance and Social Progress*, 291.
8. *World Development Indicators | The World Bank.* (n. d.). http://wdi.worldbank.org/tables
9. Radhika, C., & Parvathi, R. (2016). Intuitionistic fuzzification functions. *Global Journal of Pure and Applied Mathematics*, 12(6), 1211-1227.

10. Gong, Z., Li, L., Zhou, F., & Yao, T. (2009). Goal programming approaches to obtain the priority vectors from the intuitionistic fuzzy preference relations. *Computers & Industrial Engineering*, 57(4), 1187-1193. https://doi.org/10.1016/j.cie.2009.05.007

11. Xu, Z., & Liao, H. (2013). Intuitionistic fuzzy analytic hierarchy process. *IEEE Transactions On Fuzzy Systems*, 22(4), 749-761. https://doi.org/10.1109/tfuzz.2013.2272585

12. Genç, S., Boran, F.E., & Akay, D. (2010). Some approaches on estimating criteria weights from intuitionistic fuzzy preference relations under group decision making. *J. Multiple-Valued Logic Soft Comput*. 36, 11363–11368.

13. French, S., Hartley, R., Thomas, L. C., & White, D. J. (1993). *Multi-objective decision making: Based on the proceedings of a conference on multi-objective decision making*. Academic Press.

14. Hwang, C., & Yoon, K. (1981). Multiple attribute decision making. *Lecture notes in economics and mathematical systems*. https://doi.org/10.1007/978-3-642-48318-9

15. Xu, N. Z. (2007). Intuitionistic fuzzy aggregation operators. *IEEE Transactions On Fuzzy Systems*, 15(6), 1179-1187. https://doi.org/10.1109/tfuzz.2006.890678

16. Kahraman, C., Öztayşi, B., & Onar, S. Ç. (2018). An Integrated Intuitionistic Fuzzy AHP and TOPSIS Approach to Evaluation of Outsource Manufacturers. *Journal Of Intelligent Systems*, 29(1), 283-297. https://doi.org/10.1515/jisys-2017-0363

16. THE INFLUENCE OF WORLD MILITARY-POLITICAL SITUATIONS TO SUSTAINABLE DEVELOPMENT OF THE COUNTRY[2]

The world is going through very turbulent and difficult times. If you look at today's picture of our planet, you can see not very pleasant scenes. A pandemic lasting more than two years, conflicts and wars flaring up from time to time, the consequences of climate change, successive economic and humanitarian crises...

If you list in order the historical events that have taken place in recent years, the decisions made, then there will not be enough time for this. Therefore, we have to be satisfied with a brief overview of the results of the most important events covering military expenditures, imposed sanctions, and the pandemic.

Global military spending, as seen in figure 16.1, reached $2.113 trillion in 2021, an increase of 0.7% in real terms, according to data from the Stockholm International Peace Research Institute (SIPRI).

The top five countries that spent the most were the USA, China, India, the Great Britain and Russia, accounting for 62% of overall spending.

"Even with the economic fallout from the COVID-19 pandemic, global military spending reached record levels. Due to inflation, growth slowed in real terms, but in nominal terms, military spending increased by 6.1%" said Dr. Diego López da Silva, Senior Researcher at the SIPRI Program for Military Expenditure and Arms Production. The United States spent $801 billion on the military last year, down 1.4% from a year earlier (3.5% of GDP in 2021). China spent about $293 billion on the military in 2021, up 4.7% from 2020, while India spent $76.6 billion, up 0.9% from 2020. Figure 16.1 also shows that the growth of military spending in the world in 2019-2021 when the val-

2 Coauthor – Dr. E. Mamedov

ue of the global sustainable development index (SDI) was 66 in 0-100 scale. Military expenditure did not have effect on the sustainable development index that did not change during this period. [1].

Figure 16.1. Global military spending
Sources: SIPRI and Global Development Report 2015-2021

As can be seen from Figure 16.2, Azerbaijan's military spending as a percentage of GDP in 2016 was 3.69, and in 2021 - 5.3. This is mainly due to the war between Azerbaijan and Armenia. As a result of the war between Azerbaijan and Armenia in 1988-1994, a total of 1.7 million hectares or 20% of the territory of the Republic of Azerbaijan was occupied. These territories were under occupation for 33 years. As a result of the aggressive policy of Armenia during the war, about 900 Azerbaijani villages were plundered and destroyed, over 20,000 Azerbaijani citizens were killed, and 20 percent of the territory of Azerbaijan was occupied by the Armenian armed forces. As a result of these actions, the economic security of Azerbaijan was threatened. As a result of the war, the activities of almost 7,000 Azerbaijani enterprises were stopped, providing 24 percent of cereal production, 41 percent of alcohol production, 46 percent of potatoes, 18 percent of meat and 34 percent of milk. Armenia captured about 25 percent of the entire forest area of Azerbaijan, as well as various mineral-rich (gold, chromite and copper) deposits [2].

According to UN estimates, the total economic damage from the occupation of Azerbaijani lands by Armenia is estimated at about 53.5 billion US dollars. As can be seen from Figure 16.2, the sustainable development index (SDI) of Azerbaijan did not change much during 2015 - 2021, but in 2021, SDI grew up by 1.96 points.

The war in Ukraine is a human tragedy for the people of Ukraine, but its economic implications are global. This war impacts directly on the world trade and investment. It identifies five trade and investment channels through which countries will be affected by the war in Ukraine. These encompass disruptions to: (i) commodity markets (especially food and energy), (ii) logistic networks, (iii) supply chains, (iv) foreign direct investment, (v) specific sectors. In [3] the report finds that world trade will drop by 1 percent, lowering global GDP by 0.7 percent and GDP of low-income countries by 1 percent. Beyond these direct effects, the war's long-term implications for global trade and investment will largely depend on how governments respond to the changing geopolitical environment.

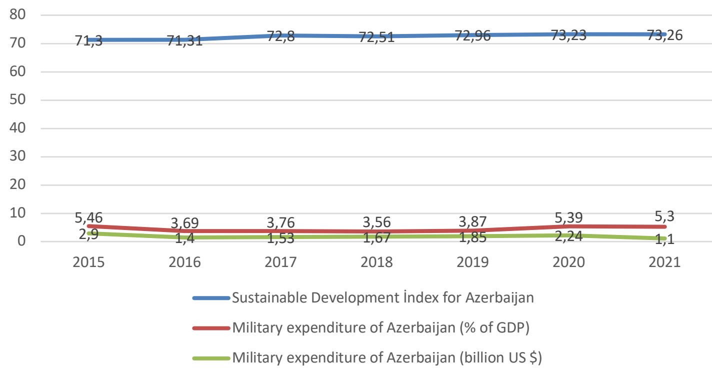


Figure 16.2. SDI and Military expenditure of Azerbaijan in 2015-2021
Sources: SIPRI and Global Development Report 2015-2021

The authorities of countries around the world have allocated about $16 trillion in total to fight the coronavirus pandemic, which has avoided the worst consequences. This was stated by the Managing Director of the International Monetary Fund (IMF) Kristalina Georgieva, speaking at a video conference organized by the American Council on Foreign Relations on March 30, 2022.

Azerbaijan has spent about 475 million US dollars to fight **the coronavirus pandemic** in 2021, the Minister of Finance of Azerbaijan noted at a meeting of the Parliament on Economic Policy, Industry and Entrepreneurship.

The allocated funds were mainly used to purchase vaccines and related medical equipment, special payments to doctors and volunteers. Pandemic in 2020-2022 greatly affected the quality of life and almost all of Azerbaijan's sustainable development goals.

Annual economic losses due to climate change in the world by 2025 could amount to \$1.7 trillion and about \$30 trillion by 2075. This is evidenced by the results of a survey conducted by New York University among 738 economists and climate change experts living in various countries.

Economists' fears about the effects of climate change have intensified since the last poll, conducted in 2015. Hundreds of economists now agree on the need to take decisive action to reduce greenhouse gas emissions. Some 74 percent of the economists surveyed said urgent and effective action is needed to reduce emissions. At the same time, 89 percent of economists are confident that climate change will increase the disproportion between countries' incomes. At the same time, 70 percent of respondents say that as the world warms, inequality will deepen within countries. In addition, 76 percent of experts predict a negative impact of climate change on global economic growth against the backdrop of economic losses.

Although the Earth's climate has fluctuated before, in the last 100 years this has happened incomparably more often. At the same time, the average surface temperature increased by about 0.6 – 0.7 °C (1.2 – 1.4 °F). This may not seem like much, but since climate has become a "non-linear" dynamic system, even small changes in temperature can cause a range of cascading effects. Scientists at the Intergovernmental Groups on Climate Change (IGCC) are constantly trying to model these changes to predict the future climate.

According to instrumental data (since 1850), the eight warmest years have been recorded since 1998, with the warmest being 2005.

It happens as a result of human activity. Our use of fuels such as oil, coal and gas, as well as deforestation, has significantly increased the amount of carbon dioxide (CO_2) in the earth's atmosphere, as well as other greenhouse gases. These greenhouse gases create a heat trapping effect (hence the name), preventing it from escaping into the atmosphere. Due to the fact that the greenhouse effect is a natural phenomenon and one of the causes of global warming, we called it the "uncontrolled greenhouse effect". Since the Industrial Revolution at the end of the 18th century, atmospheric CO_2 has risen significantly as a result of human activities, and today it is at a level that has not been observed for at least 800,000 years.

According to the World Meteorological Organization's Atlas of Mortality and Economic Loss from Extreme Weather, Climate and Hydrological Events

(1970-2019), there have been more than 11,000 disasters worldwide associated with these hazards, resulting in just over 2 million deaths, and $3.64 trillion amount of damage. The report is the most comprehensive review to date of mortality and economic loss from extreme weather, climate and hydrological events. It provides estimates for the entire 50-year period, as well as separately for each decade.

From 1970 to 2019, hazardous weather, climate and hydrological events accounted for 50% of all disasters, 45% of all recorded deaths and 74% of all recorded economic losses. More than 91% of these deaths occurred in developing countries (UN classification).

Climate change in the world influences also the **Global Food Security Index (GFSI)**. As seen from figure 16.3 the world made big gains in food security from 2012 to 2015, with overall GFSI scores jumping 6 percent. However, structural issues in the global food system led growth to slow subsequently, and for the past three years, the trend in the overall food security environment has reversed.

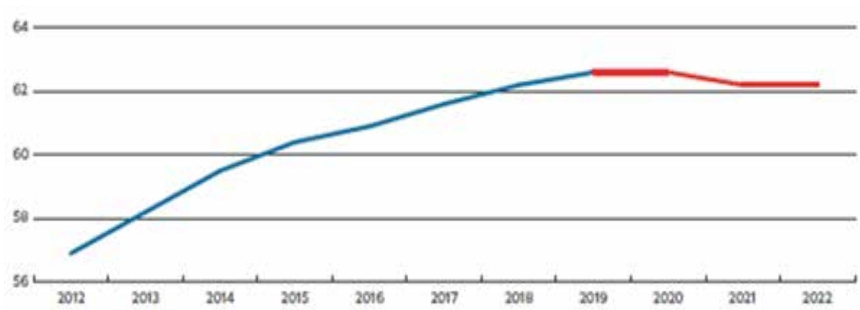


Figure 16.3. GFSI average-overall score in 2012-2022
Source: Global food security index, 2022

In general, Azerbaijan is a country that is sensitive to climate change, which affects the productivity of food production. The main areas in the agrarian regions of the country are allocated for crops, in particular cereal grain. The lack of rainfall during the growing season in regions that usually receive sufficient rainfall during the autumn season has created serious difficulties. Due to insufficient soil moisture, most of the sown seeds did not germinate, and the germinated ones did not develop. The existing unfavorable conditions for plants are considered ideal conditions for rodents, and they, taking advantage of this, increase their offspring, feed on the roots and aboveground organs of plants, causing serious damage. During sharp climatic changes, low yields are observed, crop losses increase, and the quality of products decreases. Climate change is one of the main stressors for food security. This is typical for Azerbaijan as well. Global warming causes, first of all, a serious shortage of water. Temperature increased by 1.4% over the past 30 years, precipitation decreased by 10-15%, a series of dry years shows that the country's water resources have decreased by 15% [4].

According to an expert from the Ministry of Agriculture of Azerbaijan, more than 80% of plant production in the country is produced on irrigated lands. In this regard, the depletion of water resources under the influence of climate change has put enormous pressure on agriculture, especially food security index in Azerbaijan (Figure 16.4).

As can be seen from Figure 16.4, the state of food security in Azerbaijan from 2018 to 2019 gradually improved with small deviations. But since 2019 from 64.8 has been a sharp decline with hesitate to 59.8 in 2022. This may be due to various reasons. One of these reasons can be considered a sudden pandemic of coronavirus (COVID-19) and climate change in the world.

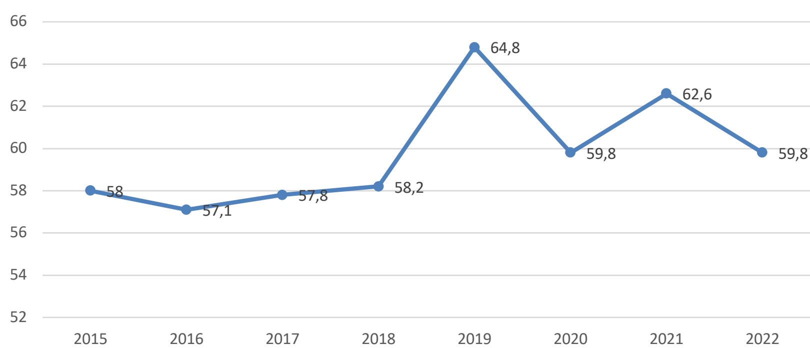


Figure 16.4. Azerbaijan Food Security Index (2015-2022)
Sources: Global Food Security Index Report (2015-2022)

The sustainable development of countries is strongly influenced by **sanctions** imposed by countries and international organizations (table 16.1). Currently, various types of sanctions are used, such as trade, military, financial, etc. These decisions are made against states or non-state actors to bring about a desired change in behavior, to protect national security interests, or to defend against alleged violations of international law. While sanctions were originally exceptions in international relations, they have become more general and unilateral.

Table 16.1. World sanctions by type

№	World sanctions by type	Years					
		2014	2015	2016	2017	2018	2019
1	Trade sanctions	116	111	112	84	88	84
2	Arms sanctions	84	83	82	70	70	65
3	Military assistance sanctions	67	64	63	58	58	54
4	Financial sanctions	162	153	151	133	144	148
5	Travel sanctions	91	87	88	92	92	93
6	Other sanctions	38	30	29	33	30	29
Total		558	528	525	470	482	473

Source: [5]

USA and EU sanctions against Russia due to the military operation in Ukraine, the impact of sanctions on the Russian economy and the ruble exchange rate, and the boomerang effect from the applied sanctions on the economies of the EU countries and the USA, introduction of personal sanctions against Russian politicians and entrepreneurs, the disconnection of Russian banks from international payment systems, the ban on technology imports, and the refusal of international companies to work in Russia have a strong impact on the sustainable development of individual countries of the world. According to economic experts, USA sanctions against Russia will have consequences for Azerbaijan, both positive and negative. Positive for the Azerbaijani economy could be the opportunity to replace Russian goods in international markets, access to which has become limited due to sanctions. However, given that Azerbaijan's export potential is not so high, it will be difficult for Azerbaijan to replace Russian goods in the markets, the expert said.

On average, the trade turnover between the Russian Federation and Azerbaijan is \$3 billion, of which about \$2.3 billion is imported from Russia; \$0.7 billion is our export. In other words, for every \$100 of Azerbaijani goods exported to Russia, we import \$300 worth goods into the country [6]. Last time in relation with War between Ukraine and Russia the European Union (EU) and United States (USA) increased economic, political and military sanctions against Russia by several times. In one of the last speech, the President of the United State Joe Biden said alternative to sanctions against Russia could be Third World War.

Deep imbalances in the global economy, hypertrophied development of the financial sector, significantly separated, in our opinion, not only from the real sector of the economy, but also in general from reality, led to a structural crisis of the entire global dollar-centric economy. We hope this will lead to an increase in trends in regionalization. At the same time, it must be noted that more effective institutions for managing the technical and economic development should ensure sustainable and advanced positive trends in the regions where they will be introduced. Therefore, in the long term, apparently, plans the main beneficiaries of the former structure of the world economy to maintain global leadership is not destined to come true and countries of the post-Soviet space, I think it is necessary realize that in this strategic hub, objectively, defeat those countries and regions that will rely on more effective development institutions.

It should be noted that the tectonic shifts that have taken place in recent years in the world are painfully reminiscent of the processes of a hundred years ago. I think that the basis for creating the prerequisites for the outbreak of the First World War was the impossibility of further coexistence of the then existing regional economic and technological zones. Since development under the model of capitalism, which at that time was already in the glut stage within the existing zones of influence, assumed the expansion of sales markets.

