ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online); DOI PREFIX:10.36962/CESAJSC

VOLUME 58 (12) ISSUE 01 2024



# THE CAUCASUS

## ECONOMIC & SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

MULTIDISCIPLINARY JOURNAL
REFEREED & REVIEWED JOURNAL

AGRICULTURAL, ENVIRONMENTAL & NATURAL SCIENCES
SOCIAL, PEDAGOGY SCIENCES & HUMANITIES
MEDICINE AND BIOLOGY SCIENCES
REGIONAL DEVELOPMENT AND INFRASTRUCTURE
ECONOMIC, MANAGEMENT & MARKETING SCIENCES
LEGAL, LEGISLATION AND POLITICAL SCIENCES
ART AND FILM STUDIES
CINEMATOGRAPHY

Platform & workflow by OJS/PKP

https://scsj.fisdd.org/index.php/CESAJSC

**The beautiful thing about learning is nobody can take it away from you—B. B. King**

**ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online); DOI PREFIX:10.36962/CESAJSC**

**VOLUME 58 (12) ISSUE 01 2024**



# THE CAUCASUS

**ECONOMIC & SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS**

**MULTIDISCIPLINARY JOURNAL**
**REFEREED & REVIEWED JOURNAL**

**JOURNAL INDEXING**

**CROSSREF**

**FREESIA ISDSJ**

**DISSEMINATION SCORES 2023 – 17.83**

**QUALITY FACTOR 2023 – 1.3**

**GEORGİA, TBİLİSİ 2024**

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



ISSN: 1987-6521 (Print); ISSN:2346-7541 (Online); DOI prefix: 10.36962/CESAJSC; UDC: 3/k-144
©Publisher: Representation of Azerbaijan International Diaspora Center in Georgia.
©Editorial office: 0165 Georgia. Marneuli municipality. Village Takalo.
©Typography: Representation of Azerbaijan International Diaspora Center in Georgia.
Registered address: 0165 Georgia. Marneuli municipality. Village Takalo.
Telephones: +994 55 280 70 12; +994 55 241 70 12 (Whatsapp),
Website: https://scsj.fisdd.org/index.php/CESAJSC
E-mail: gulustanbssjar@gmail.com; sc.mediagroup2017@gmail.com

©Publisher: ESIF NGO, I/N: 404619864
©Typography: ESIF NGO, I/N: 404619864
Registered Address / Service Address: Georgia, Tbilisi, Mtatsminda district, Jorjadze Street N 5, floor 1
Director & Shareholder: Namig Isazade
Telephones: +994 55 280 70 12; +994 55 241 70 12 (Whatsapp),
Website: https://scsj.fisdd.org/index.php/CESAJSC
E-mail: gulustanbssjar@gmail.com; sc.mediagroup2017@gmail.com

**Accepted for publication in this edition 06.02.2023**

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# TABLE OF CONTENTS

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# HYDRODYNAMIC BASES FOR CALCULATING THE MOTION OF TWO-PHASE SYSTEMS IN COMPLEX PIPELINES

**[1]Abdulaga Gurbanov, [2]Ijabika Sardarova**
[1,2]Azerbaijan State Oil and Industry University
[1]Department of Transportation and storage of oil and gas
[1] PhD, abdulaga.qurbanov@asoiu.edu.az, https://orcid.org/0000-0002-1187-8383
[2]Department of Electronics and Automation.
[2] PhD, icabika.sardarova@asoiu.edu.az, https://orcid.org/0000-0002-7719-497X

## ABSTRACT

Considering the conditions for the development of an oil field for different layers, the pipeline networks are different. Based on hydromechanics of homogenous fluid and gas, a new model of two-phase systems movement of fluid-gas type in horizontal tubes is suggested and the major calculation formula for complicated pipelines is developed. In constructing a complex system of pipelines transporting both single-phase and two-phase systems, firstly, it is necessary to consider the location of wells in the field, their initial and final flow rates, as well as the physicochemical properties. This method enables us to define the main parameters of complicated pipelines, considering the physical properties of two-phase systems.
The equation of two-phase systems movement in simple and complicated pipelines, allowing recommending using this approach in field experience, is obtained as well.
**Keywords:** shear stress, complicated pipeline, multiple connections, diameter, volumetric fluid, and gas discharge.

## Introduction

Oil fields in the world are located in different climatic zones, wells have different depths and physical and chemical properties of oil, gas, and water, which is the basis for an individual approach in the development of projects for their development. Practice shows that the system for collecting and transporting oil, gas, and water is a separate-branched network of pipelines attached to the territories of the fields. These are underground, above-ground, underwater, and surface pipelines. Taking into account the conditions for the development of an oil field for different layers, the pipeline networks are different. So, for the fields of the republic, the total length of all pipelines applied underground exceeds more than 30 thousand km. The geometric dimensions of such pipelines vary widely, from 0.1 to 1.02 m.
Basically, small-diameter pipelines (flow lines) are laid from the wellhead to group metering units. Large-diameter pipelines transport fresh water to flood the oil reservoir to maintain reservoir pressure, which increases the oil recovery factor.

## Statement of the problem

The movement of homogeneous liquids and gases in pipelines on a hydrodynamic basis plays an important role in improving the transportation process. At the same time, in this article, considering the physical properties of two-phase systems, it is important to determine the main parameters of the movement in complex pipelines, and it is important to review the methods for adjusting the movement. Determining the practical use of the equations of motion in different

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



pipelines in two-phase systems is an important issue in the definition of the advantages of the transportation system.

**Solution of the problem**

The results of the analysis show that all pipelines transporting single-phase (oil, gas, fresh or formation water), two-phase (oil and gas), or multiphase (oil, gas, and water) systems are tested for capacity, i.e.hydraulic resistance as well as mechanical strength.

Practice shows that for all work on the collection, transportation, and treatment of oil, gas, and water in a complex field development project, the location of the main oilfield facilities and communications is provided, the construction of which consumes about 50% of the capital investments allocated to the oil industry [1-4].

It is known that pipelines transporting well products on the territory of oil fields are divided into the following categories: by purpose - oil pipelines and gas pipelines, oil and gas pipelines; by the nature of the movement - with the joint movement of watered and non-watered oil; by the nature of pressure - pressure and non-pressure; according to the method of laying - underground, above-ground, underwater and suspended; by function - flow lines, prefabricated and commodity collectors; according to the hydraulic scheme of work - simple without branches, complex - with branches, which include parallel, ring and closed pipelines.

For these pipelines provided for in the complex project, hydrodynamic calculations are required. Basically, prefabricated collectors transporting gas-liquid mixtures such as oil and gas must be designed and calculated taking into account the rate of drilling of production wells, as well as the climatic conditions of the given field.

Numerous hydraulic calculations show that the rate of well commissioning affects the choice of rational diameters of prefabricated collectors. So, at low rates of putting into operation wells with a small flow rate in offshore conditions, they should be designed as two prefabricated collectors, equal in cross-sectional area to one large one, designed for the maximum productivity of all operated wells.

At high rates of well operation, it is possible to design and build one common system, i.e. one prefabricated manifold designed for maximum productivity of all connected wells [5-7]. When constructing a complex system of pipelines transporting both single-phase and two-phase systems, firstly, it is necessary to take into account the location of wells in the field, their initial and final flow rates, as well as the physicochemical properties of hydrocarbons produced from various productive horizons. Taking into account the location of wells in an oil field, the depth of the sea, the topography of the seabed and the climate makes it possible to select rational routes for all pipelines.

**Results and discussion**

Basically, hydraulic calculations are performed for simple and complex pipelines transporting both single-phase and multiphase systems.

The hydraulic calculation of a simple pipeline is reduced to determining its throughput, the initial pressure and diameter of the pipeline are necessary. Complex pipelines can be of various diameters along the line and branch.

In the hydraulic calculation of complex pipelines, four cases often encountered in field conditions are of practical interest.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



1. Distribution manifold with constant diameter for uniform and uneven selection of hydrocarbons.
2. Collector having a constant or variable diameter for uniform or non-uniform flow of fluids.
3. Common collection manifold forming parallel pipelines (looping).
4. The general prefabricated collector, having the shape of a ring.

The movement of fluid flows in various pipes and under various conditions is defined as follows.

**Sudden expansion**

When the fluid flow passes from the narrow part of the horizontal pipeline to the wider part, it is subjected to intense rotational motion. Liquid particles in such a swirling (eddy) movement are in active friction both against the walls of the tube and with each other (Fig. 1). Frictions cause a sharp loss of energy in the flow. Due to the influence of inertial forces on the flow, vortices are extinguished at some distance from the suddenly expanded part, the pressure gradually increases, and the velocity pressure and the total pressure decrease.

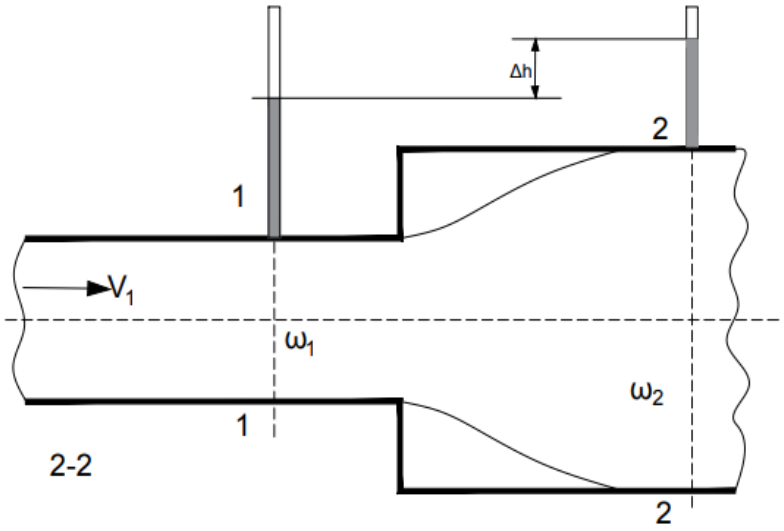



**Figure 1.** Fluid rotation in suddenly expanded parts.

In order to determine the pressure loss, let's write the Bernoulli equation for sections 1-1 and 2-2 according to Figure 1.

$$\frac{p_1}{\gamma}+\frac{v_1^2}{2g}=\frac{p_2}{\gamma}+\frac{v_2^2}{2g}+h_{1-2}$$

From here, the following expression for the pressure loss is obtained:

$$h_{1-2}=\frac{p_1-p_2}{\gamma}+\frac{v_1^2-v_2^2}{2g}=\Delta h+\frac{v_1^2-v_2^2}{2g} \qquad (1)$$

The value of the pressure difference is recorded again from a mnemonic or from a block of piezometers.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



The expressions for the local resistance coefficient are:
according to the first gear

$$\zeta_1 = \frac{2g\,h_{1-2}}{v_1^2} \qquad (2)$$

according to second gear

$$\zeta_1 = \frac{2g\,h_{1-2}}{v_2^2} \qquad (3)$$

Analytical pressure loss can be calculated based on the Bordo-Carnot theorem:

$$h_{1-2}^* = \frac{(v_1 - v_2)^2}{2g} \qquad (4)$$

Using the continuity equation and Weissbach's formula, we get the following for the local resistance coefficient:

$$\zeta_1^* = \left(1 - \frac{S_1}{S_2}\right)^2 \qquad (5)$$

and

$$\zeta_2^* = \left(\frac{S_2}{S_1} - 1\right)^2 \qquad (6)$$

Here, $S_1$ and $S_2$ are the cross-sectional areas of narrow and wide pipes, respectively.
A sudden contraction.

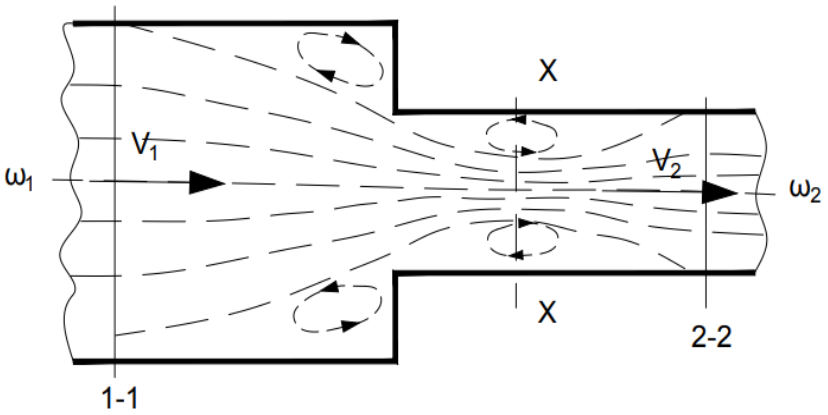



**Figure 2.** Swirling of liquid in suddenly narrowed sections.

In the case of a sudden narrowing of the flow, some of the liquid particles are separated from the general flow, forming vortex zones and joining the rotation movement (Fig. 2).
Although the number of such zones is greater than in the expansion process, the pressure loss is less. It is the compression of the flow that causes the eddies to form before the constriction. In the next short section, due to the inertial force of the liquid particles, the continuation of the movement towards the center of the flow also creates vortex zones.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



The pressure loss and the local resistance coefficient can be determined experimentally by formulas (1-3). Theoretically, the local resistance coefficient can be determined by the following formulas proposed by I. Idelchik:

$$\zeta_1^* = \frac{1}{2}\left(\frac{S_1}{S_2} - 1\right)\frac{S_1}{S_2} \qquad (7)$$

$$\zeta_2^* = \frac{1}{2}\left(1 - \frac{S_2}{S_1}\right) \qquad (8)$$

Pressure loss is calculated based on Weisbach's formulas (5) and (7):

$$h_{1-2}^* = \zeta_1^* \frac{v_1^2}{2g} \qquad (9)$$

In this paper, based on the hydraulic laws of a homogeneous liquid and gas, a model for the movement of a two-phase mixture in a pipeline is proposed and the main calculation formulas for complex pipelines are obtained. It is known that the joint transport of two-phase hydrocarbon systems through pipelines is common in the oil and gas industry. The complexity of the hydrodynamic processes that occur during the movement of the oil and gas system, which differ from calculations for a single-phase flow, is the reason that this problem has not yet found its satisfactory solution.

Processing the results of numerous theoretical and laboratory-experimental works of the classics in the hydraulics of multiphase systems A. I. Guzhova, A. A. Armanda, S. I. Kosterina, S. S. Kutateladze, V. A. Mamaeva, K.J. Xoqsidorna, G. Uollisi and others within the following parameters: [8-10]. Gas Frode $Fr_q$ =0.15-3246; Froude liquid $Fr_j$ = 0.0005-134.12; Reynolds Gas $Re_t$ =211-67500; Reynolds liquid $Re_j$ =404-18886 and with a pipe diameter D=0.02-0.05 m for various liquids, the dependence was obtained

$$\tau_c = \tau_j + \tau_r + k\sqrt{\tau_j}\tau_q \qquad (10)$$

where $\tau_c$ is the shear stress during the movement of a two-phase system;

$\tau_j, \tau_r$- are, respectively, the tangential stresses of the liquid and gas;

k -experimental parameter.

Laboratory analysis shows that this experimental parameter depends on the ratio of liquid and gas densities.

For water-air systems$k = \sqrt{\frac{p_j}{\rho_q}} = 26$, and for other liquids, $k = \sqrt{\frac{\rho_j}{p_q}} == 26 \div 33$ depending on the physical and chemical properties of liquid and gas. A complete study of this model is given in [3].

$$\Delta p_c = \Delta p_j + k\sqrt{\Delta p_j}\sqrt{\Delta p_q} \qquad (11)$$

where $\Delta p_c$ is the loss of pressure due to friction during the movement of a two-phase system;

$\Delta p_j$; $\Delta p_q$ - respectively, the friction loss during the movement of a homogeneous liquid and gas.

Taking into account separate parameters for liquid and gas, respectively, we obtain:

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$$\frac{\Delta P_c}{L} = \lambda_j \frac{v_j^2}{2D}\rho_j + \lambda_q \frac{v_q^2}{2D} p_q + k\sqrt{\lambda_j \frac{v_j^2}{2D}\rho_j \lambda_q \frac{v_q^2}{2D}\rho_q} \qquad (12)$$

where $\lambda_j$; $\lambda_q$ - respectively, the coefficients of hydraulic resistance for a homogeneous liquid and gas;
$v_j; v_q$ - respectively, the reduced velocity of liquid and gas;
$\rho_j$; $\rho_q$ - respectively, the density of liquid and gas;
D - is the inner diameter of the pipe;
L - is the length of the pipeline.
When calculating the hydrodynamics of pipelines, the Chezy formula is often used. We accept this equation for a homogeneous liquid and gas

$$\lambda_j = \frac{8g}{c_j^2} \text{ и } \lambda_q = \frac{8g}{c_q^2};$$

where $c_j$ and $c_q$ are the Chezy coefficient for liquid and gas, respectively;
g - is the free-fall acceleration.
After simple transformations, we get

$$\frac{\Delta P_C}{\rho_j g} \cdot \frac{D}{4L} = \frac{v_x^2}{c_j^2} + \frac{v_x^2}{c_q^2} \cdot \frac{\rho_q}{\rho_j} + k\sqrt{\frac{v_j^2}{c_j^2} \cdot \frac{v_q^2}{c_q^2} \cdot \frac{\rho_q}{\rho_j}} \qquad (13)$$

Let us introduce the volume-flow rate gas content into this equation:

$$\beta = \frac{v_q}{v_q + v_ж} \qquad (14)$$

It is known that the reduced velocity of liquid and gas, respectively, can be determined by the formula:

$$v_j = c_j\sqrt{RI_j} \quad \text{and} \quad v_j = c_j\sqrt{RI_q} \qquad (15)$$

where $I_j$ and $I_q$ are the hydraulic slope for liquid and gas;
R- hydraulic radius.
Then

$$\frac{\Delta p_c}{\rho_j} \cdot \frac{D}{4L} = \frac{v_j^2}{c_j^2} \cdot \left(1 + \frac{I_q}{I_j} \cdot \frac{\rho_x}{\rho_x} + k\sqrt{\frac{I_q}{I_j} \cdot \frac{\rho_x}{\rho_x}}\right) \qquad (16)$$

Denote the expression enclosed in brackets through the parameter

$$A = 1 + \frac{I_q}{I_j} \cdot \frac{\rho_r}{\rho_j} + k\sqrt{\frac{I_q}{I_j}\frac{\rho_q}{\rho_j}} \qquad (17)$$

This expression makes it possible to determine the volumetric flow rates of individual phases. So, for liquid it is

$$Q_j = v_j s = k_j\sqrt{\frac{I_j}{A}} \qquad (18)$$

where $k_j$ is the liquid flow characteristic.

Then,

$$Q_j = k_j\sqrt{\frac{h_j}{L}} \cdot \frac{1}{\sqrt{A}} \qquad (19)$$

here $h_j$ is the hydraulic head of the fluid.

Often, in difficult offshore conditions, it is recommended to build parallel pipelines, for which

$$Q_j = Q_{j_1} + Q_{j_2} \qquad (20)$$

Then, taking into account (10) and (11), we obtain

$$Q_j = k_{j_1}\sqrt{\frac{h_{j_1}}{L_1}} \cdot \frac{1}{\sqrt{A_1}} + \sqrt{\frac{h_{j_2}}{L_2}} \cdot \frac{1}{\sqrt{A_2}} \qquad (21)$$

**Conclusion**

As can be seen, using this method, it is possible to determine the main parameters for complex pipelines, taking into account the physical properties of two-phase systems.

This technique can be applied to other complex pipelines. Given the simplicity and validity of this technique by the laws of hydromechanics of a homogeneous liquid and gas, it can be recommended for widespread use in field conditions.

**Declarations**

The manuscript has not been submitted to any other journal or conference.

**Study Limitations**

There are no limitations that could affect the results of the study.

**Acknowledgment**

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCES**

1. Zuykov A. L Hydraulics textbook in 2 volumes. T1: Fundamentals of fluid mechanics / Faculty of Education and Science. Rasia. Federation, Moscow State. Builds. Univ.- Moscow: MGSU, 2014, 518 p.
2. Huseynov S. O., Abdurahimov S. H. Kahramanli S. Y. Interference in series combined local resistances in laminar mode movement (within Re=100-250) in a pipeline. //Journal of Theoretical and Applied Mechanics, 2016, No. 2, pp. 50-53.
3. Neçalov M. V., Novoselov V. F., Tuqunov P. I. Sequential pumping of oils and petroleum products through main pipelines.- Moscow: Nedra, 2015, 158 p.

4. Gurbanov A.N., Bayramov Y.N., Aliyeva Y.N. Calculation of the technological process for obtaining gas drying using polypropylene glycol. /COİA 2022. The International Conference on Control and Optimization with Industrial Applications. 24-26 August, 2022. Baku, Azerbaijan. Vol. I. pp.198-200.
5. Abdurahimov S. H. Determination of pressure loss with local resistance using a stand.- Baku, 2022, p.1-27.
6. Altshul A. D., Kiselev P. G. Hydraulics and aerodynamics. -M.: Stroyizdat, 2015, 323 p.
7. Gurbanov A.N., Sardarova I.Z., Damirova J.R. Analysis of gas preparation processes for improvement of gas transportation technology. //EUREKA: Physics and Engineering, №6 (37) 2021, Pp. 48-56. doi: https://doi.org/10.21303/2461-4262.2021.002081
8. . Salavatov T. Sh., Askerov R. Kh., Dadashzade Kh. I. Determination of bottomhole pressure and the process of exploitation of flooded basin wells.- Moscow: Gas industry, 2017, p. 26-32.
9. Ismayilova F. B. Assessment of dynamic loads in multiphase pipelines.- Baku, 2021, No. 9, p. 29-31.
10. İsmayılova Q. Q., İsmayılova F. B.,Musaev S. F. Prediction of viscosity properties of water-oil systems. //SOCAR Prossedings. Reservoir and Petroleum Engineering journal home pade: Special İssue, №1, 2021, Pp. 109-115.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-04

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# ALGORITHMS OF LIQUID LEVEL CONTROL BASED ON FUZZY LOGIC CONTROLLERS

**Kifayat Mammadova[1], Matanat Hasanquliyeva[2]**
[1,2]Azerbaijan State Oil and Industry University, [1,2]Department of Computer Engineering,
[1,2]PhD, Associate Professor, [1,2]lecturer,
[1]orcid.org/0000-0002-6530-2021; [2]orcid.org/0000-0002-7454-3396
[1]ka.mamedova@yandex.ru; [2]metahasanquliyeva@rambler.ru

## ABSTRACT

The proposed synthesis algorithm for a fuzzy – logical proportional – differential (Fuzzy PD) controller is a simple and allows using a standard form of description of linguistic variables and a minimum set of control rules (with number of three or five rules). One of the successful applications that used fuzzy control is liquid tank level control. The purpose of the proposed synthesis algorithm is to design a simulation system of fuzzy logic controller for liquid tank level control by using simulation package which is Fuzzy Logic Toolbox and Simulink in MatLab software. By doing some modification of this algorithm, the design will be very useful for the system relates to liquid level control that widely used in industry nowadays.
The influence of its barbecues on the process obtained by synthesis with a PD controller is shown. It became clear that by selecting coefficients, we could get high-speed transitions and the required quality without extreme settings. It was not possible to obtain the required process using a fuzzy controller of 3 rules. This is because the price of the derivative, that is, the rate of change in the liquid level in the tank, is not taken into account. This was taken into account in the fuzzy controller and a time adjustment of no more than 10 seconds was obtained. Fuzzy controller of 5 rules and copy of PD-controller - normalization of input and output gave close results in terms of quality and accuracy.
**Keywords:** controller, fuzzy logic controller, linguistic rules, fuzzification, defuzzification, liquid tank, toolbox, Simulink, PD – controller, overshoot, steading.

## Introduction

Fuzzy control can be described simply as control with sentences rather than equations. A fuzzy controller can include empirical rules, and that is especially useful in operator controlled plants. A comprehensive review of the classical design and implementation of the fuzzy logic controller can be found in the literature [1-3].
The main difficulty in designing nonlinear controllers is the lack of a general structure [4]. Most linear and nonlinear control solutions developed during the last three were based on precise mathematical relations. Hence, these model based approaches may not provide satisfactory solutions [5]. This motivates the interest in using fuzzy logic theory [6] and employ a mode of approximate reasoning that resembles the decision-making process of humans. FLS

1. Research institute “Geo-technological problems of gas, oil and chemistry”, Baku, Azerbaijan
2. Azerbaijan State University of Oil and Gas

Design of fuzzy controllers for the nuclear steam generator water level control were considered in [7-9].

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



If it is impossible to give an exact mathematical description of the object and its control in quantitative terms, the traditional control theory turns out to be inapplicable [10-13]. In these cases that it is advisable to use intelligent control methods to solve the problems of creating a control system specifically focused on building models that take into account the incompleteness and inaccuracy of the initial data.

**Problem statement**

In this study, we analyze the control effect of PD – and PD – controllers for liquid tank level control and compare of them.

Purpose of the work. The main purpose of this work to conduct a constructive analysis of fuzzy logic controller that ensure the activities of operators in a fuzzy process control system under conditions of uncertainty and create control algorithms based on fuzzy logic. Especially it can give more attention to various parameters, for example, time of response, the of steadying and overshoot.

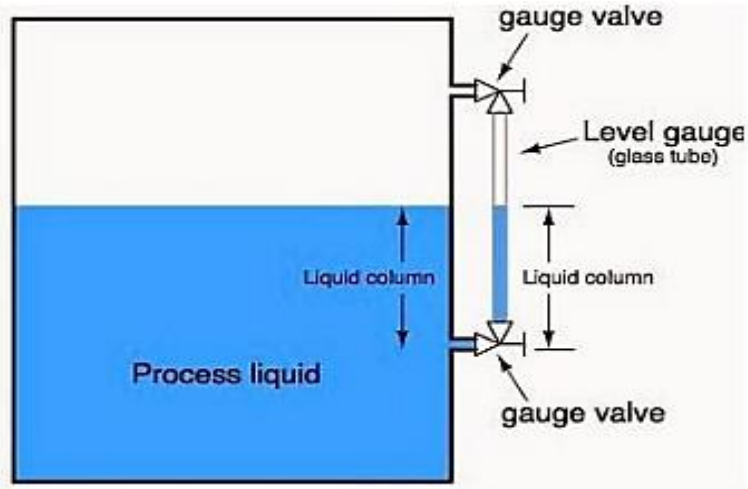
**The solution of the problem**

The cylindrical tank has several holes. Fluid enters from one orifice and exits from another. The inlet valve is controlled by changing the amount of fluid flowing. The velocity of the flowing liquid depends on the volumetric pressure, which varies with the diameter of the outlet and the level of the liquid [14]

The input to the controller is an electrical signal proportional to the error of a given variable level expectation, and the output is a voltage applied to the inductor that controls the inlet valve. The mathematical model of the control object is given by the following equation:

$$U = u_c\, h = \frac{b}{SU} - \frac{a}{S\sqrt{h}} \qquad (1)$$

where, $h$ - tank height *(m)*, $u_c$ - voltage at the output of the control device (control effect) *(v)*, $U$ - sum of voltage at the output of the control device depending on the placement of the valve, S - cross-sectional area of tank *($m^2$)*, $a$, $b$ - experimentally determined parameters (Figure 1).



ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Figure 1.** Control object - a tank with liquid in it [15,16]

The following restrictions are imposed on the synthesized system: overshoot - no more than 5%, switching process time - 10 seconds. Should be, the number of oscillations should not be more than two before the end of the transient, the fixed error should be equal to zero.
Let's assume that the control object is characterized by the following parameters (Table 1).

**Table 1.** Initial data.

| S, $sm^2$ | a | b | $h_1^{ref}$, m | $h_2^{ref}$, m | $h_{01}$, m | $h_{02}$, m |
|---|---|---|---|---|---|---|
| 50 | 7 | 11 | 1.8 | 1.25 | 0.5 | 1.6 |

Case study: Revamping a system should compare the following controllers:
1. Proportional controller (P).
2. Proportional-differential controller (PD).
3. Fuzzy controller using the following rules:
If (level is okay) then (valve is no change)
If (level is low) then (valve is open fast)
If (level is high) then (valve is close fast)
4. Fuzzy controller using the following rules:
If (level is okay) then (valve is no change)
If (level is low) then (valve is open fast)
If (level is high) then (valve is close fast)
Research and comparative analysis of the qualitative characteristics of a closed system [6-8]:
1. Evaluation of the quality of the closed system at different values of initial $h_0$ and at a given level $h^{ref}$ of liquid in the tank, control gains $K_D$ are constant to be determined in the design for set – point tracking and stability consideration.
2. Evaluate the effect by adding random noise to the system, taking into account the error from 1 to 5% when measuring the water level in the tank with sensors (transducer).
3. The outflow of water from the tank can be considered as an excitation affecting the control object. Evaluate the effect of changing the number of exit holes (cases of halving the area of outlet holes are considered).

**Controllers' setup**
The scheme described in the Simulink package of the Matlab system reflects the process of water level controller based on relation (1). The system has a closed structure with negative feedback. For simplicity, let's assume that the input is given a number equal to the value corresponding to the desired liquid level in the container. Therefore, we take the measurement factor to be 1.
Let's consider a simple P (proportional) controller to the system that implements a proportional control law. The diagram of the P-controller system is shown in Figure 2.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



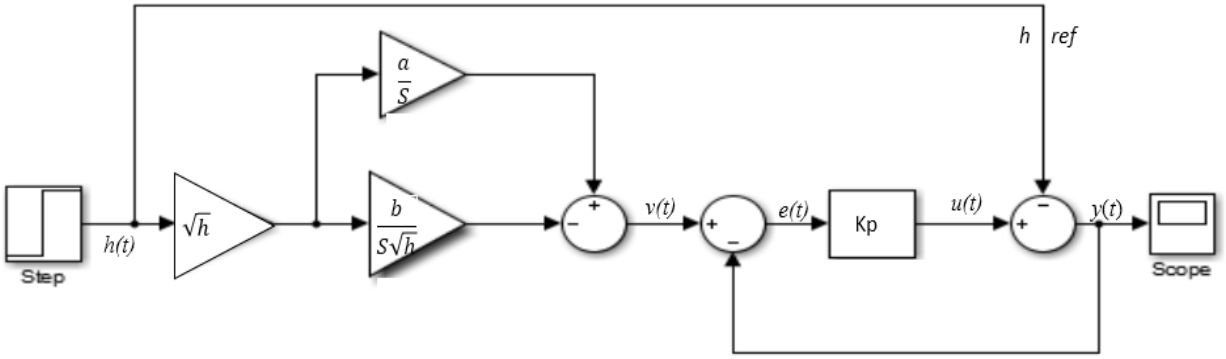



**Figure 2.** Structure diagram of the control object with P – controller.

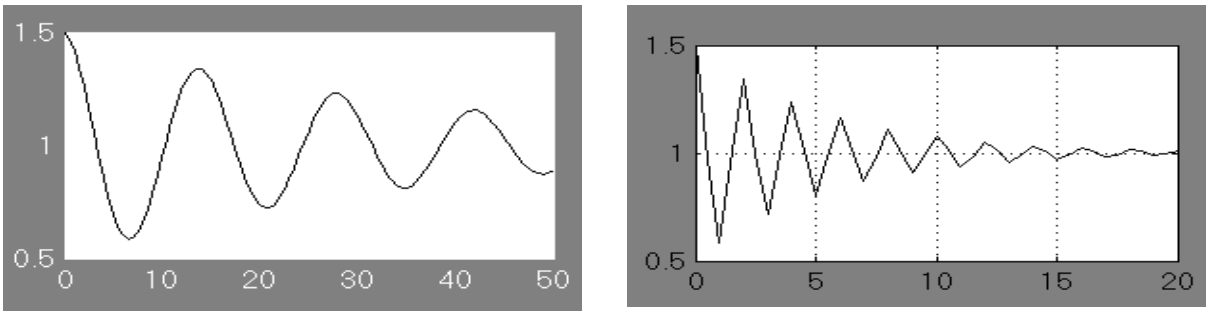



**Figure 3.** The process of the control object with P-controller: $K_P = 1$; $K_P > 1$

Obviously, by changing the gain, we get a very simple tuning mechanism. In Figure 3, you can control the dynamics of the process. By changing the gain, you can change the speed of the system, but this does not affect its quality.

We can only change the speed of the process in the formulation of the problem. In this case, the dynamics of the system will not change. With the help of the controller P, we will not be able to get the process of the required quality.

Let's see how the system works by adding a PD (proportional-derivative) controller, that is, in addition to the proportional controller, we also add a differential controller. Structure (Fig. 4). The circuit with a PD-controller is shown in Figure 5, 6.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



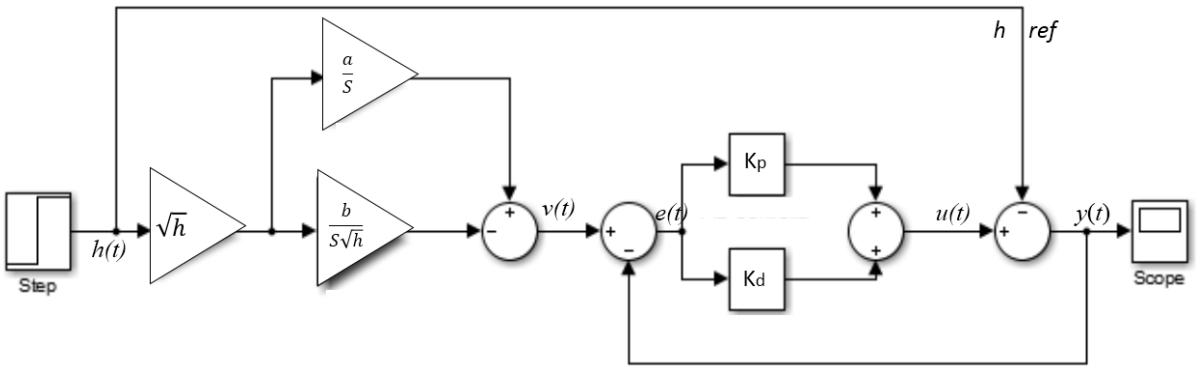



**Figure 4.** Structural diagram of the control object of the PD - controller

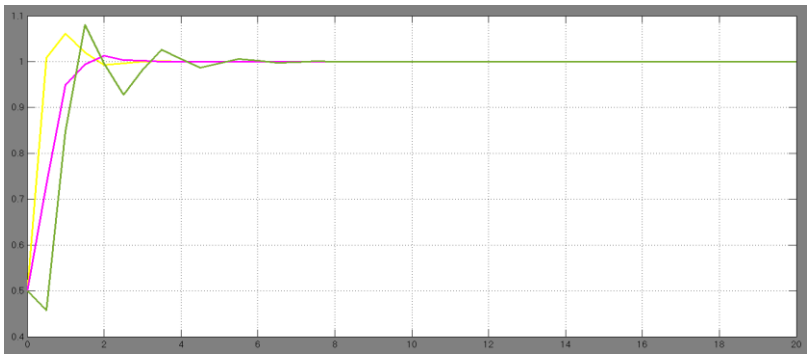


**Figure 5.** Change in the liquid level in the tank at different gains of the differential collector of the PD-controller: 1) $K_P = 50$, $K_D = 10$; 2) $K_P = 50$, $K_D = 20$; 3) $K_P = 50$, $K_D = 30$

Now we get two variable parameters for adjusting the controller. Let's consider their action separately:

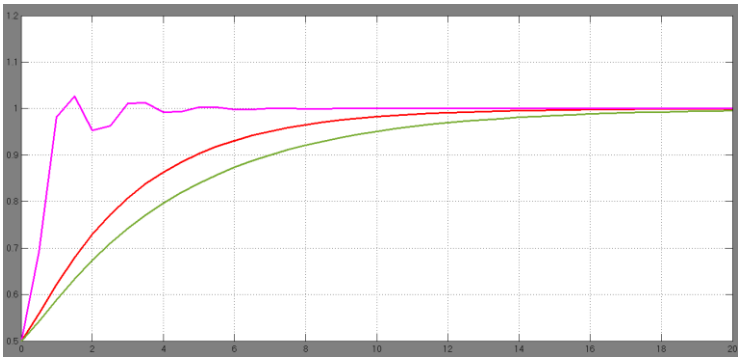


**Figure 6.** Change in the liquid level in the tank at various gains of the proportional bushing of the PD-controller 1) $K_P = 10$, $K_D = 30$; 2) $K_P = 50$, $K_D = 30$; 3) $K_P = 7$, $K_D = 30$

It can be seen from the figure that the differential clutch works in proportion to the change of the controller.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Fuzzy controllers**

Now let's consider the procedure for establishing a control law for fuzzy controllers, which is formed on the basis of the following three rules:

*If* (level is okay) *Then* (valve is no change)
*If* (level is low) *Then* (valve is close fast)
*If* (level is high) *Then* (valve is open fast)

We get the following: If the liquid level is “normal”, then the valve is left unchanged; If the liquid level is "low", then the valve closes quickly; If the liquid level is “high”, then the valve opens quickly.

The fuzzy controller model was developed on the basis of the Fuzzy Logic Toolbox package of the Matlab system. The fuzzy concepts mentioned above in brackets are described in terms of linguistic variables that are consistent with the membership function in the model. The description of the circuit in the Simulink package is shown in Figure 7.