I want to remind you that it was precisely at the beginning of the First World War that the creation of a sole emission center in the United States took place, which became a defining moment and starting point in terms of the development of the world economy in the 20th century. I believe that the creation of the Fed (Federal Reserve System) of the United States was a response to the first major crisis in the American economy in the 20th century, when the financial sector showed an inability to cope with massive defaults and bankruptcies that were associated with the impossibility of generating profits under the previous system of organization and former markets. The First World War, although it ended with the absorption of new markets and the redrawing of borders, did not result in a complete positioning of new long-term realities. Then there was the “Great Depression” in the United States, which in turn ended exactly with the start of World War II. But in my opinion, the problems of that period, which were observed in the West, became a “window of opportunity” for industrialization and economic development in Greater Eurasia. It should be noted that at that time the leadership of the USSR took advantage of this “window of opportunity” quite effectively and in a short time industrialization was carried out in the country at a high technological level, without which, you will agree, it was impossible to resist Nazi Germany, which get under control and forced a significant part of Europe to work for itself. At the same time, in my opinion, it can be stated with confidence that in the light of the complex and systemic problems that the Western Global Project is experiencing today, no purely political decisions can cancel the inevitability of a crisis within its framework, at least very similar to the crisis hundred years ago. Because it is impossible to stimulate the economy only by pumping money into the financial sector of the economy, since within the framework of the economic model that exists in the West, the efficiency of capital has fallen catastrophically. Covid-19 and all the political, economic, social and humanitarian processes accompanying it, in my opinion, clearly confirmed only what was inevitable for the order in the world. It is prime time for the changes in the world technological and economic structures. For specialists, this was clearly visible in a sharp drop in the efficiency of the main areas of the former technological order, which in turn led first to an increase in prices for the main energy carriers, and then to their natural collapse, since at those sky-high prices for the same gas and the same oil, which developed in 2000s, it became impossible to maintain profitability with falling real demand. After the spread of the pandemic, high-tech sectors of the economy received a powerful investment impetus, we should expect their final positioning as the main directions of technical and economic development in the world. At the same time, the main areas of application of these technologies are areas directly related to the development of human capital. This, of course, in the first place, health care and education. Along with this, our days are marked and characterized by a change in the world economic structure, that is, literally before our eyes, the institutions of governance that ensure the stability of the world economy over the past almost hundred years after the Great Depression are losing their effectiveness. And along with them, the only global center for economic and political decision-making based in Washington, which remained after the collapse of the USSR, is losing effectiveness and influence. By the way, where this center is based can also be considered quite arbitrary, since this center has long turned into a supranational one, which a number of experts call the “world government” or “international financial center”. And in the same way, literally before our eyes, the power and influence of the new institutional model for managing technical and economic development, which is being formed in Southeast

Asia, is growing. It is only a very superficial analysis that can connect the economic achievements of the China, and then India and a number of other Asian countries only with cheap labor in them and, as a result, the transfer of the production capacities of transnational corporations to them. A deep structural, systemic and comprehensive analysis absolutely clearly shows that these countries have formed more effective development institutions, institutions based on the mechanisms of strategic planning at the state level, as well as indicative planning at the business level. These institutions are in close cooperation as public-private partnership, where the state provides business with the infrastructure appropriate for development purposes, as well as "long, affordable money", which are the basis for a sustainable increase in investment and innovation activity.

In fact, I believe that the main information, economic and political messages of the processes associated with the coronavirus pandemic are that the former, outgoing center of technological and institutional development, relying on its unconditional hegemony on the financial and information and propaganda tracks, has unleashed a "hybrid war" in order to maintain its advantage and initiative on a planetary scale. As a result, the global financial oligarchy, which is the main beneficiary of the activities of this center, managed to dump multi-trillion-dollar obligations and deflate huge financial bubbles by implementing a large-scale dollar issue in the United States this year. But the problem of implementing this scenario is that there are objective laws of technical and economic development, and we see that it is the China that is becoming, in fact, the only large country that, following the results of even this extremely difficult year for the world economy, is confidently entering the positive dynamics of the Gross Domestic Product (GDP).

Today, it can be confidently stated that the world economy is undergoing the largest structural changes in recent decades. Before our eyes, the dollar-centric world economy that has been established for many years, based on the global system of division of labor and on the common global world market, have spent its regeneration capabilities and is cracking up. These processes, in turn, lead to the formation of new challenges for the national economies of the countries. In my opinion, it is time to realize that the time for receiving dividends from high prices for raw materials, which were formed largely due to inflation of dollar bubbles and the inflation that followed it, is coming to an end. This means that from a scientific point of view, it seems unreasonable to rely on the currency and raw materials security of the leading economies of the countries. With the inevitable drop in revenues from the export of raw materials, the countries of the region will have to, on the one hand, find opportunities to switch to a new economic management model based on an increase in investment with an emphasis on high-tech industries with a high level of innovation, and on the other hand, form expanded markets for their products.

Conclusion

The analysis of military and political events in the world shows that wars, sanctions, the coronavirus epidemic have a strong impact on the sustainable development of the world economy and some countries. As a result, the standard of living, the rate of economic growth, the population and the psychological state of the world's population are decreasing. This result should be the main warning signal for the leading countries and executives who make major decisions in the social, military-political, economic, and environmental fields. Based on the above analysis, it is necessary to state that particularly those institutions operating effectively are managing technical and economic development and provide sustainable and positive trends in the economies of these countries. Therefore, in strategic terms, apparently, the plans of the "international financial center" to maintain global leadership will not come true, and the countries of the world, I think, need to realize that in this strategic splitting, those countries and regions that is expected to win objectively rely on more effective institutions development. I think it is important to understand that without economic integration, expansion of production and marketing opportunities, none of the countries alone is able to compete with the new giants of the developing world economy.

Finally, global sustainable development will be guaranteed after the establishment of the balance of interests between the emerging macro-region powers.

References

1. Расходы стран мира на военные нужды превысили $2 трлн. (2022). РБК. https://www.rbc.ru/politics/25/04/2022/62660d739a794755712a47e4

2. Tahmazli, E. (n. d.). *Center for Analysis of Economic Reforms and Communication*. Ereforms.gov.az. https://ereforms.gov.az/en

3. Ruta, M. (Ed.). (2022). *The Impact of the War in Ukraine on Global Trade and Investment*. World Bank. https://openknowledge.worldbank.org/handle/10986/37359

4.*Hydrometeorological Center of Azerbaijan*. (n. d.). https://meteo.az

5.Kirilakha, A., Felbermayr, G., Syropoulos, C., Yalcin, E., & Yotov, Y. V. (2021). *The Global Sanctions Data Base: An Update that Includes the Years of the Trump Presidency: WP 2021-10* (Working Paper Series). School of Economics, LeBow College of Business, Drexel University. https://es.scribd.com/document/650847209/Drexel-School-of-Economics-Working-Paper-2021-10-Revised

6. *The State Statistical Committee of the Republic of Azerbaijan*. (n. d.). https://www.stat.gov.az/?lang=en

17. INTERVAL-VALUED INTUITIONISTIC FUZZY MODEL FOR SIMULATION OF AZERBAIJAN NATIONAL CYBER SECURITY INDEX[3]

17.1. Introduction

Cybersecurity is the management, governance, development, and application of information security, operational technology security, and information technology security hardware and software for obtaining regulatory compliance, protecting assets and to put at risk the assets of challengers [1].

Cybersecurity is not just a technical issue but a complex multi-faceted problem, aspects of which extend beyond social and economic development areas as international relations, trade negotiations, sustainable development, law enforcement, national and international security [2].

After the Cold War political discords entailed cyber-attacks [3], enforcing countries to develop their own cyber security systems. Cybersecurity remains reasonably important at a higher place in present-day business with the sharp and turbulent environment.

The internet has been recently turned into a locale for digital crime, cyber-attack, cyber harassment, and information leakage on a large scale. In the sequence of cyber-attacks on countries: Estonia in 2007, Georgia in 2008, Kyrgyzstan in 2009, South Korean's banks in 2010, Stuxnet malware as Iran case in 2010, Cyber espionage against US in 2012, New York dam's SCADA systems in 2016 or LinkedIn mass data cracking in 2013, Yahoo in 2014, Dropbox in 2014, and Telegram in 2016 have urged almost all national governments to reconsider the cybersecurity risk perspectives, and its potential effects on society, economy, and critical infrastructures.

According to UN report [4] main types of threat actors in the cyberenvironment are:

3 Coauthor – Dr. A. Aliyev

- Hackers - individuals or groups harming for fame or thrilling.
- Hacktivists - hackers with a specific political or ideological motive.
- Cybercriminals - actors from small outfits to large, organized crime networks who engage in crimes such as fraud, theft, extortion etc.
- Industrial spies – actors with the goal to obtain trade secrets, blackmailing for economic interest reasons, or sabotaging the competition, in the corporate world.
- States or state-sponsored groups - well-resourced actors pursuing complex objectives, employed and financed by governments or military outlets.
- Insiders - actors endangering the entity from within, including disgruntled employees and inadequately trained personnel or contracted service providers.

Participation in the Internet economy cannot be ignored by countries, which covers or influences most spheres of socio-economic prosperity. [2] Cybersecurity is affected by a number of factors within the national scope and each country should adopt the following better practices of National Cyber Security Strategy:

- Governance
- Risk management in national cybersecurity
- Preparedness and resilience
- Security of Critical Infrastructure and essential services
- Capability and capacity building and awareness raising
- Legislation and regulation
- International cooperation

Kolini and Janczewski classified the world organizations dealing with cybersecurity policy and methodology improvement where UN tops the list with 193 countries, while NATO cooperate 33 countries [5].

Despite the fact that cyber security anxieties rooted from military and politic reasons, today the reasons and motives may be numerous and to protect national digital assets from malicious attacks that can destabilize country politically, economically and etc.

Teoh and Mahmood highlight the cyber threats on digital economies and nations. They addressed security and defense issues in this regard [6].

Galinec and et al. classified the cybersecurity as: information security, information technology (IT) security, operational security, and offensive security, also distinguished the terms: cyberwarfare, cyberterrorism, cybercrime, and tried to give the definition of cybersecurity [7].

E-learning necessitates a cyber platform to run the business processes, and the platform must be protected for the users to share the data. The paper by Buja and et al. underlines the main cybersecurity features in the National e-Learning policy [8].

The National Cybersecurity Index (NCSI) developed and guided by the e-Governance Academy has since 2016 functioned as a key instrument to support cybersecurity activities and countries on increment of their national cybersecurity capacities.

The NCSI indicators were developed (diagram 1) based on the national cyber security context. The main cyber threats constituting the sub-indices bear the following concepts:

1. Making e-services inaccessible;
2. Breaking the data integrity;
3. Breaking the data confidentiality [9].

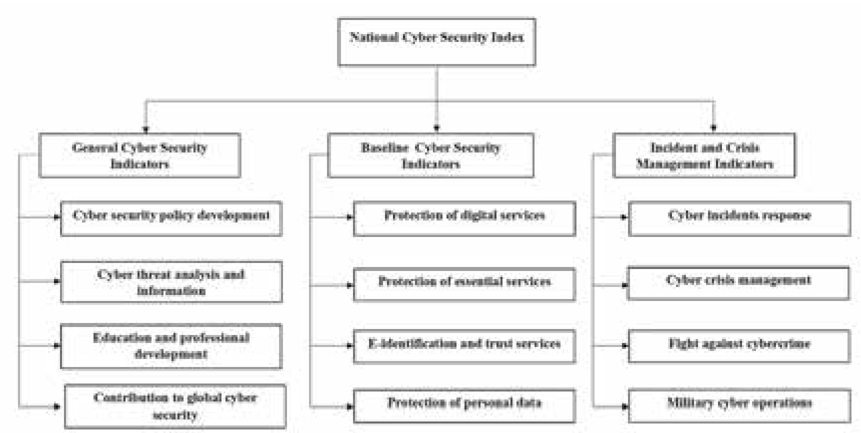


Diagram 17.1. NCSI indicators

As generalization of intuitionistic fuzzy sets, interval-valued intuitionistic fuzzy sets (IVIFS) are more effective to deal with uncertain information and to take into account ambiguity [10, 11]. With the intention to evaluate compound NCSI, interval-valued intuitionistic fuzzy weighted averaging operator (IIFWA) that is developed by Xunjie and et al. [12] will be employed. In solution of the relevant weighted linear combination problems, application of interval-valued intuitionistic fuzzy aggregation operators are uniquely effective given that those can be applied with the aim to combine multiple values into a composite quantity.

The paper is organized as following: paragraph 2 covers statement of the problem. Paragraph 3 introduces the solution algorithm for the problem. In the last paragraph, some extracts from computation, and simulation process for overall NCSI are provided.

17.2. Statement of the problem

In this paper, the main idea is to present a simulation model based on interval-valued intuitionistic fuzzy techniques for the computation and control purposes of NCSI. With this intention, a solution algorithm is developed containing interval-valued intuitionistic fuzzy tools. For the fuzzification purposes, the NCSI data for 2023 with their (maxima and minima) are acquired from e-Governance Academy Foundation [13], which is provided, in table 17.1.

Table 17.1. NCSI data on Azerbaijan

№	National Cyber Security Index	Acronyms	Data for 2023	Best case	Worst case
1. General Cyber Security Indicators		**GCSI**			
Cyber security policy development		CSPD	2	7	0
Cyber threat analysis and information		CTAI	4	5	0
Education and professional development		EPD	8	9	0
Contribution to global cyber security		CGCS	2	6	0
2. Baseline cyber security indicators		**BCSI**			
Protection of digital services		PDS	0	5	0
Protection of essential services		PES	6	6	0
E-identification and trust services		EITS	7	9	0
Protection of personal data		PPD	1	4	0

Cont…

№	National Cyber Security Index	Acronyms	Data for 2023	Best case	Worst case
3. Incident and crisis management indicators		**ICMI**			
Cyber incidents response		CIR	3	6	0
Cyber crisis management		CCM	1	5	0
Fight against cybercrime		FAC	9	9	0
Military cyber operations		MCO	3	6	0

17.3. An algorithm for computation of NCSI

The algorithm developed for computation of NCSI is introduced below:

Step 1. Interval-valued intuitionistic fuzzification of crisp data. For the fuzzification purpose, interval-valued intuitionistic fuzzification triangular function is applied [14].

$$\mu_A^-(x) = \begin{cases} \mu^- \frac{(x-a)}{(b-a)}, \\ \mu^-; \\ \mu^- \frac{(c-x)}{(c-b)}; \end{cases} \quad \mu_A^+(x) = \begin{cases} \mu^+ \frac{(x-a)}{(b-a)}, & a < x < b \\ \mu^+; & x = b \\ \mu^+ \frac{(c-x)}{(c-b)}; & b < x < c \end{cases} \tag{17.1}$$

$$v_A^-(x) = \begin{cases} 1-(1-v^-)\frac{(x-a)}{(b-a)}, \\ v^-; \\ v^- + (1-v^-)\frac{(x-b)}{(c-b)}; \end{cases} \quad v_A^+(x) = \begin{cases} 1-(1-v^+)\frac{(x-a)}{(b-a)}, & a < x < b \\ v^+; & x = b \\ v^+ + (1-v^+)\frac{(x-b)}{(c-b)}; & b < x < c \end{cases} \tag{17.2}$$

Where, $\mu^-: X \to [0,1]$, and $\mu^+ : X \to [0,1]$ denote the lower and upper membership degrees, $v^- : X \to [0,1]$, and $v^+ : X \to [0,1]$ denote the lower and upper non-membership degrees respectively.

Step 2. Construction of interval-valued intuitionistic fuzzy preference relation matrix (IVIFPRM).

In this stage based on the scale given in table 17.2, IVIFPRM is established [15].

Table 17.2. Linguistic terms for criteria preference

Linguistic terms	Acronyms	IVIFNs
Extremely important	EXI	([0.65,0.75],[0.10,0.25])
Very Important	VI	([0.60,0.70],[0.15,0.30])
Important	I	([0.55,0.65],[0.20,0.35])
Medium Important	MI	([0.50,0.60],[0.25,0.40])
Equally important	EI	([0.50,0.50],[0.50,0.50])
Medium Low Important	MLI	([0.45,0.55],[0.30,0.45])
Low Important	LI	([0.25,0.40],[0.50,0.60])

Employing the interval-valued linguistic fuzzy value counterparts of linguistic terms for criteria preference the IVIFPRM is set up for each sub-index of NCSI.

$$R = \begin{array}{c} \\ \mathrm{C}_1 \\ \mathrm{C}_2 \\ \vdots \\ \mathrm{C}_\mathrm{m} \end{array} \begin{pmatrix} \mathrm{C}_1 & \mathrm{C}_2 & \cdots & \mathrm{C}_\mathrm{n} \\ r_{11} & r_{12} & \cdots & r_{1n} \\ r_{21} & r_{22} & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{m1} & r_{m2} & \cdots & r_{mn} \end{pmatrix}$$

***Step 3*. Checking the additive consistency.** If , where stands for the preference degree interval of alternative over . Then the following conditions must hold [16] for and :

$$0 \leq \underline{r}_{ij} \leq \bar{r}_{ij} \leq 1,\ \underline{r}_{ij} + \bar{r}_{ij} = 1,\ \underline{r}_{ij} = \bar{r}_{ij} = 0.5 \ \text{ for all } \ i, j = 1,2,\ldots,n \qquad (17.3)$$

***Step 4*. Checking the multiplicative consistency.** For the multiplicative consistent interval-valued intuitionistic fuzzy preference relation , the following equations [17] must hold:

$$\tilde{\mu}_{ij}^{L} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{L} \tilde{\mu}_{kj}^{L}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{L} \tilde{\mu}_{kj}^{L}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-\tilde{\mu}_{ik}^{L})(1-\tilde{\mu}_{kj}^{L})}}, j > i+1 \qquad (17.4)$$

$$\tilde{\mu}_{ij}^{U} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{U} \tilde{\mu}_{kj}^{U}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{\mu}_{ik}^{U} \tilde{\mu}_{kj}^{U}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-\tilde{\mu}_{ik}^{U})(1-\tilde{\mu}_{kj}^{U})}}, j > i+1 \quad (17.5)$$

$$\tilde{v}_{ij}^{L} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{L} \tilde{v}_{kj}^{L}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{L} \tilde{v}_{kj}^{L}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-v_{ik}^{L})(1-\tilde{v}_{kj}^{L})}}, j > i+1 \quad (17.6)$$

$$\tilde{v}_{ij}^{U} = \frac{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{U} \tilde{v}_{kj}^{U}}}{\sqrt[j-i-1]{\prod_{k=i+1}^{j-1} \tilde{v}_{ik}^{U} \tilde{v}_{kj}^{U}} + \sqrt[j-i-1]{\prod_{k=i+1}^{j-1} (1-v_{ik}^{U})(1-\tilde{v}_{kj}^{U})}}, j > i+1 \quad (17.7)$$

***Step 5*. Calculation of Entropy.** Entropy measures are computed employing the approach established by Yager [18, 19] that is given below:

$$E_Y(A) = \frac{1}{n} \sum \frac{2 - |\mu_A^L(x_i) + \mu_A^U(x_i) - v_A^L(x_i) - v_A^U(x_i)| + \pi_A^L(x_i) + \pi_A^U(x_i)}{2 + |\mu_A^L(x_i) + \mu_A^U(x_i) - v_A^L(x_i) - v_A^U(x_i)| + \pi_A^L(x_i) + \pi_A^U(x_i)} \quad (17.8)$$

***Step 6*. Construction of Entropy matrix.** Employing formula (8) entropy matrix is constructed:

$$E = \begin{array}{c} \\ C_1 \\ C_2 \\ \vdots \\ C_m \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_n \end{array} \\ \begin{pmatrix} e_{11} & e_{12} & \cdots & e_{1n} \\ e_{21} & e_{22} & \cdots & e_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ e_{m1} & e_{m2} & \cdots & e_{mn} \end{pmatrix} \end{array}$$

***Step 7*. Obtaining the criteria weights.** Initially the entropy information measure is computed [20, 21] with the following equation:

$$E_j = \frac{1}{m} \sum_{i=1}^{m} e_{ij} \quad (17.9)$$

Then, the criteria weights are computed [20, 21] with the following equation:

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)} \tag{17.10}$$

Step 8. In this stage, interval-valued intuitionistic fuzzy weighted aggregation operator (IIFWA) is applied in order to combine interval-valued intuitionistic fuzzy values for NCSI indicators [11]:

$$IIFWA_w(\tilde{\alpha}_1, \tilde{\alpha}_2, \dots, \tilde{\alpha}_m) = \left(\left[1 - \prod_{i=1}^{m}(1 - a_i)^{w_i}, 1 - \sum_{i=1}^{m}(1 - b_i)^{w_i}\right], \left[\prod_{i=1}^{m} c_i{}^{w_i}, \prod_{i=1}^{m} d_i{}^{w_i},\right]\right) \tag{17.11}$$

Step 9. In the final step, obtained interval-valued intuitionistic fuzzy values are interpreted by linguistic terms to get comprehensible results [22]. The linguistic terms set with their interval-valued intuitionistic fuzzy values are given in table 17.3.