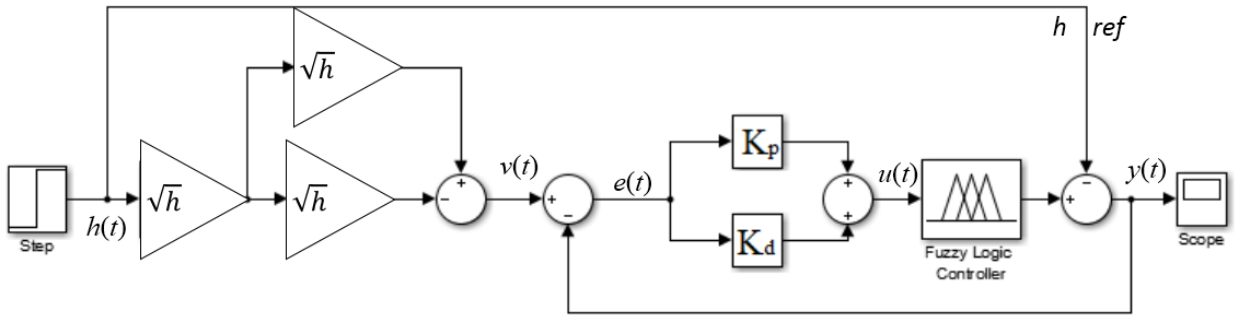



**Figure 7.** Description of a fuzzy controller control object (by 3 rules).


**Figure 8.** Structural diagram of the Fuzzy logic controller:

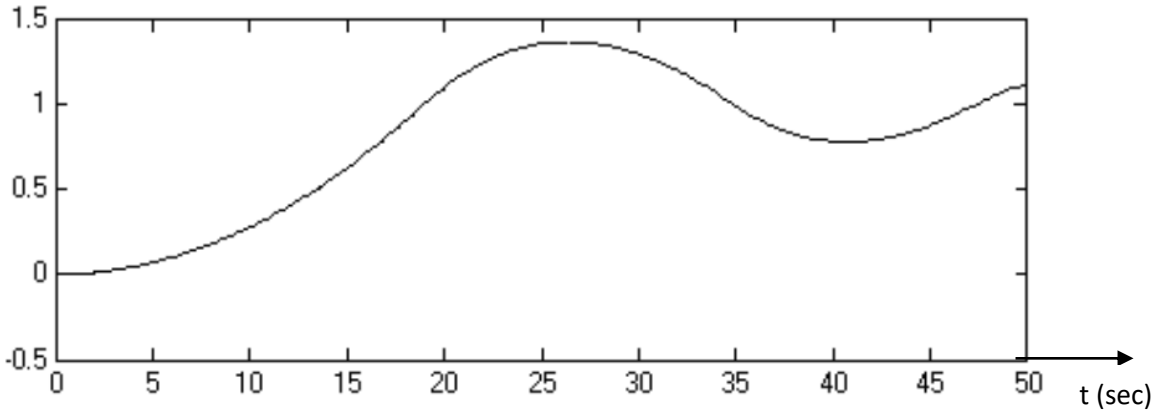



**Figure 9.** Variation of liquid capacity level (Sh) in the system with fuzzy controller (3 rules)

Introduce the input variable "level" = ($h^{ref}$ – h(t))/ $h^{ref}$ and output variable "valve" = (liquid column – free glass tube column)/liquid column. The membership function of these variables we are shown in Figure 10.

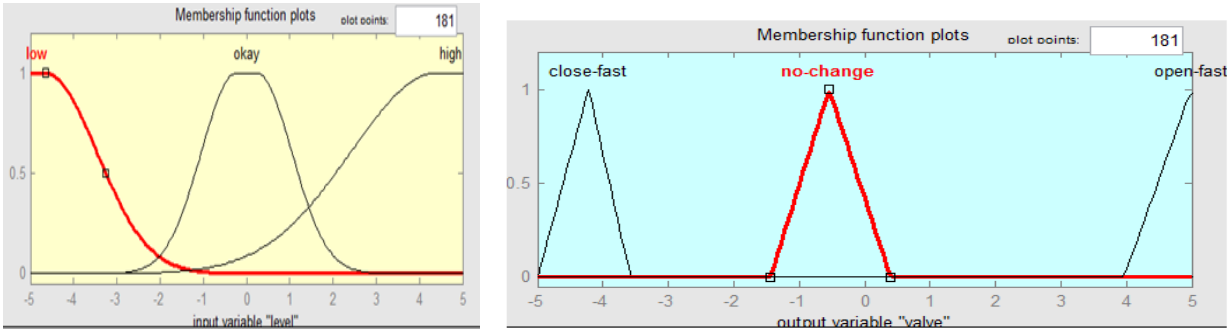



**Figure 10.** Membership function free terms ("3 rules"): a) input variable "level"; b) output variable "valve"

In Figure 10a, the lower term of the affinity function describes low, normal – normal and high – high liquid levels; in Figure 10b the term "quick close" refers to the signal of the valve "no change" – leave it unchanged, "quick open" – quickly open the valve.

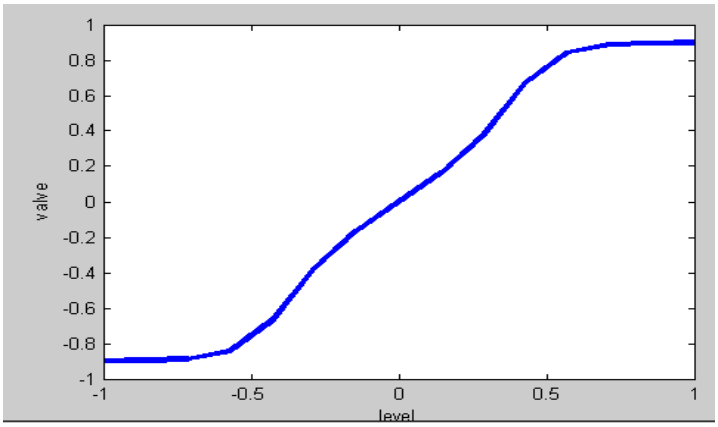



**Figure 11.** Superficial appearance of the fuzzy controller (according to three rules).

In this case, we get an unacceptable quality of the transient process. Until information about the normal level of liquid in the tank is taken into account, it is impossible to obtain the required transient process by selecting in membership function. It is necessary to submit information about the sign of the derivative to the input of the controller. This is implied by the five fuzzy rules in the controller/

Now let's build an improved fuzzy controller according to the five rules below:

*If* (level is okay) *Then* (valve is no change)

*If* (level is low) *Then* (valve is open fast)

*If* (level is high) *Then* (valve is close fast)

*If* (level is okay) *And* (rate is positive), *Then* (valve is open slow)

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



*If* (level is okay) *And* (rate is negative), *Then* (valve is close slow)

Here, in addition to the previous 3 rules, we have added two more rules that take into account the sign of the derivative. In this case, the modification of the first rule will be as follows:
*If* (level is okay) *And* (rate is null) *Then* (valve is no change)
Such a replacement does little in the simulation, as can be seen from the graph below.
Now the fuzzy controller has two inputs. One enters the liquid level, and the other enters the sign of the derivative.
Graphs characterizing the change in the liquid in the tank as a result of the simulation are shown in Figure 12.

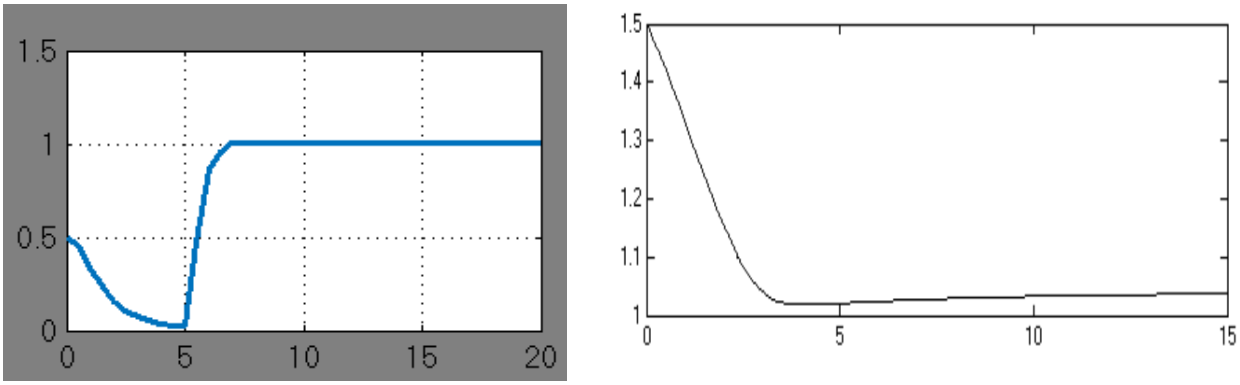



**Figure 12.** Fluid level change in a system with a fuzzy controller (5 rules): a) $h_0 = 0.5$; b) $h_0 = 1.6$

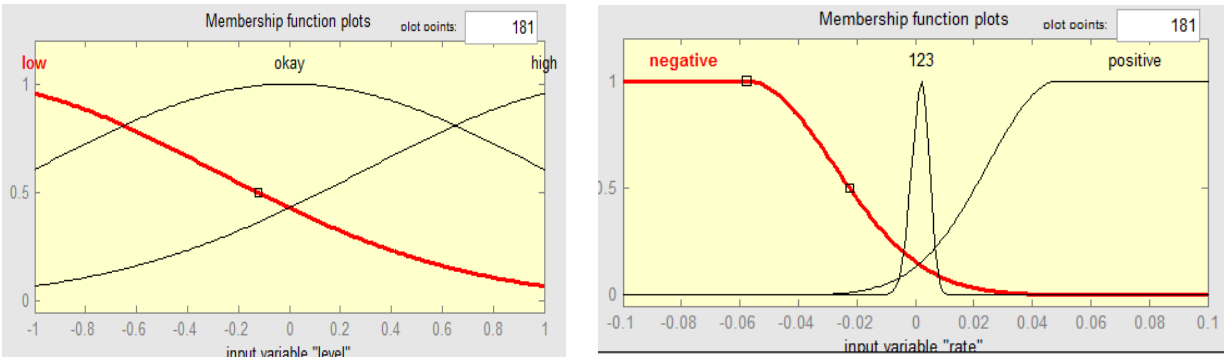



**Figure 13.** Membership function for terms (5 rules): of the input variables: a) "level"; b) "rate"

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



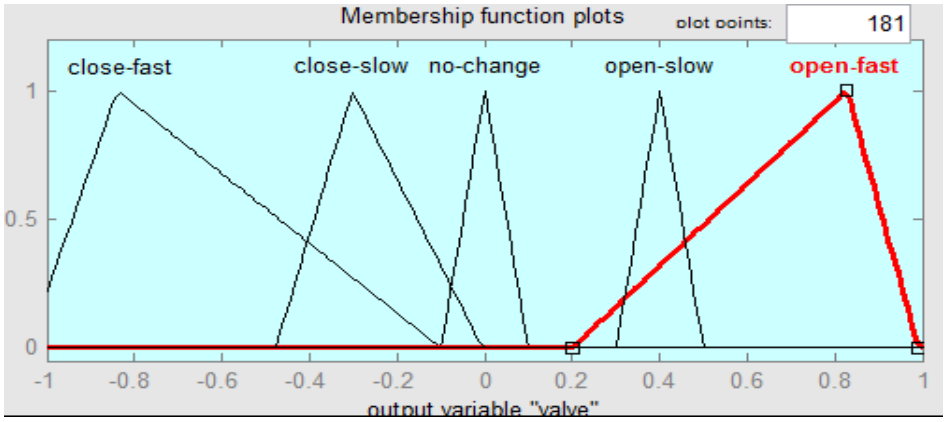



**Figure 14.** Membership function for valve output variable terms (5 rules).

We see that for the output variable corresponding to the small opening of the valve, two more terms are added. The membership function for liquid level input variables has changed significantly compared to 3rd order fuzzy controllers.
By choosing the appropriate type and form of the membership function, acceptable accuracy is achieved in addition to the normal quality process.

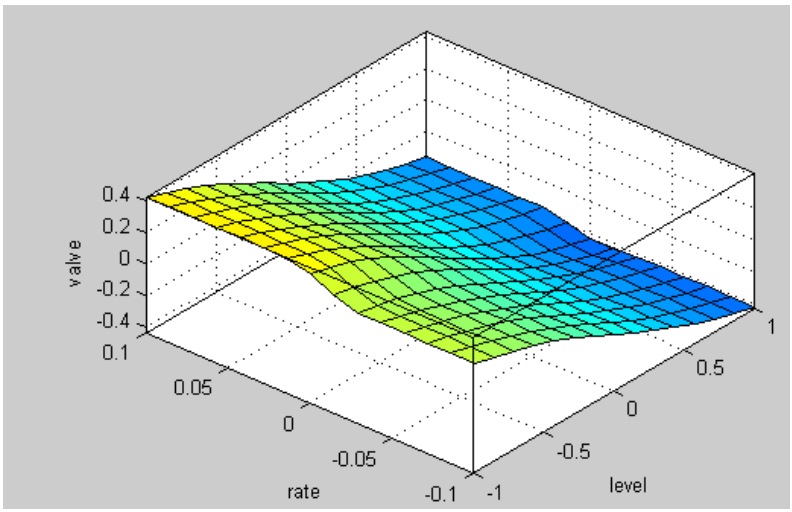



**Figure 15.** Appearance of the fuzzy controller (according to 5 rules).

Fuzzy rules, fuzzy variables and their terms are introduced from the Fuzzy Inference System (FIS) model.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



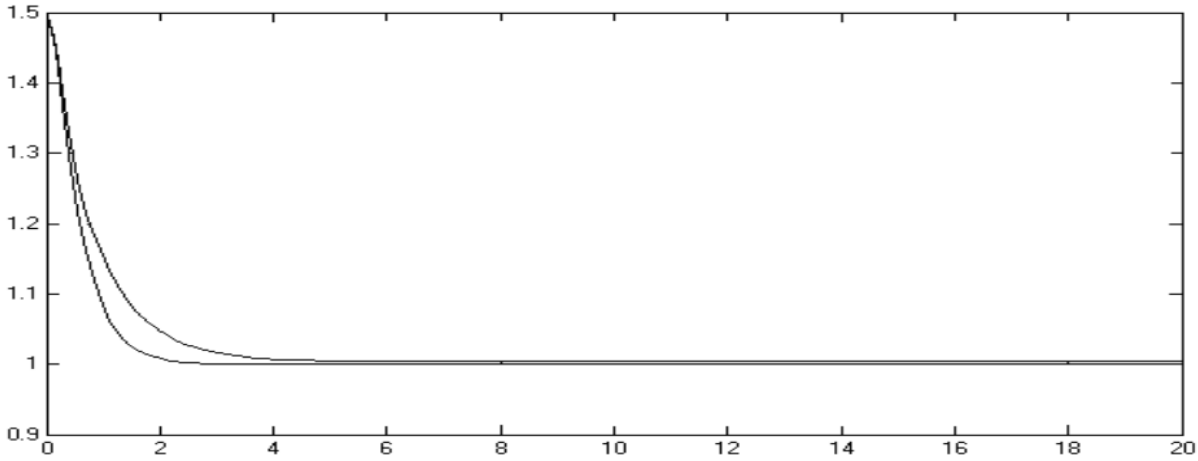



**Figure 16.** Graphs of changes in the liquid level in the tank at values of $h^{ref} = 1$ and $h_0 = 1.5$ for the PD-controller and its fuzzy copy

Thus, by normalization and on the basis of 5 rules, results were obtained that are close to the original both in quality and accuracy.

**Evaluate the quality of the closed system for the given initial levels $h_0$ and $h^{ref}$ of liquid in the tank**

Here, the following signs are accepted

1 – PD-controller;

2 – controller for 5 rules;

3 – Fuzzy controller - (copy);

Let's determine the noise intensity by three sigmas $3\sigma = \left(\frac{0.025}{3}\right)^2 = 0.0006$:

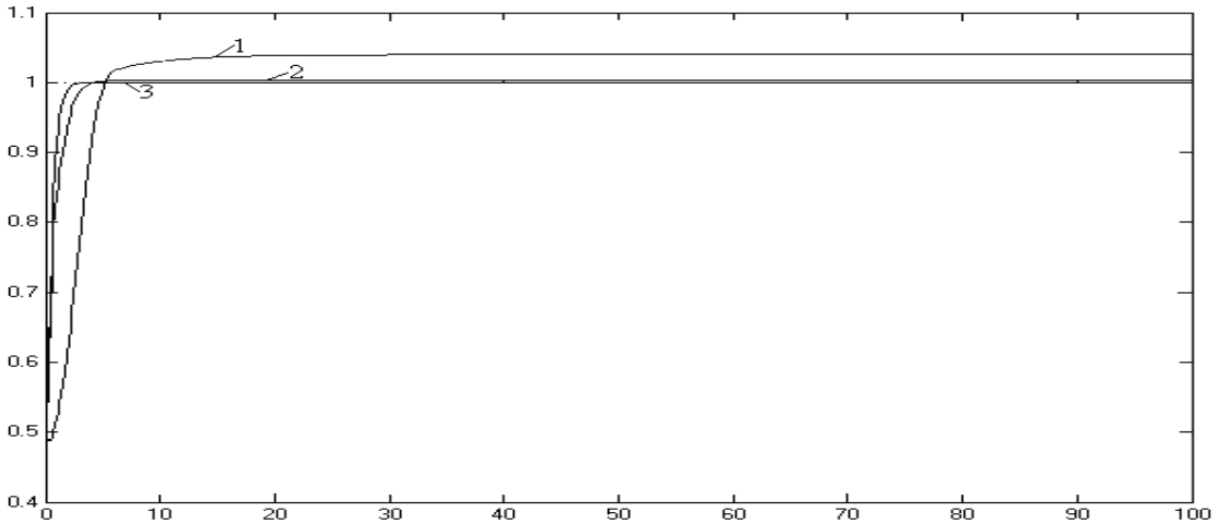



**Figure 17.** $h^{ref}$=1 and $h_0$=0.5 graphs of changes in the liquid level in the tank

A copy of the PD-controller, fuzzy controller of the 3 and 5 rules and fuzzy PD-controller for a two-valve control object was synthesized in order to maintain the liquid in the tank at a given level. The expediency of the issue was analyzed and a comparative analysis of controllers was carried out.

By choosing the P-controller, we were able to change the speed of the system, but did not change the quality, which was unsatisfactory. It is not possible to solve the problem with the P-controller.

**Conclusion**

The influence of its individual barbecues on the process obtained by synthesis with a PD-controller is shown. It became clear that by selecting coefficients, you can get high-speed transitions and the required quality without extreme settings. It was not possible to obtain the required process using a fuzzy controller of 3 rules. This is due to the fact that the price of the derivative, that is, the rate of change in the liquid level in the tank, is not taken into account. This was taken into account in the fuzzy controller and a time adjustment of no more than 10 seconds was obtained. Fuzzy controller of 5 rules and copy of PD-controller - normalization of input and output gave close results in terms of quality and accuracy.

**Declarations**

The manuscript has not been submitted to any other journal or conference.

**Study Limitations**

There are no limitations that could affect the results of the study.

**Acknowledgment**

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCES**

1. Aiswarya A.P., Akhil. S., Amal A. And Rajani S.H. Comparison of PID and Fuzzy – PID control for Nuclear Steam Boila Level Control // İnternational journal of innovative technology and research. – February-March 2015. – Vol.3., Issue No 2. – Pp. 1961-1965.
2. Laith Abed Sabri and Hussein Ahmed. Implementation of Fuzzy and PID Controller to Water Level System using LabView / International Journal of Computer Applications. – 2015. – Vol.116, No11. – Pp. 6-10.
3. Siddikov I.M. et al. Algorithms for synthesis of a fuzzy control system chemical reactor temperature // III International Worckshop on Modeling, Information Processing and computing (MIP: Computing – 2021), May 28. – Krasnojarsk, Russia, 2021. – Pp.64-70.
4. Dhanya S, Irene George, Giffy Francis, Karthika R and Bobby Abraham. Constant Water Level Controller Using Fuzzy Logic // IJARIIE. – 2016. – Vol.2, No3. – Pp.111-121.
5. Khairudin M. et al. Water level control based fuzzy logic controller: simulation and experimental works // IOP Conference Series: Materials Science and Engineering, International Conference on Technology and Vocational Teachers (ICTVT-2018) 15

November. – Yogyakarta, Indonesia, 2018. – Vol.535. DOI:10.1088/1757-899X/535/1/012021.
6. Namrata Dey, Ria Manda and M Monica Subashini. Design and Implementation of a Water Level Controller using Fuzzy Logic // International Journal of Engineering and Technology. – 2013. – Vol.5, No3. – Pp.2277-2285.
7. Fuad Alhaj Omar. Performance comparison of pid controller and fuzzy logic controller for water level control with applying time delay // Konya Journal of Engineering Sciences. – 2021. – Vol.9, No4. – Pp.858-871. DOI: 10.36306/konjes.976918.
8. Shahid H. et al. Design of a fuzzy logic based controller for fluid level application. // World Journal of Engineering and Technology. – 2016, 4(3). – Pp.469-476.
9. Muresan C.I., Birs I.R., Ionescu C.M., De Keyser R. Tuning of fractional order proportional integral / Proportional derivative controllers based on existence conditions // Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering. – 2019, 233(4). – Pp.384-391.
10. Perng J.W., Chen G.Y., Hsieh S.C. Optimal PID controller design based on PSO-RBFNN for wind turbine systems // Energies. – 2014, 7(1). – Pp.191-209.
11. Petkov P.H., Slavov T.N., Kralev J.K. Design of Embedded Robust Control Systems using MATLAB®/Simulink®. – 2018. – Vol.113.
12. Reshmi Banerjee. Water Level Controller By Fuzzy Logic // International Journal of Innovative Research in Advanced Engineering. – 2015. – Vol.2, No2.
13. Ashish Singh Thakur, Himmat Singh and Sulochana Wadhwani. Designing of Fuzzy Logic Controller for Liquid Level Controlling // International Journal of u- and e- Service, Science and Technology. – 2015. – Vol.8, No6. – Pp.267-276. http://dx.doi.org/10.14257/ijunesst.2015. 8.6.26.
14. Asaad Ahmed MAE and Zhang JM. Automatic Water Level Control System // International Journal of Science and Research. – 2015. – Vol.4, No12.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-12

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# ANALYSIS OF FUZZY IMPLICATION

**Shamil Ahmadov**
Azerbaijan State Oil and Industry University, Department of Science and Education, PhD student,
ORCID: 0000-0001-5211-4753, shamilahmadov@yandex.ru, shamil.ahmadov@ufaz.az

## ABSTRACT

Fuzzy logic (fuzzy sets) possesses some widespread application in decision-making due to its ability to handle uncertainties in the implemented data and information. The application of fuzzy logic in decision-making usually involves the design of fuzzy rule-based systems. The functioning of the designed fuzzy systems can be compactly defined as the fuzzy inference process. One of the main steps of fuzzy inference is fuzzy implication, and, therefore, the selection of proper implication function possesses the great impact on the corresponding decision-making process. The currently reported research provides a comparative analysis on two fuzzy implications: Ali-2 and Zadeh. The reported research involves the application of an efficiency index and is performed on a real-world example.
**Keywords:** Fuzzy implication, If-Then rules, membership function, fuzzy set, efficiency index

## Introduction

One of the notable issues in decision theory is the variability of the decision-related information. The applied information attributes/parameters quite often do not possess some unambiguous singular values, which means that each such attribute/parameter has some collection of potentially acceptable values. The basic procedure to deal with the aforementioned issue is generalization. The simplest generalization procedure is to bring the collection of attribute/parameter values to some singular values (crisp numbers) by means of averaging or any other technique. The more profound generalization procedure is to bring the collection of values to some crisp value intervals. One of the deficiencies emerging in the case of such generalization is that the decision process cannot differentiate between different values within the same interval – every value in the interval is equally acceptable. In order to address the deficiency of the interval-based generalization procedure, the generalization based on fuzzy sets can be applied – the fuzzy-set-based generalization procedure not only assigns a set of values to the attribute/parameter, it also associates each value with the corresponding membership degree. Thus, the values with higher membership degrees are more acceptable/relatable than the values with lower membership degrees.

Nowadays, the application of fuzzy sets is quite popular in decision-making, and one of the main application approaches is to design a decision model in the form of a fuzzy rule-based system. The functioning (not the design) of a fuzzy rule-base system can be compactly defined as the fuzzy inference process. Fuzzy inference is a sequence of steps required to obtain some output from a given input. One of the major steps in fuzzy inference is fuzzy implication. Fuzzy implication is an operation/function that computes the firing level (fulfillment degree, truth value) of an IF-THEN rule. The higher firing level means higher impact on the output of the decision model.

Professors Zadeh and Aliev [2] note in their work that fuzzy set is a universal tool for expressing imprecise uncertainties of real-life problems. In their work, it is stated that fuzzy implication is a generalization of classical implication.

The fuzzy implication is still a relatively popular topic, with numerous research providing the analysis of existing implications and/or proposing new fuzzy-implication classes. A few of the corresponding research are briefly described below.

The paper [3] provides a comprehensive survey of fuzzy implication functions, where the authors stated that". Of course, all these expressions for implications are equivalent in any Boolean algebra and consequently in classical logic. However, in fuzzy logic, these four definitions yield to distinct classes of fuzzy implications. Thus, the following question naturally arises: why so many differences models to perform this kind of operation? The main reason is that they are used to representing imprecise knowledge. Note that any "if then" rule in fuzzy systems is interpreted through one of these implication functions. So, depending on the context and on the proper rule and its behavior, different implications can be adequate in any case." Another paper [4] by the same authors provides a comparative study between Implications and D-implications. Moreover, in [5] the same authors proposed a new class of h-implications and their generalization.

Pinheiro and Bedregal in [6] provided a survey and analysis of (T, N)-implications. The same authors later used (T, N)-implications in the design of fuzzy subset hood measures [7].

The authors of [8] have provided a theoretical analysis of (S, N)-implications.

In works [9-11], the authors provided the analysis of copula-based fuzzy implications.

Authors of [12-13] presented theoretical and practical research using copula and Z inference. The authors state that the selection of proper implication function has a crucial impact on the effectiveness of fuzzy inference. Both papers propose and consider fuzzy inference based on the application of Z-set based rules.

The currently reported research in this paper is the continuation of the author's previous research on fuzzy implication, and its purpose can be defined as follows. A significant part of recent studies on fuzzy implication possesses several notable shortcomings: in this paper, we mainly focus on the absence of efficiency indices measuring the performance of fuzzy implications within the fuzzy inference engine. The currently reported research does apply the efficiency index and proposes the comparative analysis of Ali-2 and Zadeh implications on a real-world example.

The rest of the paper is organized as follows. Section 2 deals with preliminary preparations. Section 3 provides the problem statement and its solution. Finally, Section 4 concludes the paper.

**Preliminaries**

As was stated previously in the Introduction, an implication function computes the fulfillment degree of an IF-THEN rule. Let's say, we have a rule "IF *p*, THEN *q*", where *p* and *q* are some arbitrary propositions (for example, *p* = "the outdoor temperature is low" and *q* = "people tend to carry umbrellas"). An implication function computes the fulfillment degree of that rule based on the fulfillment degrees of the *p* and *q* propositions. In fuzzy logic, the fulfillment degrees of *p* and *q* usually mean the corresponding membership values. For example, the fulfillment degree of *p* = "the outdoor temperature is low" usually means that there is a linguistic term "cold" of a variable "outdoor temperature"; and, each time some input temperature comes in, its membership to the "cold" linguistic term is computed – the computed value constitutes the current fulfillment degree of *p*. In the following preliminary definitions, the fulfillment degrees of *p* and *q* are denoted as *x* and *y*, respectively.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



Definition 1 [14]. A binary operation I on [0; 1] is called a fuzzy implication if
(i) I is decreasing in the first variable,
(ii) I is increasing in the second variable,
(iii) I(0; 0)=I(1; 1)=1 and I(1; 0) = 0.
The set of all fuzzy implications is defined on [0; 1]

Definition 2 [2]. Fuzzy implications and connectives:

Zadeh implication: $I(x,y)=\max(\min(x,y),1-x)$

Mamdani implication: $I(x,y)=\min(x,y),\ \mathrm{T}=\min(\mathrm{x},\mathrm{y})$

Lukasiewicz implication: $I(x,y)=\min(1,1-x+y),\ \mathrm{T}=\max(\mathrm{x}+y\text{-}1,0)$

Klir and Yuan 1 implication: $I(x,y)=1-x+x^2y),\ \mathrm{T}=xy$

ALİ-1 implication: $I(x,y)=\begin{cases}1-x, & \text{if } \mathrm{x}<y\\ 1, & \text{if } \mathrm{x}=y,\\ \mathrm{b}, & \text{if } \mathrm{x}>y\end{cases}\ \mathrm{T}=\begin{cases}x, & \text{if } \mathrm{x}+y<1\\ 0, & \text{if } \mathrm{x}+y=1\\ \mathrm{y}, & \text{if } \mathrm{x}+y>1\end{cases}$

Ali-2 implication: $I(x,y)=\begin{cases}1, & \text{if } \mathrm{x}\le\mathrm{y}\\ (1\text{-}\mathrm{x})\wedge\mathrm{y}, & \text{if } \mathrm{x}>y\end{cases},\ \mathrm{T}=\begin{cases}0, & \text{if } \mathrm{x}+y\le1\\ \max(\mathrm{a},\mathrm{b}), & \text{if } \mathrm{x}+y>1\end{cases}$

Ali-3 implication: $I(a,b)=\begin{cases}1, & \text{if } \mathrm{x}\le y\\ \mathrm{y}/[\mathrm{x}+(1\text{-}\mathrm{y})], & \text{otherwise}\end{cases}\ \mathrm{T}=\begin{cases}0, & \text{if } \mathrm{x}+y\le1\\ 1\text{-}[(1\text{-}\mathrm{x})/(\mathrm{x}+y)], & \text{if } \mathrm{x}+y>1\end{cases}$

**Statement of the problem**

Rules were extracted from the data taken from the bank of Azerbaijan (BTB bank). The goal is to determine the status of the respondent ($Y$) based on the profit ($X_1$) and satisfaction ($X_2$) values. Linguistic values for 9 rules are given in Table 1.

**Table 1.** Fuzzy IF-THEN rule base

| Rules | Inputs | | | Outputs |
|---|---|---|---|---|
| | $X_1$ | $X_2$ | | $Y$ |
| 1 | high | High | | high |
| 2 | low | Low | | low |
| 3 | medium | medium | | medium |
| 4 | High | Low | | low |
| 5 | low | medium | | high |
| 6 | high | medium | | medium |
| 7 | medium | high | | high |
| 8 | medium | low | | low |
| 9 | low | high | | medium |

The main objective of the considered problem is to select an implication function providing superior efficiency in the fuzzy inference process.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



The process of determining the efficiency of a fuzzy implication function is presented and implemented as follows in this paper:

1. Relation is created for each rule.
2. General matrix $R = \bigcup_{i=1}^{9} R_i$ is formulated by using the created 9 fuzzy relations and implementing T norm operation over the performed implications.
3. Aggregation operator, general matrix and new input are used for determining new output.
4. Calculation efficiency index for the rules using obtained new output and outputs of the rules: $\rho_1 = \sum_{i=1}^{9} [\mu_{\tilde{Y}_i}(x) - (\mu_{\hat{Y}_i}(x)]^2$
5. Determining efficiency index of the implication.

Fuzzy relations obtained for each rule from Table 1 are shown in Tables 2-10.

**Table 2.** Relation matrix of 1-st rule

| | Output | | | | | | |
|---|---|---|---|---|---|---|---|
| | 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |
| input0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0,6 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

**Table 3**. Relation matrix of 2-nd rule

| | 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,6 | 1 | 1 | 0,2 | 0 | 0 | 0 | 0 |
| 0,2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Table 4.** Relation matrix of 3-rd rule.

| | 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 5.** Relation matrix of 4-th rule

| | 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,4 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 0,21 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 6**. Relation matrix of 5-th rule.

| | 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,4 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 0,21 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 7.** Relation matrix of 6-th rule

| | 0 | 0,4 | 0,8 | 1 | 0,8 | 0,4 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,21 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0,4 | 0 | 1 | 1 | 1 | 1 | 1 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Table 8.** Relation matrix of 7-th

| | 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,2 | 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0,4 | 0 | 0 | 0 | 0 | 0,2 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 9.** Relation matrix of 8-th rule.

| | 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0,41 | 1 | 1 | 0,2 | 0 | 0 | 0 | 0 |
| 0,2 | 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

**Table 10.** Relation matrix of 9-th rule.

| | 0 | 0,4 | 0,8 | 1 | 0,8 | 0,4 | 0 |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |

Intersection of relations is performed by using the ALI-2 conjunction connective:

$$\mu_s(x,y)=\begin{cases}0, & \mu_{R_{s,k}}(x,y)+\mu_{R_{s+i,k}}(x,y)\le 1\\ \max(\mu_{R_{s,k}}(x,y),\mu_{R_{s+i,k}}(x,y)), & \mu_{R_{s,k}}(x,y)+\mu_{R_{s+i,k}}(x,y)>1\end{cases}$$

Where s is the sequence number of a relation and k is the number of points on the relation, i=1,…7.

For demonstration purposes, the result of applying the conjunction connective between the first ($R_1$) and second ($R_2$) relations is shown in Table 11.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Table 11.** Union R1& R2

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 0 | 0 | 0 | 0 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 1 | 1 | 1 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 |

Now, we define a composed fuzzy relation matrix $R = \bigcup_{i=1}^{9} R_i$ (Table 12), which is the result of applying the conjunction connective of the Ali-2 implication over all 9 relations.

**Table 12.** Composed relation matrix.

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 1 |

During the next step, we calculate individual outputs (Table 13 and Fig. 1) of the rule using the max min composition.

**Table 13.** New obtained individual output (Y1).

| output | **0** | **0** | **0** | **0,5** | **0,6** | **0,6** | **0** |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0,5 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| 0,6 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



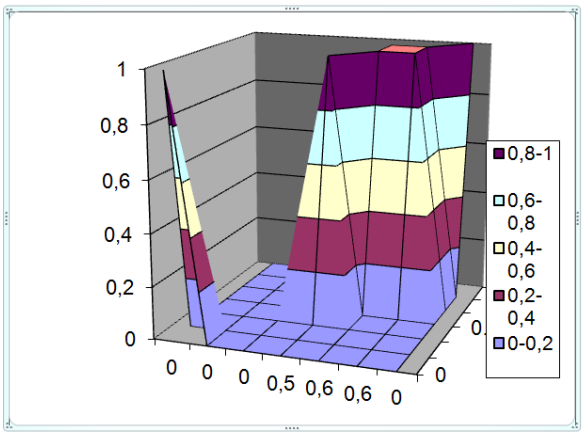



**Figure 1.** Graphical representation on Ali-2 implication

The following formula is used to calculate the efficiency index of the applied implication:

$$\rho = \sum_{i=1}^{9}[\mu_{\tilde{Y}_i}(x) - (\mu_{\hat{Y}_i}(x)]^2$$

Obtained values of the applied efficiency index for 9 rules are given below:

$$\rho_1 = 0.0141; \rho_2 = 0.0237; \rho_3 = 0.0113; \rho_4 = 0.0237; \rho_5 = 0.0141;$$
$$\rho_6 = 0.0113; \rho_7 = 0.014; \rho_8 = 0.0237; \rho_9 = 0.0113.$$

The overall efficiency index is $\rho = 0.0151$ in the case of applying the Ali-2 implication. Now, the aforementioned procedures are re-performed for the case of applying the Zadeh implication (Tables 14-16).

**Table 14.** Union R1& R2(Zadeh implication)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
| 0,6 | 0,6 | 0,4 | 0,4 | 0,4 | 0,4 | 0,4 |
| 0,2 | 0,4 | 0,8 | 0,8 | 0,8 | 0,4 | 0,2 |
| 0 | 0,4 | 0,8 | 1 | 0,8 | 0,4 | 0 |
| 0,2 | 0,4 | 0,8 | 0,8 | 0,8 | 0,4 | 0,2 |
| 0,6 | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 | 0,6 |
| 1 | 1 | 1 | 1 | 1 | 1 | 1 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Table 15.** Composed relation matrix(Zadeh implication)

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
| 0,59 | 0,59 | 0,4 | 0,4 | 0,4 | 0,4 | 0,4 |
| 0,2 | 0,4 | 0,79 | 0,79 | 0,79 | 0,4 | 0,2 |
| 0 | 0,4 | 0,8 | 1 | 0,8 | 0,4 | 0 |
| 0,2 | 0,4 | 0,79 | 0,79 | 0,79 | 0,4 | 0,2 |
| 0,4 | 0,4 | 0,4 | 0,4 | 0,4 | 0,6 | 0,6 |
| 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |

**Table 16.** New obtained individual output (Y1)(Zadeh implication)

| output | **0,2** | **0,4** | **0,5** | **0,5** | **0,5** | **0,4** | **0,2** |
|---|---|---|---|---|---|---|---|
| 0 | 1 | 0,6 | 0,2 | 0 | 0 | 0 | 0 |
| 0 | 0,59 | 0,59 | 0,4 | 0,4 | 0,4 | 0,4 | 0,4 |
| 0 | 0,2 | 0,4 | 0,79 | 0,79 | 0,79 | 0,4 | 0,2 |
| 0,5 | 0 | 0,4 | 0,8 | 1 | 0,8 | 0,4 | 0 |
| 0,6 | 0,2 | 0,4 | 0,79 | 0,79 | 0,79 | 0,4 | 0,2 |
| 0 | 0,4 | 0,4 | 0,4 | 0,4 | 0,4 | 0,6 | 0,6 |
| 0 | 0 | 0 | 0 | 0 | 0,2 | 0,6 | 1 |

Obtained values of the applied efficiency index for 9 rules are given below:

$$\rho_1 = 0.0147; \rho_2 = 0.0147; \rho_3 = 0.0051; \rho_4 = 0.0147; \rho_5 = 0.0147;$$
$$\rho_6 = 0.0051; \rho_7 = 0.014; \rho_8 = 0.0147; \rho_9 = 0.0051.$$

The overall efficiency index is $\rho = 0.010855556$ in the case of applying the Zadeh implication. Thus, as the result, we get the efficiency index of applying the Ali-2 implication to be equal to 0.0151 and the efficiency index of applying the Zadeh implication to be equal to 0.010855556. Thus, in our real-world example, the Zadeh implication seems **to perform better** since having lesser efficiency-index value:

$$\rho_{Zadeh} = 0.010855556 < \rho_{Ali-2} = 0.0151$$

**Conclusion**

Fuzzy implication is one of the main steps in the fuzzy inference process, and the selection of proper implication function in a major factor affecting the performance of the corresponding fuzzy rule-based system. In this paper, two implications Ali-2 and Zadeh are compared on a real world example. The comparison involves the application of an efficiency index and reveals the superiority of the Zadeh implication in the considered case.

This work is the continuation of the author's studies on fuzzy implications. The previous work on the outlined topic had revealed the superiority of Ali-2 implication over several other implication functions, so the current paper focuses on comparing Ali-2 with the Zadeh implication, which is among the most well-known and applied ones.

The future studies on fuzzy implications are planned to involve new implication classes, efficiency indices and different application areas such as image processing, approximate reasoning, etc.

**Declarations**
The manuscript has not been submitted to any other journal or conference.

**Study Limitations**
There are no limitations that could affect the results of the study.

**Acknowledgment**
The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCES**

1. Klir, G.J., Yuan, B. Fuzzy sets and fuzzy logic. Theory and applications. Prentice Hall, New Jersey (1995).
2. Aliev, R.A., Aliev R.R. Soft Computing and its Application. World Scientific, New Jersey, London, Singapore, Hong Kong (2001).
3. Mas, M., Monserrat, M., Torrens, J., and Trillas E. "A survey on fuzzy implication functions," IEEE Transactions on Fuzzy Systems 15, no. 6, pp. 1107–1121. (2007).
4. Mas, M., Monserrat, M., and Torrens, J. "QL-implications versus D-implications," Kybernetika 42, pp. 351–366. (2006).
5. Massanet, S., and Torrens, J. "On a new class of fuzzy implications: h-Implications and generalizations," Information Sciences 181, no. 11, pp. 2111–2127. (2011).
6. Pinheiro, J., Bedregal, B., Santiago, R. H. N. and Santos, H. "(T, N)-implications," in Proceedings of the 2017 IEEE International Conference on Fuzzy Systems (FUZZ-IEEE), pp. 1–6.(2017).
7. Pinheiro, J., Bedregal, B., Santiago, R.H.N., and Santos, H. "A study of (T,N)-implications and its use to construct a new class of fuzzy subsethood measure," International Journal of Approximate Reasoning 97, pp. 1–16.(2018).
8. Fernandez-Peralta, R.; Massanet, S.; Mesiarová-Zemánková, A.; Mir, A. "A general framework for the characterization of (S,N)-implications with a non-continuous negation based on completions of t-conorms." Fuzzy Sets Syst. 441, pp. 1–32.(2022)
9. Helbin, P.; Baczy´ nski, M.; Grzegorzewski, P.; Niemyska, W. "Some properties of fuzzy implications based on copulas." Inf. Sci. 502, pp.1–17. (2019).
10. Mesiar, R.; Kolesárová, A. Copulas and fuzzy implications. Int. J. Approx. Reason.117, pp. 52–59. **(**2020).
11. Mesiar, R.; Kolesárová, A. "Quasi-Copulas, Copulas and Fuzzy Implicators." Int. J. Comput. Intell. Syst.13, pp. 681–689. (2020).
12. Aliev, R.A., Gardashova, L.A. "Z-set Based Approach to Control System Design." In: 2021 14th International Conference on Theory and Application of Fuzzy Systems and Soft

Computing (ICAFS),. Advances in Intelligent Systems and Computing, 1306, pp.10-21(2021).
13. Gardashova, L.A. “Probabilistic implication based based Z-inference”. Advances In Intelligent Systems And Computing Series(WCIS2020), Springer, , vol 1323. pp. 33-39. (2020).
14. Michał, B., Balasubramaniam, J. “Fuzzy implications”. Studies in Fuzziness and Soft Computing**.** 2008 Springer-Verlag, Berlin Heidelberg (2008).

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-24

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# STATUS AND PROBLEMS OF DEVELOPMENT OF "GREEN" ECONOMY IN AZERBAIJAN

**[1]Arzu Mirheydarova, [2]Izabella Binyaminova**
[1,2]Azerbaijan State Oil and Industry University, [1,2]Department of Economics and Management
[1]Assistant Professor, Candidate of economic sciences, arzu.mirgeydarova@mail.ru
[2]Master student: bellabin.bb@gmail.com

## ABSTRACT

According to domestic and international experts, the most promising areas for the development of the "green economy" in the Republic of Azerbaijan (AR) are energy, transport and agriculture [1]. In recent years, numerous studies have been carried out in the AR to study the existing potential in the field of development of alternative and renewable energy. As a result of the research, the presence of large wind, solar and hydropower potential, biogas and thermal energy resources in the republic was revealed. In general, the level of opportunities for the development of alternative and renewable energy infrastructure in Azerbaijan can be compared with such countries as Denmark and Germany.
**Keywords:** green economy, sustainable development, energy, energy efficiency, renewable energy sources, transport, agriculture

## XÜLASƏ

Məqalədə perspektivli inkişaf sahələrinə dair məlumatlar ümumiləşdirilmişdir. Azərbaycan Respublikasının enerji, nəqliyyat və kənd təsərrüfatı sahələrində "yaşıl iqtisadiyyat" və ekoloji siyasəti, alternativ və bərpa olunan enerji mənbələrindən istifadə üzrə milli strategiyanın həyata keçirilməsi; günəş enerjisi, külək və hidroenergetika, geotermal enerji və biokütlə enerjisi istehsalının inkişafı üçün Azərbaycanın ən perspektivli sahələrini göstərən alternativ enerjinin inkişafı imkanları; kənd təsərrüfatının strukturu; yarımköçəri heyvandarlıqla bağlı problemlər; su ehtiyatlarından səmərəsiz istifadə; ənənəvi, alternativ və bərpa olunan enerji mənbələrinin ehtiyatları haqqında məlumat verir; Azərbaycan Respublikasında enerji və enerji səmərəliliyi sahəsində siyasətin inkişafının əsas müddəalarını və istiqamətlərini; respublikada beynəlxalq maliyyə institutları ilə birgə həyata keçirilən enerjiyə qənaət layihələri, o cümlədən Kioto Protokolu üzrə təmiz inkişaf mexanizmindən istifadə edən layihələr haqqında ümumiləşdirilmiş məlumatlar; havanın avtomobil nəqliyyatından çirklənməsinin strukturu və Azərbaycan Respublikasında avtomobil nəqliyyatının mənfi təsirinin azaldılması istiqamətində həyata keçirilən tədbirlər haqqında.
**Açar sözlər:** yaşıl iqtisadiyyat, davamlı inkişaf, enerji, enerji səmərəliliyi, bərpa olunan enerji mənbələri, nəqliyyat, kənd təsərrüfatı

### Solar energy

The climatic conditions of Azerbaijan allow the production of electricity using solar energy. The use of solar energy could help solve problems related to energy supply in certain regions of Azerbaijan. Some developed countries in the world have in recent years begun to widely implement photovoltaic programs (PVP - a method of generating electrical energy by using

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



photosensitive cells to convert solar energy into electricity). Azerbaijan's use of these programs is also relevant. It is known that the efficiency of solar installations depends on climatic conditions and the geographical location of the country. In Azerbaijan, annual solar energy radiation is 1500-2000 kW/m2 (in the USA - 1500-2000 kW/m2, in Russia - 800-1600 kW/m2, in France - 1200-1400 kW/m2, in China - 1800-2000 kW/m2). This indicates a fairly high solar intensity in the country compared to other countries, which may become a factor in attracting investment in the use of solar energy. The maximum values of the intensity of solar radiation on horizontal and normal flat surfaces are reached in the summer and differ somewhat in different regions of the republic: Pirallahi Island (near the Absheron Peninsula), Mingachevir (northeast) and Nakhichevan enclave between Armenia and Iran).

Wind energy. In terms of price, environmental friendliness and inexhaustibility of its resources, wind energy is superior to solar, water, geothermal energy and the use of biomass. Research shows that many regions of Azerbaijan have great potential for the use of wind turbines. According to calculations, the country's annual wind energy potential is 800 MW (Table 1).

**Table 1.** Potential of renewable energy sources in Azerbaijan[1]

| Source | Realizable potential MW |
|---|---|
| Small hydroelectric power stations | >400 |
| Wind Energy | >800 |
| Solar Energy | >5000 |
| Bioenergy | >1500 |
| Geothermal energy (heat only) | >800 |

**Source:** Compiled according to data from the State Agency for Alternative and Renewable Energy Sources of Azerbaijan, a government agency under the Ministry of Industry and Energy of the Cabinet of Ministers. Acts as the main regulatory agency in the field of alternative and renewable energy sources in the Republic of Azerbaijan. SAARES, 2012.

Approximate calculations equate this figure to 2.4 billion kW of electrical energy. Using such a powerful potential would save 1 million equivalent fuel and prevent the release of more waste into the atmosphere [1]. As a result of long-term observations, it was revealed that the necessary conditions of the country prevail in the Absheron Peninsula, the coastal strip and the northeastern islands of the Caspian Sea. The average speed of long-term winds is more than 6 m per second, which is a favorable factor for the use of wind energy. In the Ganja-Dashkesan zone and the territory of Sharur-Julfa in the Nakhchivan Autonomous Republic, the average annual wind speed is 3-5 m per second, there are favorable conditions for the use of medium-power wind turbines.

The following regions of the country are considered promising for the use of wind energy:

1. Baku, Sumgayit and the Absheron Peninsula with the islands nearby. Due to the intense wind force, the energy potential here is estimated at 1500 mW.
2. Caspian Sea zone and the right bank of the Kura: the potential is estimated at 500 MW.
3. The territory of the Nakhichevan Autonomous Republic with separate zones of Zangezur inclusive. The potential is estimated at 70 mW.

Data on the long-term forecast for the use of wind energy in Azerbaijan are shown in Table 2.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Table 2. Long-term forecast for the use of wind energy in the AR[2].**

| Year | 2005 | 2010 | 2015 | 2020 | 2025 |
|---|---|---|---|---|---|
| wind energy production, million kW.sec | 163 | 325 | 434 | 542 | 651 |
| fuel oil savings, thousand tons | 49 | 98 | 130 | 163 | 195 |
| decline CO2, thousand tons | 150 | 300 | 400 | 500 | 600 |

**Source:** The 1st National Climate Change Information (Phase 2), Baku 2001. http://unfccc.int/resource/docs/natc/azenc1add1.pdf

**Hydropower**

Hydropower is the main renewable source of energy supply in Azerbaijan. In 2010, hydropower accounted for 18% of electricity production. In total, Azerbaijan has 1000 MW of operating hydropower capacity, and 62 MW of hydropower capacity at the construction stage. The country's largest hydroelectric power station, Mingachevir, with an installed capacity of 402 MW, was built on the Kura River. In addition, there are currently three more hydroelectric power stations in Kura with a capacity of over 100 MW in Azerbaijan. Azerbaijan's water resources include: the lower reaches of the Kura with its numerous tributaries; the Araks River (a tributary of the Kura), flowing along the border and a group of small rivers flowing into the Caspian Sea. The country still has some hydroelectric potential that has not yet been developed. Research in this area indicates the presence of a total technical hydropower potential of the rivers of Azerbaijan of 40 TWh. At the same time, based on the findings of the review group, which was carried out in June 2012, the economically feasible potential is less than 1 TWh, which can be realized by the construction of small run-of-the-river hydroelectric power plants. This is equivalent to an installed capacity of 400 MW, according to Azerenergy[2]. Thus, hydropower resources are limited. Hydroelectric power stations are also important for the national economy of the republic for the regulation of flood waters, the production of clean electricity and the creation of new irrigation systems. The construction of 61 small hydroelectric power stations is planned in the near future. Small hydroelectric power plants are often located in populated areas far from power lines and substations of the unified energy system. In such conditions, small hydroelectric power plants ensure the satisfaction of local electricity needs and, accordingly, a number of other social problems.

**Use of biomass**

Thanks to the development of industrial production, agriculture and social services, Azerbaijan is opening up new opportunities for energy production from biomass. The country has the following sources of biomass: combustible industrial waste; forestry and wood waste; agricultural products

and organic waste; household and municipal waste, as well as waste from regions contaminated with oil and petroleum products. All these resources can be used to produce energy. Every year, Azerbaijan produces 2 million tons of solid household and industrial waste. Recycling solid household and industrial waste can become a way to heat public buildings in large industrial cities.

Currently, there are more than 200 waste disposal sites in Azerbaijan, with a total area of 900 hectares. According to estimates, the volume of methane released into the atmosphere from landfills in large cities is: in Baku - 42.8 million m3, in Ganja -7.2 million m3, in Sumgait - 6.9 million m3, etc. On the basis of these landfills, small thermal power plants can be built to produce electricity. However, only a small number of projects using biomass are being implemented in the republic. Geothermal energy (internal thermal energy of the Earth). The territory of Azerbaijan is rich in thermal waters, the reserves of which are located in the Greater and Lesser Caucasus, on the Absheron Peninsula, on the slopes of the Talysh Mountains, in the Kura River valley and in the Caspian-Guba region. The productivity of springs in the Lenkoran, Massala and Astara regions is estimated at approximately 25,000 m3 per day. The temperature at the wellhead is approximately 40°C, and water flows at a speed of 40 liters per second. The use of thermal waters in the above-mentioned areas will partially satisfy part of the need for thermal energy in everyday life and in other areas. Today, geothermal energy in Azerbaijan is used entirely for heat generation; There are no geothermal power plants for electricity production. Thermal waters are used for heating greenhouses in the Lenkoran regions, in the valley of the river. Kura (Jarly, Muradkhanly, Sor-Sor), Ganja and Yalama-Khudat. There are special purchase tariffs for wind farms and small hydropower plants, but they are too low to attract investment. In addition, this mechanism does not apply to other types of technologies based on renewable energy sources[6]. The global trend of the “green economy” in the energy sector is to increase energy efficiency in all areas of the economy and develop renewable energy.

In the electric power industry, energy savings can be achieved through the decommissioning of obsolete equipment, its replacement with new, highly efficient equipment, the construction and commissioning of high and low power power plants, the construction of new substations and transmission lines, and improving the efficiency of the sector. Rough calculations show that the volume of energy consumption in the Republic of Azerbaijan can be reduced by 20-25%.

Funds in the amount of 250 million euros were allocated to improve the energy distribution network in Baku. To solve these problems, Azerenergy is taking the following steps:

• starting from 2010, only natural gas is used instead of heating oil to produce electricity;

• the volume of fuel consumption by traditional installations decreased from 411 g/kWh in 2000 to 314 g/kWh in 2011 and is approaching the target figure of 260 g/kWh. in 2015

• development of the power transmission line network: power transmission line 220 kV Mingachevir-Absheron, financing provided by the Asian Development Bank (USD 160 million); AzGRES-Imishli 330 kV power transmission line project, financing provided by KfW (30 million euros);

• further reduction of losses during transmission and distribution of electricity – up to 10% – will be achieved through modernization of the power supply system;

• dissemination of the successful implementation of the pilot project for the installation of gas meters of the smart card type in Ganja to all regions of the country.

The European Bank for Reconstruction and Development (EBRD) assisted in the preparation of an investment program with a total financing volume of US$232 million for the reconstruction

and modernization of AzGRES (the country's largest thermal power plant), providing a loan of US$207 million. The project includes: (1) reconstruction of all turbines and boilers and modernization of the management and control system with funds from the EBRD; (2) repair of one of the sections of the cooling tower and water cooling system; and (3) implementation of environmental, health and safety measures. The project's carbon dioxide emissions savings, including fuel switching, are estimated to be 2.2 million tons per year, creating the opportunity for the company to generate additional revenue through the sale of carbon credits.

To reduce losses in heat distribution networks, which amounted to 50%, a district heating strategy for Azerbaijan was developed within the framework of a project funded by USAID. The main measures to improve the system included building more boilers for heating and minimizing heat transfer distances, because usually the distance exceeded 100 km.

After the entry into force of the Kyoto Protocol in 2005, interest in the so-called. Clean Development Mechanism projects under the Kyoto Protocol (CDM) in Azerbaijan increased. Projects to reduce GHG emissions were prepared in various sectors of the economy, but only 4 projects reached the validation stage. The main sources of CO2 emissions in Azerbaijan are the energy and industrial sectors. CO2 emissions in the energy sector come from the combustion of fuels during energy production and oil and gas extraction. Transport and populated areas are also sources of emissions. In the industrial production and use of industrial materials sector, the largest sources of CO2 emissions are the production of mineral materials and the metallurgical industry.

The main sources of GHG emissions in the oil and gas sector of Azerbaijan are the Azneft production association, the Heydar Aliyev Baku Oil Refinery and the Azerneftyag Oil Refinery, owned by the State Oil Company (SOCAR). Every year, SOCAR enterprises, operating companies and joint ventures operating in Azerbaijan emitted 3 million tons of GHGs in CO2 equivalent (including approximately 1.3 million tons of associated gas). Since the end of 2009, as a result of measures taken by SOCAR, 600 thousand tons of emissions have been disposed of. Most of the associated gas is emitted by the enterprises of the British company BP: approximately 500 thousand tons of associated gas per year in CO2 equivalent, however, with the adoption of appropriate measures, GHG emissions can be reduced by 1.2 million tons[5].

SOCAR regularly takes steps aimed at mitigating the effects of climate change. An Ecological Park has been created, where, among other things, bioselection work will be carried out to grow tree seedlings on reclaimed lands, propagate endangered species of trees and shrubs, as well as activities to inform the population about environmental issues. To meet part of the peak electricity demand through the use of alternative and renewable energy sources, the pilot project installed 4 wind generators with a capacity of 10 kW each and solar panels with a total capacity of 20 kW.

The priority area of activity in the field of energy and transport within the framework of the Action Plan includes special commitments regarding the convergence of the goals of the republic’s energy policy with the goals of the EU energy policy, including: 1) gradual convergence with the principles of functioning of the internal markets for electricity and natural gas in the EU, and 2) progress on energy grids. Of particular importance is the commitment to improving energy efficiency and the use of renewable energy sources.

The state program for the use of alternative and renewable energy sources was prepared on the basis of these laws and approved by Presidential Decree No. 462 of October 21, 2004. This program included feasibility studies for the use of renewable energy sources and the construction of small hydroelectric power stations and wind power plants. However, the implementation of the program was postponed due to lack of funding.

In order to improve the management system in the country in the field of alternative and renewable energy, in accordance with the Decree of the head of state, the State Agency of the Republic of Azerbaijan for Alternative and Renewable Energy Sources was created in 2013, a number of documents were signed and programs were adopted providing for the development of this industry.

Currently, the republic is implementing the "National Strategy for the Use of Alternative and Renewable Energy Sources in the Republic of Azerbaijan for 2012-2020."

Since 2009, Azerbaijan has been a member of the International Renewable Energy Agency (IRENA)

The climatic conditions of Azerbaijan (abundance of heat, light, length of the growing season) allow us to specialize in the cultivation of many valuable agricultural crops. The main areas of agricultural production are grain growing (wheat), cotton growing, winemaking, horticulture, tobacco growing, tea growing, vegetable growing (especially early) and livestock breeding. In the structure of agriculture in recent years, about 56% is accounted for by crop production, the rest by livestock production. The volume of agricultural production in Azerbaijan in 2014 amounted to 5.225 billion manats, or about 5.7% of GDP. The republic's agro-industrial complex is the largest employer, employing about 36% of the working population.

Like all mountainous countries, Azerbaijan is characterized by land shortage. Of the total land area (8.7 million hectares), agricultural land accounts for 4.6 million hectares, incl. more than 1.8 million hectares are arable land, 2 million hectares are perennial and winter pastures[4]. Almost half of the arable land is concentrated in the Kura-Araks lowland.

The process of reclamation of pastures and fertile areas damaged as a result of erosion, degradation, and high salinity is a long and labor-intensive task, requiring supervision by the State Committee for Land and Cartography, the Ministry of Agriculture, the Ministry of Ecology, the Land Reclamation Committee and other interested structures.

According to representatives of the OJSC Land Reclamation and Water Resources of the AR, excessive salinity is observed on 600 thousand hectares throughout the country. Unfortunately, due to the lack of an effective mechanism for administrative intervention in private property, it is not possible to centralize the efforts of regulatory authorities.

An important role is assigned to large-scale educational events through leading electronic media and, through their mediation, bringing to the attention of the population the relevance of the idea of reclamation of land plots that have fallen into disrepair.

The long-term project includes monitoring and educational programs. It is planned that after the preparation of public opinion, the main stage of the project will begin, which involves increasing forest plantings.

In addition, farmers and shepherds will be encouraged to switch to intensive livestock farming. With intensive livestock farming, production growth is achieved by increasing the productivity of animals by selecting and improving the quality of feed, available pastures, breeding the most productive breeds, etc. In this case, the productivity of meat and dairy products will increase, and there will be less cost of live weight during long herd transitions.

According to experts, the overall development of agriculture can be ensured by using the existing potential of the mountain and foothill regions of the country: "Due to the insufficient use of advanced technologies, the yield in them is much lower. Most of the land has been eroded, and the geobotanical composition of pastures has also deteriorated. To solve the problems, the following measures are proposed: introduction of a system of mountain and terrace farming;

application of measures to combat erosion (planting crops along the width of the slopes); sowing perennial herbaceous plants (alfalfa, sainfoin, etc.), as well as spring barley and millet; planting forest strips; development of terrace viticulture and fruit growing; development of tobacco and potato growing; development of sheep farming, local livestock farming and beekeeping; creation of mini-reservoirs on mountain slopes for the efficient use of rain and snow waters" [6].

Finally, at the government level a policy has been proclaimed for the development of organic agriculture, which implies a complete abandonment of the use of chemicals in field farming and the use of natural fertilizers in liquid processed form. Implementation of this course is impossible without major investments [3].

Transport is one of the main pollutants of atmospheric air, water bodies and soil. Its share in the total volume of emissions of pollutants into the atmosphere from stationary and mobile sources in developed countries of the world is 40-60%, which is higher than the share of any industry. By type of transport, pollutant emissions are distributed as follows: 80-90% of total emissions come from road transport, about 8% from railway transport, 2% from road transport, 2% from river and sea transport and just over 1% from air transport.

The impact of transport on ecosystems is expressed in consumption:

• natural resources, specifically atmospheric air necessary for the flow of work processes in internal combustion engines of vehicles;

• petroleum products and natural gas, which are fuel for engines;

• water for engine cooling systems and domestic needs of transport enterprises;

• land resources alienated for the construction of roads and railways, pipelines, river and sea ports and other transport infrastructure facilities.

As a result of this impact, there is pollution of the atmosphere, water bodies and lands, changes in the chemical composition of soils and microflora, and the formation of industrial waste, including toxic and radioactive waste, sludge, oil-contaminated soil, ash and garbage.

As can be seen, the bulk of pollutant emissions comes from road transport. It should be noted that the combustion of 1 kg of automobile fuel produces an average of 2.7 kg of CO2, which, accumulating in the upper layers of the atmosphere, enhances the "greenhouse effect." Exhaust gases from cars with gasoline engines contain carbon monoxide, nitrogen oxides and hydrocarbons among the most toxic components, and from diesel engines - nitrogen oxides, hydrocarbons, soot and sulfur compounds. One car annually absorbs an average of more than 4 tons of oxygen from the atmosphere, while emitting approximately 800 kg of carbon monoxide, 40 kg of nitrogen oxides and almost 200 kg of various hydrocarbons with exhaust gases. Moreover, these values increase sharply when operating a technically faulty vehicle [6]. In the last decade, the size of the automobile fleet of the Republic of Azerbaijan has increased 2.4 times and currently amounts to more than 1 million 150 thousand units [7]. According to calculations, the total annual volume of harmful emissions from the automobile fleet of the Republic of Azerbaijan is about 1.5 million tons (according to research, the total annual volume of harmful emissions from one average car is more than 1.3 tons). Of these, about 900 thousand tons are carbon monoxide (CO), 370 thousand tons are hydrocarbons, 1260 thousand tons are nitrogen oxides, 350 thousand tons are soot and 0.12 thousand tons are lead. Given the rapid growth of the vehicle fleet, this leads to an even greater increase in the negative impact on the environment

International experience shows that the most dangerous pollutants for public health are urban pollutants such as lead and fine aerosols. These pollutants arise when motor vehicles use leaded gasoline.

In accordance with UN recommendations, since 1997 Azerbaijan has used exclusively unleaded gasoline, which contributes to a significant reduction in lead and fine aerosols in the atmospheric air, especially in large cities of the republic.

Stationary sources of pollution primarily include gas stations (gas stations). When filling, storing and selling gasoline and other petroleum products, environmental pollution occurs as a result of evaporation and spillage. For example, the average annual loss of gasoline from one tank with a volume of 20 m3 is 6 tons. Atmospheric pollution also occurs as a result of the functioning of automobile repair and service enterprises, asphalt concrete plants and other transport infrastructure facilities. The bulk of solid waste generated annually in the motor transport complex consists of used tires, lead batteries, and plastic waste.

Highways are one of the sources of dust formation in the ground air layer. The length of highways in the Republic of Azerbaijan is 59,141 km. Of these, 29,210 km are asphalt. When cars move, abrasion occurs on road surfaces and car tires, the wear products of which are mixed with solid particles of exhaust gases. As a result, dust is formed, which in dry weather rises above the road into the air and is carried by the wind over distances of up to hundreds of kilometers.

To reduce the harmful impact of the transport system on the environment of the Republic of Azerbaijan, it is necessary to manage environmental activities. This activity consists of influencing the development of nature and society in order to maintain a stable balance of ecosystems, rational use of natural resources, reducing pollution of the atmosphere, water bodies, soil and subsoil, organizing work on the destruction and recycling of transport waste.

For rational management of environmental activities in the republic’s transport it is necessary:

• organization of effective management of environmental activities through program-target planning;
• gradual renewal of the age and structural composition of the republic's automobile fleet;
• improvement of the existing production and technical base for monitoring the technical condition and repair of vehicles;
• modernization and application of modern technologies in oil refineries in order to obtain the most environmentally friendly automobile fuel;
• creating an effective system of environmental control and monitoring using a network of stationary and mobile observation posts, as well as points for monitoring the environmental parameters of vehicles;
• combination of legal and economic methods of managing environmental activities in transport;
• application of a mandatory certification system for environmental requirements for vehicles, fuel, equipment, technology, etc.;
• development of a system of environmental training and retraining of transport specialists.

The introduction of new environmental standards in Azerbaijan for cars to improve the environmental situation began in 2010 with the introduction of the Euro-2 standard in the country. European environmental standard (norms)
"Euro"), which regulates the content of hydrocarbons, nitrogen oxides, carbon monoxide and particulate matter in car exhaust, was developed by the UN Economic Commission for Europe and was put into effect in 1992.

The State Committee for Standardization, Metrology and Patents of Azerbaijan has prepared a national standard “Road Transport. Ecological classes”, which divided vehicles into 6 classes, depending on the level of emissions. The prepared standard covers environmental standards Euro-3, Euro-4, Euro-5, and even Euro-6.

To further reduce the amount of harmful substances emitted into the atmosphere by cars, by decision of the country's Cabinet of Ministers, the Euro-4 environmental standard has been applied to cars imported and produced in Azerbaijan since April 1, 2014 (bypassing Euro-3). The restrictions will not apply only to rare cars.
In order to prevent the import into the republic of cars that do not meet Euro-4 standards, a list of requirements was determined regarding the release date of cars, which varies depending on the country of origin.

**Declarations**
The manuscript has not been submitted to any other journal or conference.

**Study Limitations**
There are no limitations that could affect the results of the study.

**Acknowledgment**
The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCE**

1. Agrarian Research Centre Azerbaijan, Monthly Bulletin, 2019 (https://atm.gov.az/pdf/bulleten-2019- dekabr-aze749.pdf?v=65)
2. Aliyev A.G. The role of ICT in increasing the level of inclusion of economic development // Problems of the Information Society, 2019, №2, pp.51–59. https://jpis.az/uploads/article/az/2019_2/THE_ROLE_OF_ICT_I N_INCREASING_ THE_LEVEL_OF_INCLUSIVENESS_OF_ ECONOMIC_DEVELOPMENT.pdf (in Azerbaijani).
3. Elshan Ahmadov (2013) Azerbaijan in the context of competitiveness, sustainable development and green economy. Materials of the Baku
4. Population Dynamics in the Post-2015. Development Agenda Report of the Global Thematic Consultation on Population Dynamics
5. Urhan Alakbarov (2014) Effective Management of Resources to Support Sustainable Development and Move towards Ecological Civilization: Experience of the Republic of Azerbaijan. Journal of Human Resource and Sustainability Studies, 2, 131-135. doi: 10.4236/jhrss.2014.23012.
6. Асадова А.В., Мухтаров А.Ш. Ресурсы геотермальной энергии по республике Азербайджан // Мониторинг: науки и технологии. – 2013. № 2. http://csmos.ru/index.php?page=mnt-issue-2013-2

7. Аникин В. Шесть республик договорились развивать органическое сельское хозяйство. 13.11.2013. http://www.vb.kg/doc/250497_shest_respyblik_ dogovorilis_ razvivat_ organicheskoe_ sels koe_hoziaystvo.html

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-35

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# ASPHALT- RESIN- PARAFFIN ASSOCIATION CRUSHING IN THE VOLUME OF OIL AND OIL EMULSION WITH NEW NANOSTRUCTURE COORDINATION POLYMERS

**[1]Elman Iskandarov, [2]Veli Nurullayev, [3]Rabiya Abishova**

[1,3]Azerbaijan State Oil and Industry University, [1]Professor, Dean of Oil and Gas Production Faculty,
[1]https://orcid.org/0000-0002-4297-0641, e.iskenderov62@mail.ru
[2]Management oil pipelines SOCAR, engineer of department “Control Quality”
[2]https://orcid.org/0000-0002-9608-600X, Veliehet1973@mail.ru
[3]PhD, Department of Mechanics, https://orcid.org/0000-0002-2533-1741, rabiya.abishova@mail.ru

## ABSTRACT

A short list of existing methods for the prevention and removal of asphalt-resin-paraffin deposits from oilfield equipment is given. Chemical methods related to the use of various additives, reagents, and remover agents are discussed in more detail. A brief description of the main classes of chemicals used in solving the problem of preventing and removing asphalt-resin-paraffin deposits is given. It has been shown that in order to select the most chemically effective ways to prevent and remove organic deposits, it is necessary to obtain an adequate understanding of the composition, properties, and structure of the source oil and the formed deposits. The mechanism of action of the reagents on asphalt-resin-paraffin deposits was clarified, and it was established that the reagents BAF-1 and BAF-2 (technical conditional name of composites) when interacting with the deposits, grind the associates and ensure their uniform distribution in the oil, which improves the rheological properties of the oil. It is indicated that the technology being put forward is based on the clathrate formation, i.e. Lewis's theory of "host-guest".
**Keywords:** asphalt-resin-paraffin deposits, crushing, factors affecting the formation of ARPD, coagulation, the chemical composition of oil, mechanism of ARPD formation, methods of ARPD control.

## Introduction

The development of the oil industry of Azerbaijan at the present stage is characterized by a decrease in the quality of the raw material base. The total balance of fields under development is dominated by fields that entered the late stage of development and, as a result, there is a significant deterioration in their structure, an increase in the share of hard-to-recover oil reserves, and flooding of formations and well products.

Thus, when producing and transporting heavy oils, the formation of asphalt-resin-paraffin deposits (APRD), the formation of which leads to a deterioration in the rheological properties of oil and a decrease in the performance of the system and the efficiency of pumping units, is a serious problem causing problems in the operation of wells, oilfield equipment and pipeline communications [1,2]. The formation of emulsions at the exit of the well together with the accompanying formation water increases sedimentation.

The fight against APRD provides for the work to prevent the formation of deposits and their removal. Several best-known and active methods are used in the oil industry to control APRD [3]. Chemicals are divided into wetting agents, modifiers, depressants, and dispersants [4, 5].

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



The wetting reagents form a hydrophilic film on the surface of the metal to prevent the wax crystals from adhering to the tubes, which creates conditions for the liquid flow to carry them away. These include polyacrylamide (PAA), IP-1;2;3, acidic organic phosphates, alkali metal silicates, and aqueous solutions of synthetic polymer surface-active substances (PSAS). The mechanism of action of depressants is the adsorption of molecules on paraffin crystals, which complicates their ability to aggregate and accumulate [6]. A fairly wide range of chemical reagents has been developed to combat APRD. Along with the high cost, a significant disadvantage of the chemical method is the difficulty of selecting an effective reagent due to the constant change in operating conditions during the development of the field. Despite the wide variety of methods for combating APRD, the problem is still far from resolved and remains one of the most important in the domestic and foreign oil production industries.

**Problem statement**

As a result of the accumulation of asphalt-resinous and paraffin deposits on the inner surface of the pipes, the pipelines are driven, which leads to a decrease in the efficiency of pumping plants and a decrease in the performance of the system as a whole. This, in turn, can lead to the exit of the pumps from the working state and the leakage of combustible substances. Vapors above the spilled liquid are capable of stable combustion. As a result, an accident may occur at the operated facility, which will lead to fires, destruction of structures, death of people, pollution of the environment, and significant losses of material assets. There are various methods used to protect oilfield equipment from APRD formation. Work to reduce the formation of APRD is carried out in two directions: preventing the formation of deposits and removing the formation. Traditional methods of combating the formation of APRD are mechanical scraping, hot oil treatment, and the use of aqueous solutions of surfactants. However, these methods have significant disadvantages: increased electrical and fire hazard; high power consumption. Methods to prevent sedimentation: In conditions of intensive formation of paraffin deposits, the inter-treatment period of the well operation (less than 30 days) is significantly reduced, and the number of washings with heated detergents or solvents based on hydrocarbon increases, which leads to an increase in the cost of oil production and a negative impact on the bottom hole zone of the formation [7, 8]. Under such conditions, the optimal method of controlling APRD is to prevent their formation by using protective coatings, physical methods, or special chemicals. Application of special protective coatings: The intensity of APRD formation depends on the nature and condition of the equipment surface. The presence of macro and micro-faults, and minor scratches contribute to the formation and significant growth of deposits. The use of special protective metal coatings made it possible to achieve a smooth surface and increase its hydrophilicity, which significantly reduces the adhesion of paraffin crystals. Paints and varnishes (ethylene and varnishes, epoxy resins), enamels, plastics, and polymer materials are used as such coatings. Heating cable lines (HCL): Thermal methods of APRD control are based on maintaining the oil flow temperature above Tnas using special heating cables. During the operation of the cable, it heats the lifting pipe along the external or internal surface, which, in turn, heats the liquid passing through the pipeline to a temperature close to or higher than the deposition temperature [9, 10].

This method is only suitable for the removal of already deposited APRD, provided that the heating current and the time from the HCL are calculated specifically in order to melt the deposits on the pipe walls. The main problem in the operation of the HCL is the failure of the cable armor during tripping operations during overhaul. Physical methods: Physical methods of influencing oil

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



lead to the destruction of the structure of oil associates. formed by ARC and paraffin hydrocarbons, which improves low-temperature properties and prevents the precipitation of paraffin. Ultrasonic processing of high-viscosity oils changes the nature of intermolecular interactions of surfactants. After such treatment of paraffinic oil, there is a decrease in viscosity by 1.8 times, a change in the nature of the flow curves, while maintaining the initial chemical composition of the oil. The use of magnetic methods is based on the magneto-dynamic effect that occurs when a liquid carrying particles with charges (ions, electrons) moves in a constant magnetic field. Under the influence of the magnetic field, the aggregates of colloidal particles of ferromagnetic iron are crushed, which leads to an increase in the number of centers of crystallization of paraffin. Small crystals remain in the upper state in the liquid flow, which ensures a multiple decrease in the rate of accumulation of crystals on the walls, and pipes [11, 12]. Vibration methods allow ultrasonic vibrations in the region of paraffin formation and, acting on paraffin crystals, cause their micro-displacements, which, in turn, prevent the deposition of paraffin on the walls of pipes. Physical methods are used quite narrowly in the field due to the difficulty of selecting the optimal treatment conditions and are not always confirmed by the effect of these methods. Chemical methods: The most widely studied and used method is the use of special chemicals based on the operation of adhesion-adsorption processes occurring at the boundaries of phases: oil system - metal surfaces, oil system - dispersed phase. The main advantage of using the above type of reagent is the improvement of the rheological properties of the oil and its resistance to the formation of deposits along the entire path from the bottom of the well. Methods of removal of formed deposits: With a long inter-treatment period or if prevention methods are not effective enough under existing operating conditions, wax deposits are formed, which is manifested in an increase in load on the column rods, a decrease in flow rate, and an increase in working pressure. To stabilize the operation of the well and prevent its failure, it is necessary to remove the formed deposits. The most widely used for these purposes are mechanical, thermal, and chemical methods. The use of APRD eliminators applies to facilities where inhibitors cannot be used: bottom-hole cleaning, well flushing before work-over, cleaning of tanks, tank farms, and oil collection systems. Mechanical methods: These methods are based on periodic cleaning of the internal surface of the pipeline using special scrapers, lowering, and lifting, which can be done using a manual winch or automatic scrapers that perform cleaning under the action of the upward flow of liquid. It is possible to use rod scrapers and centralizers for rod units when cleaning occurs during the reciprocating and/or rotating movement of the pig [13]. The use of scrapers is based on the physical properties of paraffin deposits, such as low mechanical strength and brittleness. However, these methods do not completely clear the deposits due to the shear of the scraper on the rod, in addition, the breakage and jamming of the scrapers in the well, the occurrence of scratches on the pipes, which accelerates their breakage, are quite frequent. For mechanical processing of above-ground pipelines, balls and pistons made of different materials are used, but for their use, devices for start-up and reception of cleaning equipment are needed. Thermal methods: Thermal methods are based on the ability of paraffin to melt at temperatures above 50 °C and drain from the heated surface. To create the necessary temperature, special heat sources are required, in which coolants are used (hot oil, water or hot steam), induction heaters, reagents, during the interaction of which exothermic reactions occur. A common requirement for all heating methods is the need to maintain a predetermined temperature value to completely melt the deposits. It is necessary to take into account the fact that with an increase in the molecular weight of paraffinic hydrocarbons included in the APRD, both their Tlk

and the amount of heat required to transition to the molten state increase. The process of removing paraffin deposits with hot oil occurs, on the one hand, due to softening and melting, followed by dissolving paraffin in the hot oil stream, on the other hand, due to reducing the bonding forces of the deposits with the metal surface, separating the sediment particles and removing them with the oil stream. The dissolution process depends on the amount of light hydrocarbons present in the oil and being a natural solvent. Accordingly, the more massive the hydrocarbon composition of the oil, the worse its solubility. To increase the dissolving capacity of crude oil, and also to loosen and disperse asphalt-resin-paraffin deposits, 0.02-5% vol. nonionic and cationic surfactants (oxyethylated products, aliphatic amines, lower alcohols or mixtures thereof). Paraffin, which is in a fine state, is easily removed by the oil stream. Sulfonic acid is actively used, which is part of a series of widely used reagents of the RT brand of Chimneft. Currently, among heat treatment methods, thermochemical treatment (TCT) with hot aqueous solutions of surfactants is the most widely used. Melting of deposits due to heat in aqueous solution, and special cleaning agents provide cleaning of deposits and creation of homogeneous dispersion, which prevents re-deposition of paraffin on equipment walls. Various detergents and surfactants are used as reagents for TCT processes. Reagent concentration and volume of working aqueous solutions vary and are determined primarily by sediment depth and thickness. Induction heaters placed directly in the region of the deposits are also used to melt the paraffin. To heat the pipelines, a high-frequency current is used to help create and maintain the specified temperature. Thermochemical compounds consisting of two or more reagents, which when interacting with each other generate a large amount of heat, are used to remove APRD. The heat generated leads to the heating of the reaction system, melting, and dissolution of APRD. As such compositions, solutions of diethyl-amine and hydrochloric acid, alkali metals, and their alloys are used, which emit a large amount of heat when interacting with the formation water. For the removal of ASPO, a thermochemical nitrogen-generating composition (NGC) based on the oxidative reduction reaction of aqueous solutions of ammonium salts and sodium nitrite in an acidic medium has been widely used. Common drawbacks of all thermal well dewaxing methods limiting their application include the probability of re-deposition of APRD on the surface of the well equipment when the temperature of the thermal agent drops and becomes insufficient to completely melt the wax solid; jamming and filling of working members of pumping equipment with sediment particles. Chemical method: The use of organic solvents to remove APRD is one of the most common methods. However, the sediments are characterized by a rather complex and diverse composition, so it is necessary to carry out targeted selection of the solvent, and not to carry out the semi-empirical method. The paraffin hydrocarbon solvents used can be divided into the following groups: non-polar and low-polar compounds (solvent compositions); polar compounds (alcohols, esters, esters, and derivatives thereof). The most effective is the composition of aliphatic, naphthenic, and aromatic hydrocarbons in combination with polar hetero atoms. This fact is explained by the different solubility of the components of the APRD. Solid paraffinic hydrocarbons dissolve in low-boiling aliphatic hydrocarbons, and the lower the molecular weight of the aliphatic hydrocarbons, the better the solubility. Low-boiling paraffin hydrocarbons are less effective, they are characterized by swell of APRD. The mutual dissolution of paraffinic hydrocarbons in naphthenic and aromatic hydrocarbons is hindered by the absence of solvation. The resins also contain aromatic and aliphatic structures, at the same time, the share of aliphatic carbons exceeds the share of aromatic ones so that they are quite soluble both in lower and higher alkane hydrocarbons, and naphthenic and aromatic hydrocarbons. Asphaltenes dissolve in aromatic hydrocarbons, mainly due to the

predominance of aromatic carbons over aliphatic ones. With an increase in the proportion of asphaltenes in the APRD, the percentage of aromatic hydrocarbons should be increased. Lower aliphatic hydrocarbons are natural precipitations of asphaltenes. Since the surfactant is the highest molecular weight and sparingly soluble part of the APRD, so the rate of sediment removal will be determined at the stage of its dissolution. It is most difficult to break down APRD with maximum asphaltenes and high-melting paraffin hydrocarbons due to the presence of a rigid pseudo-crystalline structure in them. The high solubility of the Olefin-Rich Hydrocarbons solvent is due to their low ionization potential. The effectiveness of such solvents is achieved by forming a π complex between polyaromatic fragments of asphaltenes and unsaturated bonds in oligomers. To increase the dissolution efficiency of paraffin compounds, compositions are proposed, which consist of a hydrocarbon solvent with the addition of surfactants, the introduction of which increases the dissolving ability due to increasing the surface activity of the solvent and by dispersing the precipitate into the volume of the solvent under the action of surfactants. As additives, nonionic surfactants, sulfonic acids and their derivatives, synthetic fatty acids, amines, acetals, polyalkylbenzene resin, pyrolysis heavy resin, catalytic cracking thermal gas oil, nitrogen-containing block copolymer of ethylene oxide and propylene oxide, phenol-formaldehyde resin are used as solvents. The general mechanism of solvent effect on APRD is the initial adhesion of solvent molecules to sediments due to intermolecular forces, change of surface properties of sediments, reduction of forces of wax particles' adhesion to equipment surface, its dissolution, and removal of oil flow. In addition to hydrocarbon solvents, aqueous solutions of surfactants are used to remove APRD, which allows controlling the properties of dispersed systems and the processes involved in them. Solutions of this type can be classified as detergent mixtures since their effect mainly leads not to the breakdown of the components of the APRD, but to their dissolution and dispersion. They are adsorbed on the surface of the deposits, reducing their surface energy, which facilitates deformation, penetrates cracks and pores, reduces adhesion on the surface of the metal, contributes to the destruction of the deposits, disperses them to form micelles that can be retained in the volume of the solvent [14]. The effectiveness of this Control Method depends on the rate of destruction and displacement of the oil film from the sediment surface; hydrophilization of the deposit surface determined by the composition and concentration of the surfactant; the rate and depth of penetration of the aqueous detergent solution into the pores of the deposits, depending on the size of the pores and the composition of the deposits; mixing intensity; changes in internal forces of interaction between APRD particles; possibility of removing sediment particles in the flow of washing liquid. A common disadvantage of almost all the formulations used to remove APRD is the selectivity of expansion, as a rule, they do not provide sufficient dissolution efficiency at high concentrations, such as surfactants and paraffin. Therefore, the search for new reagents, inhibitors, and removers of asphalt resin paraffin substances remains relevant [15].