Table 17.3. Linguistic terms and their matching interval-valued intuitionistic fuzzy scale

Linguistic terms (*LT*)	IFNs membership and non-membership function value intervals ($([\mu^-, \mu^+],[\nu^-,\nu^+])$)
Very high (VH)	([1.00, 1.00], [0.00, 0.00])
High (H)	([0.70, 0.80], [0.05, 0.10])
Medium high (MH)	([0.60, 0.70], [0.15, 0.20])
Medium (M)	([0.50, 0.60], [0.25, 0.30])
Medium low (ML)	([0.30, 0.40], [0.45, 0.50])
Low (L)	([0.15, 0.25], [0.55, 0.60])
Very low (VL)	([0.00, 0.10], [0.85, 0.90])

Step 10. **Simulation.** The initial result is obtained employing the actual data. Then different scenarios are considered with the purpose to control the NCSI index within the country level.

17.4. Computation and simulation results of NCSI

In this section, as an example, computation part for General Cyber Security Indicators is provided. Actual data converted into interval-valued intuitionistic fuzzy numbers are given in table 17.4.

Table 17.4. Data as interval-valued intuitionistic fuzzy numbers

№	Acronims	Actual Data	Interval-valued intuitionistic fuzzy numbers
1. GCSI			
1.1	CSPD	2	[0.26,0.27],[0.71,0.72]
1.2	CTAI	4	[0.72,0.76],[0.21,0.22]
1.3	EPD	8	[0.8,0.84],[0.12,0.13]
1.4	CGCS	2	[0.30,0.32],[0.67,0.68]
2. BCSI			
2.1	PDS	0	[0,0],[1,1]
2.2	PES	6	[0.90,0.95],[0.01,0.03]
2.3	EITS	7	[0.70,0.74],[0.23,0.24]
2.4	PPD	1	[0.23,0.24],[0.75,0.77]
3. ICMI			
3.1	CIR	3	[0.45,0.48],[0.51,0.52]
3.2	CCM	1	[0.18,0.19],[0.80,0.81]
3.3	FAC	9	[0.90,0.95],[0.01,0.03]
3.4	MCO	3	[0.45,0.48],[0.50,0.51]

Following the conversion of crisp data into interval-valued intuitionistic fuzzy values, referring to steps 2 to 4, IVIFPR and consistent IVIFPR matrices are constructed as below:

$$\mathrm{R} = \begin{array}{c} \\ \mathrm{CSPD} \\ \mathrm{CTAI} \\ \mathrm{EPD} \\ \mathrm{CGCS} \end{array} \begin{array}{c} \begin{array}{cccc} \quad CSPD \quad & \quad \mathrm{CTAI} \quad & \quad \mathrm{EPD} \quad & \quad \mathrm{CGCS} \quad \end{array} \\ \begin{pmatrix} ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) & ([0.55,0.65],[0.20,0.35]) & ([0.60,0.70],[0.15,0.30]) \\ ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) & ([0.55,0.65],[0.20,0.35]) \\ ([0.20,0.35],[0.55,0.65]) & ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) \\ ([0.15,0.30],[0.60,0.70]) & ([0.20,0.35],[0.55,0.65]) & ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) \end{pmatrix} \end{array}$$

$$\tilde{R} = \begin{array}{c} \\ \mathrm{CSPD} \\ \mathrm{CTAI} \\ \mathrm{EPD} \\ \mathrm{CGCS} \end{array} \begin{array}{c} \begin{array}{cccc} \quad \mathrm{CSPD} \quad & \quad \mathrm{CTAI} \quad & \quad \mathrm{EPD} \quad & \quad \mathrm{CGCS} \quad \end{array} \\ \begin{pmatrix} ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) & ([0.50,0.69],[0.10,0.31]) & ([0.55,0.74],[0.08,0.26]) \\ ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) & ([0.50,0.69],[0.10,0.31]) \\ ([0.10,0.31],[0.50,0.69]) & ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) & ([0.50,0.60][0.25,0.40]) \\ ([0.08,0.26],[0.55,0.74]) & ([0.10,0.31],[0.50,0.69]) & ([0.25,0.40],[0.50,0.60]) & ([0.50,0.50],[0.50,0.50]) \end{pmatrix} \end{array}$$

In the next step, observing the steps 5 and 6, elements of entropy matrix are assessed:

$$E = \begin{array}{c} \\ CSPD \\ CTAI \\ EPD \\ CGCS \end{array} \begin{array}{c} \begin{array}{cccc} CSPD & CTAI & EPD & CGCS \end{array} \\ \begin{pmatrix} 1 & 0.8 & 0.7143 & 0.6690 \\ 0.8 & 1 & 0.8 & 0.7143 \\ 0.7143 & 0.8 & 1 & 0.8 \\ 0.6690 & 0.7143 & 0.8 & 1 \end{pmatrix} \end{array}$$

Following the construction of entropy matrix, the criteria weights are calculated according to equations given in step 7:

$$E_1 = 0.7973, \quad E_2 = 0.8327, \quad E_3 = 0.8286, \quad E_4 = 0.7973$$

$$w_1 = 0.2718, \quad w_2 = 0.2282, \quad w_3 = 0.2282, \quad w_4 = 0.2718$$

Consequently, interval-valued intuitionistic fuzzy weighted aggregation operator is computed as an example for the General Cyber Security Indicators then in a similar way for the overall NCSI.

$$IIFWA_{GCSI} = (1 - [((1-0.26)^{0.2718} * (1-0.72)^{0.2282} * (1-0.8)^{0.2282} * (1-0.3)^{0.2718}), ((1-0.27)^{0.2718} * (1-0.76)^{0.2282} * (1-0.84)^{0.2282} * (1-0.32)^{0.2718})], [(0.72^{0.2718} * 0.21^{0.2282} * 0.12^{0.2282} * 0.67^{0.2718}), (0.72^{0.2718} * 0.22^{0.2282} * 0.13^{0.2282} * 0.68^{0.2718})] = ([0.57,0.61],[0.35,0.37])$$

Following the computation algorithm for all subindices, the NCSI is aggregated:

$$IIFWA_{NCSI} = ([0.58,0.64],[0.27,0.31])$$

In due course, for the simulation purpose five scenarios are put forward for the assessment of high level of NCSI. The possible increment of five lower indicators: Cyber security policy development, Contribution to global cyber security, Protection of digital services, Protection of personal data, and Cyber crisis management are taken into account. The obtained results shown in table 17.5 indicates that a unit change in PDS and PPD strengthens NCSI from medium to medium high, and two units change in PDS along with a unit increment in the indicators CSPD, CGCS, and CCM might improve NCSI index to the high level.

Table 17.5. Simulation results

№	Acronims	Actual Data	V1	V2	V3	V4	V5
1. GCSI							
1.1	CSPD	2	2	2	3	3	4
1.2	CTAI	4	4	4	4	4	4
1.3	EPD	8	8	8	8	8	8
1.4	CGCS	2	2	2	2	2	3

Cont…

№	Acronims	Actual Data	V1	V2	V3	V4	V5
2. BCSI							
2.1	PDS	0	1	1	2	2	3
2.2	PES	6	6	6	6	6	6
2.3	EITS	7	7	7	7	7	7
2.4	PPD	1	1	2	2	2	3
3. ICMI							
3.1	CIR	3	3	3	3	3	3
3.2	CCM	1	1	1	1	2	3
3.3	FAC	9	9	9	9	9	9
3.4	MCO	3	3	3	3	3	3
IVIFVs		[0.58,0.64], [0.27,0.31]	[0.59,0.65], [0.26,0.31]	[0.60,0.66], [0.26,0.30]	[0.61,0.67], [0.24,0.29]	[0.62,0.68], [0.24,0.28]	[0.67,0.73], [0.21,0.24]
LT		**M**	**MH**	**MH**	**MH**	**MH**	**H**

Despite the fact that linguistic terms are more helpful to understand the change in overall index, interval-valued intuitionistic fuzzy numbers are more advantageous to track the dynamics of general index within the simulation process. The simulation process is provided in diagram 17.2.

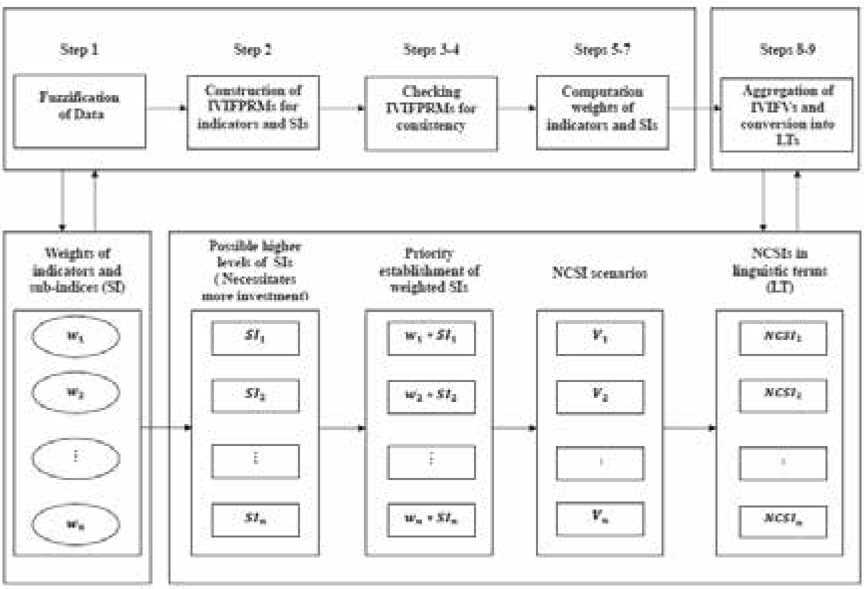


Diagram 17.2. NCSI simulation and control process

17.5. Conclusion

In this paper, the NCSI is computed with IIFWA operator taking into account weights of sub-indices and indicators. Obtained results over actual data reflect NCSI level in the country and outcomes over simulated scenarios can be used for the improvement of the NCSI index over the certain indicators. In the last section NCSI outputs as an aggregated interval-valued, intuitionistic fuzzy values are converted into linguistic terms for clear understanding. But, the computation of priority weights of indicators and sub-indices affecting the actual overall index is a different research direction. The difference of current approach from our earlier analogous methods in computation of global indices is the application of fuzzy logic based-extension instruments. The proposed approach can be applicable in computation and simulation of other socio-economic indices.

References

1. Weiss, J., Perkins, E., & Walls, A. (2013). *Definition: Cybersecurity* (Gartner Research, Ed.). https://www.gartner.com/en/documents/2510116

2. Guide to developing a National Cybersecurity Strategy. (2021). *NCS Homepage - NCS guide*. https://ncsguide.org/

3. Darıcılı, A. B., & Çelik, S. (2021). National Security 2.0: The Cyber Security of Critical Infrastructure, 259-276. https://dergipark.org.tr/en/pub/perception/issue/68005/1055264

4. Jorge, F. C., Afifi, A., Lozinskiy, N., V., & Unit, J. I. (2021). *Cybersecurity in the United Nations System organizations: report of the Joint Inspection Unit*. United Nations Digital Library System. https://digitallibrary.un.org/record/3945323?ln=ru&v=pdf

5. Kolini, F., & Janczewski, L. (2017). Clustering and Topic Modelling: A New Approach for Analysis of National Cyber security Strategies. *www.academia.edu*. https://www.academia.edu/102966717/Clustering_and_Topic_Modelling_A_New_Approach_for_Analysis_of_National_Cyber_security_Strategies

6. Teoh, C. S., & Mahmood, A. K. (2017). National cyber security strategies for digital economy. *Journal Of Theoretical And Applied Information Technology,* 95(23), 1-6. https://doi.org/10.1109/icriis.2017.8002519

7.Galinec, D., Možnik, D., & Guberina, B. (2017). Cybersecurity and cyber defence: national level strategic approach. *Automatika*, 58(3), 273-286. https://doi.org/10.1080/00051144.2017.1407022

8.Buja, A. G. (2021). Cyber Security features for National E-Learning Policy. *Türk Bilgisayar Ve Matematik Eğitimi Dergisi*, 12(5), 1729-1735. https://doi.org/10.17762/turcomat.v12i5.2169

9.*NCSI: Upgrading National Cyber Resilience - E-riigi Akadeemia*. (n. d.). E-riigi Akadeemia. https://ega.ee/publication/updating-national-cyber-resilience/

10. Atanassov, K. T. (1986). Intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 20(1), 87-96. https://doi.org/10.1016/s0165-0114(86)80034-3

11. Atanassov, K., & Gargov, G. (1989). Interval valued intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 31(3), 343-349. https://doi.org/10.1016/0165-0114(89)90205-4

12. Gou, X., Xu, Z., & Liao, H. (2015). Exponential operations of interval-valued intuitionistic fuzzy numbers. *International Journal Of Machine Learning And Cybernetics*, 7(3), 501-518. https://doi.org/10.1007/s13042-015-0434-6

13. *NCSI: Azerbaijan*. (2020). https://ncsi.ega.ee/country/az/

14. Bharati, S. K. (2021). Transportation problem with interval-valued intuitionistic fuzzy sets: impact of a new ranking. *Progress In Artificial Intelligence*, 10(2), 129-145. https://doi.org/10.1007/s13748-020-00228-w

15. Oztaysi, B., Onar, S. C., Goztepe, K., & Kahraman, C. (2015). Evaluation of research proposals for grant funding using interval-valued intuitionistic fuzzy sets. *Soft Computing*, 21(5), 1203-1218. https://doi.org/10.1007/s00500-015-1853-8

16. Zhuang, H. (2018). Additively Consistent Interval-Valued Intuitionistic Fuzzy Preference Relations and Their Application to Group Decision Making. *Information*, 9(10), 260. https://doi.org/10.3390/info9100260

17. Liao, H., Xu, Z., & Xia, M. (2014). Multiplicative consistency of interval-valued intuitionistic fuzzy preference relation. *Journal Of Intelligent & Fuzzy Systems*, 27(6), 2969-2985. https://doi.org/10.3233/ifs-141256

18. Yager, R.R. (2004). OWA aggregation over a continuous interval argument with applications to decision making. *IEEE Transactions on Systems, Man, and Cybernetics*, 34(5), 1952–1963.

19. Zhao, N., & Xu, Z. (2016). Entropy Measures for Interval-Valued Intuitionistic Fuzzy Information from a Comparative Perspective and Their Application to Decision Making. *Informatica*, 27(1), 203-229. https://doi.org/10.15388/informatica.2016.82

20. Qi, X.W., Liang, C.Y., Zhang, E.Q., & Ding, Y. (2011). Approach to interval-valued intuitionistic fuzzy multiple attributes group decision making based on maximum entropy. *Xitong Gongcheng Lilun yu Shijian/System Engineering Theory and Practice*, 31. 1940-1948.

21. Zhang, Y., Ma, P., Su, X., & Zhang, C. (2011). Entropy on interval-valued intuitionistic fuzzy sets and its application in multi-attribute decision making. *14th International Conference on Information Fusion*, 1-7. http://fusion.isif.org/proceedings/Fusion_2011/data/papers/131.pdf

22. Abdullah, L., Goh, C., Zamri, N., & Othman, M. (2019). Application of interval valued intuitionistic fuzzy TOPSIS for flood management. *Journal Of Intelligent & Fuzzy Systems*, 38(1), 873-881. https://doi.org/10.3233/jifs-179455

18. ESTIMATION OF THE SOCIAL CONSEQUENCES OF COUNTRIES ECONOMIC DEVELOPMENT

18.1. Introduction

The founders of fuzzy economics theory, Professor L. Zadeh [1], Kofmann and Professor J. Gil-Aluja [2-4], developed the methods that are used to solve contemporary problems of uncertainty in economics. One of the difficult problems to solve in socio-economic systems is the assessment of the social consequences of the functioning of the economy.

The economic development of each country is accompanied by social consequences. If development corresponds to economic growth, then social development is positive. Otherwise, social indicators such as employment, inflation, poverty increase and the general social situation of the population worsens.

In 2008, the Nobel Prize laureates Prof. J. Stiglitz, A. Sen and Prof. J. Fitoussi in the report of the Commission for Measuring Economic Performance and Social Progress [5] identified the limits of GDP as an indicator of economic performance and social progress. It has long been clear that GDP is an inadequate indicator, especially in its economic, environmental and social dimensions. The report examined how the wealth and social progress of a nation could be measured, without relying on the unidimensional GDP measure.

After report appeared some investigations, devoted to this problem. Let us note some of these works. “A Critical Analysis of Social Development: Features, Definitions, Dimensions and Frameworks” underline that social development is essentially concerned with not only the material aspect but also the non-material aspect of society and human life [6]. Hence, social development framework should take into account every aspect of social development including material and non-material.

In "The SOLA Model: A Theory-Based Approach to Social Quality and Social Sustainability" presentation of the model and on conceptual issues of social sustainability and social quality was proposed [7]. The model is based on an extensive review of alternative approaches. It is empirically validated in quality of life research in social and health care, and applied in on-going research on inclusive social policy.

Taken into account above mentioned investigations in this paper for estimation level of social consequence of Azerbaijan's economic development model were social sustainability and social quality models are proposed and given result of solution problems which relevant to the models.

18.2. Indicators of intuitionistic fuzzy logic social sustainability models

Today, there are many definitions of **social sustainability** by scientists and international organizations. Scientists and practitioners have proposed various definitions of social sustainability. Depending on the objectives of the study, we have chosen the following definition. "Social sustainability is a quality of societies. It signifies the nature-society relationships, mediated by work, as well as relationships within the society. Social sustainability is given if work within a society and the related institutional arrangements which satisfy an extended set of human needs, are shaped in a way that nature and its reproductive capabilities, are preserved over a long period of time and the normative claims of social justice, human dignity and participation are fulfilled" [8]. Core themes concern human well-being and equity, access to basic needs, fair distribution of income, good working conditions and decent wages, equality of rights, inter-and intragenerational justice, access to social and health services and to education, social cohesion and inclusion, empowerment, and participation in policy-making [9].

The elaborated approach for assessment of social sustainability goals covers the following indices: Quality of Life, Basic Human Needs, Human Capital and Research, Ecocivilization have the common indicators with Social Development Goals [10], which is described in table 18.1.

Table 18.1. Relation of Social Sustainability components with SDGs

Socio-economic indices	Sub-indices	Relation to SDGs
Quality of Life **(QLI)**	Material Wellbeing Health Political Stability and Security Political Freedom Family Life Community Life Climate and Geography Job Security Gender Equality	SDG1, SDG3, SDG5, SDG8, SDG13, SDG12, SDG16
Basic Human Needs **(BHN)**	Nutrition & Basic Medical Care Water & Sanitation Shelter Personal safety	SDG1, SDG2, SDG3, SDG6, SDG7, SDG12, SDG16
Human Capital and Research **(HCR)**	Education Tertiary education Research & development	SDG4, SDG9
Ecocivilization **(ECLI)**	Green economy Social quality Ecological quality	SDG1, SDG2, SDG3, SDG6, SDG7, SDG11, SDG12, SDG13, SDG14, SDG15
Social Mobility **(SM)**	Income mobility	SDG10

Source [6]

18.3. Indicators of intuitionistic fuzzy logic social quality models

The Social Quality approach measures the quality of the social context of everyday life, which is seen as the outcome of the dialectical relationship between the formation of collective identities and the self-realization of the human subject. It provides the essential link between need, action and policies between economic and social development. It measures the extent to which the quality of daily life provides for an acceptable standard of living, taking account of the structural features of societies and their institutions as assessed by reference to their impact on citizens. It conceptualizes 'the social' as the space created by the interaction between the economic and social structures, between structure and agency. The Social Quality model identifies four fields: economic security, social cohesion, social inclusion and the conditions for social empowerment [11] (tab. 2). Sub-indices and their indicators are given in table 18.2.

Table 18.2. Social Quality Index components

Sub-indices	Indicators
Socio-economic Security Index **(SESI)**	Unemployment/ employment security Poverty rate/income sufficiency Homelessness/Satisfaction with housing Access/sufficiency of public services
Social Empowerment Index **(SEI)**	Education level Health problems/perceived health Access to information of public services Governance/ support of citizens
Social Cohesion Index (**SCI)**	Distances Inclusion-exclusion mechanisms Sense of belonging
Social Inclusion Index **(SII)**	Recognition of human rights of all citizens Respect of rule of law Equality/Tolerance Labor market inclusion/retirement

Sources:[7,12]

18.4. Algorithm for solution problems corresponding to models

The developed algorithm [13] for computation of Sub-indices of the models includes next steps:

Step 1. Normalization of input data. In order to convert crisp input data given in different scales into fuzzy numbers, firstly the data must be normalized. On that account, max-min normalization method for the positive and negative affecting indicators is employed.

Step 2. Fuzzification of normalized data. With the purpose to convert the normalized data into fuzzy numbers, we use triangular membership fuzzification function.

Step 3. Building of the fuzzy preference relation (FPR) matrix. In this phase, FPR matrix is constructed in order to obtain the criteria weights.

Step 4. Transforming of the initial FPR matrix into consistent FPR matrix. In FPR, getting valid solution depends on FPR matrix consistency. Since the weak consistency may lead to distorted results, it is considered as a critical problem in FPRs.

The additive consistency of FPR was proved to be insufficient, for this reason, multiplicative consistency must be checked.

Step 5. Computation of the criteria weights. Next, the vector of criteria weights are assessed.

Step 6. Aggregation of fuzzified values of indicators. In this step, fuzzy weighted aggregation operator (FWA) is implemented for incorporation of intuitionistic fuzzy values (IFVs) standing for sub-indices and their indicators.

Step 7. Establishment of linguistic term set. With the purpose to recognize the level of aggregated fuzzy value among the linguistic term set, the linguistic term scale is constructed.

Step 8. Computation of similarity measures. In the final step, with the purpose to identify corresponding linguistic term to aggregated fuzzy values, similarity measures are computed.

18.5. Result of solution problem corresponding to the model estimation indicators of social sustainability

The following are the main results of the research conducted on the determination of quality of life, basic human needs, human capital and research indices, ecocivilization with intuitionistic fuzzy models, which are the main components of social sustainability:

Quality of life. The Economist Intelligence Unit [14] organization developed the Quality of Life Index **(QLI)** based on a modern unique methodology, which correlates the results of the subjective life assurance survey for Azerbaijan with QLI indicators. The obtained results for Quality of Life Index **(QLI)** are given below:

QLI(2014) – AH (Absolutely High)

QLI(2016) – AH (Absolutely High)

QLI(2018) – AH (Absolutely High)

QLI(2020) – AH (Absolutely High)

QLI(2021) – AH (Absolutely High)

The Basic Human Needs (BHN). BHN is one of the three elements of the Social Progress Index and is calculated as one of its sub-indices [15]. The Social Progress Index is a non-economic measure of the social activity of all the countries of the world.

Thus, the obtained result for 2021-year **BHN** in a linguistic term is as follows:

BHN(2021)= AH (Absolutely High)

Human Capital and Research. Data from the Global Innovation Index [16] were used to estimate the **Human Capital and Research Index (HCR)**:

The intuitionistic fuzzy values of **HCR** falling into the corresponding intervals have been replaced by linguistic terms expressing the level of **HCR** index for each year:

HCR(2015) = Very High	**HCR(2018) = Very Low**
HCR(2016) = Very Low	**HCR(2019) = Low**
HCR(2017) = Very High	**HCR(2021) = Low**

Ecocivilization Index. Ecocivilization **(ECLI)** is a new paradigm of Sustainable Development and include Green economy, Social quality, and Ecological quality. The obtained results of computation are [17]:

ECLI(2018) = ML

ECLI(2019) = L

ECLI(2020) = VL

Taking into account the results of **QLI, BHN**, **HCR** and **ECLI** indices for 2021 using fuzzy linguistic union operation, we obtain aggregated social sustainability index **(ASSI):**

$$\mathbf{ASSI} = \boldsymbol{QLI} \cup \boldsymbol{BHN} \cup \boldsymbol{HCR} \cup \boldsymbol{ECLI} = \boldsymbol{AH} \cup \boldsymbol{AH} \cup \mathbf{L} \cup \boldsymbol{L} = \boldsymbol{MH}\textbf{(Medium High)}$$

18.6. Result of solution problem corresponding to the model estimation indicators of social quality

Social Quality and its Sub-indices (Socio-economic Security Index, Social Empowerment Index, Social Cohesion Index, Social Inclusion Index) are evaluated with fuzzy logic-based extension methods as fuzzy, intuitionistic fuzzy, interval-valued intuitionistic fuzzy and hesitant fuzzy tools. Despite the fact that various approaches are applied, the elaborated algorithm for computation is common for all of Social Quality Sub-indices.

Based on the algorithm presented above **Social Security Sub-index (SESI)** is computed with the application of fuzzy instruments. The computed overall index is given both in fuzzy triangular number and linguistic term that represent **SESI** for Azerbaijan in 2021:

SESI = (0.67,0.77,0.83) = High (H)

Social Empowerment Sub-index (SEI) is computed employing intuitionistic fuzzy instruments referring to the common algorithm. Aggregated overall index for **SEI** as intuitionistic fuzzy value is given below:

SEI = (0.77,0.10)

Similarity measures between aggregated value for **SEI** and linguistic terms leads to identification the level of **SEI** for Azerbaijan in 2021**:**

***SEI* = High (H)**

Following the computation algorithm for all subindices, the **Social Cohesion Sub-index (SCI)** is computed with the application of interval-valued intuitionistic fuzzy tools. The aggregated value of **SCI** is:

***SCI* =** ([0.60,0.66],[0.27,0.30])

Similarity measures between aggregated value for **SCI** and relevant linguistic terms are computed and the highest similarity value corresponds to the linguistic term - Medium (M), and the level of **SCI** in 2021 for Azerbaijan is:

***SCI* =** Medium (M)

Following the computation algorithm for all subindices, the **Social Inclusion Sub-index (SII)** is computed with the application of hesitant fuzzy tools. The value of **SII** in linguistic term is:

***SII* =** Medium (M)

Finally, the **Social Quality Index** (SQI) is computed using fuzzy linguistic union operation, and aggregated value of all four indices given above in linguistic term is presented as:
SQI = = (Medium)

$$\mathbf{SQI} = \boldsymbol{SESI} \cup \boldsymbol{SEI} \cup \boldsymbol{SCI} \cup \boldsymbol{SII} = \boldsymbol{H} \cup \boldsymbol{H} \cup \boldsymbol{M} \cup \boldsymbol{M} = \boldsymbol{M} \text{ (Medium)}$$

One of the important factors of social sustainability and social quality of social systems is the **social mobility** of the social groups.

Social mobility (SM) is a very important index for define the level of social sustainability and social quality. Social mobility is the transition of social groups between different levels of the social hierarchy. Social mobility is measured in two ways: mobility speeds and mobility intensity. As a suitable method for measuring social mobility can be used fuzzy linguistic Markov Chain.

In order to predict **social mobility**, Theil and Fields indices were first calculated, and at the next stage, the prediction was made using the linguistic Markov chain [18].

The initial state of social mobility indicators for Azerbaijan by economic strata for the last period **SM(2020)** = (0, 0.07, 0.47, 0.18, 0.04) corresponds to the following linguistic social mobility vector: **SM(2020)** = (VL, L, VM, L, L).

The transition matrix from one socio-economic class to another was determined based on the dynamics of households by social class based on income.

Fuzzy linguistic Markov chain was used in order to forecast the social mobility intensity for 2021-2023 for each of the social classes and the following fuzzy linguistic prediction vectors were obtained:

SM(2021) = (VL, L, VM, L, L)

SM(2022) = (VL, L, VM, L, L)

SM(2023) = (VL, L, VM, L, L)

From the obtained results, it can be seen that there was no change in the indicators of mobility in social classes. The lack of change in mobility indicators by social strata over the next three years is due to the fact that the transition matrix is cumulative and covers the near term. If the transition matrix is ideal, that is, if the transition from the very poor to the poor, from the middle to the upper class and staying in the upper class is high (H), and the other transitions are medium (M), then the mobility indicators for social classes will accumulate at the medium (M) level. This means a stable and ideal state of social mobility.

In this study, the indicators of mobility of social groups were calculated separately for the years 2009, 2015, 2020, and the Fields and Ok indexes for the period 2009-2020. It was determined that the mobility indicators for the very poor class were very low, for the low-income class it was average, and for other classes it was low.

The forecast of the indicators for the next years through the fuzzy linguistic Markov chain showed that there will be no significant change. Since high mobility indices are an indicator of no need for redistribution of income in the society, the research conducted in this direction can be useful in the preparation of social policy programs.

18.7. Conclusion

Proposed approach to define social consequences of economic development of the country by using social sustainability and social quality indices give us possibility for wide analysis of socio-economic system functioning. Applying the instruments of intuitionistic fuzzy logic theory takes into account uncertainty of indicators of social system and we get more objective results for define social progress process in the country.

References

1. Zadeh, L. (1965). Fuzzy sets. *Information And Control*, 8(3), 338-353. https://doi.org/10.1016/s0019-9958(65)90241-x

2. Kaufmann, A., & Gil-Aluja, J. (1986). *Introducción de la teoría de los subconjuntos borrosos a la gestión de las empresas*. Milladoiro.

3. Gil-Aluja, J. (1996). Towards a new paradigm of investment selection in uncertainty. *Fuzzy Sets And Systems*, 84(2), 187-197. https://doi.org/10.1016/0165-0114(96)00068-1

4. Gil-Aluja, J. (1999). Elements for a theory of decision in uncertainty. *Applied optimization*. https://doi.org/10.1007/978-1-4757-3011-1

5.Stiglitz, J., Sen, A., & Fituossi, J.P. (2009). *Report of the Commission on the Measurement of Economic Performance and Social Progress*, 291.

6.Ali, I. A. M., Mustafa, O. M., & Barom, M. N. B. (2019). A Critical Analysis of Social Development: Features, Definitions, Dimensions and Frameworks. *Asian Social Science*, 16(1), 14. https://doi.org/10.5539/ass.v16n1p14

7.Pieper, P., Karvonen, S., Vaarama, M.: The SOLA Model: A Theory-Based Approach to Social Quality and Social Sustainability. Social Indicators Research, 146:553–580 (2019). https:// doi.org/10.1007/s11205-019-02127-7.

8.Littig, B., & Griessler, E. (2005). Social sustainability: a catchword between political pragmatism and social theory. *International Journal Of Sustainable Development*, 8(1/2), 65. https://doi.org/10.1504/ijsd.2005.007375

9.McGuinn, J. (2020). *Social sustainability: Concepts and benchmarks* (Policy Department for Economic, Scientific and Quality of Life Policies [European Parliament], Ed.). https://www.europarl.europa.eu/RegData/etudes/STUD/2020/648782/IPOL_STU(2020)648782_EN.pdf_

10. Inter-Agency and Expert Group on Sustainable Development Goal Indicators. (2016). *Final list of proposed Sustainable Development Goal indicators*.
https://sustainabledevelopment.un.org/content/documents/11803Official-List-of-Proposed-SDG-Indicators.pdf

11. Abbott, P., & Wallace, C. (2011). Social Quality: A Way to Measure the Quality of Society. *Social Indicators Research*, 108(1), 153-167. https://doi.org/10.1007/s11205-011-9871-0

12. Villatoro, P. (2007). *A system of indicators for monitoring social cohesion in Latin America*. ONU. Repositorio digital. Comisión Económica para América Latina y el Caribe (CEPAL). https://hdl.handle.net/11362/2888

13. Hasanli, Y., & Aliyev, A. (2024). Fuzzy Models for Assessment of Socio-economic Security Index. *Lecture notes in networks and systems* (pp. 290-298). https://doi.org/10.1007/978-3-031-76283-3_39

14. The Economist Intelligence Unit's quality-of-life index. (2005). In *https://www.economist.com*. The World.
https://www.economist.com/media/pdf/quality_of_life.pdf

15. *2021 Social Progress Index*. (2021). https://www.socialprogress.org/index/global/results

16. Cornell University, INSEAD, & WIPO. (2015). *The Global Innovation Index 2015: Effective Innovation Policies for Development.*

17. Imanov, G., & Aliyev, A. (2023). Intuitionistic fuzzy pattern recognition model in assessment of ecological civilization index. *Science*. https://www.academia.edu/110693872/Intuitionistic_fuzzy_pattern_recognition_model_in_assessment_of_ecological_civilization_index

18. Imanov, G.J., & Aliyev, A.Z. (2019). Fuzzy linguistic forecasting of social mobility. *The Journal of Economic Science: Theory and Practice*, 76(2).

19. FUZZY ANALYSIS OF GLOBAL UNCERTAINTY FACTORS AFFECTING THE AZERBAIJANI ECONOMY

19.1. Introduction

In recent years, the global pandemic, the Ukrainian-Russian war, and climate change have created uncertainties that significantly affect economic development. These challenges have led to a negative impact on the growth rate of Gross Domestic Product (GDP) in different countries, increased levels of inflation, fluctuating fuel prices, and numerous social indicators. Various international organizations analyze these issues and offer advice to mitigate them in the future. Wars, diseases, and natural disasters occurring worldwide in recent years have further exacerbated uncertainties and hindered the development of countries. Azerbaijan's economy is also susceptible to these negative situations, as evident from Tables 19.1-19.3, which characterize the economic indicators of Azerbaijan from 2015 to 2022, reflecting the influence of COVID-19, the Ukrainian war, and climate change.