**Solution of the problem**

As is known, aggregative-unstable oil systems are characterized by the variability of the state of the medium due to the continuous structuring of asphaltenes particles both among themselves and the wall of the porous medium and a change in their physical properties, i.e. a change in the volume and size of the particles as a result of their interaction, collision, coagulation and crushing at a certain concentration of particles in a closed volume. The relationship between the structure and viscosity of oil dispersion systems, as well as the features of their non-Newtonian flow, is explained by a change in structure as a result of the emergence (coagulation) and destruction of

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



aggregates of asphaltenes particles. Petroleum structured systems containing crystals of high molecular weight paraffin, resins, and asphaltene particles at very low laminar flow rates or in the absence of flow form a chain or, in the extreme case, a continuous network between each other and a structural porous medium. Oils characterized by non-Newtonian properties (Bingham liquids) acquire the ability to flow in a porous medium only after the destruction of this mesh during coagulation of the $\tau \gg \tau_0$ (where $\tau_0$ is the yield strength), and small external stresses

produce elastic deformation of the mesh and the framework [16, 17]. The interaction of asphaltenes particles is accompanied by the creation, thanks to the Brownian diffusion movement of individual particles, of sufficiently strong aggregates of coagulation nature, and above all doublets, triplets. At high flow rates, the formation of aggregates from asphaltenes particles is carried out due to turbulent diffusion and turbulent transfer. These structures are unstable and can disintegrate into separate particles as a result of crushing aggregates under the action of shear flow, and the equilibrium shifts towards the formation of individual particles as the shear rate increases. Therefore, the rate of change in the number and size of particles in a unit volume is determined by the rates of coagulation, crushing and destruction.

$$\frac{dN}{dt} = U_k - U_d$$

here, $N$ is the current number of particles in the volume, $U_k$ is the coagulation rate, $U_d$ is the crushing rate. Depending on the conditions of the flow of the oil medium (temperature, pressure, speed, shear stress, surface tension, viscosity, and density of asphaltenes and oil) and the number of particles, the coagulation and crushing processes of the aggregates are reversible, that is, both the formation of aggregates and their deformation and destruction are observed in the system at the same time. In the extreme case of an infinite shear rate $\tau \gg \tau_0$ or$U_d \gg U_k$, complete

destruction of aggregates up to a single particle is possible and the flow of structured oils or oil emulsions approaches the flow of conventional Newtonian liquids. In particular, the collision frequency of two asphaltene particles in volume during laminar flow as a result of Brownian diffusion can be defined by the following expression [18, 19].

$$\omega = 4\pi(D_1 + D_2)(R_1 + R_2)N_0,$$

where $\omega$ is the frequency of collision of two particles with sizes $R_1$ and $R_2$ and with diffusion coefficients $D_1$ and $D_2$, $N_0$ is the initial content of asphaltene particles in a unit volume of oil. As a result of the collision and fixation of two particles with sizes a1 and a2, an interfacial film of a round section is formed, the radius of which can be determined in the form of [20] and

$$R_k = \left[\frac{3\pi}{4} P_m (k_1 + k_2) a_r\right]^{1/3},$$

and here $R_k$ is the radius of the interfacial film, $R_m$ is the maximum compressive pressure, $k_1$, $k_2$ is the elastic coefficient of each particle, $a_r = a_1a_2/(a_1 + a_2)$ is the average particle size. In [20], the

expression for hydrodynamic compression pressure of two particles in a turbulent flow is defined as

$P_m = \pi a_r^2 \rho_c \bar{u}^2$,

$\bar{u}^2$is the rms fluctuation velocity of the turbulent flow. It is important to note that only by breaking the interfacial film can single particles of size be formed $a = \left( \sum_{i=1}^{n} a_i^3 \right)^{1/3}$. The problems of coagulation of asphaltenes, taking into account the influence of temperature and high pressure, are devoted to the work [21, 27]. The purpose of this study is to study the phenomena of coagulation and crushing of asphaltene particles in a structured oil medium using chemicals.

**Experimental part**

**Description of the installation.** During experiments, a standard ARN-2 distillation apparatus was used according to GOST 11011-85. Radiograph "Rigaku MİNİFlex 600." Scanning Electron Microscope "JEOL JESM-6610LV."

The tar was obtained under vacuum conditions from oil samples on a standard APN-2 distillation apparatus according to GOST 11011-85, equipped with rectifying columns in the temperature range 450-550 °C. Tar yield of 12% (312 g) of the oil sample's weight in 600 g.

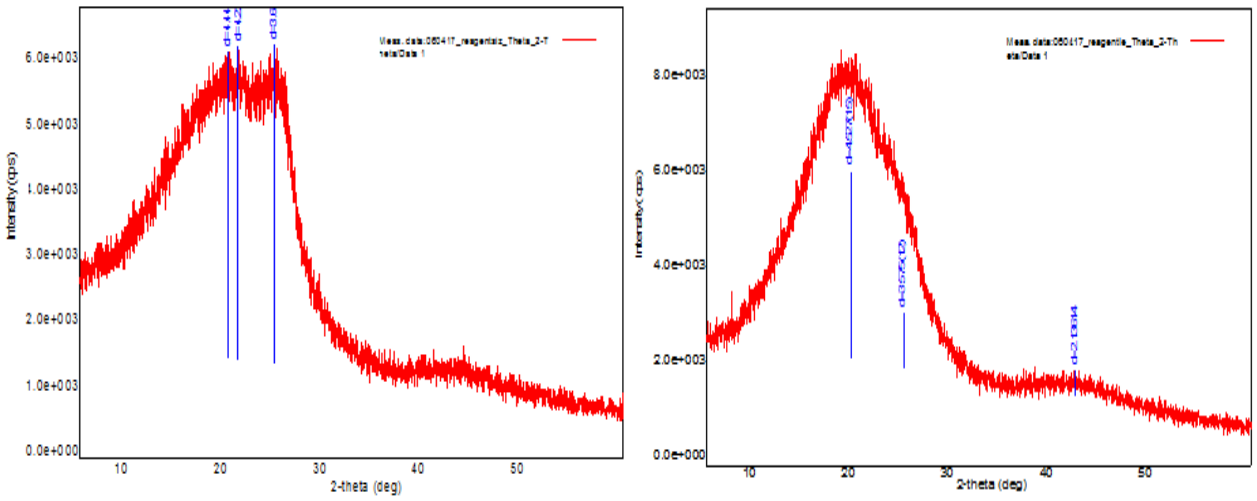
**Results and discussion**

The results of experimental studies showed that BAF-1 and BAF-2 reagents (technical conditional name of composites) based on coordination polymers of iron (III) with terephthalic acid and phthalic acid reduce the viscosity of petroleum products such as heavy and crude oil, facilitate transportation from the underground formation from the production site to the oil refinery or oil storage facility, increase production, clean the tanks of oil and petroleum products sludge [23-18]. It is also known that all these properties of oils (increased viscosity, transportation difficulties, reduced production, formation of sludge in tanks, etc.) are directly related to ARPD formation. Taking into account the above, we have developed a new multifunctional chemical technology to prevent or remove already-formed ARPD. To clarify the mechanism of action of the reagents, we conducted radiographic and electron-microscopic studies. To conduct the studies, 40 ml of a composite solution of reagents was added to samples of oil (300 ml each) taken from the same well (№ 1573), and the other was left unchanged and distilled until a tar fraction was obtained.

As is known, the composition of tar includes paraffin, aromatic naphthenates (45-95%), asphaltenes (3-17%), petroleum resins (2-38%), and metal atoms. Depending on the nature of the oils and the yield of the transparent fraction, the tar density varies from 0,95 to 1,03 g/cm$^3$, the coke content is 8-26% (weight), and the melting point is 12-55 °C. It is also known that during atmospheric and vacuum distillation, the chemical composition of oils does not change. Therefore, the results of analyses obtained for dry oil products are directly related to the oils themselves. The results are shown in Figures 1 (a, b), 2 (a, b) respectively.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS






a b

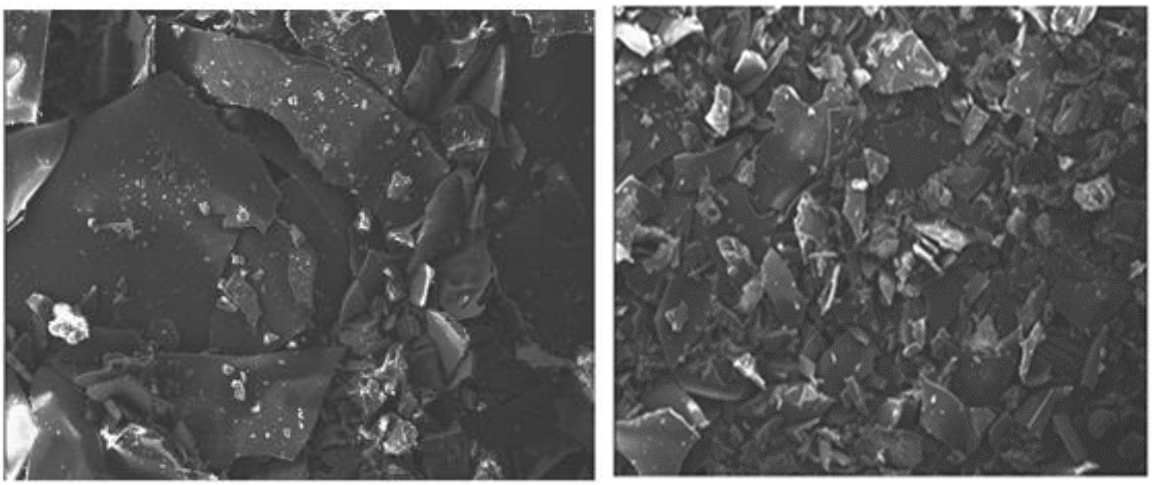
**Figure 1**. a) Dry X-ray sample of reagent-free oil, b) Dry X-ray sample of reagent-oil sample with reagent.

The X-ray diffraction pattern (Fig. 1) shows that the dry product without a reagent oil sample consists of three distinct phases with interplanar distances of 4,44, 4,22, and 3,64. On the radiograph (Fig. 2) taken from the dry sample of the oil product with the reagent, the third phase completely disappears and in the first two phases, the maxima are shifted to low-angle sides, i.e. the interplanar distances increase. The results of electron microscopic examination of a reagent-free oil sample (Fig. 3) showed that an association consisting of asphaltenes, resins, and paraffin is present in the dry residue, which deteriorates the rheological properties of the oils. The results of the electron microscopic examination of the sample with the reagent (Fig. 4) indicate that the association is in a fractured form and distributed in oil, i.e. in a dissolved state. The disappearance of the third phase (Fig. 1) with an interplanar distance (d = 3.60) shows that porous reagents (pore size is approximately 20A° BAF-1 and BAF-2 with the third phase form non-covalent compounds with self-organization and self-construction, i.e., when the reagent interacts with oil, non-covalent sketching interactions occur between porous coordination polymers and chromatic and hetero atom macro associates of the third phase.

The first and second ASFAs released from the third phase turn into fine particles and dissolve in oil. In this regard, the rheological properties of oil are improved. And increasing the interplanar distance of the first and second phases shows that their structure is changing. Comparative radiographs of dry oil products without reagents and with reagents are presented in Figure 3.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS





a b

**Figure 2.** a) Electron microscopic image of dry oil sample without reagent, b) Electron microscopic image of dry oil sample with reagent.

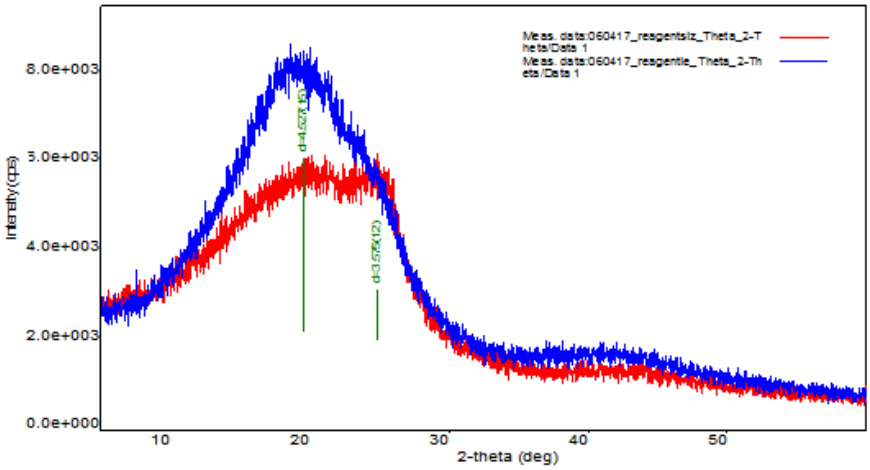



**Figure 3**. Comparative X-ray of dry oil products without reagent (red) and with reagent (black).

The results of electron microscopic analysis also clearly show that in the dry product of reagent-free oil, APRD is in solid mass and degrades its properties. And in a dry oil product with an APRD reagent, the associates are divided into small particles, i.e. in oil they are distributed evenly and therefore the rheological properties of oil are improved. This further proves that reactants with chromatic hetero atoms form non-covalent compounds. Thus, the results of the studies show that these reagents can solve all problems arising from APRD formation, in particular, improve the oil recovery of wells, reduce the viscosity of heavy oils, increase the efficiency of transporting such oils, and ensure the efficiency of cleaning oil tanks from oil deposits and oil products. The technology we put forward is based on clathrate formation, that is, Lewis's master-guest theory. The technology we put forward is based on clathrate formation, that is, Lewis's master-guest theory. According to this theory, the "host" reagent, having crystalline pores or channels, with

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



self-organization and self-construction absorbs the "guest" -their solid phase of oil with an interplanar distance of 3.64 (Fig. 1 (a)). As a result of this, association fragmentation occurs, which significantly improves the rheological properties of oils.

For the experimental study, a 1% solution of reagents BAF-1 and BAF-2 (conditional name of reagents) in diesel alkaline waste (DAW) in the amount of 200 g was prepared. To do this, one gram from the two coordination polymers BAF-1 and BAF-2 was taken and dissolved in 198 g of diesel alkali waste. This solution was used to reduce the viscosity of the Murad-Khanly mixed oil. The rheo physical and chemical characteristics of Muradkhanlinsky mixed oils are presented in table 1.

**Table 1**. Rheophysical and chemical characteristics of Muradkhanly mixed oils.

| Rheo physical and Chemical Parameters | Value | Methods of analysis |
|---|---|---|
| Density, kg/m$^3$ | 876,7 | ГОСТ 3900 |
| Kinematic viscosity, mm$^2$/s | 83,32 | ГОСТ 33 |
| Amount of resins, % | 18,32 | Chromatography |
| Amount of asphaltenes, % | 4,86 | ГОСТ 11858 |
| Amount of paraffins, % | 6,21 | ГОСТ 11851 |
| Saturated vapor pressure, кPa | 23,4 | ГОСТ 1756 |
| Chilling temperature, $^0$C | +9 | ГОСТ 20287 |
| Mechanical mixture, % | 0,0234 | ГОСТ 6370 |
| Amount of salts, mq/l | 47,3 | ГОСТ 21534 |
| Amount of water, % | 0,15 | ГОСТ 2477 |

Further, the effect of the nanometer on the rheo physical-chemical properties of various mixed oils. The Results of the display check, that these characteristics of different oils deteriorate due to the formation of intermediate phases. Therefore, there was a need to clean the DAW. Purification of DAW was carried out as follows: a mixture of reagent and clay was added to the determined DAW co-number. The clay is run after the separation of the Muradhanlinskaya crude oil. The calculated amount of clay is mixed with the nanometer and added to the DAW. For a certain time, the gray color of the clay gradually turns to tone-no-brown. And the dark brown DAW soon acquires a light-lo-brown color. The results of the analyses of crude (1) and purified (2) DAW are given in Table 2. As can be seen from Table 2, all the characteristics of the purified DAW (2) are lower than the crude, in particular, the amount of resins and asphaltenes after purification is reduced by 75.6 and 78.8%, respectively, which determines the viscosity of oils of 80%. The purpose of DAW purification is to reduce the number of resins and asphaltenes in it, which, when the prepared nano-reagent- DAW composite is added to oil, are superimposed on resins and asphaltenes in the oil co-plant. At the same time, the number of oils in the samples increases, which leads to excess costs of the nanometer. Therefore, the composite was prepared with purified DAW.

**Table 2.** Rheo physical and Chemical Characteristics of Crude and Purified DAW (20$^0$C).

| Parameters | DAW 1 | DAW 2 | Methods of analysis |
|---|---|---|---|
| Density, kg/m$^3$ | 1050,5 | 987,2 | ГОСТ 3900 |
| Kinematic viscosity, mm$^2$/s | 4,21 | 1,43 | ГОСТ 33 |
| Amount of resins, % | 19,48 | 4,75 | Chromatography |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



| | | | |
|---|---|---|---|
| Amount of asphaltenes, % | 2,78 | 0,59 | ГОСТ 11858 |
| Amount of paraffins, % | - | - | ГОСТ 11858 |

For the experiment, the most viscous oil of the Azerbaijan fields was taken - Muradkhanlinsky mixed oils, the rheo physical and chemical characteristics of which are presented in table 1. Next, the effect of the nanometer on the viscosity of Muradhan-Linskaya oil was studied. For this, 100 ml of Muradhanlinskaya mixed oil was taken and 1% nanomer was added to it in DAW (2). After adding each portion, the kinematic viscosity of the sample was measured. The measurement results are given in Table 3.

**Table 3**. Oil viscosity trend as a function of quantity composite.

| Amount of composite in oil, ml | Kinematic viscosity of oil, $mm^2/s$ |
|---|---|
| - | 83,32 |
| 5 | 78,91 |
| 10 | 72,18 |
| 20 | 50,43 |
| 25 | 48,69 |
| 30 | 45,22 |
| 40 | 43,37 |
| 45 | 46,21 |
| 50 | 51,42 |

As can be seen from Table 3, with the addition of 20 ml of 1% composite to the oil, the kinematic viscosity of the sample decreases sharply to 50.43 $mm^2/s$. Thereafter, by adding 25, 30, 40 ml of composite, the viscosity of the sample was gradually reduced to 43.37 $mm^2/sec.$ and thereafter, the formation of a new phase is observed. With the formation of a new phase, an increase in the viscosity of the sample to the value of 51.42 $mm^2/s$ begins. The consumption of the composite is 50 ml. The decrease in kinematic viscosity from the amount of surfactants has also been studied. The results of the experiments showed that the increase in the number of surfactants negatively affects the decrease in the kinematic viscosity of hydrocarbons. Despite the fact that there is no pattern between the amount of surfactant and the kinematic viscosity of the hydrocarbon, but, ultimately, the latter decreases. The most important method of introducing the reagent into the system is the method used, which is a cavitation treatment with hydrodynamic cavitation, which requires optimization of the cavitation process. To avoid the re-occurrence of cavitation, shut-off valves must be inserted into the system. The results of the studies showed that when using the complex method, the viscosity of oil decreases significantly.

## Conclusion

The presence of a certain concentration of asphaltenes, resins, and paraffin in the oil composition (at low temperatures), and their coagulation with the formation of strong structures between each other and a solid surface gives the oils a non-Newtonian character. These studies have shown that the proposed reagents, when interacting with oil, lead to the crushing of asphaltene-tar-paraffinic asymates, as a result of which the structure of the oil, its mobility, fluidity, viscosity, and, in general, the entire oil quality bank are significantly changed. The following conclusion can be drawn from the results of the experiments: the optimal composition of the reagent-household

water-surfactant composite consists of 1 g of reagent, 98 g of economic water, and 1 drop of sulfinol, and the optimal volume of the composite is 40 ml per 300 g of oil.

**Declarations**

The manuscript has not been submitted to any other journal or conference.

**Study Limitations**

There are no limitations that could affect the results of the study.

**Acknowledgment**

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCES**

1. Petrova L. V., Yarullin D. R. Evaluation of the effect of asphalt resin paraffin deposits on oil well performance // IOP Conference Series: Materials Science and Engineering, 2019, № 6, P. 1-4.
2. Nurullayev V. H., Gurbanov G. R., Abdullayeva Z. A. Analysis of the effect of high molecule components on the realogy of oil disperser systems.- 2022, № 1, P. 75-83.
3. Gurbanov G.R., Ahmadov S.F. Adigozalova M.B. et.al. Investigation of the effect of the pour point depressant “Difron-420” on the formation of paraffin sediments in the laboratory conditions // Azerbaijan Oil Industry. 2020, No.12, pp.30-36
4. Mehrotra A. K. Haj-Shafiei S, Ehsani S. Predictions for wax deposition in a pipeline carrying paraffinic or ‘waxy’ crude oil from the heat-transfer approach // Pipeline Sci Eng. 2021, No.1, P. 428–435.
5. Kolesova S.B., Nasyrov A.M., Polozov M.B. Reducing the effect of free gas on the operation of pumping equipment // Ekspozitsiia neft' i gaz. 2018, No. 6, P. 48-51
6. Kopish, M., & Marques, W. Leveraging Technology to Promote Global Citizenship in Teacher Education in the United States and Brazil // Research in Social Sciences and Technology. 2020, No. 5, P. 45-69.
7. Nurullayev V. H., Usubaliev B. T., Gurbanov G. R. Coordination compounds for rheological and physical-chemical regularity of energy consumption decrease while transporting crude oils // Turkish Journal of Engineering, 2023, № 3, P. 180-185.
8. Nurullayev V. H., Usubaliev B. T., Gurbanov G. R. Investigation of effect of additives on rheological properties and asphalt-rezin-paraffin compounds of crude oil // World Scientific News, 2021, № 2, P. 148-160.

9. Nurullayev V. H., Usubaliyev B.T. Tagiyev D. B. Coordination Compounds for Rheological and Physical-Chemical Regularity of Energy Consumption Decrease While Transporting Crude Oils // Nanoscience and Nanotechnology. 2021, № 1, P. 1-5.
10. Nurullayev V. H., Usubaliyev B.T. Tagiyev D. B. The study on the reduction of the viscosity of transported heavy crude oil by Fe (II) and Fe (III) complexes with phthalic acid // Iranian Journal of Chemistry and Chemical Engineering. 2019, № 6, P. 135-140.
11. Nurullayev V. H., Usubaliyev B.T. New methods of struggle with asphalt-rezin-parafin deposits in processes of oil transportation // Proceedings on Engineering. 2021, № 2, P. 193-2000.
12. Nurullayev V. H., Murvatov F. T., Abdullayeva Z. A. The application of condensate in the synthesis of nano-structured polymer-based composites for enhanced oil recovery // SOCAR Proceedings. 2022, № 1, P. 79-83.
13. Nurullayev, V. H., Murvatov F. T., A. Gasimzade A. V. On the issues of perspectives for the development of the Siyazan monoclinal oil field of the republic Azerbaijan // SOCAR Proceedings. 2022, № 1, P. 84-89.
14. Nurullayev V. H., Usubaliyev B.T. Using New Nanostructured Coordination Polymer Additives BAF-1 and BAF-2 in Crude Oils // American Journal of Applied and Industrial Chemistry. 2021, № 2, P. 1-6.
15. Nurullayev V. H., Usubaliev B. T., Gurbanov G. R. The effectiveness of the coordination compounds to improve the rheological properties of oils during transportation // New Materials, Compounds and Applications. 2022, № 3, P. 202-213.
16. Ilyushin PY, Vyatkin KA, Kozlov AV. Investigation of rheological properties of oil during the formation of wax deposits // Results Eng. 2022, № 14, P. 19-24.
17. Lateef, A. O., Bin, M. S. H., & Ademola, F. J. Performance assessment based on Intelligent power management for standalone PV system in remote area of Ibadan, Nigeria // Journal of Applied Engineering Science. 2019, No. 1, P. 52-60.
18. Pavel Ilyushin, Kirill Vyatkin, Daniel Andreev. Study of the influence of dosing conditions of wax inhibitors on its efficiency using numerical simulation // Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering. 2023, No. 2, P. 14-21.
19. Sandyga M. S., Struchkov I. A., Rogachev M. K. Research of temperature conditions of organic sediments formation in the productive formation at paraffinic oil well production // Perm J Petroleum Mining Eng. 2021, No. 21, P. 84–93.
20. Haj-Shafiei S, Mehrotra AK. Achieving cold flow conditions for waxy mixtures with minimum solid deposition // Fuel. 2019, No. 235, P. 1092–1099.
21. Ilyushin P. Y., Vyatkin K. A., Kozlov A. V. Development of a method for estimating thermal conductivity of organic deposits on the wax flow loop laboratory installation // Int J Eng. 2022, No.35, P. 1178–1185.

22. Usubaliev B. T., Tagiyev D. B., Nurullayev V. H. et. al. Synthesis and Physico-Chemical Studies of Complex Compounds of Iron (II) and (III) with Phthalic Acid // Journal of Nanomaterials and Molecular Nanotechnology. 2017, V. 6, Issue 5, P. 1-5.
23. Ridzuan N, Subramanie P, Uyop MF. Effect of pour point depressant (PPD) and the nanoparticles on the wax deposition, viscosity and shear stress for Malaysian crude oil // Pet Sci Technol. 2020, No. 38, P. 929–935.
24. Yao B, et al. Advances in and perspectives on strategies for improving the flowability of waxy oils // Energy Fuels. 2022, No.36, P. 7987–8025.
25. Usubaliev B. T., Ramazanova E. E., Nurullayev V. H., et al. Method of reducing viscosity of commercial oils. Eurasian Patent. 2018, № 030154.18.
26. Usubaliev B. T., Ramazanova E. E., Nurullayev V. H., et al. Method of cleaning oil tanks. Eurasian Patent. 2018, № 030108.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-45

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# INVESTIGATION OF PRECIPITATION KINETICS OF VARIOUS BALLASTS IN "UNDESIRABLE" OIL MIXTURES

**[1]Fidan Ismayilova, [2]Gulnara Zeynalova, [3]Khadija Jahangirova**
[1,2,3]Azerbaijan State Oil and Industry University
[1,2] Department of "Transportation and Storage of Oil and Gas"
[1]Associated professor, https://orcid.org/0000-0002-5849-2488, fidan.ismayilova.2014@mail.ru
[2]Teacher, https://orcid.org/0000-0003-2717-2155, Email: gulnara.zeynalova93@mail.ru
[3]Laboratory assistant of the department, "Industrial Safety and Labor Protection"
[3]https://orcid.org/0009-0002-1084-5501, [3]Email: xedi1996@mail.ru

## ABSTRACT

Research results in recent years show that there are specific problems associated with blending different types of crude oil. Incompatibility of mixed oils, in particular, can lead to clogging and sometimes even shutdown of pipeline systems. One of the reasons that causes the immiscibility of various crude oils, is the presence of solid organic matter in the form of precipitated resins and asphaltenes in the mixture of oils. These are ballast substances, that often precipitate from the solution of a mixture of oils. In order to study the influence of the mixing factor of crude oils on the quality characteristics of oils, various samples of oils and their mixtures were studied in laboratory conditions. It was found that when mixing oils, nonlinear deviations in the properties of the mixture occur and noticeable anomalies in changes in quality indicators can be expressed in oil mixtures. In this case, the content of ballasts such as resin and asphaltenes in the mixture does not change according to the additivity rule.

In the article, we studied the precipitation kinetics of various ballasts (resins, asphaltenes , and paraffins, as well as water, salts, and mechanical mixtures) in "undesirable" mixtures of oils. It was found that the bulk of all ballasts precipitate within 8–10 hours. Studies have shown that, depending on the chemical composition of oils, their formation of "undesirable" mixtures can also occur in the intensive deposition of various ballasts.

**Keywords:** oil mixing, physical and chemical properties, mechanical mixtures, ballast deposition, asphaltenes.

## Introduction

In the practice of oil and gas extraction, in the processes of transportation and storage of oil and oil products, cases of mixing of various types of products are very common. Mixing of oils occurs during their collection and transportation in collector-discharge lines, pipelines, and tanks. As a rule, the mixing of separate oil products occurs in the contact zone and mixing tanks of the two products during their consecutive transportation through the same pipeline. Mixing of different types of oil in oil fields also happens when there are not enough tanks. In such cases, mixing of separate oils of different properties occurs as a result of collecting them in the same tank, which greatly affects their quality indicators and correct accounting. In such cases, it is not accidental that there is an imbalance in the accounting during their reception and delivery. The experience of recent years shows that for some oil mixtures, there are often cases of abnormal, sharp changes in density, viscosity, volume, and other parameters, as well as, analyzing the kinetics of deposition of chemical ballasts of practical importance [1-3].

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Statement of the problem**

As it is obvious that, the construction of transportation networks and the location of production areas do not allow the transportation of oil from the field to the points of consumption with the initial quality indicators. The existing networks of in-field and main oil pipelines can technologically transport oil only in the form of mixtures. However, there are specific problems arising from the mixing of different types of crude oil. One of the main problems is the "undesirable" mixtures of oils, which leads to contamination of equipment (pipelines, tanks, heat exchangers, furnaces, rectification columns, etc.), and sometimes a complete shutdown.

The results of research show that one of the reasons that make the mixing of different types of crude oils "undesirable" is the presence of organic solids in the form of precipitated asphaltenes. It is known that asphaltenes are soluble in aromatic compounds such as toluene, but not in paraffinic compounds such as n-pentane. The main problem with the presence of asphaltenes in various crude oils is that asphaltenes are often separated from these mixtures in the form of sediments. As long as there is a need to create practical and cost-effective means and methods for mixing different types of oils, these problems remain unresolved.

Recent research suggests that nonlinear deviations (errors) in the quality of mixtures of different types of oils from existing ideal oil models are most likely due to the structural transformation of oil nanophase [4-9]. "Undesirable" manifestations of asphaltenes in oil mixtures are possible at concentrations corresponding to the boundaries of the nanophases.

**Solution of the problem**

The existing various models of the processes under consideration do not yet allow us to predict the changes in the quality of the oil mixtures used with the accuracy necessary for engineering calculations. Therefore, there is a need to add and improve criteria to assess the "undesirable" as well as the "optimal" concentration of asphaltene and other high-molecular chemical compounds, taking into account the interaction of individual components in transported oil mixtures.

In order to study the effect of mixing different types of oils on their rheological and physicochemical properties, oil samples of different fields and their mixtures were studied in the laboratory [10-13]. The physicochemical properties of the tested crude oil of the Bulla (BO) and Garachukhur (GO) fields of Azerbaijan, as well as research methods, are shown in Table 1.

**Table 1.** Physicochemical indicators of crude oil from Bulla (BO) and Garachukhur (GO) fields of Azerbaijan.

| **Indicators** | **Crude oils** | | Research methods |
|---|---|---|---|
| | BO | GO | |
| Density at $20^0$ C, kg/m$^3$ | 973,4 | 914,7 | AUSS 3900 |
| Kinematic viscosity at $20^0$ C, sst. | 15,76 | 6,41 | AUSS 33 |
| Resin, % of mass | 10,27 | 13,28 | Chromatograph |
| Asphaltenes, % of mass | 0,23 | 0,64 | AUSS 11858 |
| Paraffins, % of mass | 13,34 | 2,53 | AUSS 11851 |
| Saturated vapor pressure, kPa | 16,2 | 9,7 | AUSS 1756 |
| Set point, °C | +9 | +3 | AUSS 20287 |
| Mechanical mixtures, % of mass | 5,72 | 6,42 | AUSS 6370 |
| Salts, mg/l | 480,6 | 530,3 | AUSS 21534 |
| The amount of water, % of mass | 43,2 | 56,4 | AUSS 2477 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



As can be seen from Table 1, the BO and GO oil samples differ from each other due to their rheological and physicochemical properties. In the example of BO and GO oils, it was determined that, regardless of the mixing sequence [15-19], there are nonlinear deviations in the quality of the mixture. Anomalies of quality indicators are also evident in the oil mixtures ("GO" + "BO") and ("BO" + "GO").

In particular, the results of determining the physicochemical parameters of a mixture of oils (GO + BO) depending on the mass fraction of BO oil in the mixture are shown in Table 2. Based on the data in Table 2, the dependence of the mixture parameters (density, kinematic viscosity, resin content, asphaltenes , and paraffins) on the mass fraction of mixed oils was constructed. These dependencies are presented respectively in Fig. 1-5.