The effects of the COVID-19 crisis on Azerbaijan's economic security was studied, revealing its profound influence on oil-exporting countries' economies, including Azerbaijan's, through its impact on global oil prices. With Azerbaijan's export heavily reliant (90 percent) on energy, particularly oil, the drop in oil prices due to the OPEC+ deal to cut supplies has significantly affected the country's foreign direct investment index, oil income, and overall economic growth, leading to increased levels of unemployment and inflation [1].

Furthermore, the study indicates a decrease in Azerbaijan's foreign direct investment, oil production, and income from tourism and other industries during the COVID-19 crisis, exacerbating issues such as poverty, unemployment, and inflation. Collectively, these challenges pose a significant threat to Azerbaijan's economic security.

Table 19.1. Economic indicators of Azerbaijan before and after the influence of COVID-19 (Sub-index 1)

№	Economic indicators	2015	2016	2017	2018	2019	2020	2021	2022
1	Real GDP growth, at constant market prices	1.1	-3.1	0.2	1.5	2.5	-4.3	5.6	4.6
2	Weight of oil and gas production in the % of GDP	25.3	29.3	32.3	37.1	33.6	24.3	33.5	44.0
3	FDI (% of GDP)	7.63	11.88	7.02	2.98	1.50	0.51	-1.71	-4.74
4	Inflation (consumer price index) (%)	4.0	12.4	12.9	2.3	2.6	2.8	6.7	13.8
5	Revenues from tourism, mln. AZN	36.48	36.76	41.03	56.44	63.36	16.15	22.61	53.35

Source: World Bank, Poverty & Equity and Macroeconomics, Trade & Investment Global Practices

Table 19.1 shows that the real GDP growth fluctuated over the years. There was a decline in 2016 and 2020, which could be attributed to the global economic slowdown and the impact of COVID-19. Notably, there was a significant rebound in GDP growth in 2021 and 2022, indicating some recovery from the effects of the pandemic. Azerbaijan's economy heavily relies on oil and gas production, as evidenced by the significant percentage of GDP contributed by this sector. The weight of oil and gas production in GDP increased steadily over the years, with a notable spike in 2022, suggesting a growing reliance on the energy sector. Foreign Direct Investment (FDI) as a percentage of GDP fluctuated over the years, with a general declining trend. The negative values in 2021 and 2022 indicate a withdrawal of foreign investment, possibly due to economic uncertainties surrounding the pandemic. Inflation remained relatively moderate in the earlier years but experienced significant fluctuations in later years. There was a notable increase in inflation in 2016 and 2021, which could be attributed to various factors including changes in demand-supply dynamics and economic policies. Revenues from tourism showed a generally increasing trend from 2015 to 2019, indicating growth in the tourism sector. However, there was a sharp decline in tourism revenues in 2020, likely due to travel restrictions and the impact of the COVID-19 pandemic. The subsequent recovery in 2021 and 2022 suggests some revival in the tourism industry, although it may not have fully recovered to pre-pandemic levels.

Primarily, the data indicates that Azerbaijan's economy experienced significant fluctuations and challenges due to the COVID-19 pandemic, with varying impacts on different sectors such as oil and gas, foreign investment, inflation, and tourism.

The Russian invasion of Ukraine has generated chaos, uncertainty, and a pressing need for stability in many countries. Azerbaijan is not exempt from the repercussions, facing not only political challenges but also significant socio-economic effects as a result of the conflict. The war has disrupted the flow of crude oil, impacted energy prices, hydrocarbon exports, and product prices. Additionally, from a social perspective, there has been a notable increase in the number of migrants/refugees and ethnic Azerbaijanis (more than 1 million currently residing in Russia) returning to the country following the conflict [2].

One potential measure to address these challenges is to reduce the fees associated with money transfers from Russia to Azerbaijan. Presently, many companies such as Zolotaya Korona, Western Union, and others impose high fees for these transactions. The Azerbaijani government could incentivize local banks to lower these fees, thereby facilitating an increase in remittances from Russia and Ukraine to Azerbaijan. This could help alleviate some of the economic strain caused by the Ukrainian war

Table 19.2. Economic indicators of Azerbaijan before and after the influence of Ukrainian war (Sub-index 2)

№	Economic indicators	2015	2016	2017	2018	2019	2020	2021	2022
1	Oil exports thsd. barrels/day	703.30	698.81	650.45	652.95	741.83	673.82	667.21	632.85
2	Money transfers from Russia to Azerbaijan (mln.$)	950	912	1016	1101	564.74	606.06	623.06	2969.44
3	Oil prices (Average Azeri LT CIF, $)	52.39	43.73	54.19	71.31	64.28	41.96	70.86	101.56
4	Gross income of travel agencies and tour operators -total mln. AZN	36.48	36.76	41.03	56.44	63.36	16.15	22.61	53.35
5	Number of migrants from Ukraine and Russia (in person)	1029	1036	1137	1206	660	511	735	996

Source: World Bank, Poverty & Equity and Macroeconomics, Trade & Investment Global Practices

In Table 19.2 illustrated that the volume of oil exports remained relatively stable from 2015 to 2019. There was a slight decline in 2020 and 2021, which could be attributed to various factors including changes in global oil demand and prices. The further decrease in 2022 suggests ongoing challenges in the oil export sector. Money transfers from Russia to Azerbaijan showed a fluctuating pattern over the years. There was a significant increase in 2022, possibly due to changes in geopolitical relations or economic factors related to the Ukrainian war. Oil prices experienced fluctuations over the years, influenced by various global factors including supply-demand dynamics and geopolitical tensions. There was a notable increase in oil prices in 2022, which could be attributed to geopolitical tensions arising from the Ukrainian war and its impact on global oil markets. The gross income of travel agencies and tour operators showed a general increasing trend from 2015 to 2019, indicating growth in the tourism sector. However, there was a sharp decline in 2020, which could be attributed to travel restrictions and the impact of the COVID-19 pandemic. The subsequent recovery in 2021 and 2022 suggests some revival in the tourism industry, although it may still be below pre-pandemic levels. The number of migrants from Ukraine and Russia fluctuated over the years. There was a significant decline in 2020 and 2021, possibly due to the impact of the COVID-19 pandemic on migration patterns. The increase in 2022 could be influenced by various factors, including the Ukrainian war and its impact on migration flows in the region.

Typically, the data suggests that the Ukrainian war has had various impacts on Azerbaijan's economy, including changes in oil exports, money transfers, oil prices, tourism, and migration patterns. These effects highlight the interconnectedness of regional economies and the influence of geopolitical events on economic indicators.

Climate change poses a significant risk to achieving favorable development outcomes, and the World Bank Group is committed to aiding countries in integrating climate action into their core development agendas.

In Azerbaijan, climate change is anticipated to affect food production through both direct and indirect impacts on crop growth processes. Direct effects encompass changes in carbon dioxide availability, precipitation patterns, and temperatures, while indirect effects include alterations in water resource availability and seasonality, transformations in soil organic matter, shifts in pest profiles and the spread of invasive species, as well as a decrease in arable land due to land degradation and desertification [3].

Research indicates that, on average, a one-degree increase in ambient temperature can lead to a 0.5%–8.5% rise in electricity demand [4].

Economic indicators influenced by climate change are outlined in Table 19.3.

Table 19.3. Economic indicators of Azerbaijan under influence of climate change (Sub-index 2)

№	Economic indicators	2015	2016	2017	2018	2019	2020	2021	2022
1	Total sown area under agricultural crops, thsd.ha	1585.39	1628.31	1665.71	1738.04	1717.05	1630.94	1644.45	1623.96
2	Cotton fields, thsd. ha	18.68	51.37	136.41	132.51	100.11	100.30	100.59	104.27
3	Labor productivity, thsd $	11344.46	7954.53	8475.13	9655.68	10066.5	9042.8	11348.4	16079.6
4	Energy consumption, PJ	381.34	396.05	391.83	414.10	399.81	395.82	420.40	461.35

Source: World Bank, Poverty & Equity and Macroeconomics, Trade & Investment Global Practices

The total sown area under agricultural crops showed a fluctuating pattern over the years in Table 19.3. There was a general trend of increase from 2015 to 2018, followed by a slight decrease in subsequent years. Changes in the sown area could be influenced by various factors including climate conditions, agricultural policies, and market demand. The area dedicated to cotton fields experienced significant fluctuations over the years. There was a notable increase from 2015 to 2017, followed by a decline in 2018 and subsequent stabilization. Changes in the area dedicated to cotton fields could be influenced by factors such as climate conditions, crop rotation practices, and market demand for cotton products. Labor productivity showed fluctuations over the years, with a general increasing trend from 2015 to 2022. There were fluctuations in labor productivity, which could be influenced by various factors including technological advancements, changes in workforce skills, and economic policies. Energy consumption exhibited a fluctuating pattern over the years, with slight fluctuations around a general increasing trend. Changes in energy consumption could be influenced by economic growth, industrial activities, technological advancements, and energy efficiency measures.

Overall, the data suggests that climate change may have influenced certain economic indicators in Azerbaijan, particularly those related to agriculture and energy consumption. Fluctuations in agricultural sown area and productivity may reflect the impact of changing climate conditions on agricultural activities. Additionally, changes in energy consumption patterns may also be influenced by climate-related factors such as changes in temperature and precipitation patterns.

According to research conducted by the United Nations International Strategy for Disaster Reduction (UNISDR) and World Bank (2009), drought is considered the largest risk in Azerbaijan, resulting in an average annual loss of USD 6 million, followed by floods (USD 5.7 million), earthquakes (USD 1.6 million), and landslides (USD 0.3 million). The 20-year return period loss for all hazards is estimated at USD 71 million (0.23 percent of GDP), while the 200-year return period loss is projected at USD 179 million (0.57 percent of GDP). Additionally, the average annual economic losses caused by all natural hazards are estimated at nearly USD 50 million [5].

In recent years, intensive research has been conducted in the field of analyzing the problems of uncertainty affecting the global economy and individual countries. Among them, I would like to mention the following investigations:

The working paper by H. Ahir and et.al focuses on the World Uncertainty Index, which measures uncertainty across the globe. They find that this index tends to spike during significant events such as the Gulf War, the Euro debt crisis, the Brexit vote, and the COVID-19 pandemic. The paper likely delves into how these spikes in uncertainty impact economic behavior, investment decisions, and overall global economic stability [6].

The paper by C. C. Chen and et.al examines the Economic Policy Uncertainty (EPU) index and the impact of semantics on its effectiveness. The authors investigate various neural network models to select the best-performing classifier for removing noise caused by keyword matching in constructing the EPU index. Their empirical results suggest that the de-noised EPU index is valuable for predicting economic variables and generates superior out-of-sample forecasts. Moreover, they find that the effects of policy uncertainty shocks on core macroeconomic variables align with predictions from macroeconomic theory. This indicates the importance of considering semantics in constructing uncertainty indices and highlights the potential implications for economic forecasting and policy analysis [7].

By utilizing information from tables 19.1-19.3 and applying a fuzzy algorithm, the level of uncertainty under the influence of COVID-19, the Ukrainian war, and climate change can be determined. The level of uncertainty is categorized as very high, high, middle, very low, and low.

19.2. An algorithm for evaluating the level of uncertainty

The following algorithm for evaluation and simulation of GGI is given beneath, which also can be addressed as FPRM.

Step 1. Normalization of crisp data. For the conversion of the crisp data provided in Table 19.1 into fuzzy numbers (FNs), normalization is initially required. The max-min normalization method is employed for this task. The equation for the positive indicators is:

$$Y^{+} = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{19.1}$$

The negative indicators are normalized as:

$$Y^{-} = \frac{x_{max} - x}{x_{max} - x_{min}} \tag{19.2}$$

Where, x-are indicators, and -are worst and best cases, respectively.

Step 2. Fuzzification of normalized data. For the conversion of normalized data into triangular fuzzy numbers **(**TFNs), the range of the universe R in [0, 1] is divided into the predefined number of fuzzy variable intervals k (if k=7, in linguistic terms, they will be: very low, low, medium-low, medium, medium-high, high, very high):

$$n = \frac{R}{k} \tag{19.3}$$

On this account, the normalized values of indicators are appertained to the corresponding intervals in order to form corresponding fuzzy triangular numbers.
Step 3. Construction of triangular fuzzy numbers-based preference relation matrix (FPM). FPM is constructed subjectively as the fuzzy analogue of crisp analytical hierarchy comparison matrix:

$$P = \begin{bmatrix} (1,1,1) & p_{12} & \cdots & p_{1n} \\ p_{21} & (1,1,1) & \cdots & p_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ p_{n1} & p_{n2} & \cdots & (1,1,1) \end{bmatrix} \tag{19.4}$$

where, the elements of FPM - $p_{ij} = [l_{ij}, m_{ij}, u_{ij}]$ are fuzzy triangular numbers.

Step 4. Construction of fuzzy complementary and reciprocal triangular fuzzy numbers-based preference relation matrix (FCRRM). P is defined as a complementary triangular numbers-based preference matrix [8] if the following conditions are satisfied:

$$\begin{gathered} p_{ij} = 0.5 \\ p_{ij}^{L} + p_{ji}^{R} = p_{ij}^{M} + p_{ji}^{M} = p_{ij}^{R} + p_{ji}^{L} = 1 \end{gathered} \tag{19.5}$$

where, p_{ij}^{L}, p_{ij}^{M}, and p_{ij}^{R} denote the left, middle and right values of triangular fuzzy number elements of FCRRM.

A fuzzy complementary triangular fuzzy numbers-based preference matrix can be transformed into reciprocal triangular fuzzy numbers-based preference matrix as [9]:

$$r_{ij} = \frac{1}{1 + p_{ij}} \tag{19.6}$$

where, r_{ij}- are the elements of fuzzy complementary and reciprocal triangular numbers-based preference matrix.

Step 5. Checking the consistency of FCRRM. Credible operations using FAHP relies on verifying whether the FCRRM is consistent. When dealing with fuzzy preference relations, several properties or conditions need to be examined. Among these, the followings must be checked :

1. Triangle condition [10]:

$$r_{ij} + r_{jk} \geq r_{ik}, \forall\, i, j, k \tag{19.7}$$

2. Additive transitivity [11,12]:]:

$$\begin{gathered}\left(r_{ij} - 0.5\right) + \left(r_{jk} - 0.5\right) = (r_{ik} - 0.5), \forall\, i, j, k \quad or \\ r_{ij} + r_{jk} + r_{ik} = \frac{3}{2}, \forall\, i, j, k\end{gathered} \tag{19.8}$$

3. Multiplicative transitivity.

Chiclana and et al. [13] introduced a novel definition of multiplicative transitivity for complementary preference relations, and proposed a comprehensive complementary preference relation using n-1 comparison values. Xia & Xu [14] proposed the following equations to improve multiplicative consistency:

$$\tilde{r}_{ik}^{L} = \frac{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{L}}{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{L} + \prod_{l=0}^{k-(i+1)} (1 - r_{(i+l)(i+l+1)}^{L})}, \; i < j < k \tag{19.9}$$

$$\tilde{r}_{ik}^{M} = \frac{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{M}}{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{M} + \prod_{l=0}^{k-(i+1)} (1 - r_{(i+l)(i+l+1)}^{M})}, \; i < j < k \tag{19.10}$$

$$\tilde{r}_{ik}^{R} = \frac{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{R}}{\prod_{l=0}^{k-(i+1)} r_{(i+l)(i+l+1)}^{R} + \prod_{l=0}^{k-(i+1)} (1 - r_{(i+l)(i+l+1)}^{R})}, \; i < j < k \tag{19.11}$$

where, $\tilde{r}_{ik}^{L}$, $\tilde{r}_{ik}^{M}$ and $\tilde{r}_{ik}^{R}$ denote the left, middle and right values of triangular fuzzy number elements of consistent FCRRM.

In the fuzzy analytic hierarchy process, the inconsistency of preference relations may cause distorted calculation results [15-16]. So, prior to the computation of criteria weights, checking FPR consistency is a must.

Step 6. Obtaining the criteria weight vector. According to Chang's method [17], the criteria weights are calculated based on the following rules:

Rule 1. Fuzzy synthetic value is calculated with the following equation:

$$S_i = \sum_{j=1}^{n} \tilde{r}_{ij} \odot \left[\sum_{i=1}^{n} \sum_{j=1}^{n} \tilde{r}_{ij} \right]^{-1} \quad (19.12)$$

Rule 2. For each compared synthetic values possibility degrees are calculated:

If $S_i = (a_i, b_i, c_i)$ and $S_k = (a_k, b_k, c_k)$ are convex fuzzy numbers, and $\mu_{Si}(d) = hgt(Si \cap S_k)$ then:

$$V(S_i \geq S_k) = 1 \text{ iff } S_i \geq S_k,$$

$$V(S_k \geq S_i) = hgt(S_i \cap S_k) = \mu_{S_i}(d) = \frac{a_i - c_k}{(b_k - c_k) - (b_i - a_i)} \quad (19.13)$$

where d is the ordinate value of intersection point of μ_{Si} and μ_{Sk}

Rule 3. Weight of *i-th* criterion is evaluated as followings:

$$d'(A_i) = \min_k (V(S_i \geq S_k)) \quad (19.14)$$

$$w_i = (d(A_1), d(A_2), \ldots, d(A_n))^T \quad (19.15)$$

Step 7. Aggregation of indicators and sub-indices. In this step, fuzzy weighted aggregation operator (FWA) is applied to combine fuzzy values (FVs) of GGI indicators and sub-indices [18]:

$$FWA = \sum_{i=1}^{n} \tilde{X}_i w_i \quad (19.16)$$

where, $\tilde{X}$ - are fuzzified values of GGI indicators or sub-indices, w_i - are weights of indicators or sub-indices.