**Table 2.** Changes in the physicochemical parameters of the BO+GO oil mixture.

| Indicators | **Mass fraction of BO oil in the mixture** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **0,01** | **0,05** | **0,10** | **0,15** | **0,20** | **0,30** | **0,35** | **0,40** | **0,42** | **0,44** | **0,46** | **0,48** |
| Density at $20^0$ C,kg/м$^3$ | 908,5 | 917,6 | 920,3 | 923,8 | 926,7 | 932,1 | 936,4 | 939,1 | 942,5 | 943,4 | 945,7 | 946,6 |
| Kinematic viscosity at $20^0$C,cst | 7,36 | 8,75 | 9,48 | 11,59 | 13,83 | 15,95 | 19,46 | 24,84 | 28,35 | 34,42 | 42,35 | 49,27 |
| Resin, % of total mass | 13,19 | 13,11 | 13,07 | 13,02 | 12,89 | 13,26 | 13,35 | 13,39 | 13,42 | 13,46 | 13,51 | 13,65 |
| Asphaltenes, % of total mass | 0,65 | 0,62 | 0,59 | 0,56 | 0,54 | 0,57 | 0,60 | 0,62 | 0,63 | 0,64 | 0,65 | 0,67 |
| Paraffins, % of total mass | 2,59 | 3,29 | 4,12 | 4,86 | 5,34 | 7,35 | 8,16 | 8,67 | 8,73 | 8,86 | 8,89 | 9,05 |
| Vapor pressure, kPa | 9,8 | 10,1 | 10,2 | 11,8 | 12,3 | 11,9 | 11,8 | 11,5 | 11,3 | 11,2 | 11,1 | 10,9 |
| Pour point, °C | +3 | +3 | +3 | +3 | +6 | +6 | +6 | +6 | +6 | +6 | +6 | +6 |
| Mechanical impurities, % of total mass | 6,39 | 6,38 | 6,37 | 6,36 | 6,35 | 6,21 | 6,19 | 6,17 | 6,16 | 6,15 | 6,14 | 6,13 |
| Salts , mg/l | 528,6 | 526,4 | 523,1 | 520,9 | 518,7 | 512,3 | 511,9 | 510,7 | 509,8 | 509,1 | 508,3 | 507,2 |
| Water content, % of total mass | 55,3 | 54,8 | 53,6 | 52,9 | 52,1 | 51,3 | 50,8 | 50,2 | 49,9 | 49,6 | 49,2 | 48,7 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



| Mass fraction of BO oil in the mixture | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0,50 | 0,52 | 0,54 | 0,56 | 0,58 | 0,60 | 0,62 | 0,68 | 0,75 | 0,80 | 0,85 | 0,90 | 0,92 | 0,94 | 0,96 | 0,98 |
| 950,3 | 952,1 | 954,5 | 955,8 | 956,5 | 955,8 | 954,2 | 954,7 | 958,6 | 961,5 | 964,3 | 967,6 | 968,8 | 969,7 | 971,1 | 972,4 |
| 56,09 | 58,41 | 62,35 | 67,83 | 71,62 | 69,33 | 65,24 | 59,16 | 31,95 | 26,45 | 20,89 | 18,54 | 17,92 | 15,30 | 14,12 | 13,61 |
| 13,92 | 14,08 | 14,12 | 14,25 | 14,39 | 14,08 | 13,56 | 13,24 | 12,85 | 12,62 | 12,09 | 11,98 | 11,76 | 11,52 | 11,41 | 11,25 |
| 0,69 | 0,72 | 0,74 | 0,76 | 0,78 | 0,69 | 0,63 | 0,61 | 0,58 | 0,49 | 0,43 | 0,39 | 0,36 | 0,34 | 0,32 | 0,30 |
| 9,07 | 9,21 | 9,26 | 9,34 | 9,42 | 10,08 | 10,21 | 10,76 | 11,34 | 11,43 | 11,71 | 12,54 | 12,63 | 12,72 | 12,85 | 13,08 |
| 10,8 | 10,6 | 10,4 | 10,2 | 9,8 | 10,2 | 10,6 | 11,3 | 11,8 | 12,5 | 13,7 | 14,5 | 14,8 | 14,9 | 15,2 | 15,6 |
| +6 | +6 | +9 | +9 | +9 | +9 | 0 | 0 | 0 | 0 | 0 | +3 | +3 | +3 | +3 | +3 |
| 6,12 | 6,11 | 6,09 | 6,07 | 6,05 | 6,03 | 6,01 | 5,98 | 5,97 | 5,95 | 5,93 | 5,89 | 5,86 | 5,84 | 5,82 | 5,78 |
| 506,4 | 505,8 | 505,1 | 504,3 | 503,2 | 501,4 | 500,8 | 498,5 | 497,6 | 495,3 | 492,7 | 490,6 | 489,5 | 488,9 | 487,6 | 486,9 |
| 48,5 | 48,1 | 47,6 | 47,2 | 46,9 | 46,8 | 46,6 | 46,5 | 45,1 | 44,9 | 44,7 | 44,5 | 44,2 | 43,9 | 43,7 | 43,6 |

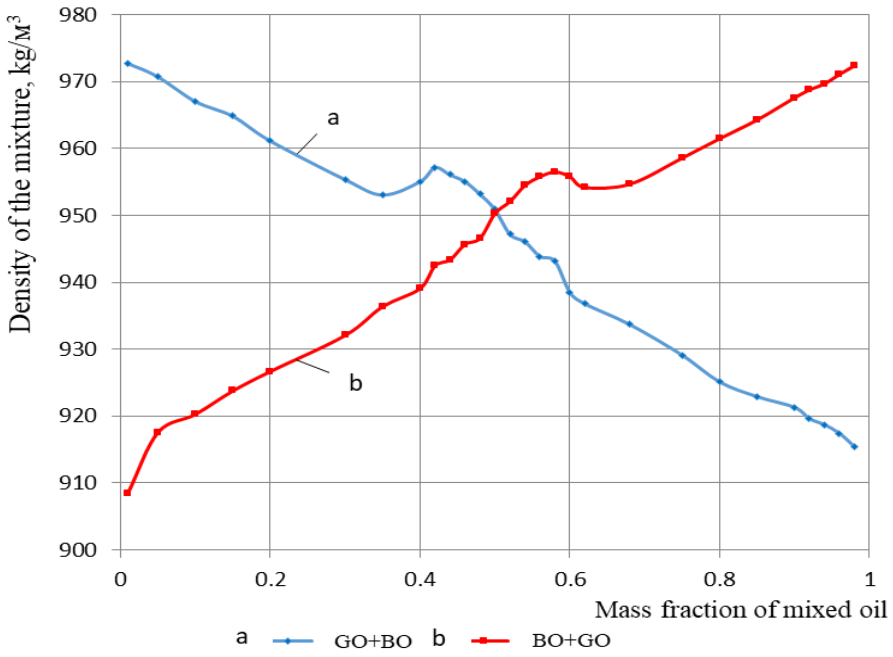



**Figure 1**. Variation of the density of the mixture

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



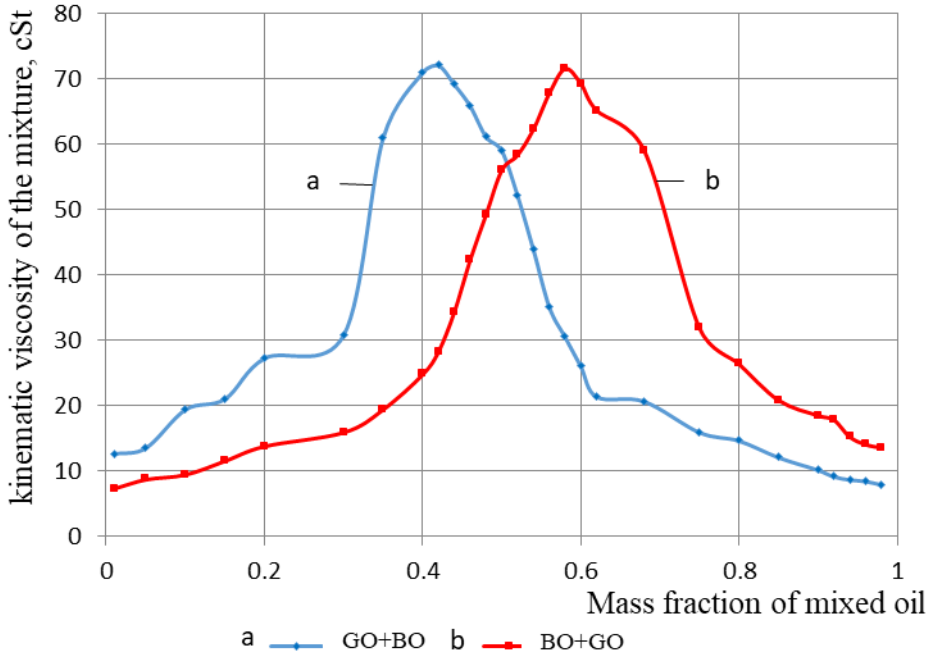



**Figure 2**. Variation of kinematic viscosity of the mixture.

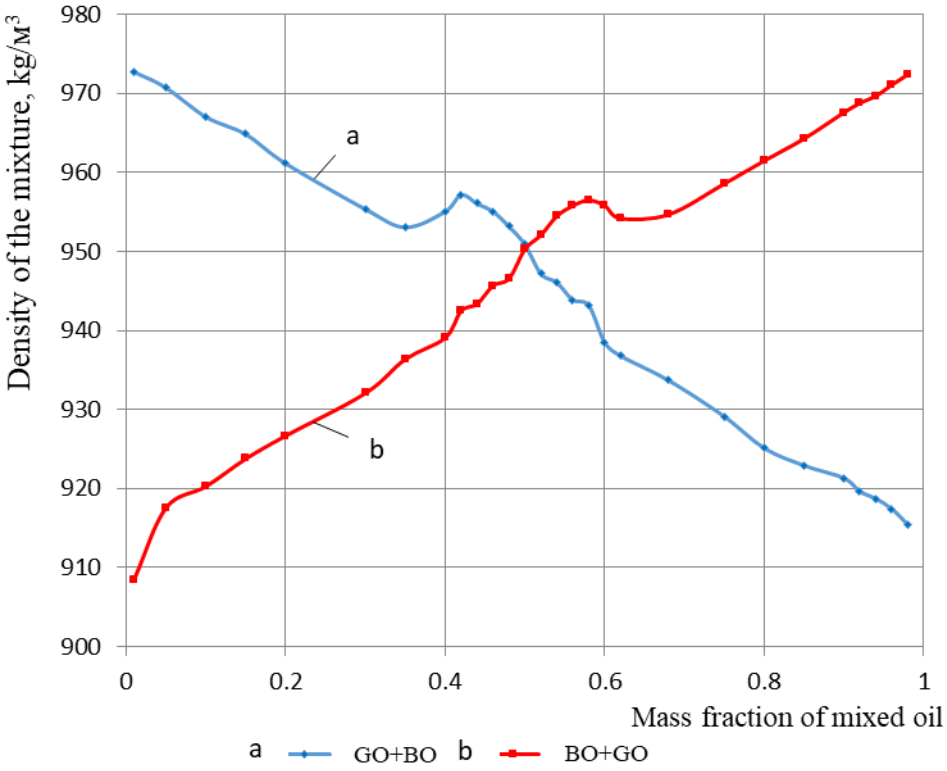



**Figure 1**. Variation of the density of the mixture.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



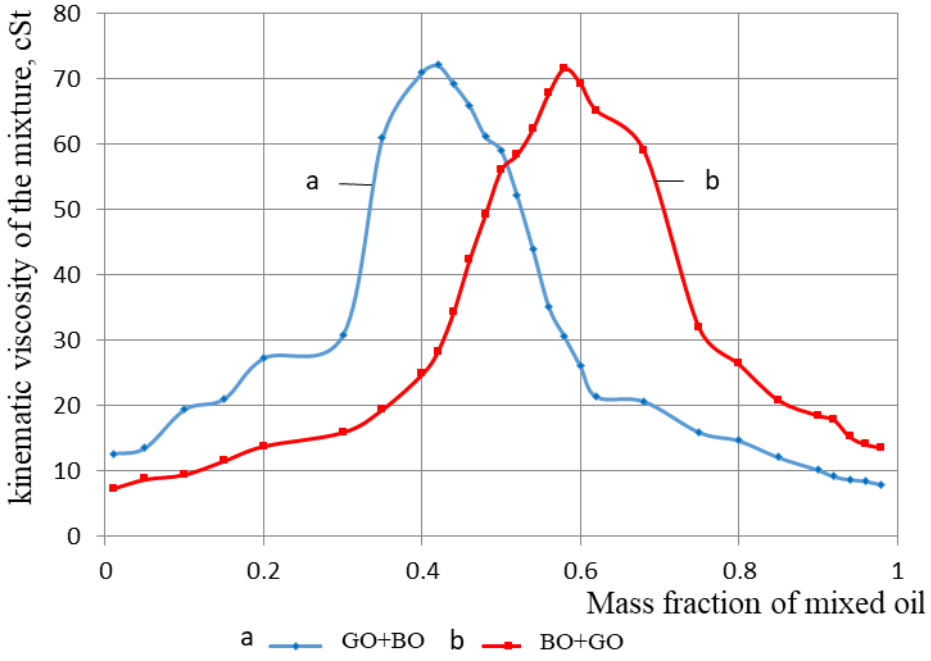



**Figure 2**. Variation of kinematic viscosity of the mixture.

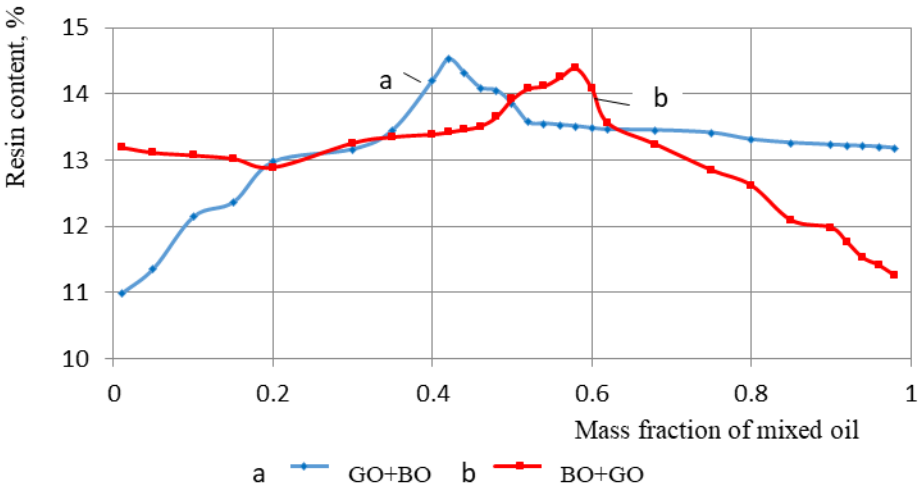



**Figure 3**. Changing the resin content in the mixture.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



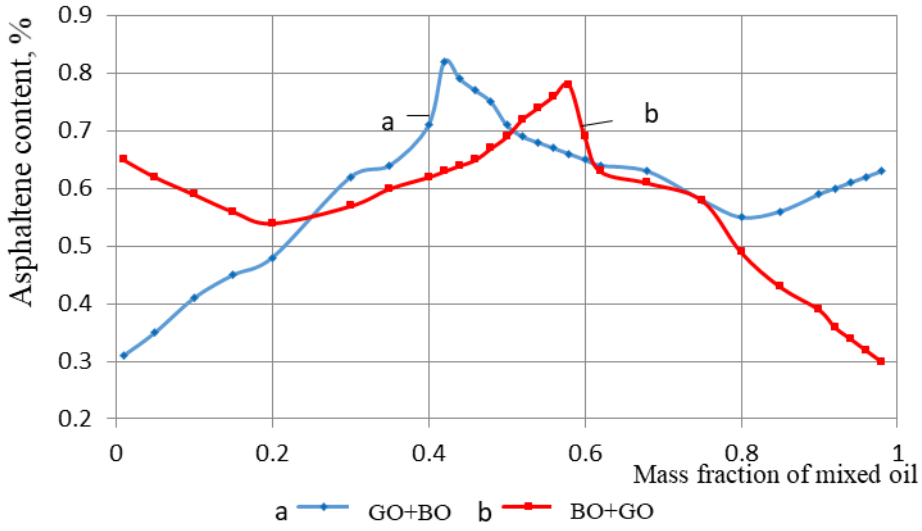



**Figure 4**. Changing the asphaltene content in the mixture.

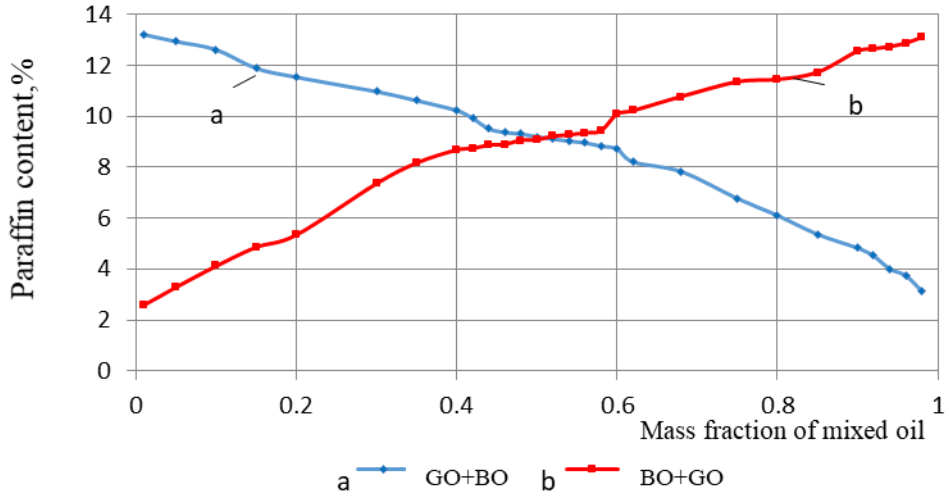



**Figure 5**. Changing the paraffin content in the mixture

As can be seen from Fig. 1-5, characteristic qualitative and anomalous changes in the abovementioned indicators occur in the mixture (GO + BO) at mass fractions of 0.58 and 0.42 of the mixed oils "BO" and "GO", respectively. From Fig. 3-5 it is also clear that, unlike the paraffin content, changes in the content of resins and asphaltenes in a mixture of oils do not occur according to the additivity rule. These circumstances once again confirm the absence of additivity rules in oil mixtures [20].

**Results and discussion**

Then, the sedimentation kinetics of different ballasts under standard conditions in the above-mentioned mixtures of "GO" and "BO" oils (42-58%) were studied. For this purpose, immediately after the preparation of each mixture, it was kept to settle at a temperature of 20 $^0$C and the amount of ballasts deposited in it was determined every hour in accordance with the

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



relevant standards. The results of hourly measurements to determine the amount of RAP (resin-asphaltene-paraffin), mechanical mixtures, water , and salt ballasts in the GO: BO (42-58%) oil mixture and the total amount of deposits of ballasts that accumulated during the day are shown in Table 3.

Based on the data in Table 3, the time dependence of the number of deposits of ballasts (RAP + mechanical mixtures, water, and salts) was established. The dependence reflecting the sedimentation kinetics of ballasts in oil mixtures are shown in Figure 6. As can be seen from Figure 6, most of all ballasts are set down within 8–10 hours. Also, the amount of sediment increases intensively for up to 8 hours, and then begins to decrease sharply. After 10 hours, the deposition process slows down and practically overs.

## Conclusion

Our research has shown that, depending on the chemical composition of different oils, the formation of "undesirable" in the mixture can also be manifested by the intensive deposition of various ballasts, which can lead to contamination of facilities and, in some cases, may result in the shutdown of technological oil storage and transportation pipelines.

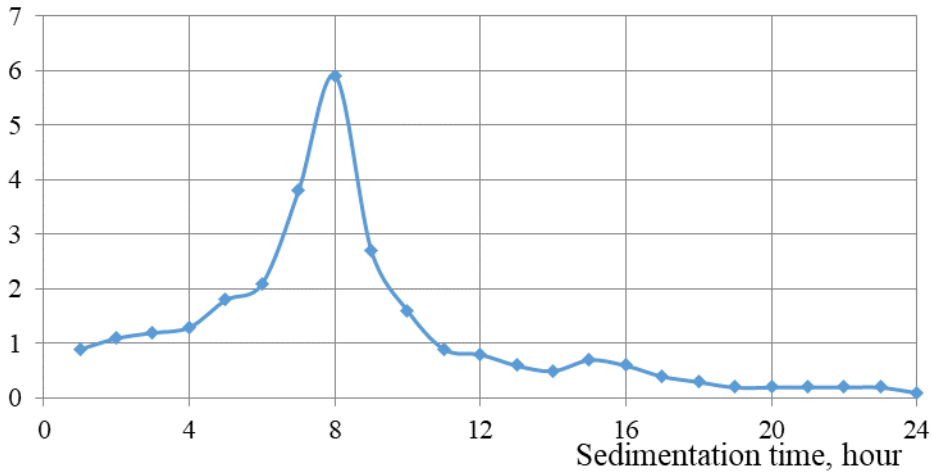
**Table 3.** Sedimentation kinetics of ballasts in GO: BO (42:58%) mixtures at t=20 $^0$C.

| **Ballasts** | **Time, hour** | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 |
| RAP+ Mechanical mixtures, % of mass | 0,03 | 0,04 | 0,05 | 0,06 | 0,08 | 0,11 | 0,19 | 0,28 | 0,18 | 0,09 | 0,05 | 0,04 |
| Total amount of RAP+ Mechanical mixtures, % of mass | 0,03 | 0,07 | 0,12 | 0,18 | 0,26 | 0,37 | 0,56 | 0,84 | 1,02 | 1,11 | 1,16 | 1,20 |
| Water, % of mass | 0,9 | 1,1 | 1,2 | 1,3 | 1,8 | 2,1 | 3,8 | 5,9 | 2,7 | 1,6 | 0,9 | 0,8 |
| Total amount of water, % of mass | 0,9 | 2,0 | 3,2 | 4,5 | 6,3 | 8,4 | 12,2 | 18,1 | 20,8 | 22,4 | 23,3 | 24,1 |
| Salts, % of mass | 10,1 | 11,3 | 11,6 | 12,1 | 12,5 | 13,2 | 14,3 | 20,5 | 16,3 | 12,1 | 11,2 | 10,1 |
| Total amount of salts, % of mass | 10,1 | 21,4 | 33,0 | 45,1 | 57,6 | 70,8 | 85,1 | 105,6 | 121,9 | 134,0 | 145,2 | 155,3 |

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



| Ballasts | Time, hour | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 |
| RAP+ Mechanical mixtures, % of mass | 0,03 | 0,03 | 0,03 | 0,03 | 0,02 | 0,02 | 0,02 | 0,02 | 0,02 | 0,01 | 0,01 | 0,01 |
| Total amount of RAP+ Mechanical mixtures, % of mass | 1,23 | 1,26 | 1,29 | 1,32 | 1,34 | 1,36 | 1,38 | 1,40 | 1,42 | 1,43 | 1,44 | 1,45 |
| Water, % of mass | 0,6 | 0,5 | 0,7 | 0,6 | 0,4 | 0,3 | 0,2 | 0,2 | 0,2 | 0,2 | 0,2 | 0,1 |
| Total amount of water, % of mass | 24,7 | 25,2 | 25,9 | 26,5 | 26,9 | 27,2 | 27,4 | 27,6 | 27,8 | 28,0 | 28,2 | 28,3 |
| Salts, % of mass | 9,1 | 6,2 | 9,3 | 8,3 | 5,2 | 4,8 | 4,5 | 4,1 | 3,9 | 3,5 | 3,7 | 3,6 |
| Total amount of salts, % of mass | 164,4 | 170,6 | 179,9 | 188,2 | 193,4 | 198,2 | 202,7 | 206,8 | 210,7 | 214,2 | 217,9 | 221,5 |



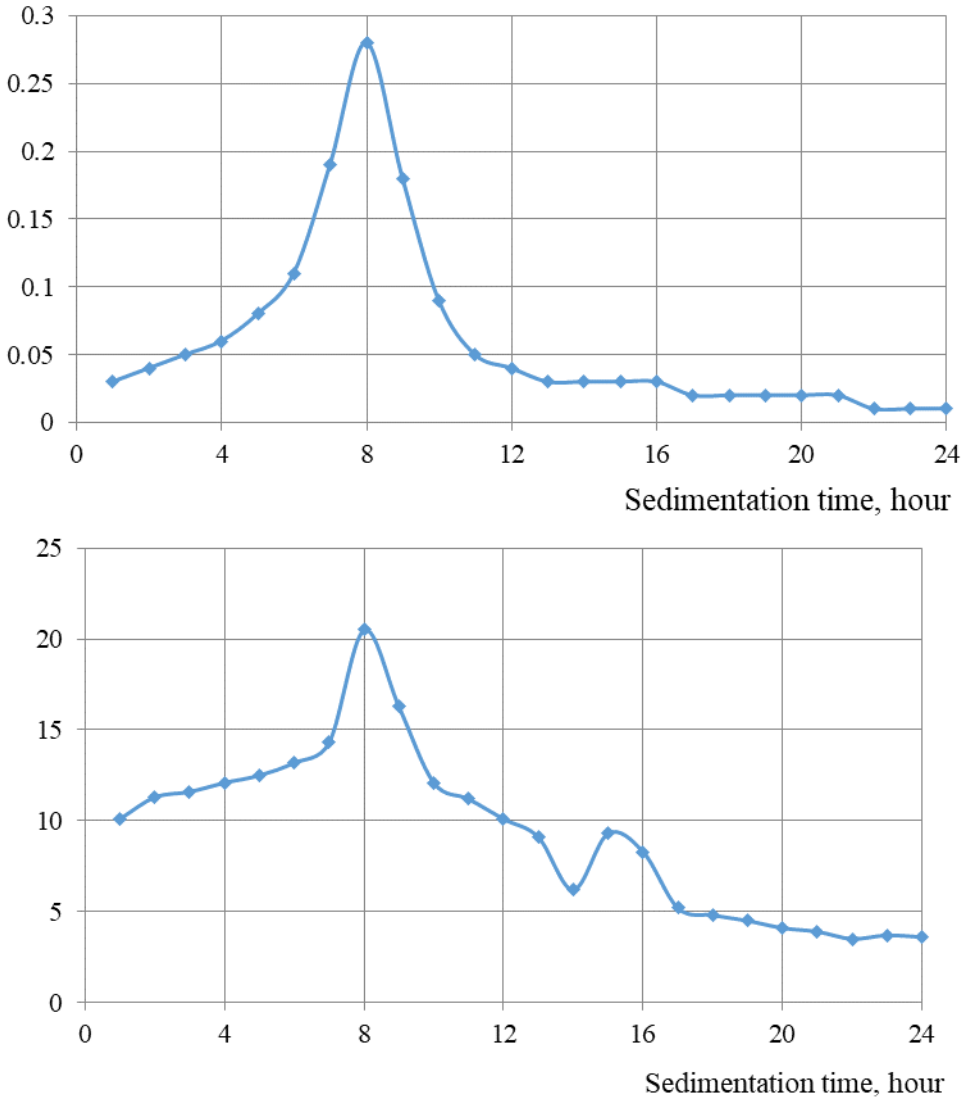



**Figure 6**. Sedimentation kinetics of ballasts in GO: BO (42:58%) mixtures at t=20 $^{0}$C

**Declarations**
The manuscript has not been submitted to any other journal or conference.

**Study Limitations**
There are no limitations that could affect the results of the study.

**Acknowledgment**
The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

## REFERENCES

1. Nurullayev V. H., Usubaliev B. T., Gurbanov G. R. Coordination compounds for rheological and physical-chemical regularity of energy consumption decrease while transporting crude oils // Turkish Journal of Engineering, 2023, № 3, P. 180-185.
2. Nurullayev V. H., Usubaliev B. T., Gurbanov G. R. Investigation of effect of additives on rheological properties and asphalt-rezin-paraffin compounds of crude oil // World Scientific News, 2021, № 2, P. 148-160.
3. Nurullayev V. H., Usubaliyev B.T. New methods of struggle with asphalt-rezin-paraffin deposits in processes of oil transportation // Proceedings on Engineering. 2021, № 2, P. 193-2000.
4. Ismayilov G.G., Serkebaeva B.S., Adygezalova M.V. On some problems of infield treatment of oil and water// Bulletin of the Higher Technical Educational Institutions of Azerbaijan, Vol. 18, № 1, 2016, p.29-38
5. Ismayilova, F. B. Formation of sedimentation in oil mixing. // Azerbaijan Oil Industry, no. 12 December 15, 2020. Pp. 36–38. http://dx.doi.org/10.37474/0365-8554/2020-12-36-38.
6. Ismayilov G.G., Nurmamedova R.G., Nurullayev V.Kh., Zeynalov R.L. On specific problems in the mixing of oils. // Journal of Azerbaijan Oil Industry, 2015, no.10, pp. 30–37.
7. Ismayilov G.G., Nurullayev V.KH., Adygezalova M.B. On the rheo-nano-chemical characteristics of oil mixtures. Heralds of Azerbaijan Engineering Academy, 2017, vol. 9, no. 4, pp. 75–85.
8. Ismayilov G.G., Adygezalova M.B., Zeynalov R.L. Manifestation of “incompatibility” in oil mixtures.//Teoreticheskaya i prikladnaya mekhanika, 2016, no. 3–4, pp. 114–117.
9. M.B. Adygezalova. ON THE FRACTAL PROPERTIES OF BALLAST DEPOSITION DURING OIL BLENDING // Transport and storage oil products and hydrocarbon feedstocks, 2020. № 4. Pp. 34–36.
10. Ilyushin PY, Vyatkin KA, Kozlov AV. Investigation of rheological properties of oil during the formation of wax deposits // Results Eng., 2022, № 14, P. 19-24.
11. Pavel Ilyushin, Kirill Vyatkin, Daniel Andreev. Study of the influence of dosing conditions of wax inhibitors on its efficiency using numerical simulation // Proceedings of the Institution of Mechanical Engineers, Part E: Journal of Process Mechanical Engineering, 2023, No. 2, P. 14-21.
12. Sandyga M. S., Struchkov I. A., Rogachev M. K. Research of temperature conditions of organic sediments formation in the productive formation at paraffinic oil well production // Perm J. Petroleum Mining Eng., 2021, No. 21, P. 84–93.
13. Haj-Shafiei S, Mehrotra AK. Achieving cold flow conditions for waxy mixtures with minimum solid deposition // Fuel, 2019, No. 235, P. 1092–1099.
14. Ilyushin P. Y., Vyatkin K. A., Kozlov A. V. Development of a method for estimating thermal conductivity of organic deposits on the wax flow loop laboratory installation // Int J. Eng., 2022, No.35, P. 1178–1185.
15. Yao B, et al. Advances in and perspectives on strategies for improving the flowability of waxy oils // Energy Fuels, 2022, No.36, P. 7987–8025.

16. Struchkov, M.K.Rogachev. Wax precipitation in multicomponent hydrocarbon system. // J Petroleum Exploration and Production Technology, 2017, 7: Pp. 543–553 DOI 10.1007/s13202-016-0276-0.
17. Struchkov IA, Rogachev MK // Risk of wax precipitation in oil well. Nat Res. 25(2016): Pp.1–7
18. Ju Xue, Changjun Li, Qianwei He. Modeling of wax and asphaltene precipitation in crude oils using four-phase equilibrium. // Fluid Phase Equilibria, Volume 497, 1 October 2019, Pages 122-132.
19. Haijun Luo, Jiangbo Wen, Chunlei Lv, Zhihua Wang. Modeling of viscosity of unstable crude oil–water mixture by characterization of energy consumption and crude oil physical properties. // Journal of Petroleum Science and Engineering, Volume 212, May 2022, 110222.
20. G.G.Ismayilov, E.Kh.Iskandarov, F.B.Ismayilova. DEPOSITION OF CHEMICAL BALLASTS IN "UNDESIRABLE" OIL MIXTURES / International Conference on actual Problems of Chemical Engineering, Dedicate to the 100th anniversary of ASOIU, Baku, Pp 397-399.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI:10.36962/CESAJSC58012024-59

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# INFORMATION SECURITY RISKS MONITORING AND MANAGEMENT SYSTEM

**Ferid Agayev[1], Khatire Hesenli[2], Rahib Agababayev[3]**
[1,2]Azerbaijan State Oil and Industry University,
[1]Electronics and Automation, PhD, agayev_f_h@yahoo.com
[2]Computer engineering, PhD student, doc.xatire.hesenli@gmail.com
[3]Azerbaijan Technical University, Cyber Security, Teacher, rahib.agb@gmail.com
[1]ORCID: 0000-0001-5435-8719, [2]ORCID: 0000-0001-9527-6488, [3]ORCID: 0000-0002-1536-0741

## ABSTRACT

In this research, the information phenomenon is examined from a wide perspective, the concepts of data, information and inventory are explained, the impact and dimensions of information technologies on information are revealed, the difficulty of obtaining information security arising from the need to protect information is investigated, and the main elements of information security are highlighted. This work summarizes the security processes needed to create effective information security in an environment where information security attacks are increasing in both number and variety. As a result, the issues explained, investigated and summarized were widely evaluated, and an important step was taken to create a new technology.
**Keywords:** inventory, security, information security, information

## Introduction

Although this article is designed to improve the management of cybersecurity risks in critical infrastructure, it can be used by organizations in any sector or community. The project enables organizations, regardless of the degree or size of their cybersecurity risk, to apply risk management principles and best practices to improve cybersecurity – improving security and resilience [4].

## The concept of information security

What is security? There is no single definition of "Information security". The concept of "information security" is always related to a specific subject (acting) in certain conditions (environment) (for example, information security of any system or organization).

The article examines information security at the organizational level. As we mentioned above, there is no specific definition of information security, but the most complete definition that can be given to this concept at the level that we will investigate is as follows: In an environment where access to information is provided permanently, information is kept confidential from the server to the client, without its integrity being violated, without being subject to change and by outsiders. The process of delivering it under fully protected conditions without being intercepted by is defined as information security[5].

## Problem statement

Organizational information security consists of complex processes that must be managed under a single roof, influenced by many factors such as human factor, education, technology. The management of these processes, the construction of security systems in accordance with

international standards, and the standardization work under the management of information security at a high level continue rapidly[3].

It has become almost necessary for administrations, organizations and enterprises to apply information security standards in their organizations in order to ensure information security within the framework of certain security standards and to be able to continue their business processes without damage or with minimal damage in the face of internal and external threats. Organizational information security can be thought of as identifying the weaknesses of organizations' information assets and taking measures by conducting necessary security analyzes in order to protect them from unwanted threats and dangers.

With the widespread use of the Internet, protection or security gaps in information systems have also begun to increase. Many safeguards and projects have been developed and are still being developed to ensure privacy, integrity and continuity in information systems.

Within the framework of the research, literature research was first conducted, the existing projects were reviewed, their advantages and disadvantages were examined, and we created our product based on all this extensive research. We can refer to the general standards and the literature we refer to during the research[6].

There are 14 categories in ISO 27001 annex A. How you meet these requirements when building an information security management system depends on the specifics of your organization. This standard can be described as a catalog of its security controls, as well as a management direction for information security. Its purpose is to manage the direction and support of information security according to the requirements of the organization, ensuring that employees and contractors understand their responsibilities and are appropriate for their assumed roles.

Now let's move on to SANS (sysadmin, audit, network, security) - prioritizing security measures and implementing them is the first step, and the SANS Institute has developed a list of the top 20 most important security controls that businesses should implement. These include some obvious steps, such as a thorough inventory of all network devices and software, implementing secure hardware configurations, and ensuring data recovery, but also some less obvious areas. Even if an organization can't manage all the Top 20, it's a good list to include in a comprehensive set of targets that is updated periodically as the threat landscape changes[7]:

1. Equipment Inventory
2. Software Inventory
3. Hardware and Software Secure Configurations on Mobile Devices, Laptops, Workstations and Servers
4. Assessment and elimination of persistent sensitivity
5. Malware protection
6. Software Security
7. Wireless network access control
8. Data recovery capability
9. Security Skills Assessment and Appropriate Training to Fill Gaps
10. Secure Configurations for Network Devices such as Firewalls, Routers, and Switches
11. Restriction and control of network ports, protocols and services
12. Controlled use of administrative rights
13. Border Protection
14. Maintenance, monitoring and analysis of audit logs
15. Controlled access based on need to know

16. Monitoring and control of accounts.
17. Data protection.
18. Incident response and management.
19. Secure Network Engineering.
20. Provision of intervention trials and assignments

The next one we will talk about is Cobit. Today, Cobit is used worldwide by all IT business process managers to equip them with a model to value the organization and implement better risk management practices related to IT processes[8]. The Cobit control model guarantees the integrity of the information system. It is a framework created by ISACA (Information Systems Audit and Control Association) for IT governance and management. It is designed as a supporting tool for management and allows bridging the crucial gap between technical issues, business risks and control requirements. Cobit is a universally recognized guideline that can be applied to any organization in any industry. In general, Cobit ensures the quality, control and reliability of information systems in an organization, which is the most important aspect of every modern business. Cobit business orientation involves linking business goals to IT infrastructure, providing various maturity models and indicators that measure success in defining the related business responsibilities of IT processes[9]. The main focus of COBIT 4.1 is illustrated by a process-based model divided into four specific areas:

1. Planning and Organization
2. Delivery and support
3. Acquisition and implementation
4. Monitoring and evaluation

We can go to the detailed information section about Information Security Risk Monitoring and Management System - ISRMMS, which is the first national product that we created taking into account the standards and international requirements that we talked about above.

ISRMMS (after that, the system)- This system was a unified platform developed for IT management in the institution. Main functions:

• Automation of inventory and preparation of statistical indicators
• Monitoring of resources
• Registration and analysis of risks
• Incident registration and analysis
• Sending Notices
• Registration of documents

**The solution of the problem**

In this system, it is ensured that information is delivered from the server to the client or from the client to the server in a confidential manner, without breaking the integrity, without being changed and without being intercepted by outsiders, under fully protected conditions. Unlike all other systems written so far, this system uses the RSA encryption algorithm. Initially, this function of the system takes precedence over others [1].

The system was primarily implemented to monitor resources on all Microsoft Windows Operating Systems (OS). Monitors OS CPU, RAM, Network, Permanent memory indicators in real-time environment and saves the results. Also, the OS takes inventory of all the resources of the running machine. Based on the indicators applied to the use of resources, the changes are reported in the

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



alarm and warning format. The system is written in the C# programming language in .Net and consists of 3 parts: Agent, Web Interface and Web Service.

The agent part, which runs in the background in OSes and runs without any negative impact on their operating process - can be loaded directly in MSI format or through a centralized control (Domain Control) system. Data is stored in a DB defined in SQL. The Agent transmits the Data to the server in an encrypted form and at a certain time interval. Registration and search of all available and changed resources of the agent applied assets, used software is carried out through the web service [10].

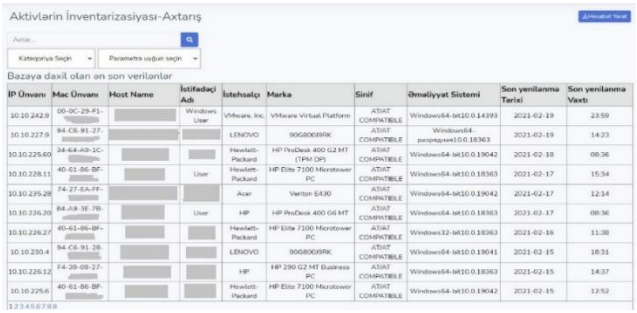



**Figure 1.** Asset inventory – search.

All resource manufacturers, settings, etc. preparation of statistics based on indicators is ensured.