Step 8. Establishment of linguistic term set with fuzzy scale for FPRM. The linguistic term set with their corresponding boundaries of fuzzy variables is constructed subjectively, which is given in table 19.2.

Table 19.4. Linguistic terms and their matching fuzzy scale

Linguistic terms	Boundaries of fuzzy variables
Very high (VH)	(0.855, 1.000)
High (H)	(0.715, 0.860)
Medium high (MH)	(0.575, 0.720)
Medium (M)	(0.428, 0.578)
Medium low (ML)	(0.286, 0.431)
Low (L)	(0.140, 0.288)
Very low (VL)	(0.000, 0.145)

Step 9. Computation of similarity measures. Vector similarity measure between two fuzzy numbers [19] can be computed with the following equation:

$$S_{VS}(\tilde{A}, \tilde{B}) = \frac{2\sum_{i\in\{l,m,u\}} a^i b^i}{\sum_{i\in\{l,m,u\}} a^i a^i + \sum_{i\in\{l,m,u\}} b^i b^i} \tag{19.17}$$

where, $\tilde{A} = (a^l, a^m, a^u)$, $\tilde{B} = (b^l, b^m, b^u)$ – are two fuzzy numbers.

Step 10. Defuzzification. In the final step, the fuzzy values of indices are defuzzified using the following equation:

$$c = \frac{l + m + r}{3} \tag{19.18}$$

where, l, m, and r – are left, middle and right values of fuzzy triangular numbers.

19.3. Data analysis and computation results

The data analysis and computation results offer valuable insights into the intricate dynamics of uncertainty impacting the Azerbaijani economy. Through a rigorous examination of various economic indicators and the application of a fuzzy algorithm, we have gained a nuanced understanding of the multifaceted challenges posed by global uncertainties (Table 19.5).

Table 19.5. Obtained fuzzy results for Uncertainty Index for Azerbaijan

Years	Fuzzy values of sub-indices and overall index				Defuzzified UI	Linguistic value of UI
	Sub-index 1	Sub-index 2	Sub-index 3	Uncertainty Index (UI)		
2015	(0.63,0.69,0.78)	(0.26,0.35,0.40)	(0.16,0.21,0.30)	(0.42,0.49,0.56)	0.49	M
2016	(0.43,0.49,0.57)	(0.28,0.32,0.40)	(0.22,0.30,0.36)	(0.34,0.40,0.47)	0.40	ML
2017	(0.42,0.50,0.56)	(0.14,0.23,0.28)	(0.47,0.55,0.61)	(0.34,0.42,0.48)	0.41	M
2018	(0.53,0.58,0.67)	(0.23,0.31,0.38)	(0.62,0.71,0.77)	(0.45,0.52,0.60)	0.52	M
2019	(0.55,0.65,0.70)	(0.48,0.56,0.63)	(0.52,0.60,0.66)	(0.52,0.61,0.67)	0.60	MH
2020	(0.39,0.44,0.53)	(0.19,0.25,0.33)	(0.34,0.44,0.48)	(0.32,0.38,0.46)	0.38	ML
2021	(0.48,0.55,0.62)	(0.21,0.27,0.35)	(0.49,0.55,0.63)	(0.40,0.46,0.54)	0.46	M
2022	(0.33,0.37,0.48)	(0.43,0.51,0.58)	(0.62,0.70,0.77)	(0.42,0.48,0.57)	0.49	M

The results obtained from the algorithm were defuzzified to obtain a clear understanding of the dynamics of the indices, as presented in Table 19.6.

Table 19.6. Defuzzified results for Uncertainty Index for Azerbaijan

№	Uncertainty index and sub-indices for Azerbaijan	Time							
		2015	2016	2017	2018	2019	2020	2021	2022
1	Uncertainty index of the level of impact of COVID19 on the economic indicators of Azerbaijan	0.70	0.50	0.49	0.60	0.63	0.45	0.55	0.40
2	Uncertainty index of the level of impact of Ukrainian-Russian war on the economic indicators of Azerbaijan	0.34	0.33	0.22	0.31	0.55	0.26	0.28	0.51
3	Uncertainty index of the level of impact of Climate change on the economic indicators of Azerbaijan	0.23	0.29	0.54	0.70	0.59	0.42	0.56	0.70
4	Aggregated uncertainty index for Azerbaijan	0.49	0.40	0.41	0.52	0.60	0.38	0.46	0.49

The computation results, presented through fuzzy indices, provide a comprehensive overview of uncertainty levels across different time periods. From the uncertainty index of the COVID-19 impact to the uncertainty index of climate change, each index offers valuable insights into the evolving economic landscape of Azerbaijan. By aggregating these indices, we gain a holistic understanding of the overall uncertainty faced by the country. The dynamics of Uncertainty index and sub-indices for Azerbaijan is given in Figure 19.1.

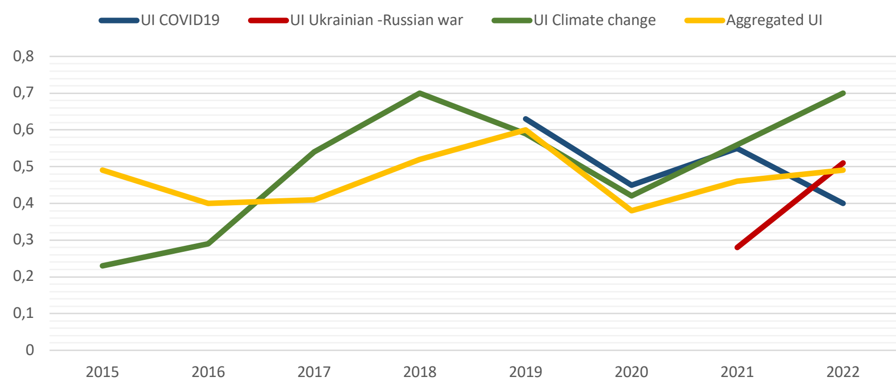


Figure 19.1. Chart of Uncertainty index and sub-indices dynamics for Azerbaijan

Uncertainty index of the level of impact of COVID-19 on the economic indicators of Azerbaijan: This index measures the uncertainty regarding the impact of the COVID-19 pandemic on Azerbaijan's economic indicators. It shows a trend of increasing uncertainty from 2019 to 2020 before slightly decreasing in 2021 and 2022.

Uncertainty index of the level of impact of the Ukrainian-Russian war on the economic indicators of Azerbaijan: This index measures the uncertainty related to the impact of the Ukrainian-Russian war on Azerbaijan's economic indicators. It starts in 2021 and increases notably in 2022.

Uncertainty index of the level of impact of climate change on the economic indicators of Azerbaijan: This index measures the uncertainty concerning the impact of climate change on Azerbaijan's economic indicators. It shows fluctuations over the years but generally increases from 2015 to 2022.

Aggregated uncertainty index for Azerbaijan: This index represents the overall uncertainty in Azerbaijan's economic indicators, taking into account various factors including COVID-19, the Ukrainian-Russian war, and climate change. It shows fluctuations over the years, with the highest uncertainty in 2019.

Overall, the data suggests that uncertainty in Azerbaijan's economic indicators has been influenced by various factors including external events like the COVID-19 pandemic, regional conflicts, and climate change. It is important for policymakers and stakeholders to consider these uncertainties when making decisions and planning for the future.

19.4. Conclusion

In conclusion, the analysis of global uncertainty factors affecting the Azerbaijani economy highlights the significant challenges posed by events such as the COVID-19 pandemic, the Ukrainian-Russian war, and climate change. These factors have led to fluctuations in key economic indicators including GDP growth, foreign direct investment, inflation, oil prices, tourism revenues, and migration patterns.

The COVID-19 pandemic has particularly impacted Azerbaijan's economy, with significant declines in GDP growth, foreign direct investment, and tourism revenues. The Ukrainian-Russian war has further exacerbated economic uncertainties, particularly affecting oil exports, energy prices, and migration patterns. Additionally, climate change poses long-term risks to agricultural productivity, energy consumption, and overall economic stability in Azerbaijan.

Through the use of fuzzy algorithms and analytical tools, the level of uncertainty in Azerbaijan's economy has been assessed, revealing fluctuations over time and highlighting the need for adaptive policy measures to address these challenges. It is crucial for policymakers to consider the interconnectedness of global events and their impacts on national economies when formulating strategies for economic resilience and development.

Overall, this analysis underscores the importance of proactive measures to mitigate the effects of global uncertainty factors on Azerbaijan's economy and ensure sustainable growth and development in the face of ongoing challenges.

References

1. Dadparvar, N. S., & Azizi, N. S. (2021). Exploring the Effects of the COVID-19 Crisis on Azerbaijan's Financial Security. *International Relations And Diplomacy*, 9(1). https://doi.org/10.17265/2328-2134/2021.01.003

2. Namazova, F. (2024). *Ukrainian war and its impact on socia-economic situation in Azerbaijan*. UNEC Tədqiqat Fondu. https://www.unectf.org/fidan-namazova/

3. *Climate risk Country profile: Azerbaijan*. (2021). Asian Development Bank. https://www.adb.org/publications/climate-risk-country-profile-azerbaijan

4. Santamouris, M., Cartalis, C., Synnefa, A., & Kolokotsa, D. (2014). On the impact of urban heat island and global warming on the power demand and electricity consumption of buildings—A review. *Energy And Buildings*, 98, 119-124.
https://doi.org/10.1016/j.enbuild.2014.09.052

5. Babakhanov, N. & Aliyev, I. (2014). *Natural Disasters in Azerbaijan*. http://www. respublica-news.az/index.php/elm-v-t-hsil/item/2823-azaerbaydzanda-taebii-faelakaetlaer

6. Ahir, H., Bloom, N., & Furceri, D. (2022). *The World Uncertainty Index*. https://doi.org/10.3386/w29763

7. Chen, C., Huang, Y., & Yang, F. (2023). Semantics matter: An empirical study on economic policy uncertainty index. *International Review Of Economics & Finance*, 89, 1286-1302. https://doi.org/10.1016/j.iref.2023.08.015

8. Xu, Z. (2003). On priority method of triangular fuzzy number complementary judgement matrix. *Journal of systems engineering*.

9. Gong, Z., & Liu, S. (2006). Consistency and priority of triangular fuzzy number complementary judgment matrix. *Control and Decision,* 21, 903–907.

10. Luce, R.D., & Suppes, P. (1965). Preferences, Utility and Subject Probability. *Handbook of Mathematical Psychology*, Vol: III, 249–410.

11. Tanino, T. (1984). Fuzzy preference orderings in group decision making. *Fuzzy Sets And Systems*, 12(2), 117-131. https://doi.org/10.1016/0165-0114(84)90032-0

12. Tanino, T. (1988). Fuzzy Preference Relations in Group Decision Making. *Lecture notes in economics and mathematical systems* (pp. 54-71). https://doi.org/10.1007/978-3-642-51711-2_4

13. Chiclana, F., Herrera-Viedma, E., Alonso, S., Alberto, R., & Pereira, M. (2007). Preferences and Consistency Issues in Group Decision Making. *Springer eBooks* (pp. 219-237). https://doi.org/10.1007/978-3-540-73723-0_12

14. Xia, M., & Xu, Z. (2011). Methods for fuzzy complementary preference relations based on multiplicative consistency. *Computers & Industrial Engineering*, 61(4), 930-935. https://doi.org/10.1016/j.cie.2011.06.005

15. Dubois, D., & Prade, H. M. (1980). *Fuzzy Sets and Systems: Theory and Applications*. Academic Press.

16. Saaty, T.L. (1980). *The Analytic Hierarchy Process*. McGraw-Hill.

17. Chang, D. (1996). Applications of the extent analysis method on fuzzy AHP. *European Journal Of Operational Research*, 95(3), 649-655. https://doi.org/10.1016/0377-2217(95)00300-2

18. Yager, R. (1988). On ordered weighted averaging aggregation operators in multicriteria decisionmaking. *IEEE Transactions On Systems Man And Cybernetics*, 18(1), 183-190. https://doi.org/10.1109/21.87068

19. Zhang, L., Xu, X., & Tao, L. (2013). Some Similarity Measures for Triangular Fuzzy Number and Their Applications in Multiple Criteria Group Decision-Making. *Journal Of Applied Mathematics*, 2013, 1-7. https://doi.org/10.1155/2013/538261

20. Rahmani, A., Lotfi, F. H., Rostamy-Malkhalifeh, M., & Allahviranloo, T. (2016). A New Method for Defuzzification and Ranking of Fuzzy Numbers Based on the Statistical Beta Distribution. *Advances In Fuzzy Systems*, 2016, 1-8. https://doi.org/10.1155/2016/6945184

20. FUZZY ESTIMATION OF THE SUSTAINABLE LEVEL OF ECONOMIC DIVERSIFICATION IN A COUNTRY

The world is facing social and economic challenges of an unprecedented nature. Many countries are attempting to reverse the losses caused by the cascading crises that have followed the climate change, disasters and wars, which threaten hard-won development gains and make the achievement of the Sustainable Development Goals. These challenges necessitate a transformation towards more diversified, productive and sustainable economies, to spur economic growth, create more and better jobs and increase resilience to future crises. This is in line with the Bridgetown Covenant, which identifies "transforming economies through diversification" as one of the four major transformations needed to move to a more resilient, digital and inclusive world of shared prosperity. In such pursuits, developing countries strive to foster the emergence of more productive and sustainable economic activities given the technological level of the current production base and the incentives created by domestic and global demand. [1].

Economic diversification is defined by the United Nations as *"the process of shifting an economy away from a single income source toward multiple sources from a growing range of sectors and markets."* [2] It typically falls into one of two categories: product diversification and export diversification. The former refers to diversifying an economy in regards to the goods and services it produces, while the latter is about introducing new products into an economy's export portfolio and breaking into new markets.

Economic diversification is defined here as the shift toward a more varied structure of trade and output so as to increase productivity, create jobs and provide the base for sustained poverty-reducing growth.   Output diversification results from the shift across sectors, industries, and firms. It captures the dynamics of structural transformation, because successful diversification of domestic production entails resource reallocation across and/or within industries from low productivity activities to those with higher productivity. Trade diversification occurs in three ways: (a) the export (or import) of new products (good or services); (b) the export (or import) of existing products to new markets, and (c) quality upgrading of exported (or imported) products.

In general, the economic diversification indices can be classified into two groups: one group that measures a country's absolute specialization (e.g. ogive index, entropy index, Herfindahl Hirschmann index, Gini index, diversification index); and a second group that measures a country's economic structure from a reference group of industries (e.g. Theil index, relative Gini index, inequality in productive sectors). Indices that measure absolute specialization indicate the level of specialization in a country [3] (e.g. if a small number of industries exhibit high shares of the overall employment of the country or the income of the country).

The annual Global Economic Diversification Index (GEDI) and Report are to be published for the first time in 2021 by Mohammed bin Rashid School of Government UAE. The pursuit of economic diversification is a catalyst for equitable growth, sustainable development and a key driver for achieving global economic resilience, which includes three sub-indices: output, taxes revenue and trade:

1. Output: The share of GDP contributed by different sectors such as agriculture, industry, services, and manufacturing.

2. Export Diversification: The diversity of products and services a country exports, typically measured through the Herfindahl-Hirschman Index (HHI) or similar metrics.

3. Tax Revenue Diversification: The extent to which a government's tax revenues come from a variety of sources rather than being reliant on a single commodity or industry.

Each of these sub-indices of GEDI consists of multiple underlying indicators. By using the principal components analysis (PCA) method, a dimensionality reduction technique, a sub-index score is obtained. This produces one value for each of the three sub-indices. The averaging of these three values -by taking their simple arithmetic mean- produces the final overall GEDI score for the country. Taking the simple arithmetic mean of the three sub-indices to produce the final score implies that equal weightage - or importance - is given to each of the trade, government revenue and output pillars in their contribution to economic diversification [4].

There are several key contributions of GEDI in the study of economic development and resilience:

- **Reducing Vulnerability to Commodity Price Volatility**: The GEDI has been instrumental in highlighting the **vulnerabilities of resource-rich countries** (e.g., Azerbaijan, Saudi Arabia, Nigeria), which tend to suffer from "Dutch disease" or the "resource curse." Studies such as **Gelb (2010)** argue that countries overly reliant on a single sector (e.g., oil) often face greater volatility and slower long-term growth. The GEDI has been used to push for economic diversification strategies in these countries [5].

- **Diversification as a Driver of Sustainable Growth**: One of the central insights from the GEDI-related research is that diversification is a critical component of **sustainable economic growth**. **Hausmann, Hwang, and Rodrik (2007)** argued that countries with more diversified economies tend to grow faster because they are less susceptible to sector-specific downturns. By assessing economic structures through the GEDI, countries can better understand the sectors they need to develop in order to foster balanced growth [6].

- **Cross-Country Comparisons and Policy Benchmarking**: The GEDI enables cross-country comparisons, helping policymakers benchmark their country's economic structure against more diversified economies. For instance, countries like **Norway** have been praised for their success in diversifying away from oil through a strong services sector and technology innovation, while **Venezuela** and **Nigeria** are often used as cautionary tales of countries that have failed to diversify. The GEDI provides a useful framework for these comparisons, as seen in **Koren and Tenreyro (2007)**, who discussed diversification as an insurance mechanism against economic volatility [7].

- **Encouraging Non-Oil Sector Development**: A major theme in the literature on economic diversification is the importance of **non-oil sector development**. The GEDI has provided the empirical backing for policy reforms aimed at developing sectors like **manufacturing**, **tourism**, and **services** in oil-dependent economies. For example, **Cherif and Hasanov (2014)** discuss how non-oil growth is crucial for ensuring long-term economic sustainability in the Gulf Cooperation Council (GCC) countries, which are heavily reliant on hydrocarbons [8].