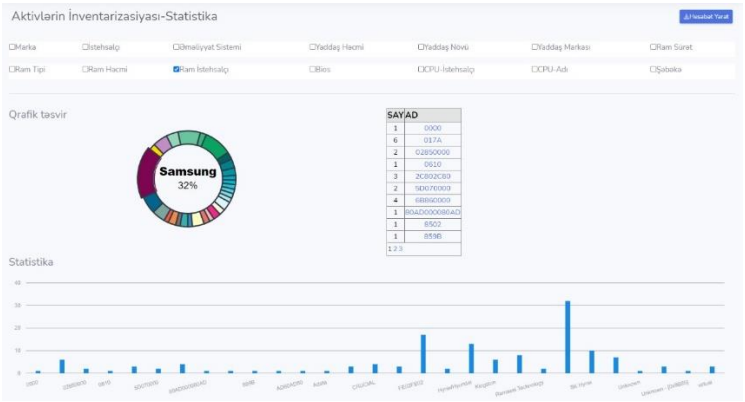



**Figure 2.** Inventory of assets - statistics.

Asset resources are monitored in real time, graphs are drawn up, and notifications are sent based on the applied limits.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



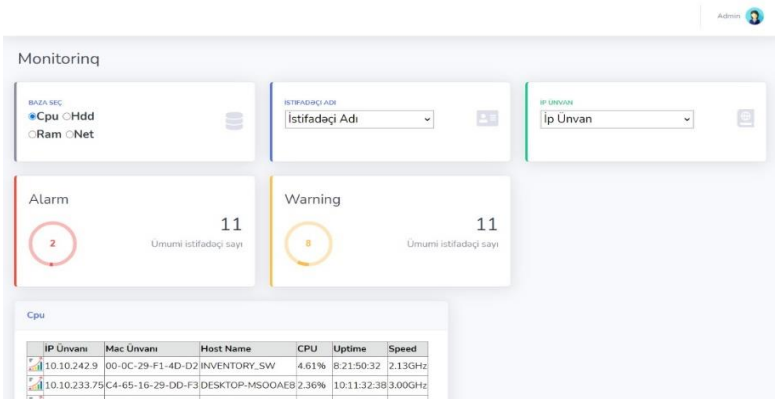



**Figure 3.** Monitoring

Through the system, it is possible to obtain a monitoring report for periods or a set time interval. According to the selected category, it is possible to get either just the data of the day, the data of the selected dates, or even the data of the selected hours on the selected dates.


**Figure 4.** Monitoring report

Registration and analysis of Information Security risks and incidents are ensured in the institution.


**Figure 5.** Registration of risks.

**Conclusion**
**ISRMMS the benefits of drying the application:**

• Conducting an audit of asset resources and software.
• Risk assessment and analysis.
• Conducting statistics based on collected data.
• Implementation of the requirements of international IT security standards.
• Monitoring of resources.
• Incident registration and investigation.
• Registration of documents.
• Easy to use interface.
• It can be adapted to the infrastructure and requirements of the institution.

**Advantages over other systems:**

• Infrastructure integration – Unlike other open source systems, no additional configurations are required.
• Functionality – The mentioned functions are open source.
From more software packages to get on systems and configurations should be used.
• Financial costs – Less than the costs of paid software to be used to provide the mentioned functions.
• Technical support – The system is locally manufactured and can be customized according to the customer's requirements.
• Security – The system uses encryption with agents for data collection and is owned by the system. Also, all data in the system is encrypted.

**Declarations**

The manuscript has not been submitted to any other journal or conference.

**Study Limitations**

There are no limitations that could affect the results of the study.

**Acknowledgment**

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

**REFERENCES**

1. Kerimov S.Q., Hebibullayev S.B., Ibrahimzade T.I. Informatics, 2010.
2. Kerimov S.Q. Information Systems, 2010.
3. https://www.simplilearn.com/what-is-cobit-significance-and-framework-rar309-article#:~:text=COBIT%20stands%20for%20Control%20Objectives,for%20IT%20governance%20and%20management.
4. https://searchsecurity.techtarget.com/definition/COBIT
5. https://www.networkworld.com/article/2992503/sans-20-critical-security-controls-you-need-to-add.html
6. https://www.sans.org/about/?msc=main-nav

7. Dulaney E., Easttom C. CompTIA Security+ Study Guide Exam SY0-501 // 7th Edition. – 2018.
8. Wiley-IEEE. Engineering. Information. Security. Jul. 2011.
9. ISO-IEC_27001-2013-Requirements-original.
10. https://berkarat.com/rsa-sifreleme-algoritmasi/#include

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-71

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# INTELLIGENT CONTROL SYSTEM OF MULTI-MOTION MOBILE ROBOT

**Kifayat Mammadova[1], Aytan Aliyeva[2]**
[1,2]Azerbaijan State Oil and Industry University, [1,2]Department of Computer Engineering
[1]PhD, Associate Professor, lecturer; ORCID: 0000-0002-6530-2021, ka.mamedova@yandex.ru
[2]PhD student, eliyevaayten1707@gmail.com

## ABSTRACT

Technical devices with irregular motion are described by complex non-linear differential equations, as they have an uncertain environment. Due to interactions and simplifications in these types of control objects, their mathematical models may have certain errors. For this reason, by known methods, for example, the linear matrix inequality method, Lyapunov's quadratic function, etc. The synthesized automatic control systems (ACS) for dynamic objects written by nonlinear mathematical models based on the quadratic matrix determined by The synthesis of regulators for the management of dynamic objects described in nonlinear and uncertain conditions is based on fuzzy logic theory. Since the controllers synthesized by fuzzy logic are based on knowledge, their application to other objects (robots) is limited. In such systems, it is difficult or not at all to determine the dependencies between ACS quality indicators, stability and object parameters. Taking into account the above, a method of analytically parametric synthesis of regulators that ensures the degree of stability and accuracy in ACS's designed for fuzzy TS-type dynamic objects is proposed.

In the article, the solution to the problem of the synthesis of the control system of the mobile robot was considered, and it was successfully applied in the multi-motion mobile robot system. Modeling and experimental results confirm that the operation and stability of the obtained system fully meet the technical requirements. The proposed method has led to an increase in both tracking and control accuracy during high-speed movements.

**Keywords:** multi-motion mobile robot, mathematical model, mechatronic modules, fuzzy TS model, robust controller, fuzzy logic.

## Introduction

Technical devices with an irregular motion, for example, manipulative robots [1,4], mechatronic modules, technological mechanisms, dynamic control objects have uncertain conditions. Control objects of this type are described by complex nonlinear differential equations [1, 2, 4, 5, 12, 13]. Also, the relationships and simplifications in these types of control objects may have errors in their mathematical models. With these more well-known methods, I think the directed matrix inertia method, Lyapun's quadratic function, $V(t) = x^T(t)Px(t)$-$P$ to generate a quadratic matrix defined by non-linear mathematical models for automatic control of written objects systems (AIS) cannot meet the requirements for high quality, including robustness [3-6, 8, 12, 13]. Synthesis of controllers for control of dynamic objects - mobile robots described by nonlinear and uncertainty models versus fuzzy logic theory. Since the controllers synthesized by fuzzy logic are based on knowledge, their application to other objects - robots is limited. Also, in such systems, it is difficult or impossible to change dependencies on the quality indicators and stability of the AIS and the parameters of the object. Analytical parametric synthesis of controllers providing required

stability and accuracy is provided in AISs designed for dynamic objects written by nonlinear multi-link differential equations that can be brought to TS (Tagaki-Sugeno) type mathematical models. Analytically synthesized parametric TS type fuzzy controller application to the control of a multi-motion mobile robot and the requirement for AIS modeling have not been formulated. MM mobile robot with robust control system provides maximum possible stability and fast operation in terms of both speed and coordinates.

Motion control of an intelligent wheeled mobile robot in unstructured environments is presented in [13]. Fuzzy control of wheeled mobile robot movement in obstacles and unstructured environments is proposed. The outputs of the fuzzy controller are the difference of the angular velocity between the left and right wheels of the mobile robot and the velocity of the mobile robot. The simulation results show the effectiveness and reliability of the obstacle avoidance behavior in an unstructured environment and the speed control of the proposed fuzzy control strategy for the multi-motion mobile robot movement. In this work, wireless sensor-based remote control of mobile robot movement in unstructured environments is proposed by applying Sun SPOT technology.

In this work, a method of analytical synthesis of fuzzy TS model controllers is proposed, which provides robustness due to the stability of irregularly moving dynamic objects with parametric uncertainty.

**Mathematical model of robust controller for dynamic objects with uncertainty written by multi-link fuzzy TS model.**

The dynamic movement of kinematic items (joints) of most mobile and manipulative robots is written by $n$-order multi-link nonlinear differential equations [6, 8, 12, 13]. Non-linear mathematical models of robots can sometimes be replaced by fuzzy TS-type models [3-6, 8, 12, 13]. In control systems written with a fuzzy TS-type model, in solving the problem of the synthesis of the regulator, the conditions of stability (stability) satisfaction are mainly used. In this case, it is not determined whether the degree of stability is high or not. In addition, in some methods, it is not possible to take into account the degree of satisfaction of the requirements of the control system to other quality criteria in the process of synthesis of the regulator. For example, in the linear matrix inequality (LMI-linear matrix inequalities) method, which is used to solve the problem of the synthesis of the regulator in non-linear dynamic objects, only the conditions for the stability of the system are taken into account. In this method, the problem of synthesis is a sequential iterative procedure, and it is not possible to take into account other quality parameters of the system. In the linear matrix inequality method, the set parameters of the regulator can be quite large and have different signs. In practice, this is not always possible. In other words, there are no restrictions on the tuning parameters of the regulator. This is unacceptable from the point of view of practical implementation. Dynamic objects with many uncertainties and irregular motions, such as MM mobile robots, can be generally written in the form of a fuzzy differential embedding equation:

$$\begin{gathered}\dot{x}(t) \in f(x(t),u(t),p), \\ y(t) \in \varphi\big(x(t),u(t)\big), \\ x \in R^{n_x}, u \in R^{n_u}, t\epsilon[t_0,t_N], p \in P\end{gathered} \qquad (1)$$

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



Here, the vectors characterizing the technical characteristics of the $x$-object are vague, imprecise parameters: $nx = dimx$-dimensional vector, $u$ - $nu = dimu$ - dimensional vector, $p$-$n_P = dimp$-dimensional vector. Sometimes, some of them express external excitatory influences. $y(t)$ is the object's output variable of size $my = dimy$. $P$ - characterizes the range (multiple) of changes of $p$ parameters with uncertainty. $[t_0,t_n]$ is the time interval of the control process.

When opening the parametric uncertainty of the object, that is, when synthesizing the regulator, usually in most cases the vector $p$ is described as a set of fuzzy numbers $\tilde{p} = [\tilde{p}_1, \tilde{p}_2, \ldots \tilde{p}_{np}]$, or as a set of interval numbers:

$$p_i = Supp\ \tilde{p}_i = [p_i^{\propto 1}, p_i^{\propto 2}],\ \ i = \overline{1, n_p} \qquad (2)$$

Here, $p_i^{\propto 1}$ and $p_i^{\propto 2}$ are the values of the left and right boundaries of the interval numbers, respectively. If the function $f(\cdot)$ in the model (1) is known, then the change of the state coordinates of the object will directly depend on the variation of the parameters. When designing many practical control systems, the interval over which the input vector varies is taken as the assumed nominal values. This is called the constructor's subjective evaluation. Approximation of imprecise and uncertain interval parameters with only nominal values is mainly based on concepts of fuzzy sets, i.e. "Soft Computing". Undefined dynamic objects can be described by a mathematical model of various forms, for example [1-3, 9, 10]:

$$\dot{\tilde{x}}(t) = A\tilde{x}(t) + B\tilde{u}(t)$$
$$\tilde{y}(t) = C\tilde{x}(t) \qquad (3)$$

or

$$\dot{x}(t) = \tilde{A}x + \tilde{B}u$$
$$y(t) = \tilde{C}x \qquad (4)$$

In model (3), A, B, and C are smooth-ordinary coefficient matrices of appropriate size. In model (4), $\tilde{A}$, $\tilde{B}$, and $\tilde{C}$ are matrices of fuzzy numbers of suitable size. By describing this type of object with ordinary differential equations with interval coefficients, it is possible to analytically synthesize the interval-valued parameters of the regulator, which ensures stable movement of the control system [7].

The behavior of a number of uncertain, nonlinear dynamic objects, including manipulators and mobile robots, such as multi-motion mobile robots, can be described by the following TS-type fuzzy model:

$$Q_i\text{: IF } z_1(t)\ is\ M_1^i \text{ AND } z_2(t)\ is\ M_2^i \ldots \text{ AND } z_n(t)\ is\ M_n^i$$
$$\text{THEN, } \dot{x} = A_i x(t) + B_i u(t),\quad y(t) = C_i x(t),\quad i = \overline{1, q} \qquad (5)$$

where, $M_n^i$ - is the fuzzy term set of the jth state change of the object, having the membership function $\mu_j^i$. $A_i$, $B_i$, and $C_i$ are parametric matrices of dimensions $A$ ($n \times n$ - dimensional), B (n×m dimensional), $C$($r \times n$ dimensional) corresponding to linguistic rule. $i$, respectively, $i = \overline{1, q}$ is the serial number of linguistic rules. The vector of state and output variables of the uncertain,

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



nonlinear object described by the model (5) can be described by the differential equation (6) with sufficient accuracy:

$$\dot{x}(t) = \sum_{i=1}^{q} \mu_i(x) \left(A_i x(t) + B_i u(t)\right), y(t) = \sum_{i=1}^{q} \mu_i(x) C_i x(t) \qquad (6)$$

The functions $\mu_i(x)$– here [1-3] are basically defined as follows:

$$\mu_i(x) = \frac{\omega_i(x)}{\sum_{i=1}^{q} \omega_i(x)}, \omega_i(x) = \Pi_{j=1}^{q} \varkappa_j^i, i = \overline{1,q} \qquad (7)$$

One of the requirements for controlling an object (for example, a multirole mobile robot) is that the system provides tracking of both the state variables (velocity) and the output variables task. That is, it must be managed astatically due to the error. To meet the demand, it is necessary to formalize the structure of the regulator in the control system as follows:

$$T_i: \text{IF } x_1(t) \text{ is } M_1^i \text{ AND } x_2(t) \text{ is } M_2^i \ldots \text{ AND } x_n(t) \text{ is } M_n^i$$
$$\text{THEN, } u_i = K_i x(t) + G_i e(t), i = \overline{1,q} \qquad (8)$$

Here, $e(t)$ is the deviation of the object's output $y(t)$-variables vector from the task $ytask(t)$-values. Is defined as follows:

$$\dot{e}(t) = y_{tap}(t) - y(t) = y_{tap}(t) - \sum_{i=1}^{q} \mu_i(x) C_i x(t) \qquad (9)$$

Based on expressions (6), (8) and (9), the mathematical model of the closed-feedback control system can be written as follows [9]:

$$\dot{x}(t) = \sum_{i=1}^{q} \mu_i(x) A_i x(t) + \sum_{i=1}^{q} \mu_i(x) B_i \left(\sum_{j=1}^{q} \mu_i(x) (K_j x(t) + G_j e(t)\right) \qquad (10)$$

Taking into account (9) and making some simple transformations in the expression (10), the mathematical model of the closed fuzzy control system can be written as follows [9]:

$$\tilde{\dot{x}}(t) = \sum_{i=1}^{q} \mu_i \sum_{j=1}^{q} \mu_j \tilde{A}_{ij}(p) \tilde{x}(t) + N y_{tap}(t)$$

$$y(t) = \sum_{i=1}^{q} \mu_i \tilde{C}_i \tilde{x}(t) \qquad (11)$$

here,

$$\tilde{A}_{ij}(p) = \begin{bmatrix} A_i(p) + B_i(p) K_i & B_i(p) G_i \\ -C_i & 0 \end{bmatrix},$$

$$N = \begin{bmatrix} 0 \\ \hline E \end{bmatrix},$$

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$$\tilde{C}_j = [C_i \quad 0], \tilde{x}(t) = \begin{bmatrix} x \\ e \end{bmatrix}, \qquad i, j = \overline{1, q}$$

$$A_i(p) = A_i + \Delta A_i, B_i(p) = B_i + \Delta B_i, \quad 0 \le \Delta A_i \ll A_{inom}, 0 \le \Delta B_i \ll B_{inom} \qquad (12)$$

$\tilde{x}(t)$–$2n_x$ -dimensional, $y_{task}(t)$–$n_y = n_x$ are vectors, $E - n_x \times n_x$ is a unit matrix, $0 - n_x \times n_x$ is a zero matrix. Taking into account statements (5), (8) and (9), the structural scheme of the TS-type fuzzy control system is depicted in Figure 1.

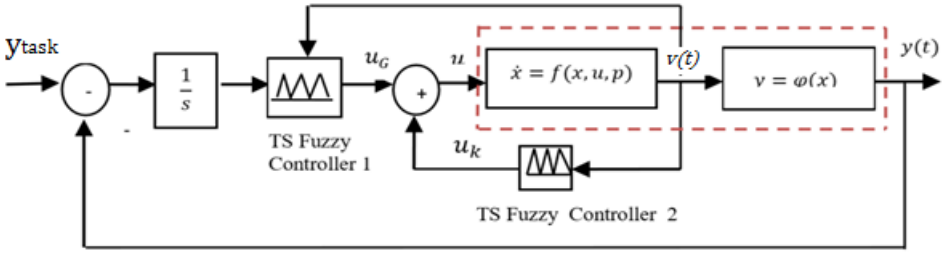



**Figure 1.** Generalized structural scheme of the state and error astatic fuzzy TS model control system.

$\Delta A_i$ and $\Delta B_i$ are parametric biases that take into account the parametric uncertainties of the object, and in some cases, they are taken equal to 0.1-2.0% of the corresponding nominal value.

**Statement of the problem**

Taking into account the fact that the uncertain, non-linear multi-link control system has an astatic property with respect to the variables expressed in (6)-(9), and the requirement to satisfy the robustness according to the degree of stability of the state variables, the problem of the synthesis of the regulator can be formalized as follows. For an object with uncertainties that can be written by the expression (6), it is necessary to synthesize a robust TS-type fuzzy controller so that the multi-link and multidimensional closed control system can track the output coordinates task effects $ytas$k$(t)$ and the planned movement trajectory with high accuracy. That is, under the conditions of astatic due to error.

$$\lim_{t \to \infty} e(t) = 0, \qquad (13)$$

and parametric uncertainties (12), let it satisfy the maximum degree of stability possible according to state coordinates

$$J_1^i = \max_{K,G}(-Re(\lambda^i(A_i(p), K_i, G_i) = \delta_i + \max_{K,G}(-Re(\check{\lambda}^i(A_i, K_i, G_i))), \qquad (14)$$

$$J_2^i = \min_{K,G} \|e(A_i, K_i, G_i)\|, \qquad (15)$$

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$$J_3^i = \max_{K,G}\left\{m^i = \frac{\left|-Re(\lambda^i(A_i(p),K_i,G_i)\right|}{\left|Im(\lambda^i(A_i(p),K_i,G_i)\right|}\right\}, \quad (16)$$

$$K_i \in K,\ G_i \in G,\ i = \overline{1,q}.$$

Here, $\boldsymbol{\delta_i} > 0, \forall i \in \overline{1,q}$ - characterizes the possible maximal value of the degree of stability of the system according to each linguistic rule. Given the (6)-(9) structure of the management system, let's draw up the characteristic equation for each linguistic rule:

$$D_i(\lambda) = (s+\lambda_{1i})\dots(s+\lambda_{ni}) = \left(s+\delta_i+\check{\lambda}_{ni}\right) = 0, i = \overline{1,q} \quad (17)$$

Depending on the conditions for satisfying the stability of the motion, the $K_i$ və $G_i$, $i = \overline{1,q}$ parameters of the tuning coefficients matrices of the robust TS-type fuzzy controller can be determined analytically [2,10].

**The solution of the problem**

Let's explain the method of solving the problem of the synthesis of the TS-type fuzzy controller on the example of a specific control object, for example, a mobile robot [12]. A multi-motion (MM) mobile robot has four wheels and three state variables $(t) = [\dot{x}_w(t),\dot{y}_w(t),\dot{\varphi}_w(t)]$ and $u(t) = [u_1(t),u_2(t),u_3(t),u_4(t)]$ (controlling effects) and is written with a non-linear model [5]. After performing some simple transformations on this model ($u(t) = B\bar{u}(t), \bar{u}(t) = [\bar{u}_1(t)\ \bar{u}_2(t)\ \bar{u}_3(t)]$), the MM mobile robot below can be written as a nonlinear model with uncertainty.

$$Q_i: \text{IF } \dot{\varphi}_w(t) \text{ is } M^i \text{ THEN, } \dot{x} = A_i x(t) + B_i\bar{u}(t), y(t) = C_i x(t),\ \ i = \overline{1,q} \quad (18)$$

$$A_1 = \begin{bmatrix} a_1 & 0 & 0 \\ 0 & a_1 & 0 \\ 0 & 0 & a_3 \end{bmatrix}, A_2 = \begin{bmatrix} a_1 & -a_2 d & 0 \\ a_2 d & a_1 & 0 \\ 0 & 0 & a_3 \end{bmatrix}, \quad A_1 = \begin{bmatrix} a_1 & a_2 d & 0 \\ -a_2 d & a_1 & 0 \\ 0 & 0 & a_3 \end{bmatrix}, B_i = \mathrm{I},$$

$$C_i = \mathrm{I}$$

or

$$\ddot{x}_w(t) = a_1\dot{x}_w(t) + \ddot{\bar{u}}_{1l}(t),$$
$$y_w(t) = a_1\dot{y}_w(t) + \bar{u}_{2i}(t),$$
$$\ddot{\varphi}_w(t) = a_3\dot{\varphi}_w(t) + \bar{u}_{3i}(t), i = 1 \quad (19)$$

$$\ddot{x}_w(t) = a_1\dot{x}_w(t) - \ddot{a}_2 d\dot{y}_w + \bar{u}_{1l}(t),$$
$$y_w(t) = a_2 d\dot{x}_w(t) + a_1\dot{y}_w(t) + \bar{u}_{2i}(t),$$
$$\ddot{\varphi}_w(t) = a_3\dot{\varphi}_w(t) + \bar{u}_{3i}(t), i = 2 \quad (20)$$
$$\ddot{x}_w(t) = a_1\dot{x}_w(t) + \ddot{a}_2 d\dot{y}_w + \bar{u}_{1l}(t),$$
$$y_w(t) = -a_2 d\dot{x}_w(t) + a_1\dot{y}_w(t) + \bar{u}_{2i}(t),$$
$$\ddot{\varphi}_w(t) = a_3\dot{\varphi}_w(t) + \bar{u}_{3i}(t), \quad i = 3 \quad (21)$$

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



Here ***I*** is a three-dimensional uniform matrix, coefficients $a_1$, $a_2$, $a_3$ are determined depending on the physical and geometrical parameters of the MM mobile robot [12]:

$$a_1 = -2\mathrm{J}/(mr^2 + 2\mathrm{I}_w)\,, a_2 = 2\mathrm{I}_w/(mr^2 + 2\mathrm{I}_w), a_3 = -4cL^2/(4\mathrm{I}_w mL^2 + \mathrm{I}_v r^2) \qquad (22)$$

Parametric uncertainty is mainly related to $a_2\varphi w(t) = a_2 d$ in model (23), i.e.

$$a_{2i} = a_2\dot{\varphi}_{nom}(t) + \Delta a_2 = a_2 d + \Delta a_2, \Delta a_2 \in [0,\sigma], \sigma = 0.001 a_2\dot{\varphi}_{nom}(t) \qquad (23)$$

Given the structure of the object (22) ($x3$ does not depend on the state variables $x1$, $x2$) and (8), the structure of control (regulation) for each linguistic rule can be determined as follows:

$$\begin{gathered}
\bar{u}_{1i}(t) = k_{11i}\dot{x}_1(t) + g_{11i}(y_{1T} - x_1),\ \bar{u}_{2i}(t) = k_{22i}\dot{x}_2(t) + g_{22i}(y_{1T} - x_2),\\
\bar{u}_{3i}(t) = k_{33i}\dot{x}_3(t) + g_{33i}(y_{1T} - x_3),\quad i = 1\\
\bar{u}_{1i}(t) = k_{11i}\dot{x}_1(t) + k_{12i}\dot{x}_2(t) + g_{11i}(y_{1T} - x_1),\\
\bar{u}_{2i}(t) = k_{21i}\dot{x}_1(t) + k_{22i}\dot{x}_2(t) + g_{22i}(y_{1T} - x_2),\\
\bar{u}_{3i}(t) = -k_{33i}\dot{x}_3(t) + g_{33i}(y_{1T} - x_3),\quad i = 2\\
\bar{u}_{1i}(t) = k_{11i}\dot{x}_1(t) + k_{12i}\dot{x}_2(t) + g_{11i}(y_{1T} - x_1),\\
\bar{u}_{2i}(t) = k_{21i}\dot{x}_1(t) + k_{22i}\dot{x}_2(t) + g_{22i}(y_{1T} - x_2),\\
\bar{u}_{3i}(t) = k_{33i}\dot{x}_3(t) + g_{33i}(y_{1T} - x_3),\quad i = 3\\
\bar{u}_{1i}(t) = k_{11i}\dot{x}_1(t) + k_{12i}\dot{x}_2(t) + g_{11i}(y_{1Tap} - c_{22}x_2)\\
\bar{u}_{3i}(t) = k_{33i}\dot{x}_3(t) + g_{33i}(y_{1T} - C_{33}x_3),\ i = \overline{1,q}
\end{gathered} \qquad (2.8)$$

Taking into account the mentioned properties and (22)-(24), then the free movement of the system for each linguistic rule can be written by the following equations (for simplicity, we do not show the indices of the number of linguistic rules $i = \overline{1,q}$:

$$\begin{gathered}
\ddot{x}_1(t) = (a_1 - k_{11})\dot{x}_1 - (a_2 d + \Delta a_2 + k_{12})\dot{x}_2 + g_{11}x_1\\
\ddot{x}_2(t) = (a_2 d + \Delta a_2 - k_{21})\dot{x}_1 + (a_1 - k_{22})\dot{x}_2 + g_{22}x_2\\
\ddot{x}_3(t) = -k_{33i}\dot{x}_3 + g_{33}x_3
\end{gathered} \qquad (25)$$

or

$$\begin{gathered}
[s^2 + (k_{11} - a_1)s - g_{11}]X_1(s) = -[s(a_2 d + \Delta a_2 + k_{12})]X_2(s)\\
[s^2 + (k_{22} - a_1)s - g_{22}]X_2(s) = -[s(k_{21} - (a_2 d + \Delta a_2)]X_1(s)\\
[s^2 + k_{33}s - g_{33}]X_3(s) = 0
\end{gathered} \qquad (26)$$

$|k_{12}|=|k_{21}|$ and $|g_{11}|=|g_{22}|$, $c_{11}=c_{22}=c_{33}=1$ can be accepted. Based model of the system (27), it seems the $x3$-coordinate does not directly depend on other coordinates. In this case, one of the characteristic equations of the system is described by a 4-form and the other by a 2-form equation:

$$s^4 + s^3[k_{11i} + k_{22i} - 2a_1] + s^2[(k_{11i} - a_1)(k_{22i} - a_1) - 2g_{11i} + (a_2 d + \Delta a_{2i})^2 - k_{12}^2 i] +$$

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$$+s[2a_1 g_{11i} - (k_{11i} + k_{22i})] + g_{11i}^2 = 0$$
$$s^2 + sk_{33i} - g_{33i} = 0,\ i = \overline{1,q} \qquad (27)$$

In the system written in the form of the characteristic equation (27), we determine the expressions of dependence on the parameters of the distribution of the roots by the method of analytical synthesis proposed in [1, 2]. It is appropriate to solve the problem analytically in two variants, i.e., for cases where the roots are negative real and complex. As in [1, 2], the parametric characteristic equations of the system $D(\lambda)$=0; and its derivatives – D΄(λ), D˝(λ) of the appropriate characteristic equation expressed by roots $\Phi(\lambda)$=0; and from the equality conditions of its appropriate derivatives Φ΄(λ), Φ˝(λ) the analytical expressions of the parameters $Ki$ and $Gi$ of the controllers for the state variables and the error are determined. In the first option, that is, if the roots of the characteristic equation are negative and equal, the dependence of the tuning parameters of the regulator on the degree of stability and the parameters-coefficients of the object is expressed as follows [7]:

$$J^i + \delta = \frac{-k_{11} - a_{11}^i}{2};\ g_{11}^i = (-k_{11}^i - a_1^i)^2/4 \qquad i = \overline{1,q}$$
$$k_{11}^i = k_{22}^i = -2(J^i + \delta^i) - a^i$$
$$g_{22}^i = (-k_{11}^i - a_1^i)^2/4 \qquad (28)$$

In the second option, for the case where the roots of the characteristic equation of the system are complex, i.e., after accepting

$$\lambda_{r12}^i = -(J_r^i + \delta_r) \pm j(J_r^i + \delta_r)\frac{1}{m_{ri}},\ i = \overline{1,q} \qquad r = 1,2$$

and performing the appropriate conversion operations, we get the following analytical expressions:

$$k_{11}^i = -2(J_r^i + \delta_r^i) - a_1^i \quad r = 1 \quad g_{11}^i = (-k_{11}^i + a_1^i)^2(1 + \frac{1}{m_{r1}^2})/4$$
$$k_{22}^i = -2(J_r^i + \delta_r^i) - a_1^i \quad r = 2 \quad g_{22}^i = (-k_{22}^i + a_2^i)^2(1 + \frac{1}{m_{r2}^2})/4 \qquad (29)$$
$$k_{33}^i = -2(J_r^i + \delta_r^i) - a_1^i \quad r = 3 \quad g_{33}^i = (-k_{33}^i + a_2^i)^2(1 + \frac{1}{m_{r3}^2})/4$$

The use of expressions (28) or (29) in determining the parameters of the regulators according to the state variables, that is, the matrices $K^i$ and $Gi$, is determined directly depending on the requirements for stability degrees and the mathematical models of the object on the appropriate linguistic rules [9].

Computer modeling of the synthesized intelligent control system in the Matlab environment

Let's perform the process of fuzzy modeling of MM mobile robot with the help of Matlab program Simulink and FLT software package. As shown in Figure 2, let's model the structure of the control object S model of the MM mobile robot [10, 11].

The parameters applied in the S model are as follows:

$a_1 = a_2 = 0.0599$;

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$a_3$ = -0.07444;
integrator = 0.6;
integrator 1 = 0.5;
integrator 2 = 0.2.

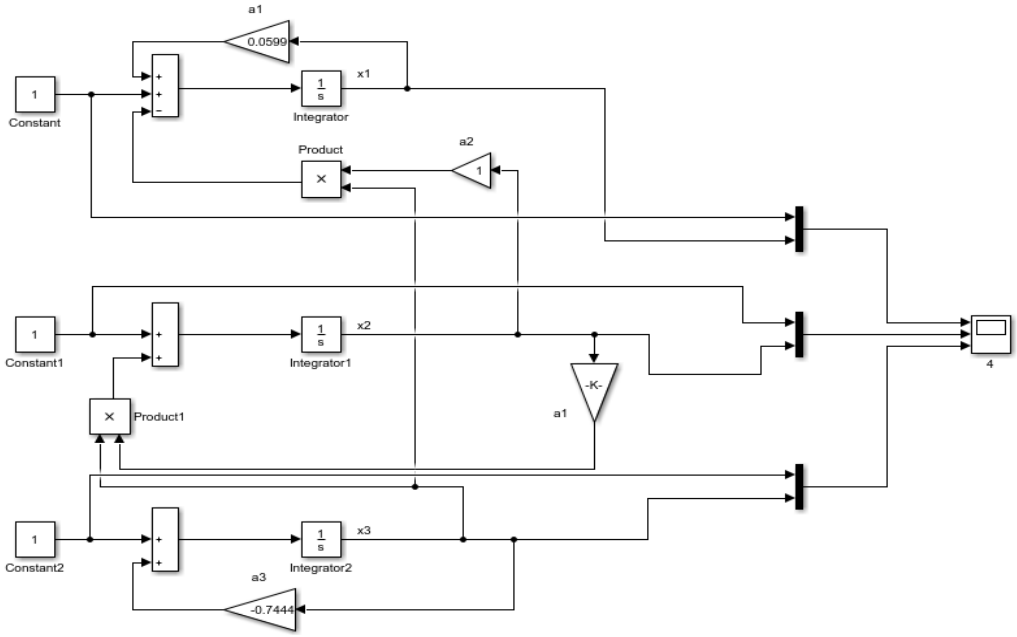



**Figure 2.** S model of MM mobile robot – control object.
1. After writing the parameters, you need to simulate and view the results of the *S* model.
2. The results of the simulation of the MM mobile robot - object *S* model can be viewed through the scope block (Figure 3).

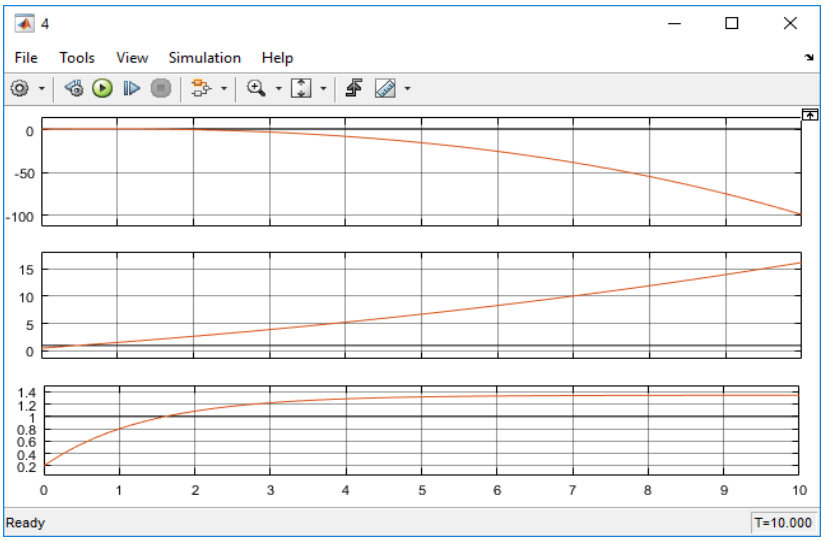



**Figure 3**. Simulation result of the MM mobile robot object.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



As can be seen from the result, unlike the given task, the result needs to be adjusted. For this, firstly, a new S model should be established, that is, rules should be drawn up based on the regulatory system and the FLT package. Then, the model S of the MM mobile robot should be included in the subsystem in the controller.

Modeling of the regulatory system based on the Simulink package in the MATLAB environment of the MM mobile robot control system

The control system of the MM mobile robot is built on the basis of FLT and Simulink packages. First, we build the S model of the regulator using the Simulink package of the Matlab program (Figure 4).

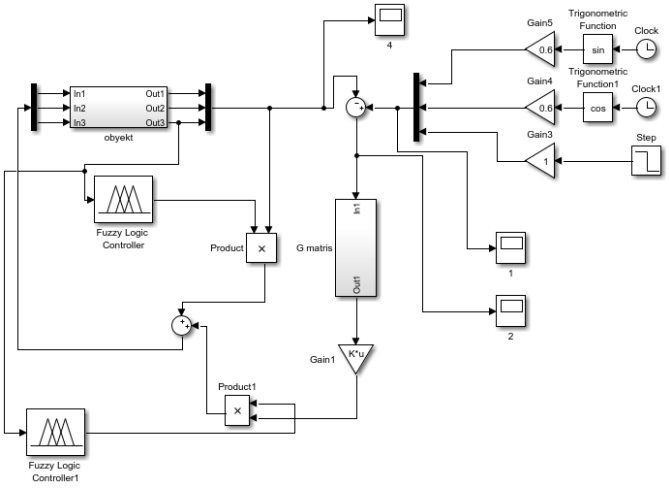
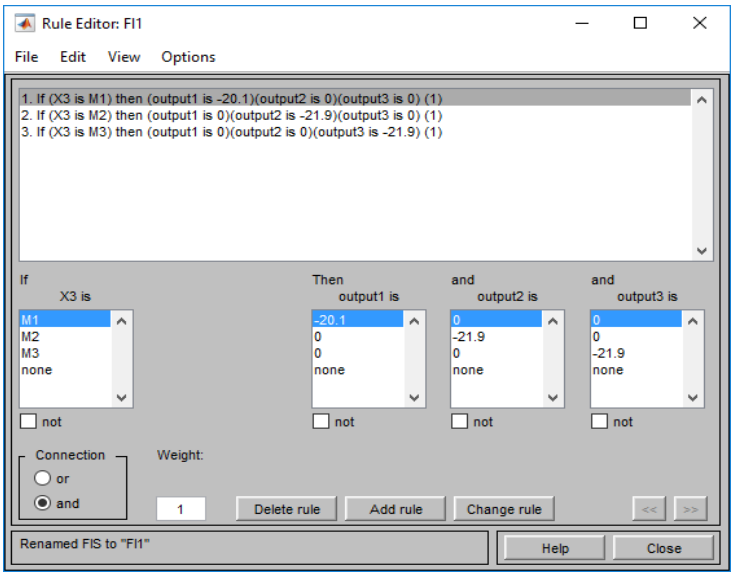



**Figure 4**. Model S of the regulatory system of the MM mobile robot.

After building the S model of the regulatory system, we compile the fuzzy term sets based on the Fuzzy Logic Toolbox package and build the rules (Figure 5).



ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**Figure 5.** Procedure for entering rules.

TS-type fuzzy controllers are added to the fuzzy logic controller blocks shown in Figure 6, where shows the model of the object in the subsystem of the regulatory system.

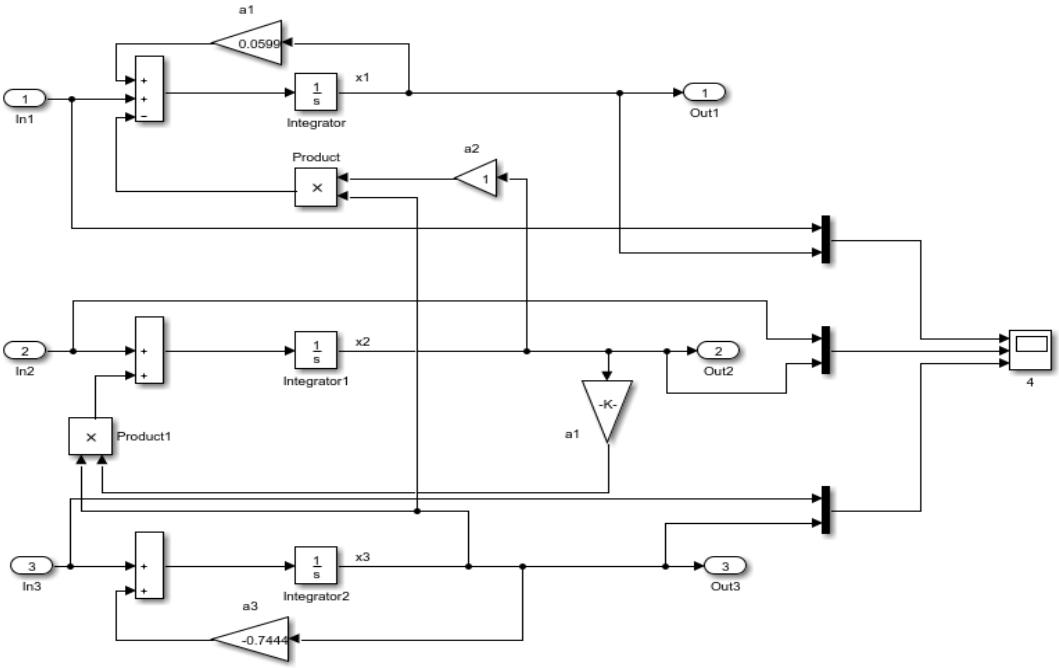



**Figure 6.** A model of an object in a regulatory system subsystem.

Figure 7 illustrates the perfect tuning performance. The control of the MM mobile robot is stable and provides high quality indicators. The object adjustment time does not exceed 0.3 seconds.

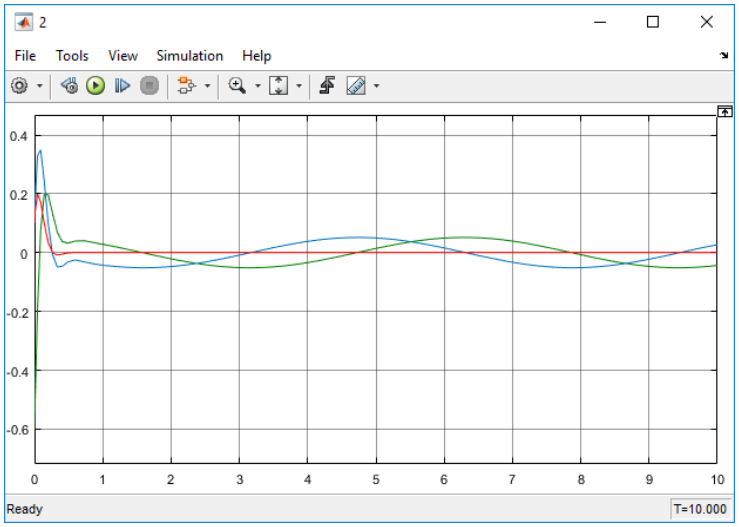



**Figure 7.** Output process curve of MM mobile robot controller.

## Conclusion

The solution to the issue of the synthesis of the control system of the mobile robot was considered in the article. The control system of the mobile robot was designed based on the Simulink package of the MATLAB environment. The proposed controller modeling method has been successfully applied to the MM mobile robot system. Modeling and experimental results confirm that the operation and stability of the obtained system fully meet the technical requirements. The proposed method has led to an increase in both tracking and control accuracy during high-speed movements.

## Declarations

The manuscript has not been submitted to any other journal or conference.

## Study Limitations

There are no limitations that could affect the results of the study.

## Acknowledgment

The author would like to express gratitude to the care support workers and elderly individuals who participated in this study, sharing their invaluable insights and experiences. Their cooperation and openness have significantly contributed to the depth and richness of the research findings.

## REFERENCES

1. Aliyev R.A., Ahmadov B.O., Seyidov M.I., Alizade A.V. Intelligent robots. – Baku: ADNA, 2011. – Pp.193-199.
2. Aliyev R.A., Jafarov S.M., Babayev M.C., Zeynalov E.R., Huseynov B.G. Control in robotic systems. – Baku: Nargiz, 2004.
3. Deussen O., Lindemeier T., Pirk S., Tautzenberger M. Feedback-guided stroke placement for a painting machine // Proceedings of the Eighth Annual Symposium Computational Aesthetics in Graphics, Visualization, and Imaging. – 2012. – Pp. 25-33. http://dx.doi.org/10.2312/COMPA ESTH/COMPAESTH12
4. Gyula Mester. Intelligent Mobile Robot Motion Control in Unstructured Environments. // Acta Polytechnica Hungarica. – 2010, 7(4). – Pp.153-165. https://www.researchgate.net/ publica-tion/49619356
5. Jafarov S.M., Babayev M.J., Zeynalov E.R., Guseynov B.G., Mamedov V.M. Synthesis of control system of fuzzy multiconnectioned dynamic object in sliding regime with variable structure / First International Conference on Soft Computing With Word in System Analysis, Decision and Control. – Antalya, Turkey, June 6-8, 2001. – Pp.243-247. https://oyu.edu.az/ uploads/journals/oyu.edu.az_1653513864.pdf.
6. Jamshed Iqbal et.al. Automating industrial tasks through mechatronic systems – a review of robotics in industrial perspective // Tehnicki Vjesnik. – June 2016. – Pp.917-924. https://www.researchgate.net/publication/280642894
7. Jha A.K. Intelligent Control and Path Planning of Multiple Mobile Robots Using Hybrid Ai Techniques / PhD thesis. – 2016. – 213 p. http://ethesis.nitrkl.ac.in/7416/1/2016_PhD_AK Jha_ 510ME109.

8. Kazuma Sasaki, Kuniaki Noda, Tetsuya Ogata. Visual motor integration of robot's drawing behavior using recurrent neural network // Robotics and Autonomous Systems. – December 2016. – Vol.86. – Pp.184-195. https://doi.org/10.1016/j.robot. 2016.08.022
9. Lokhin V.M. et al. /Intelligent Feedback, Knowledge Processing and Self Learning in the Control Systems of the Autonomous Robots and Multi-Agent Robotic Groups // Mehatronika, avtomatizacija, upravlenie – Mechatronics, Automation, Control. – 2015. – Issue 16. – Vol.8. – Pp.545-555. https://doi.org/10.17587/mau.16.545-555
10. Mammadova K.A. Mathematical Modeling and Simulation of Robotic Dynamic Systems // News of Azerbaijan Engineering Academy / International scientific and technical journal. – 2022. – Vol.14, No4. – Pp. 98-111. http://www.ama.com.az/wp-content/uploads/2022/12/N14-N14-N14-4.pdf
11. Mammadova K.A., Mammadova B.A. Otslejivaniye stocnix vod s pomosyu robotizirovannıx datcikov so smortfonami // Ejemesyacnıy naucniy jurnal Nasionalnaya Assosiasiya Uconix (NAU). ISSN Print 2412-5291. – 2021. – Vol.1, №73. – Pp.48-54. https://cyberleninka.ru/article/n/otslezhivanie-stochnyh-vod-s-pomoschyu-robotizirovannyh-datchikov-so-smartfonami
12. Silva-Ortigoza R., Marcelino-Aranda M., Silva-Ortigoza G., Hernández-Guzmán V.M., Molina-Vilchis M.A., Saldaña-González G., Herrera-Lozada J.C. and Olguín-Carbajal M. Wheeled mobile robots. // A review IEEE Latin America Transactions. – 2012. – Vol.10, No 6. – Pp.2209-2217. Available at http://www.ewh.ieee.org/reg/9/etrans/eng/
13. Thomas B. and Hans J. Agricultural robotic platform with four wheel steering for weed detection. // Biosyst. Eng. – 2004, 87(2). – Pp.125-136. https://www.fsantos.utad.pt/bibliografia/BE04-87-2(125-136).pdf

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-78

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# КОНЦЕПЦИЯ ЛОГИСТИЧЕСКОЙ СИСТЕМЫ ПРОМЫШЛЕННОГО ПРЕДПРИЯТИЯ

**Григорий Левкин[1], Андрей Ларин[2]**
[1]Омский государственный университет путей сообщения, к.вет.н., доцент, lewkin_gr@mail.ru (Россия)
[2]Омский государственный университет путей сообщения, к. т. н., доцент, larinan75@mail.ru (Россия)

## РЕЗЮМЕ

В статье рассмотрены особенности концепции логистической системы промышленного предприятия с учетом тенденций изменения рыночного окружения и информационного обеспечения транспортно-складских процессов, отечественного опыта развития систем управления материальных потоками.
**Ключевые слова:** концепция логистики, промышленное предприятия, функциональная область логистики предприятия, материальный поток

## ABSTRACT

The article discusses the features of the concept of the logistics system of an industrial enterprise, taking into account the trends of changing the market environment and information support of transport and warehouse processes, domestic experience in the development of material flow management systems.
**Keywords:** logistics concept, industrial enterprises, functional area of enterprise logistics, material flow.

## Введение

Логистика как концепция управления потоковыми процессами получила развитие в связи с выделением в качестве объекта управления материального потока. Исторически логистика развивалась в военной сфере, что закреплено в научной и учебной литературе, но также к источникам развития логистического знания следует отнести торговлю и управление домашним хозяйством.

При адаптации научных знаний к практической деятельности необходимо учитывать не только отраслевые особенности, к которым относится промышленное предприятия, но также и культурные, национальные традиции ведения хозяйственной деятельности, географические характеристики использования времени и пространства при планировании логистической деятельности.

Все это свидетельствует о необходимости учета исторического опыта развития экономики и коммерческой деятельности с учетом информации из иностранных источников литературы, но и ее адаптации к условиям хозяйствования в регионах Российской Федерации.

## Цель исследования

адаптировать основные положения концепции логистики к особенностям функционирования промышленного предприятия.

**Задачи исследования**

обосновать использование концепции логистики для промышленного предприятия;
дополнить и уточнить основные положения концепции логистики промышленного предприятия с учетом специфики России как особой цивилизации;
Объект исследования – логистическая система промышленного предприятия.
Предмет исследования – формирование концепции логистики промышленного предприятия.
Научная новизна исследования заключается в сопоставлении основных положений концепции логистики с культурными, природно-географическими и историческими особенностями Российской Федерации, что позволит адаптировать лучшие логистические практики к отечественной экономике.

**Обоснование использования концепции логистики в деятельности промышленного предприятия**

Концепция логистики предприятия – это система взглядов и положений к организации логистических процессов путем рационализации движения материальных потоков на предприятии [2].
Разработка концепции логистики предприятия включает в себя:

- формализацию и декомпозицию логистических процессов;
- совершенствование видов логистической деятельности, связанных с контролем за перемещением внутреннего материального потока;
- внедрение логистических принципов и закономерностей в деятельность подразделений, которые ответственны за планирование перемещения материальных потоков и управление запасами.

Внедрение и реализация концепции логистики предприятия позволяет отразить количественные и качественные характеристики материальных потоков с целью снижения уровня логистических затрат и повышения уровня обслуживания внутренних и внешних потребителей материальных потоков.
Выбор организационных подходов к планированию логистической деятельности, методов контроля и учета выполнения логистических операций, глубины декомпозиции направлений логистической деятельности зависит от специфики деятельности предприятия, состава материальных потоков, существующего положения дел в области внутренней логистики предприятия, особенностей организации снабжения и сбыта, множественности источников поставки комплектующих и состава клиентской базы при сбыте готовой продукции.
Одним из существенных моментов в реализации логистической деятельности является учет характеристик рынка сбыта готовой продукции и точное определение необходимой модели управления материальными потоками на предприятии – толкающей или тянущей модели [2]. В зависимости от использования тянущего или толкающего принципа при управлении логистическими процессами на предприятии определяется количество запасов комплектующих или готовой продукции, особенностей организации производства.
В настоящее время на отечественных предприятиях отмечается конфликт между программой планового производства (толкающая модель) и внеплановыми заказами, направленными на «вытягивание» материального потока (тянущая модель).

Например, необходимость перестройки логистической системы предприятия на использование тянущей модели управления материальными потоками на предприятии связана с противоречием между типом логистической системы (толкающая) и рынком сбыта, что приводит к потере эффективности и слабой ориентации на потребности клиентов.

При разработке и внедрении концепции логистики необходимо изменить подходы к отражению внутренних процессов предприятия, в том числе с помощью соответствующего программного обеспечения. После разработки рамочной концепции логистики промышленному предприятию необходима ее дальнейшая детализация с учетом проблем, выявленных в процессе проведения глубинных интервью, и декомпозиция на уровне выполнения логистических функций и логистических операций, их количественных и качественных характеристик.

Анализ результатов исследования типичных проблем в логистической деятельности показывает, что проблемы логистического характера отмечаются во всех функциональных областях логистики (снабжение, производство, сбыт) и логистических функций, которые относятся к соответствующей функциональной области логистики: внутренняя и внешняя транспортировка, складирование в снабжении, производстве и сбыте, управление запасами в снабжении, производстве и сбыте. Все это свидетельствует об отсутствии системности в организации движения внутренних материальных потоков.

Внедрение концепции логистики связано с переформатированием процессов предприятия и соотнесением их с картой движения материального потока, привязкой логистических функций и операций к подразделениям предприятия с учетом принципов централизации и децентрализации (необходимость осознанного выбора централизации или децентрализации отдельных логистических функций для повышения качества их выполнения или экономии временных и трудовых ресурсов предприятия).

Глубинная детализация логистических операций позволяет обеспечить прозрачность и управляемость логистических процессов, уменьшить потери рабочего времени за счет исключения нерациональных и дублирующих операций, снизить логистические затраты и исключить логистические издержки (непроизводительные затраты), обеспечить снижение затрат на «омертвленные» запасы, обеспечить планирование логистических процессов, что в результате повысит надежность и гибкость логистической системы предприятия.

Одним из необходимых направлений деятельности сотрудников подразделений предприятия, связанных с организацией движения материальных потоков, является логистический анализ. В настоящее время в работе отечественных предприятий отмечается дефицит аналитической работы из-за нерационального использования временных ресурсов предприятия, а также отсутствия аналитических инструментов у работников предприятия, в том числе из-за неполного использования возможностей программного обеспечения.

Первым и основным шагом к формированию концепции логистики промышленным предприятием является определение структуры логистической системы предприятия (Рисунок 1), производственные мощности которого могут быть территориально рассредоточенными.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



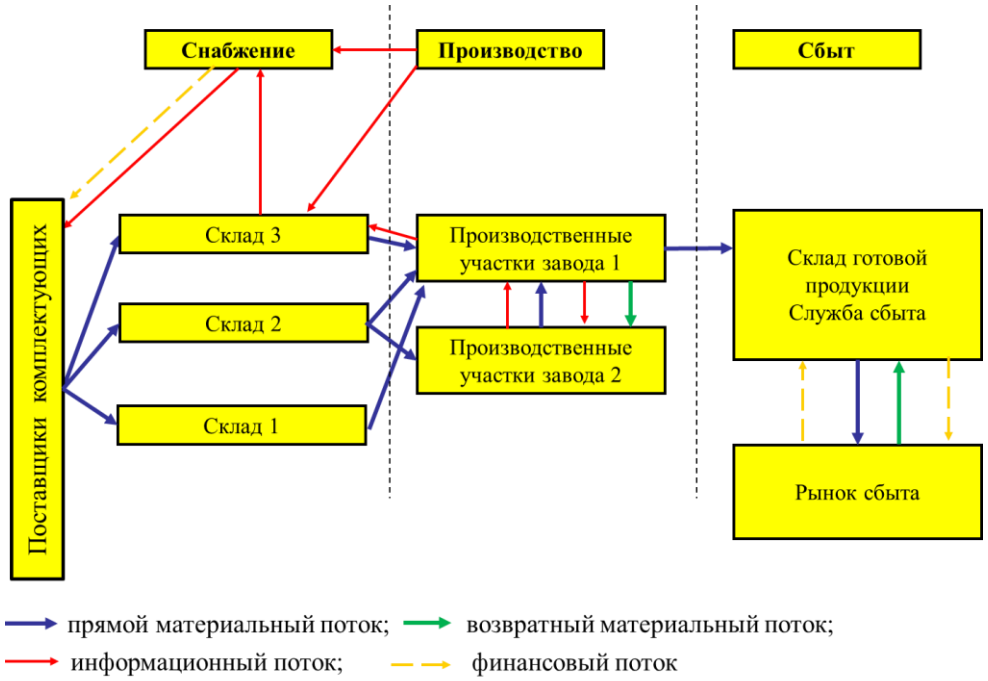



**Рисунок 1.** Структура логистической системы предприятия

Таким образом, при внедрении логистической концепции в деятельность промышленного предприятия необходимо проводить глубинную детализацию логистических операций на основе структурно-функционального подхода.

**Основные положения концепции логистики промышленного предприятия**

Формирование концепции логистики связано с учетом отраслевой специфики предприятия, возможностями совершенствования подходов к управлению материальными потоками. Основные положения концепции, изложенные в доступной литературе, необходимо дополнить и уточнить в соответствии с деятельностью промышленного предприятия и отечественного опыта хозяйствования, связанного с территориальными, географическими особенностями, а также менталитетом народов, населяющих Россию.

Положение 1. Реализация принципа системного подхода на макро- и микроуровне.

Максимальный экономический эффект можно получить только путем улучшения показателей совокупного материального потока на всём его протяжении, то есть на пути от первичного источника комплектующих до потребителей готовой продукции, включая обратные и возвратные материальные потоки. При этом все звенья логистической цепи должны работать как единая система. На предприятии необходимо выделить сквозной материальный поток и определить ответственное лицо или подразделение за его перемещение через предприятие. Системность в организации перемещения материального потока позволяет решить проблемы с излишними запасами / дефицитами за счет диспетчирования потоков и календарного планирования, составления расписаний движения транспортных средств и контроля за их движением.

Положение 2. Использование логистики обратных материальных потоков на крупных промышленных предприятиях

Промышленные предприятия являются потребителями большого количества ресурсов при осуществлении производственного процесса. Часть приобретенных ресурсов в процессе производства отбраковывается. При этом в процессе производства на этот отбракованный материал были затрачены: человеко-часы, топливно-энергетические ресурсы, ресурсы оборудования. Все это, так или иначе, приводит к увеличению итоговой себестоимости продукции промышленного предприятия.

Для снижения итоговой себестоимости продукции, необходимо с максимальной выгодой вторично использовать отходы. При грамотном управлении обратными материальными потоками можно получить дополнительную прибыль [1, 7].

Применение концепции логистики обратных материальных потоков вписывается в концепцию бережливого производства и принципа конкурентоспособности продукции за счет снижения первоначальной себестоимости продукции.

На рисунке 2 отображен процесс движения первичных материалов и сырья с учетом вторичных потоков для промышленного предприятия.

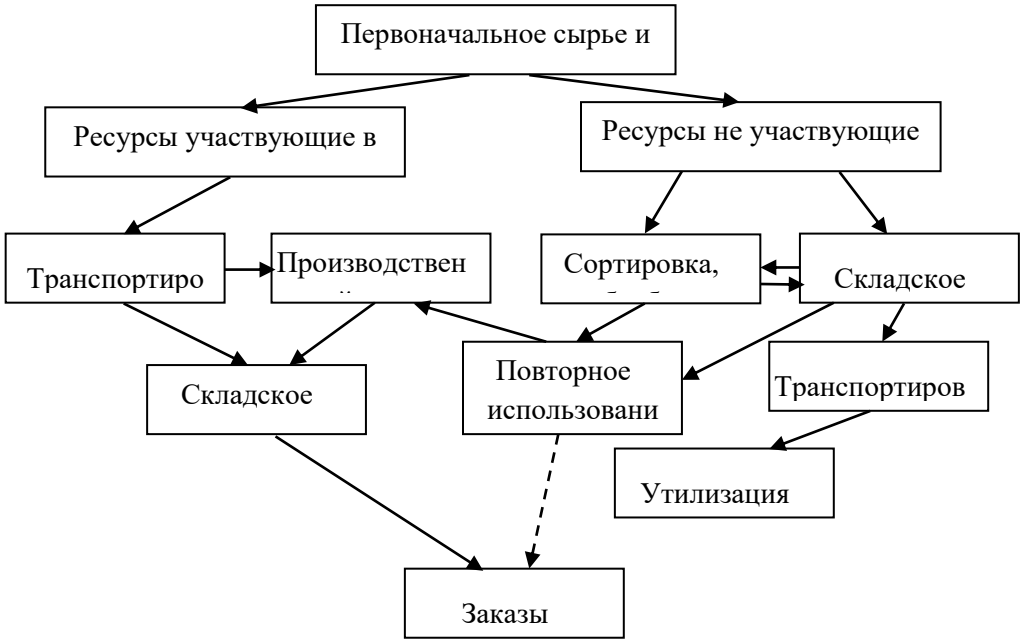



**Рисунок 2.** Алгоритм работы последовательного дискретного процесса обработки материалов с учетом обратных материальных потоков

Для эффективного использования вторичных ресурсов на любом промышленном предприятии первоначально решаются следующие задачи: составляется перечень заказов с полным перечнем необходимых материальных ресурсов для выполнения данного заказа с учетом потребных производственных мощностей; составляются подробные схемы перемещения востребованных в производственном процессе материалов; разрабатывается алгоритм участия прямой и обратной логистики в производственном процессе

промышленного предприятия, определяется возможность учета и классификации отходов производства; определяют систему адресного хранения отходов; определяется принцип и технология переработки отходов; определяется возможность использования переработанных отходов в производственном процессе; определяются способы утилизации отходов, которые невозможно использовать в процессе производства; формирование системы технико-экономических показателей возникновения и переработки промышленных отходов.

В соответствии с вышеперечисленным, классификация отходов должна производиться с учетом следующих параметров: габарито-размер; объем отбраковки; качественно-количественный состав; возможность повторного использования в производственном процессе; оценка непригодного материала в дальнейшем производственном процессе; адресное хранение отбракованного материала с учетом возможности повторного использования и оценочной стоимости полностью непригодного материала.

Положение 3. Учёт логистических затрат при перемещении материального потока через предприятие на основе их пооперационного учета.

Управлять логистическими затратами можно лишь в том случае, если их точно измерить и выделить из общих затрат предприятия. Традиционные системы учёта затрат не позволяют это осуществить. Для рационального управления материальными потоками необходимо владеть информацией о характере взаимовлияния отдельных статей затрат [1].

В качестве элемента учета логистических затрат рассматриваются операции, выполняемые при перемещении материальных и сопутствующих потоков. Кроме того, очень важно разграничить логистические затраты (планируемые и необходимые расходы на выполнение логистических операций) и логистические издержки (не планируемые и не рациональные расходы, потери).

Для реализации этого положения необходимо провести декомпозицию логистической системы предприятия до логистических операций и наладить их операционный учет – в начале объем выполнения операций, а затем затраты на выполнение операций, разграничить рациональные расходы (на транспортировку, содержание запасов, складирование) и не рациональные расходы (сверхнормативные расходы на транспорт, складирование, управление запасами и т.д.). В настоящее время логистические затраты и издержки не выделены из общих затрат предприятия, а также в понимании руководителей часто отсутствует разграничение на логистические затраты и издержки, так как в системе бухгалтерского учета отсутствуют такое разделение.

Положение 4. Рациональное планирование рабочего времени и использование временных ресурсов предприятия.

Для реализации этого положения необходим пооперационный учет логистической деятельности подразделений, связанных с перемещением материальных потоков предприятия, с целью исключения дублирования операций и выявления нерационального использования времени работников. Полученные результаты могут быть использованы для стимулирования работников склада и водителей транспортных средств к выполнению качественной работы или повышению производительности за счет прямой привязки параметров материальных и информационных потоков к результатам труда работников. Стимулирование работников, выполняющих логистическую деятельность, должно быть динамическим с учетом достижения поставленных целей. В качестве измерителей целей предприятия в области логистической деятельности могут быть использованы увеличение

производительности, снижение количества ошибок и опозданий комплектации, отгрузки или доставки между подразделениями.

Положение 5. Повышение уровня сервиса за счет гибкости логистической системы предприятия и внедрения тянущей модели управления материальными потоками.

Использование тянущей модели позволяет снизить уровень «омертвленных» запасов комплектующих и готовой продукции. Предполагает пересмотр технологии производства и сбыта, направленность на работу с потенциальными клиентами, а также создание категорий внутренних поставщиков и потребителей материального потока с установлением критериев уровней их обслуживания. Под термином «гибкость» следует понимать быстроту реагирования на потребности рынка со стороны подразделений предприятия, которые связаны с перемещением материального потока, начиная со снабжения, заканчивая отгрузкой готовой продукции. В то же время возможна комбинация толкающей и тянущей модели по отношению к снабжению и сбыту соответственно, но все нововведения в области логистики могут быть безуспешными при отсутствии единой информационной системы, наличии «черного ящика» в отношении запасов комплектующих в производстве. Все новации в области логистики предприятия возможны после создания сквозного информационного потока, который должен стать основой создания логистической системы предприятия.

Положение 6. Способность логистических систем к адаптации в условиях неопределенности окружающей среды.

Способность предприятий к адаптации является существенным фактором устойчивого положения на рынке. При использовании концепции логистики проявляется эффект самоорганизации служб предприятия, устраняются межфункциональные конфликты.

Положение 7. Принятие решений на основе экономических компромиссов.

Это означает, что увеличение затрат в одном из звеньев логистической цепи допустимо и необходимо при условии, что оно приведет к снижению затрат или повышению прибыли в целом по предприятию или в цепи поставок [4]. Для оценки целесообразности затрат необходимо проводить логистический анализ от общего к частному: вначале оценка проблем предприятия в целом, а затем их детализация (декомпозиция) до уровня логистических операций. В настоящее время на предприятии отмечается механическое снижение затрат на закупку путем установления контроля со стороны планово-экономического отдела, что противоречит логистическому положению принятия решения на основе экономических компромиссов и может привести к отрицательному результату (экономическим потерям предприятия в среднесрочной перспективе). Экономить нужно, но обдуманно и на основе рациональных доводов, результатов логистического анализа. Здесь уместно привести русскую пословицу «*Скупой платит дважды*», так как логистическое мышление заложено в русской культуре, что находило отражение в народном творчестве и истории русского предпринимательства.

Положение 8. Сквозное управление материальными и сопутствующими потоками на предприятии.

Для рационального управления сквозным материальным потоком предприятия назначаются ответственные лица («хозяин материального потока»), в качестве которых можно рассматривать:

- руководителей подразделений функциональных областей логистики (снабжение, производство, сбыт) – это уровень управления логистическими функциями,

связанными с фактическим перемещением материального потока (транспортировка, складирование);

- сотрудников специального подразделения (отдел логистики), которые выполняют организационные и аналитические логистические функции – управление запасами, управление логистическими рисками, организация межфункционального взаимодействия между подразделениями предприятия, устранение межфункциональных конфликтов, управление сквозным материальным потоком.

Положение 9. Использование русского опыта логистической деятельности.

Источниками знания о логистике является Священное писание (пример не только предвидения Иосифом будущего голода в Египте, но и последующие за ним решения по созданию гигантского резервного запаса), военная логистика, история предпринимательства в России и в Сибири, художественная литература русских писателей, опыт хозяйственной деятельности предприятия.

Из истории военной логистики известно, что между гениальным полководцем и гениальным логистом можно поставить знак равенства.

Цитата: «Все привыкли к тому, что Суворов – великий полководец – так, будто он и родился уже боевым командующим полка. Но начинал Александр Васильевич как интендант, по-нашему прапорщик. Гений войны часто любит больше правильное снабжение, чем героизм. И Суворов, будучи уже блестяще обученным военным, к первому своему военному заданию – по снабжению своего полка провиантом – отнесся с полнейшей самоотдачей. Ему нужно было перевезти груз к городу Мемелю (теперь Клайпеда) по реке Данге, но она уже тогда была довольно мелкой, это заранее никто не проверил, баркасы сели на мель. Суворов тут применил свой талант «кризисного менеджера»: в кратчайшие сроки нанял подводы – сотни единиц – у местных жителей, уместившись при этом в бюджет. За это командующий и приближенный Елизаветы Петровны граф Бутурлин выразил благодарность Суворову» [5].

Цитата: Русский писатель Иван Шмелев в книге «Лето Господне» привел пример логистического решения у крестьян Царской России: «А мороз такой, что воздух мерзнет. Инеем стоит, туманно, дымно. И тянутся обозы – к Рождеству. Обоз? Ну, будто, поезд... только не вагоны, а сани, по снежку, широкие, из дальних мест. Гусем, друг за дружкой, тянут. Лошади степные, на продажу. А мужики здоровые, тамбовцы, с Волги, из-под Самары. Везут свинину, поросят, гусей, индюшек, - «пылкого морозу». … Все распродадут, и сани, и лошадей, закупят красного товару, ситцу, - и домой, чугунной. Чугунка? А железная дорога. Выгодней в Москву обозом: свой овес-то, и лошади к продаже, своих заводов, с косяков степных» [8].

Цитата: Тобольские губернские ведомости, XIX век «Действительно, купец Дудиков покупает много хлеба в Каинском округе и в Тарском. Из Каинска по Тартасу (на котором строятся балки) и Оми справляют в г. Омск. Из слободы Такмыкской отправляются им зимним путем на ярмарки в Тобольск или в Ишим коровье масло, сало, кожи. Откуда в свою очередь привозит красный товар – самовары, железную, стеклянную, глиняную посуду, чай, сахар и проч. Часть красного товара развозится приказчиками по округу, остальное раскупается на дому. Выгоды очевидны. Под хлеб, масло, сало и кожи дается нередко вперед, или деньгами или товаром, иногда за полгода и более, следовательно, цена товару назначается довольно умеренная, но, впрочем, своеобразная с годом. Купец не доставить товара ко времени крестьянину, так сказать не смеет, исключая редкие случаи,

иначе он теряет на будущее время надежного покупателя. Присутствие между крестьянами такой денежной личности как купец Д. – находка, потому что все, что крестьянин имеет продать, он продает так сказать у себя дома купцу и по цене не намного выше той, какую он взял бы в городе. Но здесь уже и тот расчет, что выигрывается время, а им-то и дорожит наш крестьянин как единственной драгоценностью».

Положение 10. Рациональное сочетание централизации и децентрализации в управлении логистическими процессами.

Регламентация логистических процессов, координация логистической деятельности концентрируется в единой службе логистики (стратегический и тактический уровень), но логистические функции выполняться в подразделениях предприятия (оперативный уровень). Централизация обеспечивает преимущества при консолидации отгрузок и эффективный анализ логистических затрат, децентрализация позволяет принимать решения на месте, исходя из опыта и знаний исполнителей.

Идея централизации проникла в умы людей уже давно и связана, прежде всего, с пониманием окружающего мира с позиции отдельного закрытого человека (эгоцентризм). Западный и восточный мир имеет существенные отличия в управлении государствами и религией. Например, западный католический мир в большей степени религиозно централизован, а восточный православный – децентрализован, но территориальное управление с позиции масштаба территорий имеет противоположные тенденции. Все это исторически привело к двум разным системам мировоззрения народов, населяющим Европу и Россию, так как в России на определенном этапе развития произошло объединение обширных территорий под единым политическим центром управления [2]

Отличия западной и восточной систем мировоззрения приводят к взаимному непониманию, которое заключается в отличии роли государства в экономических процессах, разности и разнообразии культур народов, населяющих государство. Развитие западного мира идет в направлении глобализации, постепенном обезличивании индивидуальности человека и сведение его роли к винтику в большой машине.

В западной цивилизации человеку идеологически отводится роль центра мира как материального объекта, поэтому материальное обеспечение жизнедеятельности общества в целом на первом месте. Это обеспечение является избыточным, так как материальный человек стремится к безграничному приобретению материальных благ, исходя из этого выстраивается экономика и производственная сфера. Стремление к личному обогащению человека приводит к созданию крупных производств, транснациональных корпораций, которые за счет масштаба деятельности получают способность обеспечивать неограниченный круг лиц продуктами питания, одеждой и техникой [3].

При этом общество потребителей становится зависимым и не в состоянии обеспечить себя всем необходимым самостоятельно. Люди теряют самостоятельность не только в этой части, но и в части самостоятельности мышления, так как вместе с материальной обеспеченностью (централизованной) появляется обеспечение централизованной информацией, развивается единая информационная среда, а неограниченному кругу лиц навязываются единые стереотипы мышления. В то же время происходит постоянное разобщение людей, живущих рядом, так как влияют ложные стереотипы с одной стороны, а с другой стороны. каждый человек замыкается в себе.

**Вывод**

Таким образом, концепция логистики включает в себя положения, методы, лучшие практики. Реализация принципов логистики промышленным предприятием обеспечивает снижение уровня логистических затрат, повышение качества обслуживания клиентов, упорядоченность процессов межфункционального и межорганизационного взаимодействия. Для включения промышленного предприятия в цепь поставок с возможностью наделением функций фокусной компании необходимо совершенствование физических процессов в логистической поддержке предприятия и развитие логистического менеджмента на предприятии.

**Декларации**
Рукопись не была представлена в какой-либо другой журнал или на конференцию.

**Ограничения исследования**
Ограничений, которые могли бы повлиять на результаты исследования, нет.

**Подтверждение**
Автор хотел бы выразить благодарность работникам службы поддержки и пожилым людям, которые приняли участие в этом исследовании, поделившись своими бесценными знаниями и опытом. Их сотрудничество и открытость в значительной степени способствовали глубине и богатству результатов исследований.

**ЛИТЕРАТУРА**

1. Il'ina S. A. Kontseptsiya vozvratnoy logistiki na vysokotekhnologichnom proizvodstve / S. A. Il'ina, V. N. Prokudin, E. D. Shirshov // Ekonomika vysokotekhnologichnykh proizvodstv. – 2023. – T. 4. – № 2. – S. 133-156.
2. Levkin, G. G. Logistika: uchebnik / G. G. Levkin, A. M. Popovich.. – Omsk.: OmGU im. F.M. Dostoyevskogo, 2014.
3. Levkin G. G. Tsentralizatsiya i detsentralizatsiya logisticheskikh sistem / G. G. Levkin // Aktual'nyye problemy logisticheskogo upravleniya i instrumenty ikh resheniya. Sbornik materialov Vserossiyskoy nauchno-prakticheskoy konferentsii. Velikiy Novgorod: Novgorodskiy gosudarstvennyy universitet imeni Yaroslava Mudrogo, 2021. C. 93-100.
4. Nichiporenko, V. V. Kategoriya ekonomicheskikh kompromissov i etapy razvitiya logistiki / V. V. Nichiporenko // V sbornike: Prinemanskiye nauchnyye chteniya. Sbornik nauchnykh trudov XIII Mezhdunarodnoy nauchno-prakticheskoy konferentsii. – Grodno: Universitet prava i sotsial'no-informatsionnykh tekhnologiy, 2023. – S. 213-218.
5. Suvorov – intendant [elektronnyy resurs]. URL: https://cyrillitsa.ru/past/94185-chto-aleksandr-suvorov-govoril-o-svoem.html
6. Tobol'skiye gubernskiye vedomosti, 1866 god [elektronnyy resurs]. URL: http://www.omskmap.ru/point/takmyk/lore/96.

7. Shakhnazaryan S.A, Potapova S. V. Problemy opredeleniya ponyatiya «vozvratnaya logistika» i yeye roli v upravlenii tsepyami postavok / S. A. Shakhnazaryan, S. V. Potapova // Izvestiya Ural'skogo gosudarstvennogo ekonomicheskogo universiteta. — 2013. — № 2. — T.46. — S.123–128.
8. Shmelev I. S. Leto Gospodne [elektronnyy resurs]. URL: https://azbyka.ru/fiction/leto-gospodne/

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-91

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# RƏQƏMSAL İQTİSADİYYAT VƏ SÜNİ İNTELLEKT

**Sədaqət İbrahimova, Mənsur Bağırzadə**
[1,2]ADNSU, "Menecment" kafedrası,
[1]Dosent, ibrahimovasadagat06@gmail.com, ORCID: 0000-0000-1317-4806
[2]Magistrant

## XÜLASƏ

İnformasiya emalı texnologiyalarının inkişafı iqtisadi fəaliyyət sahəsinə böyük təsir göstərməkdədir. Rəqəmsal iqtisadiyyatın inkişafı sənaye və istehlakçılar, rəqiblər və təchizatçılar, hökumətlər və insanlar arasında daha şaxələndirilmiş qarşılıqlı əlaqə və koordinasiya modellərinin yaranmasına səbəb olub. İnkişaf etməkdə olan texnologiyalarla idarə olunan ağıllı şəhərlər XXI əsrdə müxtəlif ölkələrin inkişaf məqsədlərindən birinə çevrilib. Müasir iqtisadi və sənaye siyasətinin əsasını rəqəmsal siyasət təşkil edir. Sosial bazar iqtisadiyyatının uğurlu modeli hələ də siyasi kompas kimi aktualdır, lakin o, yeni şəraitə uyğunlaşdırılmalıdır. Transformasiya edən aparıcı sənayeni orta biznes və startaplarla birlikdə üç bərabər sütun təşkil etməlidir.
Neft-qaz sənaye sahəsində ənənəvi fəaliyyətin rəqəmsal texnologiyalardan istifadə istiqamətində dəyişdirilməsi məsələsi müasir dövrdə mühüm əhəmiyyət kəsb edir. Rəqəmsal neft-qaz sənayesini təşkil edən ağıllı quyular, ağıllı yataqlar, pilotsuz karbohidrogen hasilatı texnologiyaların SOCAR-da təbiqi də olduqca mühüm bir məsələdir. Məqalədə rəqəmsal iqtisadiyyat və süni intellekt arasındakı əlaqə analiz edilmiş, eyni zamanda rəqəmsal neft-qaz sənayesinin mühüm xüsusiyyətləri barədə müəyyən məlumatlar verilmişdir. Süni intellektin təkamülü ilə dünyada yarımkeçiricilər, proqram təminatı, aparat, internet xidmətləri və digər şirkətlər kimi müxtəlif sahələrdə texnologiya sənayesi eyni vaxtda müəyyən problemlərlə üzləşirlər. Süni intellektin inkişafı istehlakın canlanmasına, əksər peşələrdə məhsuldarlığın artmasına, risklərin daha yaxşı idarə edilməsinə ümid verir. Eyni zamanda inkişaf etmiş ölkələrdə iş yerlərinin kütləvi şəkildə bağlanması, bacarıqların təkmilləşdirilməsi, potensialın genişləndirilməsi həyəcanı artırır. Süni intellekt maşın və insan arasındakı əlaqəni dəyişdirməyə kömək edir. Süni intellekt sahəsindəki irəliləyişlər istehsal sistemlərinin avtomatlaşdırılmasına və gücləndirilməsinə təkan verir. Süni intellekt fəaliyyətin bir çox sektorlarında, xüsusilə də neft-qaz sənayesində yeni biznes modellərinin yaradılmasının aparıcı qüvvəsi hesab olunur. Neft və qaz şirkətlərinin texnoloji inkişafı informasiyaya tələbatın kəskin artması və informasiya texnologiyalarından istifadənin genişlənməsilə müşayiət olunur. Ümumiyyətlə, "əşyaların interneti", "bulud texnologiyaları", "rəqəmsal sahələr" və digər qabaqcıl texnologiyalar neft-qaz şirkətlərinin fəaliyyətinin səmərəliliyinin artırılması üçün ciddi potensial yaratmağa qadirdirlər.
**Açar sözlər:** rəqəmsal iqtisadiyyat, süni intellekt, rəqəmsal texnologiyalar, neft-qaz sənayesi, rəqəmsal transformasiya, səmərəliliyin artırılması.