- **Role in Global Policy**: The GEDI has increasingly been incorporated into **global economic policy frameworks**. Institutions like the **World Bank** and the **IMF** have encouraged the use of the GEDI in their policy recommendations to developing countries. For instance, in their reports, the IMF has stressed the need for oil-exporting countries to diversify their tax bases, reduce reliance on oil revenues, and invest in other sectors to ensure fiscal sustainability.

The GEDI has enriched the literature on **economic diversification** by offering a robust measure that captures the complex dynamics of sectoral contributions, export variety, and tax revenue sources. It highlights the need for countries, particularly those dependent on a single resource or industry, to diversify their economies to achieve **long-term stability and sustainable growth**. As global economies become increasingly interconnected and volatile, the role of economic diversification, as measured by the GEDI, will likely remain a central focus in both academic research and policy discussions. In this paper by using indicators of output, trade and tax revenues and applying agent-based models for economic diversity approach (ABMED) was used in computation of Global Economic Diversification Index (GEDI) level. For the computation purpose, we applied fuzzy dynamic pattern recognition model (FDPRM). We developed a process illustrating the sustainable level of economic diversification of the country on example Azerbaijan, which given in the figure 1.

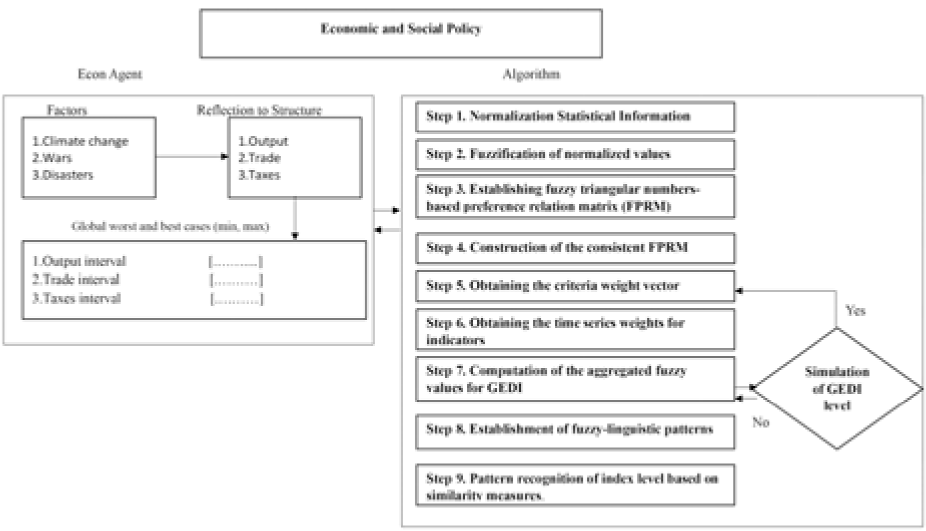


Figure 20.1. Architecture of the ABMED

Description of ABMED structure

The factors disasters, the Ukrainian-Russian war, and climate change have led to fluctuations in key economic indicators including GDP growth, foreign direct investment, inflation, oil prices, tourism revenues, and migration patterns. Additionally, climate change poses long-term risks to agricultural productivity, energy consumption, and overall economic structural stability in Azerbaijan [9].

Influence of three above mentioned factors to structures of output, trade and the taxes of revenue are given in tables 1-3.

Table 20.1. Structure of output for Azerbaijan

Sub Index	Variables	Years							Global worst and best cases (min, max)	
		2016	2017	2018	2019	2020	2021	2022	Worst	Best
Output	GDP for Azerbaijan, billion $ - **GDP**	37.87	40.87	47.11	48.17	42.69	54.83	78.81	0.05	25000.00
	Agruculture, value added, as a percentage of GDP - **AGR**	6.18	5.60	5.61	5.21	5.70	6.74	5.88	0.00	45.90
	Gross fixed capital formation as a percentage of GDP - **GFC**	25.03	23.82	20.69	21.13	22.67	16.59	12.00	6.60	61.50
	Industry as a percentage of GDP -**IND**	40.40	43.20	48.30	45.50	37.60	46.70	55.40	37.60	46.70
	Manufacturing value added, as a percentage of GDP - **MAN**	4.89	4.70	4.62	5.00	6.1	6.83	5	2.50	40.10
	Total Natural resources rents as a % of GDP - **NAT**	15.33	20.97	29.36	25.48	18.80	29.9	31.00	0.10	50.00

Sub Index	Variables	Years							Global worst and best cases (min, max)	
		2016	2017	2018	2019	2020	2021	2022	Worst	Best
Output	Services value added, as a percentage of GDP **-SER**	38.70	37.60	34.80	36.50	42.40	37.60	32.00	21.80	79.30
	Medium and high technology manufacturing value added share in total manufacturing value added **-TECH**	10.13	10.82	10.29	11.28	15.23	12.98	14.00	5.00	80.00
	Manufacturing value added per capita - **MAP**	262.00	257.00	271.00	297.00	324.00	386.00	396.00	182.00	63799.00

Sources [10-15]

As shown from Table 1, Azerbaijan's **GDP** grew significantly from $37.87 billion in 2016 to $78.81 billion in 2022, reflecting strong economic recovery. The share of **agriculture** in GDP **decreased** from 6.18% in 2016 to 5.88% in 2022, indicating a slight decline in its contribution. **Industry** increased from 40.40% to 55.40%, underscoring its growing importance. **Manufacturing** value added fluctuated but remained low, at around 5-6%. The **services** sector showed some volatility, ranging from 32% to 42.40%, indicating a secondary role to industry.

Table 20.2. Structure of trade for Azerbaijan

Sub Index	Variables	Years							Global worst and best cases (min, max)	
		2016	2017	2018	2019	2020	2021	2022	Worst	Best
Trade	Total value of exports (bln USD) - **EXP**	13.38	15.31	19.49	19.64	13.73	22.21	38.10	0.01	615.00
	Fuel exports as percentage of merchandise exports **-FEX**	91.70	90.60	91.74	90.65	87.25	88.4	88.00	0.00	99.70

Cont…

Sub Index	Variables	Years							Global worst and best cases (min, max)	
		2016	2017	2018	2019	2020	2021	2022	Worst	Best
Trade	Export market concentration index (Hirschman -Herfindahl Index, HHI) - **EXI**	0.10	0.11	0.12	0.13	0.12	0.19	0.20	0.00	0.80
	Total value of imports (bln. USD) - **IMP**	8.47	8.77	11.46	13.65	10.73	11.70	13.80	0.05	3300.00
	Manufactured exports as a percentage of total merchandise exports - **MEX**	2.85	3.15	2.80	2.50	2.85	3.50	4.78	0.00	438.00
	Medium and high technology manufactured exports as a percentage of total manufactured exports *(Medium and high technology exports (percentage manufactured exports))* - **MHT**	3.00	3.00	4.00	5.00	7.00	2.00	4.00	0.00	91.70
	Merchandise trade as a percentage of GDP -**MER**	57.03	59.38	67.46	69.13	57.30	62.09	60	17.00	343.50
	Total value of services exports - **TSE**	3.10	3.00	3.40	3.50	2.10	2.50	2.80	10.00	945.00
	Export product concentration index -**EIN**	0.536	0.540	0.544	0.505	0.452	0.414	0.630	0.10	0.90
	Import product concentration index - **IIN**	0.080	0.069	0.075	0.085	0.093	0.117	0.150	0.00	0.80

Sources [10-15]

Table 2 illustrates that exports surged from $13.38 billion in 2016 to $38.10 billion in 2022, with **fuel exports** consistently making up nearly 90% of total merchandise exports. Imports also rose, indicating increasing domestic demand. The **export concentration** index increased, suggesting growing dependence on fewer products for export revenue.

Table 20.3. Structure of tax revenue for Azerbaijan

Sub Index	Variables	Years							Global worst and best cases (min, max)	
		2016	2017	2018	2019	2020	2021	2022	Worst	Best
Revenue	Total revenue as a percentage of GDP-**TR**	28.97	23.48	28.10	29.79	35.93	28.57	22.93	0.10	73.30
	Tax revenue as a percentage of GDP **-TA**	14.95	13.30	13.22	14.35	15.37	13.57	15.58	0.60	48.40
	Goods and services tax revenue as a percentage of GDP *(Taxes on goods and services (percentage of revenue))* - **GS**	23.67	22.4	19.49	17.74	18.05	20.89	23.69	0.00	31.60
	Income tax revenue as a percentage of GDP-**IT**	1.63	1.48	1.22	1.16	1.59	1.28	1.10	0.00	22.10
	Excise tax revenue as a percentage of GDP **-ET**	1.04	0.87	0.91	1.04	0.43	0.32	1.02	0.00	21.00
	Trade revenue as a percentage of GDP **-TR**	1.58	1.49	1.63	1.64	1.60	1.46	1.23	0.00	22.60

Sources [10-15]

Table 3 demonstrates that tax revenue as a percentage of GDP remained steady, fluctuating between 13.22% and 15.58%. **Goods and services taxes** were a significant portion, reaching 23.69% in 2022, while **income and excise taxes** remained relatively low contributors.

An algorithm for computation and simulation of GEDI level

The algorithm developed for computation of GEDI include the following steps:

Step 1. Data Collection and Preprocessing. The algorithm begins with the collection of relevant economic data. This data is gathered from both global sources and national statistical committee of Azerbaijan [10-15]. Preprocessing involves normalization of raw data (tables 1-3) to a comparable scale before the fuzzification of data. The normalization equation for the positive indicators is:

$$Y^+ = \frac{x - x_{min}}{x_{max} - x_{min}} \tag{20.1}$$

The negative affecting indicators are normalized with the following equation:

$$Y^- = \frac{x_{max} - x}{x_{max} - x_{min}} \tag{20.2}$$

Step 2. Fuzzification of normalized values. For each normalized data point, we create a triangular fuzzy number (TFN) with a predefined spread (e.g., 0.01).

Step 3. Establishing fuzzy triangular numbers-based preference relation matrix (FPRM). In this stage to obtain criteria weights, FPRM is constructed based on table of fuzzy Lickert scales [16] between 1-9 (table 4).

Table 20.4. Fuzzy scales between 1- 9

1 - 9 Scales	Meanings
(0.12,0.13,0.15)	*x_j is extremely preferred to x_i*
(0.15,0.17,0.20)	*x_j is strongly preferred to x_i*
(0.20,0.25,0.33)	*x_j is definitely preferred to x_i*
(0.33,0.50,1.00))	*x_j is slightly preferred to x_i*
(1,1,1)	*x_j is the same as x_i*
(1,2,3)	*x_i is slightly preferred to x_j*
(3,4,5)	*x_i is definitely preferred to x_j*
(5,6,7)	*x_i is strongly preferred to x_j*
(7,8,9)	*x_i is extremely preferred to x_j*
Complementary number	*If the preference degree or intensity of alternative x_j over x_i is r_{ij}, then the preference degree or intensity of alternative x_j over x_i is $r_{ji} = 1- r_{ij}$.*

Using the developed fuzzy Lickert scale from table 4, the FPRM is built:

$$\tilde{R} = \begin{bmatrix} (1,1,1) & \tilde{r}_{12} & \cdots & \tilde{r}_{1n} \\ \tilde{r}_{21} & (1,1,1) & \cdots & \tilde{r}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{r}_{n1} & \tilde{r}_{n2} & \cdots & (1,1,1) \end{bmatrix} \tag{20.3}$$

Step 4. Construction of the consistent FPRM. In the FAHP, obtaining feasible solution depends on checking whether FPRM is consistent or not. With the purpose to check consistency of FPRM, the following rules must be followed:

The lower, medium and upper values of FPRM are decomposed and three $\bar{C}_L$,$\bar{C}_M$, $\bar{C}_U$ matrices [17, 18].

Rule 1. Eigenvalues $\bar{\lambda}_L$, $\bar{\lambda}_M$, $\bar{\lambda}_U$ of $\bar{C}_L$,$\bar{C}_M$, $\bar{C}_U$ matrices are computed by solving the following fuzzy linear homogenous system of equations:

$$C_L\, w_L + C_M\, w_M + C_U\, w_U - \lambda_L\, w_L + \lambda_M\, w_M + \lambda_U\, w_U = 0 \tag{20.4}$$

$$\begin{cases} \bar{C}_L = 2C_L + C_M \\ \bar{C}_M = C_L + 4C_M + C_U \\ \bar{C}_U = C_M + 2C_U \end{cases} \qquad \begin{cases} \bar{\lambda}_L = 2\lambda_L + \lambda_M \\ \bar{\lambda}_M = \lambda_L + 4\lambda_M + \lambda_U \\ \bar{\lambda}_U = \lambda_M + 2\lambda_U \end{cases} \tag{20.5}$$

Rule 2. Consistency index is evaluated with the following equation [19]:

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{20.6}$$

Consistency ratio is evaluated as follows:

$$CR = \frac{CI}{RI} \tag{20.7}$$

RI, referred to as random consistency, is dependent on the matrix size *n,* and its values, as suggested by Saaty [19], are presented in Table 5.

Table 20.5. Average random consistency RI

n	1	2	3	4	5	6	7	8	9	10	11	12
TI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.58

Step 5. Obtaining the criteria weight vector. The criteria weights are calculated based on the following rules:

To compute the criteria weights, we follow these steps:

1. *Computation of the distance measures:* The distances between fuzzy elements of FPRM and minimum and maximum fuzzy values (given in Table 4) are calculated with the equation [20] given below:

$$d = \sqrt{\frac{1}{3}\left[(a_{ij} - a_s)^2 + (b_{ij} - b_s)^2 + (c_{ij} - c_s)^2\right]} \tag{20.8}$$

Where $r_{ij} = (a_{ij}, b_{ij}, c_{ij})$ are triangular fuzzy number elements of FPRM, and $r_s = (a_s, b_s, c_s)$ and are fuzzy preference values given in table 7.

2. Computation of entropy for each element of FPRM matrix: The entropy of each element is calculated using a ratio-based measure of entropy [21], defined as:

$$E(r_{ij}) = \frac{d_n}{d_f} \tag{20.9}$$

where d_n is a distance (r_{ij}, r_{min}) from r_{ij} to the minimum value of r_s, and d_f is a distance (r_{ij}, r_{max}) from r_{ij} to the maximum value of r_s [22] among fuzzy values for criteria preferences given in table 4.

$$w_j = \frac{1 - E_j}{\sum_{j=1}^{n}(1 - E_j)} \tag{20.10}$$

This equation ensures that the criteria with lower entropy (higher information content) receive greater weights.

Step 6. Obtaining the time series weights for indicators. In this step, weights of indicators as time series data are computed, which namely provide dynamicity of computation of GEDI within fuzzy dynamic pattern recognition model (FDPRM). Guangxu and et.al [23] proposed an entropy equation based on deviation degrees for the assessment of objective weights:

$$E_j = -k \sum_{i=1}^{m} \frac{D_{ij}}{D_j} \ln \frac{D_{ij}}{D_j}, \quad i=1,2,\ldots,m,\ j=1,2,\ldots,n \tag{20.11}$$

where $k = 1/\ln m$, D_{ij} - is the deviation degree between alternative with index i and any other alternative, D_j - is the deviation degree between all alternatives and any other alternative in the FPRM.

We developed the entropy equation for the time-series data [24] (vector) as below:

$$E_j = -\frac{l}{\ln m}\left(\frac{D_j}{\sum_{j=1}^{m} D_j} \ln \frac{D_j}{\sum_{j=1}^{m} D_j}\right), \quad j=1,2,\ldots,m \tag{20.12}$$

where m- is the number of observations in time series data (indicators), $Dj = X_j - X_{max}$ for positive indicators, and $D_j = X_j - X_{min}$ for negative indicators.

Next, the degree of differences df_j are calculated:

$$df_j = 1 - E_j,\ j=1,2,\ldots,n \tag{20.13}$$

Eventually, the time-series (indicators) weights are computed:

$$\lambda_j = \frac{df_j}{\sum_{j=1}^{n} df_j} \qquad j=1,2,\ldots,n \tag{20.14}$$

Step 7. Computation of the aggregated fuzzy values for GEDI. In this step, fuzzy hybrid weighted aggregation operator (FHWA) is practiced to incorporate the fuzzy values of GEDI indicators [24, 25]:

$$\widetilde{SI}_{FHWA} = \sum_{i=1}^{k} \tilde{I}_i * \frac{\lambda_{ij} w_i}{\sum_{i=1}^{n} \lambda_{ij} w_i} \tag{20.15}$$

where, $\tilde{I}_i$ - are fuzzified values of GEDI indicators, w_i- are weights of indicators as criteria, λ_i- are weights of time series data of indicators.

Next, fuzzy weighted aggregation operator (FWA) is used to incorporate fuzzy values of GEDI sub-indices [25]:

$$\widetilde{GEDI}_{FWA} = \sum_{i=1}^{l} \widetilde{SI}_i * w_i \tag{20.16}$$

where, $\widetilde{SI}$ - are fuzzy values of GEDI sub-indices, - are weights of sub-indices.

Step 8. Establishment of fuzzy-linguistic patterns. In this step, for the identification of aggregated fuzzy values of GEDI and conversion it into linguistic terms we built the linguistic terms set with their corresponding interval fuzzy values, which is given in table 6.

Table 20.6. Linguistic terms and their matching fuzzy scale

Linguistic terms	TFNs in [0, 1]
Very high (VH)	(0.858, 1.000)
High (H)	(0.715, 0.857)
Medium high (MH)	(0.572, 0.714)
Medium (M)	(0.429, 0.571)
Medium low (ML)	(0.286, 0.428)
Low (L)	(0.143, 0.285)
Very low (VL)	(0.000, 0.142)

Step 9. Pattern recognition of index level based on similarity measures. Vector similarity measure between two fuzzy numbers [26] can be computed with the application of following equation:

$$S_{VS}(\tilde{A}, \tilde{B}) = \frac{2\sum_{i\in\{l,m,r\}} a^i b^i}{\sum_{i\in\{l,m,r\}} a^i a^i + \sum_{i\in\{l,m,r\}} b^i b^i} \tag{20.17}$$

where, $\tilde{A} = (a^l, a^m, a^r)$, $\tilde{B} = (b^l, b^m, b^r)$ – are two fuzzy numbers.

GEDI Computation: Actual Values and Future Simulation Projections

In this section, after computation results of GEDI, the simulation process for defining different level of GEDI were carried out. As an example, the main parts of calculation of Tax Revenues sub-index are provided. According to step 3, FPRM is built as given below:

Table 20.7. Tax Revenues FPRM

$$\begin{array}{c} \\ TR \\ TA \\ GS \\ IT \\ ET \\ TT \end{array}\begin{pmatrix} TR & TA & GS & IT & ET & TT \\ (1,1,1) & (1,1.5,2) & (1.5,2,2.5) & (2,2.5,3) & (2.5,3,3.5) & (3,3.5,4) \\ (0.5,0.67,1) & (1,1,1) & (1,1.5,2) & (1.5,2,2.5) & (2,2.5,3) & (2.5,3,3.5) \\ (0.4,0.5,0.67) & (0.5,0.67,1) & (1,1,1) & (1,1.5,2) & (1.5,2,2.5) & (2,2.5,3) \\ (0.33,0.4,0.5) & (0.4,0.5,0.67) & (0.5,0.67,1)) & (1,1,1) & (1,1.5,2) & (1.5,2,2.5) \\ (0.29,0.33,0.4) & (0.33,0.4,0.5) & (0.4,0.5,0.67) & (0.5,0.67,1) & (1,1,1) & (1,1.5,2) \\ (0.25,0.29,0.33) & (0.29,0.33,0.4) & (0.33,0.4,0.5) & (0.4,0.5,0.67) & (0.5,0.67,1) & (1,1,1) \end{pmatrix}$$

Following the construction of FPRM, its consistency is checked. Referring to step 4 the following crisp matrices (tables 8-10) were built:

Table 20.8. $\bar{C}_L$ matrix (lower)

$\bar{C}_L$						**Eigen values**	$\bar{\lambda}_L$
3	3.5	5	6.5	8	9.5	15.8206	15.8206
1.67	3	3.5	5	6.5	8	0.1990	
1.3	1.67	3	3.5	5	6.5	0.1990	
1.06	1.3	1.67	3	3.5	5	0.6613	
0.91	1.06	1.3	1.67	3	3.5	0.5942	
0.79	0.91	1.06	1.3	1.67	3	0.5258	

Table 20.9. $\bar{C}_M$ matrix (middle)

$\bar{C}_M$						Eigen values	$\bar{\lambda}_M$
6	9	12	15	18	21	36.5166	36.5166
4.18	6	9	12	15	18	0.0445	
3.07	4.18	6	9	12	15	0.0445	
2.43	3.07	4.18	6	9	12	-0.2059	
2.01	2.43	3.07	4.18	6	9	-0.2059	
1.74	2.01	2.43	3.07	4.18	6	-0.1958	

Table 20.10. $\bar{C}_U$ matrix (upper)

$\bar{C}_U$						Eigen values	$\bar{\lambda}_U$
3	5.5	7	8.5	10	11.5	21.0318	21.0318
2.67	3	5.5	7	8.5	10	-0.1587	
1.84	2.67	3	5.5	7	8.5	-0.1587	
1.4	1.84	2.67	3	5.5	7	-0.9736	
1.13	1.4	1.84	2.67	3	5.5	-0.8703	
0.95	1.13	1.4	1.84	2.67	3	-0.8703	

Eigenvalues of matrices $\bar{C}_L$, $\bar{C}_M$, $\bar{C}_U$ are found using R programming. Referring to equation (5) eigenvalues of crisp matrices are also computed:

$$\begin{cases} 2\lambda_L + \lambda_M = 15.8206 \\ \lambda_L + 4\lambda_M + \lambda_U = 36.5166 \\ \lambda_M + 2\lambda_U = 21.0318 \end{cases} => \begin{cases} \lambda_L = 4.8952 \\ \lambda_M = 6.0301 \\ \lambda_U = 7.5008 \end{cases}$$

According to the equations (6-7) Consistency index and ratio of (for table 12) are computed:

$$CI = \frac{6.0301-6}{6-1} = 0.006, \quad CR = \frac{0.006}{1.24} = 0.005, \quad CR \le 0.10$$

Referring to the step (5) indicators weight vector for tax revenues sub-index is computed:

w = (0.1763,0.1762,0.1739,0.1691,0.1608,0.1438)

Next, based on step 6, weights of time series data are computed that are given in table 11.

Table 20.11. Time series weights of GEDI indicators

Indicators	Time series weights - λ_{ij}						
	2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**
Total revenue as a percentage of GDP	0.1416	0.1347	0.1401	0.1431	0.1653	0.1409	0.1343
Tax revenue as a percentage of GDP	0.1467	0.1321	0.1318	0.1389	0.1558	0.1332	0.1615

Cont…

Indicators	Time series weights - λ_{ij}						
	2016	2017	2018	2019	2020	2021	2022
Goods and services tax revenue as a percentage of GDP	0.1619	0.1464	0.1327	0.1298	0.1301	0.1375	0.1616
Income tax revenue as a percentage of GDP	0.1600	0.1466	0.1345	0.1333	0.1569	0.1365	0.1322
Excise tax revenue as a percentage of GDP	0.1578	0.1388	0.1417	0.1544	0.1266	0.1270	0.1537
Trade tax revenue as a percentage of GDP	0.1450	0.1343	0.1570	0.1531	0.1489	0.1322	0.1296

Consequently, referring to step 7, Aggregated fuzzy values for tax revenue sub-index for 2022 is computed:

$$\widetilde{SI}_{\text{FHWA}}\text{(Tax Revenues)} = (0.2963,0.3119,0.3275) \times 0.1622 + (0.2977,0.3134,0.3291) \times 0.1950 + (0.7122,0.7497,0.7872) \times 0.1925 + (0.0474,0.0499,0.0524) \times 0.1532 + (0.0459,0.0483,0.0508) \times 0.1694 + (0.0500,0.0500,0.0600)\times 0.1277 = (0.2649,0.2788,0.2928)$$

In a same way, aggregated values of the rest sub-indices of GEDI are obtained:

$$\widetilde{SI}_{\text{FHW A}}\text{(Output)} = (0.2200,0.2315,0.2431)$$

$$\widetilde{SI}_{\text{FHW A}}\text{(Trade)}=(0.1468,0.1546,0.1623)$$

Consequently, aggregation of all four sub-indices produces the overall index:

$$\text{GEDI}_{\text{FW A}}\ (2022) = (0.2118,0.2230,0.2341)$$

Finally, similarity measures between aggregated value for GEDI and relevant linguistic terms given in table 6 are computed (table 12):

Table 20.12. Computed similarity values in line with linguistic terms

Linguistic terms	Similarity values
Very high (VH)	0.2928
High (H)	0.3372
Medium high (MH)	0.3949

Cont…

Linguistic terms	Similarity values
Medium (M)	0.4696
Medium low (ML)	0.5555
Low (L)	**0.5896**
Very low (VL)	0.2811

Obviously, the highest similarity value corresponds to the linguistic term – Low (L), based on similarity measures for aggregated fuzzy values of GEDI, the corresponding linguistic terms were selected, which represent GEDI for Azerbaijan from 2016 to 2022:

Table 20.13. GEDI for Azerbaijan from 2016 to 2022 in linguistic terms

Overall Index	Years						
Global Economic Diversification Index for Azerbaijan in Linguistic terms	2016	2017	2018	2019	2020	2021	2022
	L	L	L	L	L	L	L

The computation of the Global Economic Diversification Index (GEDI) for Azerbaijan from 2016 to 2022 shows that despite variations in individual indicators over the years, the overall GEDI consistently falls within the "Low" (L) linguistic term, based on the fuzzy aggregation of sub-indices (Output, Trade, Tax Revenues). This suggests that Azerbaijan's economic diversification remains limited during the period under study.

Simulation of GEDI Levels: Scenario-Based Future Projections

In this stage we turn to global worst and best cases (min, max), and we divided the intervals for Output, Trade and Taxes into three linguistic variables (low-V1, middle-V2, high-V3). The simulation process was applied to four indicators of Output (given in table 14) for improvement the level of GEDI in the future using the data of 2022 year. In low scenario (V1), the agriculture value added as a percentage of GDP, and manufacturing as a percentage of GDP were both increased by up to 20%. In the middle scenario (V2), the services value added as a percentage of GDP was increased by up to 50%, while agriculture value added as a percentage of GDP, and manufacturing as a percentage of GDP were raised to 30%. In the high scenario (V3), building upon the V2 scenario, the industry value added as a percentage of GDP was further increased to 60%. During the computation process, we returned to step 5 of the algorithm and adjusted the weights for the GEDI sub-indices

(0.40 for Output, 0.30 for Trade, and 0.30 for Taxes) to sub-indices of GEDI, taking into account for the scenarios provided in table 14.

As a result, in the low scenario (V1), the GEDI level remained at a "Low" rating. However, in both the middle (V2) and high (V3) scenarios, the GEDI level was upgraded to a "Medium-Low" (ML) rating, reflecting a significant potential for economic diversification.

Table 20.14. Simulation scenarios for GEDI.

№	Changing Output indicators	Scenarios (possible future increase in data)		
		V1	V2	V3
1	İndustry value added as % of GDP	55.4	55.4	60
2	Services, value added as % of GDP	32.10	50	50
3	Agriculture, value added as % of GDP	20	30	30
4	Manufacturing, as % of GDP	20	30	30
Effect on Output (in fuzzy values)		(0.3006,0.3165,0.3323)	(0.3922,0.4128,0.4334)	(0.4009,0.4220,0.4431)
Effect on GEDI (in fuzzy and linguistic values)		(0.2438,0.2566,0.2694) L	(0.2804,0.2951,0.3099) ML	(0.2839,0.2988,0.3137) ML

Conclusions

The analysis conducted in this paper, based on data from 2016 to 2022, reveals that Azerbaijan's GEDI levels have consistently been rated as "Low." A detailed review of the composition of Output, Trade, and Tax Revenues suggests that the low GEDI level is largely due to the dominance of the oil sector and the relatively low contributions from agriculture and services to the GDP.

The GEDI results indicate a need for more robust policy interventions aimed at enhancing the diversification of Azerbaijan's economy. This could involve fostering growth in non-oil sectors, improving tax efficiency, and expanding the variety of goods and services involved in trade. The algorithm has successfully quantified and assessed Azerbaijan's economic diversification, but the "Low" ratings over the years underscore the persistence of structural economic challenges.

Future research will aim to further disaggregate Output, Trade, and Tax Revenue indicators for more granular modeling of Azerbaijan's economic diversification efforts by application of AI tools, particularly Large Language models.

References

1. *Multi-year Expert Meeting on Investment, Innovation and Entrepreneurship for Productive Capacity-building and Sustainable Development, tenth session*. (2023). UN Trade And Development (UNCTAD). https://unctad.org/meeting/multi-year-expert-meeting-investment-innovation-and-entrepreneurship-productive-capacity-8

2. United Nations Climate Change. (n. d.). *Economic diversification*. https://unfccc.int/topics/resilience/resources/economic-diversification.

3. *Economic Diversification Guidance Note Trade and Competitiveness Global Practice Draft*. (2017). https://unfccc.int/files/cooperation_support/response_measures/application/pdf/technical_paper_economic_diversification.pdf

4. Mohammed bin Rashid School of Government (Ed.). (2021). The Global Economic Diversification Index 2022. *economicdiversification.com*. https://economicdiversification.com/wp-content/uploads/2021/12/Mock-report.pdf

5. Gelb, A. (2010). *Economic Diversification in Resource-Rich Countries*. Center for Global Development.

6. Hausmann, R., Hwang, J., & Rodrik, D. (2007). What you export matters. *Journal of Economic Growth*, 12(1), 1-25. https://doi.org/10.1007/s10887-006-9009-4

7. Koren, M., & Tenreyro, S. (2007). Volatility and Development. *Quarterly Journal of Economics*, 122(1), 243-287. https://doi.org/10.1162/qjec.122.1.243

8. Cherif, R., & Hasanov, F. (2014). Soaring of the Gulf Falcons: Diversification in the GCC Oil Exporters in Seven Propositions. *IMF Working Paper*.

9. Imanov, K. (2024). Fuzzy analysis of global uncertainty factors affecting the Azerbaijani economy. In Racef (Ed.) *Las expectativas económicas inciertas en el inquietante orden mundial.*(221-239) https://racef.es/archivos/publicaciones/web_racef_s_academicaginebra_ms89_24_ok.pdf

10. *The State Statistical Committee of the Republic of Azerbaijan*. (n. d.). https://www.stat.gov.az/?lang=en

11. *World Bank Open Data*. (n. d.). World Bank Open Data. https://data.worldbank.org/indicator

12. *Indicators*. (n. d.). https://www.ceicdata.com/en/indicators

13. *Global economy, world economy | TheGlobalEconomy.com*. (n. d.). TheGlobalEconomy.com. https://www.theglobaleconomy.com/

14. WTO | documents and resources gateway. (n. d.). https://www.wto.org/english/res_e/res_e.htm

15. *UN comtrade*. (n. d.). https://comtradeplus.un.org/

16. Memmedova, K., & Ertuna, B. (2023). Development of a fuzzy Likert scales to measure variables in social sciences. *Information Sciences*, 654, 119792. https://doi.org/10.1016/j.ins.2023.119792

17. Praščević, N., & Praščević, Ž. (2016). Application of fuzzy AHP method based on eigenvalues for decision making in construction industry. *Tehnicki Vjesnik - Technical Gazette*, 23(1). https://doi.org/10.17559/tv-20140212113942

18. Aliyev, R., Temizkan, H., & Aliyev, R. (2020). Fuzzy Analytic Hierarchy Process-Based Multi-Criteria Decision Making for Universities Ranking. *Symmetry*, 12(8), 1351. https://doi.org/10.3390/sym12081351

19. Saaty, R. (1987). The analytic hierarchy process—what it is and how it is used. *Mathematical Modelling*, 9(3-5), 161-176. https://doi.org/10.1016/0270-0255(87)90473-8

20. Chu, T. (2002). Facility Location Selection Using Fuzzy TOPSIS Under Group Decisions. *International Journal Of Uncertainty Fuzziness And Knowledge-Based Systems*, 10(06), 687-701. https://doi.org/10.1142/s0218488502001739

21. Szmidt, E., & Kacprzyk, J. (2000b). Distances between intuitionistic fuzzy sets. *Fuzzy Sets And Systems*, 114(3), 505-518. https://doi.org/10.1016/s0165-0114(98)00244-9

22. Szmidt, E., Kacprzyk, J., & Bujnowski, P. (2010). On some measures of information and knowledge for intuitionistic fuzzy sets. *Notes on Intuitionistic Fuzzy Sets*, 16(2), 1-11

23. Li, G., Kou, G. G., & Peng, Y. (2015). Dynamic fuzzy multiple criteria decision making for performance evaluation. *Technological And Economic*

Development Of Economy, 21(5), 705-719. https://doi.org/10.3846/20294913.2015.1056280

24. Imanov, G., & Aliyev, A. (2024). Intuitionistic fuzzy pattern recognition model in assessment of the social empowerment index for Azerbaijan. *Research Square*. https://doi.org/10.21203/rs.3.rs-3955897/v1

25. Yager, R. (1988). On ordered weighted averaging aggregation operators in multicriteria decisionmaking. *IEEE Transactions On Systems Man And Cybernetics*, 18(1), 183-190.
https://doi.org/10.1109/21.87068

26. Zhang, L., Xu, X., & Tao, L. (2013). Some Similarity Measures for Triangular Fuzzy Number and Their Applications in Multiple Criteria Group Decision-Making. *Journal Of Applied Mathematics*, 2013, 1-7. https://doi.org/10.1155/2013/538261

PHOTO GALLERY

(2013-2024)

Professor Gorkhmaz Imanov received his credentials as a RACEF Corresponding Academician for Azerbaijan at a ceremony held on 25th April 2013.

Professor Gorkhmaz Imanov, giving his talk at the admission ceremony, along with President, Jaime Gil Aluja, and other fellow Academicians.

Professor Gorkhmaz Imanov at the admission ceremony. President, Jaime Gil Aluja, and other fellow Academicians.

Gorkhmaz Imanov with Academicians and assistants at the admission ceremony.

Professor Gorkhmaz Imanov's speech at the X International Conference of RACEF in November 2015.

Group photo of the Academicians at the X International Conference in Barcelona, November 2015.

Family photo of the joint Academic International Event of the RACEF and the University of Beira Interior in Portugal, June 2019.

Family photo of the joint Academic International Event of the RACEF and the University of Beira Interior in Portugal, June 2019.

Professor Gorkhmaz Imanov at the plenary session at the XIV International Annual Meeting of RACEF in November 2019.

Family photo at the closing ceremony of the XIV RACEF Annual Meeting, November 2019.

Annual Meeting RACEF, Barcelona, November 2021.

Family photo at the XVII International Annual Meeting RACEF, Barcelona 2022.

Group photograph of the joint Academic International Event of the RACEF and the Swiss UMEF-University, Switzerland, April 2024.

Professor Gorkhmaz Imanov at the XIX International Annual Conference held in Barcelona on 15th November 2024 along with RACEF President, Jaime Gil Aluja.

Real Academia

de Ciencias Económicas y Financieras

RACEF PUBLICATIONS

Real Academia
de Ciencias Económicas y Financieras