## Giriş

Rəqəmsal texnologiyaların insan həyatının bütün sahələrində fəal tətbiqi biznes modellərini dəyişdirir, şirkətlərin qlobal bazara çıxma prosesini sürətləndirir, kadrların işə götürülməsi üçün yeni şərait yaradır, insan əməyinin müəyyən növlərini alqoritmlər və maşınlarla əvəz edir. Eyni zamanda, rəqəmsallaşma və texnoloji yeniliklər imkanlar yaradır: yeni iş yerləri; insanın yaradıcı potensialını üzə çıxaran məşğulluq sahələrinin genişləndirilməsi və s. Rəqəmsal iqtisadiyyatda

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



əmək prosesinin transformasiyası proseslərinin başa düşülməsi, əmək sahəsində işçinin maşın üzərində üstünlüklərinin müəyyən edilməsi, rəqəmsal əmək bazarında onun mövqeyinin gücləndirilməsi üçün tədbirlərin işlənib hazırlanması üçün yeni yanaşmalar tələb edir. Ümumiyyətlə, "rəqəmsal transformasiyanın yaranması sürətli rəqəmsallaşmaya və ənənəvi iqtisadi strukturların və biznes modellərinin dəyişməsinə səbəb olmuşdur".[1]

Müəyyən edilmişdir ki, adi əməliyyatları əhatə edən iş yerləri əməyə tələbat tamamilə texnologiyalarla əvəz olunana qədər azalma riski altındadır və bu prosesin əksinə olaraq, yaradıcılıq fəaliyyətində əmək resurslarına tələbat artır.

Süni intellektin əmək bazarının obyektindən subyektə çevrilməsinin mümkün tendensiyaları qismən və ya tamamilə, süni intellektin hüquqi statusunun qanunvericiliklə tənzimlənməsi şərtilə müəyyən edilir. İşçinin əmək bazarında mövqeinin möhkəmləndirilməsinin əsas istiqamətləri, onun, yəni, insanın yaradıcılıq potensialının inkişafı üçün əlverişli mühitin formalaşdırılması və ömürboyu təhsil konsepsiyasının həyata keçirilməsi deməkdir. Qeyd olunan istiqamətlər milli və regional hakimiyyət orqanlarının dəstəyini və onların maraqlı və fəal yerli icmalarla qarşılıqlı əlaqəsini tələb edir.

2030-cu ilədək rəqəmsal iqtisadiyyat, qlobal ÜDM-in yarıdan çoxunu təşkil edəcəkdir. Aydın şəkildə demək olar ki, biz rəqəmsallaşmanın üstünlük təşkil etdiyi həyat tərzinə və iqtisadi sistemə daxil olmaq üzrəyik. Yarımkeçirici hesablama sürətinin artması informasiyaların ötürülmə sürətini xeyli artırır. Yarımkeçirici texnologiyalarının təkamülü elektron komponentləri daha kiçik hala gətirir və daha kiçik və ənənəvi analoq komponentlər rəqəmsallaşmağa başlayıb. Hazırda "SOCAR-2035" strategiyasına uyğun şəkildə "texnoloji proseslərin qabaqcıl standartlar səviyyəsində optimallaşdırılması üçün rəqəmsal dünyanın yeniliklərinin istehsalata tətbiq edilməsi istiqamətində işlər görülür". [2]

Rəqəmsal iqtisadiyyat, ənənəvi sənayenin iqtisadi modelini texnologiya ilə birləşdirir və keçmişdəki fiziki modeli virtual mühitə genişləndirir. Rəqəmsal və intellektual texnologiyaların tətbiqi neft və qaz yataqlarının istismarının səmərəliliyini artırmağa və əmək xərclərini optimallaşdırmağa imkan verir. Neft-qaz kompleksinin rəqəmsallaşdırılması, əməliyyat xərclərini əhəmiyyətli dərəcədə azaltmaqla, çıxarılan karbohidrogen ehtiyatlarının payını artıra bilər. Məsələn, rəqəmsal texnologiyaların tətbiqi neft sənayesinin dünya üzrə orta göstəricisi olan 30%-la müqayisədə 50%-ə çatdırmağa imkan verir.[3]

Müxtəlif neft-qaz şirkətlərində ən çox istifadə olunan ağıllı texnologiyalar Cədvəl 1-də verilmişdir.

**Cədvəl 1.** Müxtəlif neft-qaz şirkətlərində ən çox istifadə olunan ağıllı texnologiyalar.

| Şirkət | Texnologiya |
|---|---|
| Shell | Ağıllı yataq |
| Chevron | İntellektual yataq |
| BP | Gələcəyin yatağı |
| Petoro | Ağıllı əməliyyatlar |
| Statoil Hydro | İnteqrasiya edilmiş əməliyyatlar |
| Halliburton | Real vaxt rejimində idarəetmə |
| Schlumberger | Ağıllı quyular |
| OD | Düzgün istiqamət |
| DOFF | Gələcəyin rəqəmsal neft yatağı |

| | |
|---|---|
| CapGemini | İntellektual yatağın optimallaşdırılması və uzaqdan nəzarət |
| IAOM, ADCO | İnteqrasiya edilmiş aktivlərin idarə edilməsi modeli |
| Qazprom neft | Rəqəmsal yataq |
| Lukoil | İntellektual yataq |

Mənbə: [4]

Məqalədə əsas məqsəd, süni intellekt əsasında neft-qaz sektorunun rəqəmsal transformasiyasının ümumi konsepsiyasını formalaşdıran nəzəri prinsiplərin, metodoloji elementlərin, elmi-metodiki vasitələrin praktiki əhəmiyyəti ilə iqtisadi inkişafa nail olmaqdan ibarətdir.

Rəqəmsal iqtisadiyyat yeni iqtisadi şəraitdə müxtəlif innovativ rəqəmsal texnologiyaların və çarpaz domen inteqrasiya platformalarının istifadəsi kimi müəyyən edilə bilər. B2B və B2C istifadəçiləri üçün mal və xidmətlərin alış və satış strukturunu və iqtisadi dəyərini yenidən formalaşdırmaq üçün innovativ xidmət modelləri təmin olunmalıdır. İnnovativ rəqəmsal texnologiyalara süni intellekt (AI), məlumat analitikası, bulud hesablamaları, virtual reallıq (VR), genişlənmiş reallıq (AR) və blokçeyn (Blockchain) və digər inkişaf etməkdə olan elm və texnologiyalar daxildir.

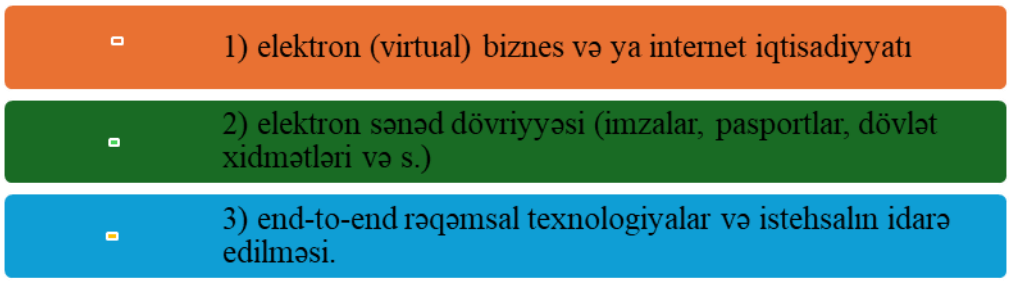
Rəqəmsal iqtisadiyyat son illərdə getdikcə daha çox əhəmiyyət kəsb edir. Rəqəmsal iqtisadiyyat, biznes əməliyyatlarını həyata keçirmək və asanlaşdırmaq üçün rəqəmsal texnologiyalardan və internetdən istifadə edir. Məhsullar və xidmətlər onlayn olaraq təklif olunur və alqı-satqı prosesi rəqəmsal şəkildə baş verir. Mallar və ya xidmətlər tez-tez rəqəmsal olaraq təqdim edilir və virtual ödəniş vasitələrindən istifadə erilir. Şirkətlər və istehlakçılar arasında qarşılıqlı əlaqələr də əsasən rəqəmsal şəkildə baş verir: veb brauzer, proqram, e-poçt, söhbət vasitəsilə və s. İnformasiyanın rəqəmsallaşdırılması daha sürətli və daha səmərəli ünsiyyətə imkan verir, qlobal bazarlara çıxışı asanlaşdırır və iş proseslərinin avtomatlaşdırılmasına kömək edir.

Müasir dövrdə SOCAR-da “ağıllı quyu” texnologiyalarının tətbiqi mühüm əhəmiyyət kəsb edir. “Ağıllı quyu” texnologiyalarının tətbiqi yatağın istismar xərclərinin 20% azalmasına gətirib çıxarır ki, bu da neftin qiymətinin “aşağı düşməsi” şəraitində şirkətin rəqabət qabiliyyətini artırmağa imkan verir.[3]

Tədqiqatçılara görə, qlobal ÜDM və məşğulluğun mühüm hissəsi olan rəqəmsal iqtisadiyyat xüsusilə inkişaf etməkdə olan ölkələrdə sürətlə inkişaf edir. Bununla belə, onun hərtərəfli ölçüləri yoxdur və onun bu bölgələrdəki çətinliklərini və nəticələrini başa düşmək üçün əlavə tədqiqatlar tələb olunur.[5]

Rəqəmsal iqtisadiyyat e-ticarət, rəqəmsal platformalar və tələb olunan xidmətlər də daxil olmaqla müxtəlif yeni biznes modellərinin yaranmasına səbəb olub. Onların hərəkətverici qüvvələrinə bulud hesablamaları, süni intellekt (AI) və əşyaların interneti (IoT, İnternet of Things) daxildir. Bu texnologiyalar sayəsində şirkətlər fərdiləşdirilmiş məhsul və xidmətlər təklif edə, müştərilərinin davranışlarını daha yaxşı anlaya və əməliyyatlarını daha səmərəli edə bilərlər.

Rəqəmsal iqtisadiyyatın və ya rəqəmsal texnologiyalara əsaslanan iqtisadi fəaliyyətin bugünkü anlayışının mənşəyi XX əsrin son onilliyində ortaya çıxdı. Onları üç sahəyə bölmək olar (Şəkil 2)




**Şəkil 2.** Rəqəmsal texnologiyalara əsaslanan iqtisadi fəaliyyətin üç sahəsi.

Rəqəmsal iqtisadiyyatın yaranması yüksək intellektual əməyin və informasiya məhsullarından istifadənin üstünlük təşkil edən rolu ilə xarakterizə olunan dünya təsərrüfat sisteminin inkişafında müasir mərhələ kimi informasiya iqtisadiyyatının yaranmasından əvvəldir. "Rəqəmsal iqtisadiyyatın əsas dayağı hiperbağlantıdır ki, bu da internet, mobil texnologiyalar və əşyaların interneti (IoT) əsasında insanlar, təşkilatlar və maşınlar arasında artan multivektorlu əlaqələr deməkdir. [6]

Şirkətlərin rəqəmsallaşması, süni intellekt və sənayenin və avtonom nəqliyyatın robotlaşdırılması bütün dünyada milyonlarla iş yerinin ləğvi deməkdir. Sosial sığortaya töhfə verən və fərdi gəlir vergisinə cəlb olunan işdən əldə edilən gəliri azaldacaqlarını düşünənlər var və onlar başqa gəlirlə əvəz edilməlidir. SOCAR-da süni intellekt texnologiyaları ilə təchiz edilmiş dronlar eyni vaxtda istixana qazı emissiyalarını aşkar etməyə və ölçməyə imkan verir.

Süni intellekt (AI) insanlarla eyni imkanlara malik maşınlar yaratmaq məqsədi ilə təklif olunan alqoritmlərin birləşməsi kimi başa düşülə bilər. Əslində, bu, insanın zəka ilə əlaqəli müəyyən əməliyyatları yerinə yetirmək üçün nəzərdə tutulmuş bir kompüter proqramıdır, məsələn, öz-özünə öyrənmə, buna görə də sistemin xarici məlumatları, düzgün şərh etmək, qeyd olunan məlumatlardan öyrənmək bacarığı kimi müəyyən edilmişdir.

**Cədvəl 2.** Süni intellekt sahəsi üzrə lider olan ölkələr.

| 2024-cü ildə süni intellekt sahəsi üzrə lider olan 10 ölkə | | |
|---|---|---|
| 1 | Amerika Birləşmiş Ştatları | Süni intellekt üzrə tədqiqatçıların demək olar ki, 60%-i Amerika universitetləri və şirkətləri üçün işləyir və bu sahəyə ümumilikdə 249 milyard dollar özəl maliyyə vəsaiti ayırmışdır. |
| 2 | Cin | Süni intellekt tədqiqatın göstəricisi 11 %-dir və 2022-2023-cü illər arasında 95 milyard dollar özəl investisiya cəlb edib. |
| 3 | Böyük Britaniya | Böyük Britaniya 2035-ci ilə qədər 1 trilyon dollara çatacağını təxmin etdiyi 21 milyard dollarlıq cari qiymətləndirmə ilə ABŞ və Çindən sonra dünyanın üçüncü ən böyük süni intellekt bazarıdır. |
| 4 | İsrail | İsrailin yerli texnoloji səhnəsi 2013-2022-ci illər arasında 11 milyard dollar özəl sərmayə əldə edərək dünyada dördüncü ən yüksək olan, süni intellekt inkişafının ön sıralarında yer almışdır. |
| 5 | Kanada | Kanada 2022-2023-cü illər arasında ölkədə süni intellekt üzrə tədqiqatlara 2,57 milyard dollar sərmayə qoyulub, belə ki, ümumi süni intellekt sərmayəsi 8,64 milyard dollara çatıb. |
| 6 | Fransa | Fransa 2013-2022-ci illərdə süni intellekt üzrə tədqiqatlara 338 startap və 7 milyard dollar özəl sərmayə qoymuşdur |

| | | |
|---|---|---|
| 7 | Hindistan | Hindistan təkcə 2023-cü ildə süni intellektə 3,24 milyard dollar investisiya qoyub. |
| 8 | Yaponiya | Yaponiyada 294 süni intellekt startapı var və 2013-2022-ci illər arasında süni intellektə 4 milyard dollar özəl investisiya əldə edib. |
| 9 | Almaniya | Almaniya qlobal süni intellekt bazarında 245 startapı özündə əks etdirən və 2013-2022-ci illər arasında süni intellektə 7 milyard dollar özəl sərmayə qoyub. |
| 10 | Sinqapur | 2021-ci ildə Sinqapur hökuməti Milli Süni İntellekt Strategiyasının bir hissəsi olaraq beş il ərzində süni intellektə 362 milyon dollar sərmayə qoymağı öhdəsinə götürdü. |

Mənbə: [7].

Rəqəmsallaşma, iqtisadiyyatı mürəkkəb vergi problemləri ilə üzləşdirir. Mövcud vergi qanunvericiliyi, ümumiyyətlə vergitutma hüquqlarını müəyyən etmək üçün həm milli səviyyədə, həm də ikiqat vergitutma müqavilələrində fiziki iştirak tələb edir. Bu o deməkdir ki, fiziki müəssisəsi olmayan rəqəmsal fəaliyyət göstərən şirkətlər çox vaxt vergiyə cəlb edilmir. Google, Amazon və ya Meta kimi yüksək rəqəmsallaşmış şirkətlər buna görə də bir çox ölkədə az və ya heç vergi ödəmirlər. Son illərdə yeni vergi təklifləri ortaya çıxmışdır. Belə ki, V.Meysel ölkədə hansısa şirkətin satış gəlirləri əsasında bu cür gəlirin əldə olunduğu şirkətin işçilərinin sayına görə avtomatlaşdırma vergisini təklif etmişdir. Vergi, gəlir yaratmaq üçün daha az işçidən istifadə edən bir şirkətin, eyni işi görməklə, daha çox işə götürən şirkətdən daha perspektivlidir. Onun təklifi iki məqsəd güdən kompüterlərdən alınan əmək haqqı vergisi kimi təsvir olunur: insan-kompüter sinerjisinə sərmayə qoymaq və dövlətə gəlir təmin etmək kimi vasitələrlə şirkətə iş yerləri yaratmaq üçün stimul təklif etmək. [8]

Hazırda rəqəmsal texnologiyalar cəmiyyətin və iqtisadiyyatın ayrılmaz hissəsinə çevrilib. Rəqəmsal transformasiya özü ilə bir çox üstünlüklər gətirdi, eyni zamanda müvafiq tənzimləmə tələb edən yeni problemlər və risklər yaratdı. Xatırladaq ki, "SOCAR 2006-cı ildən rəqəmsal transformasiyaya başlayıb və Qafqazda resurslarının planlaşdırılmasını (ERP) tətbiq edən ilk müəssisədir. [9]

Neft-qaz sənayesinin rəqəmsal transformasiyası prosesinin üç əsas mərhələsi müəyyən edilmişdir: avtomatlaşdırma, rəqəmsallaşma və intellektuallaşdırma. Bu mərhələlərin hər birinin yetkinliyini qiymətləndirmək üçün xüsusi meyarlar təyin edilməlidir. Ümumiyyətlə, innovasiya, rəqabət və sosial məsuliyyət arasında tarazlığı təmin etmək üçün məqsədyönlü rəqəmsal siyasət lazımdır. Bu kontekstdə məlumatların qorunması, kibertəhlükəsizlik, şəbəkə neytrallığı və əqli mülkiyyətin qorunması kimi məsələlər nəzərə alınmalıdır. Bir çox rəqəmsal fəaliyyət sərhədləri aşdığı üçün beynəlxalq səviyyədə əməkdaşlıq böyük əhəmiyyət kəsb edir. Beynəlxalq müqavilələr və normalar rəqəmsal iqtisadiyyatda vahid standartların və təcrübələrin yaradılmasına kömək edir.

Süni intellektin bəşəriyyət üçün təhlükə hissi bir sıra tədqiqatçıların fikirlərində mövcuddur. Futuroloqlar elmi və texnoloji tərəqqinin idarəolunma qabiliyyətinin itiriləcəyi və süni intellektin özünü təkmilləşdirə biləcəyi 2070-ci ildə texnoloji unikallığın baş verəcəyini proqnozlaşdırırlar. Süni intellekt təhlükə yaradacaq dərəcədə inkişaf etdikdə, mübarizə aparmaqdansa, kompüterlərlə birləşmək lazım gələcək.[10] Yəni tək doğru inkişaf yolu, ancaq bəşəriyyətin və maşınların "mehriban" və yanaşı yaşaması ola bilər.

Hazırda istifadə olunan materiallar və kvant texnologiyalarına keçidlə bağlı süni intellektin məhsuldarlığının artmasının texnoloji məhdudiyyətləri mövcuddur. Beynimizdə 100 milyard neyron, süni intellekt sahəsində isə 100 min neyron var. Süni intellektə tətbiq olunan iqtisadi tədqiqatlar rəqəmsal iqtisadiyyatdan daha çox fiziki iqtisadiyyata uyğun olan tədqiqat metodologiyalarını tətbiq edir. Onlar neoklassik mikroiqtisadiyyat və makroiqtisadiyyat

paradiqmalarında lövbər olaraq qalırlar. Onların heterojenliyinə və qeyri-müəyyənliyinə baxmayaraq, bu tədqiqatlar bir neçə tendensiyanı vurğulayır.

Süni intellektin fəlsəfəsini ilk açıqlayan şəxs məşhur ingilis məntiqçisi və riyaziyyatçısı Alan Turinq olmuşdur. Süni intellektin əlavə dəyəri əsasən istehlaka təsirlərə, məhsuldarlığın artmasına və daha yaxşı risklərin idarə edilməsinə əsaslanır. Bu dəyər yaratma rıçaqları peşələrə görə, həm də zamanla və məkanda dəyişir. Süni intellekt iş yerlərini məhv etməkdən daha çox, peşələr və tapşırıqlar üçün daha transformativ olur. Müəyyən texnologiyaların gələcəyinə təsir edən qeyri-müəyyənliklər səbəbindən bu fenomeni qısamüddətli və orta müddətli kənarlaşdırmaq çətindir. Süni intellektin təsirləri, süni intellekt və internet arasında müəyyən edilə bilən sinerjiləri kifayət qədər inteqrasiya etmir, eyni zamanda yeni öyrənmə və təşkilati modellərin töhfələrini lazımi səviyyədə qiymətləndirmir. Əksinə, AI-nin müsbət təsirləri texnoloji maneələr, institusional maneələr və sosial müqavimət nəticəsində yaranan bəzən yayılmış mənfi təsirlərlə qismən kompensasiya olunur.

Domenlərarası inteqrasiya platformaları rəqəmsal iqtisadiyyat tətbiqlərinə istinad edir ki, bu da tez-tez orijinal sənayedən kənarda üzləşməli olan üç növ problemin inteqrasiyasını tələb edir: (Şəkil 3)


**Şəkil 3.** Domenlərarası inteqrasiya platformaları. [10]

1) Sənayelərarası inteqrasiya platforması: Bir çox tətbiqlərin müxtəlif sənaye sahələri və ya peşəkar sahələrlə birləşdirilməsinin tələb olunduğu bir tendensiya halına gəldi və bu, son dərəcə çətin sənayelərarası inteqrasiya ilə nəticələndi. Çünki sənaye sahələri müxtəlif sənaye mədəniyyətinə və peşəkar biliklərə malikdir.

2) Regionlararası inteqrasiya platforması: dünyanın heç bir milli sərhədləri olmadığı üçün, bir çox tətbiqlər, onlayn fəaliyyət, çox vaxt müxtəlif coğrafi bölgələri əhatə edir. Elektron ticarət ənənəvi fiziki kanalların coğrafi məhdudiyyətlərini pozur və ölkə üzrə idxal və ixrac ticarəti üçün vergi məsələləri yaradır.

3) Nazirliklərarası görüşlər inteqrasiya platforması: Sənayelərarası və regionlararası əməkdaşlıq müxtəlif məsul dövlət qurumlarını əhatə etdiyi üçün müvafiq qaydalar da müxtəlif hökumət bölmələrini əhatə edəcək. Əvvəlcə ənənəvi sənaye sahələrinə nəzarət edən hökumət bölmələri münaqişələri həll etmək üçün inkişaf etməkdə olan texnologiya sahələrində digər bölmələrlə koordinasiya etməlidir.

İnnovativ xidmət modelləri müxtəlif inkişaf etməkdə olan biznes modellərini əhatə edir. Rəqəmsal iqtisadiyyat sənayesi üç sahəni əhatə edir:

1) rəqəmsal texnologiya sənayesi;

2) rəqəmsal texnologiya tətbiqi sənayesi;
3) innovativ rəqəmsal texnologiya sənayesi.

Rəqəmsal texnologiya sənayesinə informasiya proqram təminatı və xidmətləri, onlayn kommunikasiya xidmətləri, kompüterlər və rabitə avadanlığı, yarımkeçirici və elektron komponentlərin istehsalı, sosial şəbəkələr, rəqəmsal reklam və marketinq, rəqəmsal əyləncə və oyunlar və digər rəqəmsal məzmun daxildir. Rəqəmsal texnologiya tətbiqi sənayesinə istehsal, topdan və pərakəndə satış, nəqliyyat və logistika, yaşayış və ictimai iaşə, təhsil, maliyyə və sığorta kimi ənənəvi sənayelərdə rəqəmsal xidmətlər, həmçinin şirkət tərəfindən dəstəklənən 5+N innovativ tətbiq sənayesinin rəqəmsallaşdırılması daxildir. İnnovativ rəqəmsal texnologiya sənayesinə maliyyə texnologiyaları, rəqəmsal təhsil, səhiyyə texnologiyaları və s. kimi innovativ texnologiyaların rəqəmsal xidmətləri daxildir.

Rəqəmsal iqtisadiyyatın arxitekturası altı əsas aspekti əhatə edir:
1) sənaye ekosistemi;
2) rəqəmsal infrastruktur;
3) innovativ xidmət modelləri;
4) rəqəmsal istedadlar;
5) qanunlar və qaydalar;
6) rəqəmsal bərabərlik.

- Sənaye Ekosistemi – domenlərarası əməkdaşlıq, proqram təminatı və aparat inteqrasiyası vasitəsilə müxtəlif maraqlı tərəfləri bir araya gətirməkdir.
- Rəqəmsal infrastruktur - yüksək sürətli genişzolaqlı şəbəkə, şəbəkə təhlükəsizliyi, məlumatların təhlili, Open API və digər ümumi rəqəmsal texnologiyalardır.
- Yenilikçi xidmət modelləri - dağıdıcı biznes modelləridir.
- Rəqəmsal istedadlar - sahələrarası təcrübə və beyin dövranı kimi bacarıq və işçi qüvvəsi ehtiyaclarıdır.
- Qaydalar və sistemlər - rəqəmsal və virtual dünya ilə əlaqəli qaydalar, tənzimləyici sandbox (Regulatory Sandbox) vasitəsilə yeni əməliyyat modellərinin sınaqdan keçirilməsi və s.
- Rəqəmsal bərabərlik - vətəndaşların iştirakını təşviq edən Dövlət-Özəl-Xalq Tərəfdaşlığı (4P), rəqəmsal insan hüquqları, o cümlədən şəxsi məlumatların məxfiliyi və əqli mülkiyyət və s.

Rəqəmsal iqtisadiyyatın diqqət mərkəzində sənayenin rəqəmsallaşması ilə həyatın və cəmiyyətin inteqrasiyası pozucu innovasiya ilə ortaya çıxan xidmətlərə gətirib çıxaracaq. OECD hesab edir ki, rəqəmsal dövrün gəlişi mövcud sənaye məhsuldarlığını 5-10% artıracaq. Dünyada 14 milyarddan çox qoşulmuş cihaz olacaq, bank əməliyyatlarının 90%-i və alış-verişin 80%-i onlayn həyata keçiriləcək və hazırda uşaqların 65%-i "Gələcəyin işləri", hələ mövcud olmayan işlər olacaq. Rəqəmsal iqtisadiyyatın sənayelərarası innovativ inteqrasiya olunmuş xidmətlərin rəqəmsal iqtisadiyyatın böyüməsinin açarına çevriləcəyi və gələcək iqtisadi inkişaf üçün yeni idarəetmənin olacağı gözlənilir.

Rəqəmsal iqtisadiyyatda texnologiya biznes proseslərini dəyişdirmək, məhsul və xidmətlər təklif etmək və qarşılıqlı əlaqələri asanlaşdırmaq üçün istifadə olunur. Bu sahədə yeni qaydalar planlaşdırılır. Məsələn, 2020-ci ildən etibarən **"**SOCAR "SAP UFAM" əsasında neft və qazçıxarma əməliyyatlarının rəqəmsallaşmasını həyata keçirir"**.** [11] Rəqəmsal siyasət rəqəmsal iqtisadiyyat üçün möhkəm çərçivə yaratmalı və məlumatların qorunması qaydalarına, kibertəhlükəsizliyə və ədalətli rəqabətə diqqət yetirməlidir. Bir çox rəqəmsal şirkətlər də bərpa

olunan enerjilərdən istifadə edir və ESG meyarlarına əməl etməyə çalışırlar. Bununla onlar həm iqtisadi, həm də ekoloji məqsədlərə cavab verirlər.

Süni intellekt (AI) tərəqqinin mühərrikidir və gələcək rifahımızın əsasıdır. Buna görə də AI texnologiyaları iqtisadiyyatın bütün sahələri üçün böyük əhəmiyyət kəsb edir. Süni intellekt, xüsusən proseslərin avtomatlaşdırıldığı şirkətlərdə və biznes sahələrində səmərəliliyin artmasına və xərclərə qənaətə səbəb ola bilər. Məsələn, süni intellektlə idarə olunan avtomatlaşdırma optimallaşdırılmış istehsal və logistikaya imkan verir. Məlumat analitikası müştəri seçimləri və bazar tendensiyaları haqqında dərin fikirlər təmin edə bilər. Bundan əlavə, süni intellekt işçiləri bir çox gündəlik fəaliyyətlərdə dəstəkləyə bilər - bu da öz növbəsində ixtisaslı işçi çatışmazlığını azalda bilər.

Süni intellektin uğurlu tətbiqi üçün həlledici amil onun tətbiq olunacağı şirkətin nə qədər rəqəmsal olmasıdır. Şirkətin rəqəmsallaşma dərəcəsi şirkətin müxtəlif sahələrinin nə dərəcədə rəqəmsal şəbəkəyə qoşulduğunun və şirkətdəki proseslərin rəqəmsal şəkildə həyata keçirildiyinin göstəricisidir ki, bu da süni intellektdən istifadə etməklə avtomatlaşdırma və avtonom üçün ilkin şərtdir. Bu, həmçinin rəqəmsal süni intellekt tətbiqinin şirkət strukturuna nə qədər asanlıqla inteqrasiya oluna biləcəyinin göstəricisidir. Daxili rəqəmsallaşmanın çərçivəsini təşkil edən şirkətdən kənar amillər də mühüm rol oynayır. Şirkətdən kənar texniki infrastruktur, İnternetin mövcudluğu şirkətlərin rəqəmsallaşmasına və AI-nin tətbiqinə kömək edəcək şəkildə tərtib edilməlidir.

Süni intellekt tətbiqlərinin uğurlu olması üçün onlar düzgün məlumatlara daxil ola bilməlidirlər. Süni intellekt yalnız öyrəndiyi məlumatlar qədər yaxşı ola bilər. Şirkətlər məlumatlarının yüksək keyfiyyətdə strukturlaşdırılmasını təmin etməlidirlər. Məlumatların bu mövcudluğu həm də etik komponentə malikdir. Əgər reallığın hissələri müvafiq rəqəmsal məlumatlarla təmsil olunmursa, AI bu reallığa uyğun gələ bilməz və təhrif olmadan işləyə bilməz.

Süni intellektin tam potensialından istifadə etmək üçün müxtəlif məlumat mənbələrinin qüsursuz inteqrasiyası və şəbəkələşməsi tələb olunur. Bu, müvafiq interfeyslərin həyata keçirilməsini tələb edir - çox vaxt yalnız daxildə deyil, həm də xarici olaraq, bəzi AI tətbiqləri üçün ERP sistemləri kimi daxili məlumat mənbələrini xarici məlumat mənbələri ilə əlaqələndirmək müəyyən məna kəsb edə bilər.

Süni intellektdən uğurla istifadə etmək üçün şirkətlər, məlumatların manipulyasiyasının qarşısının alınmasını təmin etməlidirlər. Məlumatlara giriş üçün aydın siyasət və prosedurlar yaradılmalıdır. Eyni zamanda məlumatlara çıxışın monitorinqi və qeydiyyat mexanizmləri tətbiq edilməlidir. Şirkətlər məlumatların qorunmasının qanuni tələblərinə əməl etməlidirlər. Bura məlumatların istifadəsilə bağlı şəffaf məlumatın verilməsi və zəruri hallarda razılığın alınması daxildir.

Bütün bu tələblərə uyğun olaraq, şirkətlər məlumatların necə işlənəcəyi və onların necə toplanması, yenilənməsi, saxlanması və silinməsi ilə bağlı aydın təlimatlara ehtiyac duyur.

**Nəticə**

Sənaye iqtisadiyyatından rəqəmsal iqtisadiyyata keçdiyimiz bir vaxtda müasir bazar iqtisadiyyatının nəzəri əsaslarına diqqət yetirmək olduqca mühüm məsələdir. Sənaye iqtisadiyyatından fərqli olaraq, rəqəmsal iqtisadiyyatda məxfiliklə bağlı problemlər yaranır. Rəqəmsallaşma müxtəlif risklər, o cümlədən şəxsi məlumatların və korporativ məlumatların sızması ilə bağlı narahatlıq yaradır. Bundan əlavə, zərərli kiberhücumların yayılması bu günə qədər davam edən bir problemdir.

Müasir biznes səhnəsi rəqəmsal iqtisadiyyat səbəbindən dəyişdi və getdikcə daha mürəkkəb münasibətlər qurmaqla, rəqəmsal perspektivdən həyata keçirilməlidir. Bu amilin bazar rəqabətindən sağ çıxmaq üçün zəruri bir perspektiv olduğunu söyləmək olar. Rəqəmsallaşma dalğasına qoşulmaqla və müştərilər üçün ən yaxşı təklifləri çatdırmaqla şirkət yaxşı əlaqələr qura bilər. Rəqəmsal iqtisadiyyat, şübhəsiz ki, müştərilərlə əlaqələr qurmaq konsepsiyasını dəyişdi. Süni intellektin rəqəmsal iqtisadiyyatda getdikcə daha mühüm rol oynaması, məlumatların təhlilindən tutmuş məhsul və xidmətlərin fərdiləşdirilməsinə qədər bütün sahələrdə özünü biruzə verir, eyni zamanda məxfilik, məlumatların təhlükəsizliyi və istifadəsilə bağlı mühüm suallar doğurur. Süni intellektdən sui-istifadə və zərərli tətbiqlər bazarlarda sabitliyi poza, dezinformasiyanın yayılmasını sürətləndirə və münaqişələri gücləndirə bilər.

Neft-qaz sənayesində rəqəmsal transformasiyanın tətbiqi zamanı xarici və daxili amilləri, texnoloji və institusional imkanları, insan kapitalının vəziyyətini və inkişafını nəzərə almaq lazımdır. Neft və qaz müəssisələrinin rəqəmsal transformasiyası kontekstində biznes proseslərinin davamlılığının idarə edilməsi üçün nəzəri və metodoloji əsasları, tətbiqi metod və vasitələrin hazırlaması ilə bağlıdır. Ümid edirik ki, SOCAR-da rəqəmsal transformasiya və süni intellektdən istifadə sahəsində aparılan işlər genişləndiriləcək və bu sahədə mühüm nailiyyətlərə imza atılacaqdır.

**Bəyannamələr**

Əlyazma başqa heç bir jurnala və ya konfransa təqdim edilməyib.

**Təhsil Məhdudiyyətləri**

Tədqiqatın nəticələrinə təsir göstərə biləcək məhdudiyyətlər mövcud deyil.

**Təşəkkürlər**

Müəllif bu tədqiqatda iştirak edən, öz dəyərli fikirlərini və təcrübələrini bölüşən qayğı göstərən işçilərə və yaşlı insanlara təşəkkürünü bildirir. Onların əməkdaşlığı və açıqlığı tədqiqat nəticələrinin dərinliyinə və zənginliyinə əhəmiyyətli dərəcədə kömək etmişdir.

## ƏDƏBİYYAT

1. Özbay, R.D. & Yılmaz Genç, S. Dijital Ekonomi: Sistematik Bir Literatür Araştırması/ Journal of Emerging Economies and Policy 2023 8(2).
2. “SOCAR Ar-Ge ve İnovasyon A.Ş”. 2024. https://www.socar.az/az/page/socar-ar-ge-ve-inovasyon-as.
3. Ерёмин, Н. А. и др. Настоящее и будущее интеллектуальных месторождений / Н. А. Ерёмин, А. Н. Дмитриевский, Л. И.Тихомиров//Нефть.Газ.Новации.-2015.- № 12. - С. 44-49.
4. https://naukaneftegaz.livejournal.com/525.html.
5. Bukht, R., & Heeks, R. (2017). Defining, conceptualizing and measuring the digital economy. Development Informatics working paper, (68).
6. Qasımlı V., Talıbova M., Quliyeva G., Museyibov A., Mirzəyev F., Qədəşov A., Əhmədova G. Rəqəmsal iqtisadiyyat. Bakı, ”Azprint”nəşriyyatı, 2023, 262 səh.
7. Keary T. Top 10 Countries Leading in AI Research & Technology in 2024. 29 January 2024, https://www.techopedia.com/top-10-countries-leading-in-ai-research-technology.

8. Meisel, W. The Software Society, Trafford, EE.UU., 2017, p. 220.
9. David Eaves. When measuring the digital economy, measure the (creative) destruction too. URL:https://www.eaves.ca/2010/11/02/when-measuring-the-digital-economy-measure-the-destruction-too (дата обращения: 26.08.2019).
10. Топилин М. О модернизации системы профессиональных квалификаций. URL: http://www. kremlin.ru/events/president/news/61095 (дата обращения: 26.08.2019).
11. SOCAR discloses ongoing digital transformation projects. 2022. https://en.trend.az/business/3559756.html.
12. SOCAR "Rəqəmsal yataq" layihəsinə başlayır. 23.04.2020. https://ikisahil.az/post/151490-socar-reqemsal-yataq-layihesine-bashlayir.

## DIGITAL ECONOMY AND ARTIFICIAL INTELLIGENCE

**Sadagat İbrahimova[1], Mansur Bagyrzade[2]**
[1]Azerbaijan State Oil and Industry University, Economics Department of Management,
[1] Docent, PhD in Economics Department of Management, ibrahimovasadagat06@gmail.com,
ORCID: 0000-0000-1317-4806
[2]Master's student,

## ABSTRACT

The development of information processing technologies has already had a great impact on the field of economic activity. The development of the digital economy has led to more diversified patterns of interaction and coordination between industries and consumers, competitors and suppliers, governments and people. Smart cities controlled by emerging technologies have become one of the development goals of various countries in the 21st century. Modern economic and industrial policy is based on digital policy. The successful model of the social market economy is still relevant as a political compass, but it must be adapted to new circumstances. Transforming leading industries should form three equal pillars, along with mid-sized businesses and startups.

Changing traditional activities in the field of oil and gas industry in the direction of using digital technologies is of great importance in modern times. The application of smart wells, smart fields, unmanned hydrocarbon production technologies that make up the digital oil and gas industry is also a very important issue in SOCAR. The article analyzed the relationship between the digital economy and artificial intelligence, and also provided information on the important features of the digital oil and gas industry. With the evolution of artificial intelligence, technology industries in various fields such as semiconductors, software, hardware, Internet services and other companies around the world are simultaneously facing unprecedented challenges and excitement. The development of artificial intelligence promises a revival of consumption, increased productivity in most professions, better risk management, but also raises fears of mass destruction of jobs, extensive reskilling, expansion of capacity in developed countries. Artificial intelligence is helping to transform the relationship between machine and human. Advances in artificial intelligence are driving the automation and enhancement of manufacturing systems. Artificial

intelligence is considered to be the driving force behind the creation of new business models in many sectors of activity, especially in the oil and gas industry. The technological development of oil and gas companies is accompanied by a sharp increase in the demand for information and the expansion of the use of information technologies. In general, the "internet of things", "cloud technologies", "digital fields" and other advanced technologies are capable of creating significant potential for increasing the efficiency of oil and gas companies.

The active application of digital technologies in all areas of human life changes business models, accelerates the process of companies entering the global market, creates new conditions for hiring personnel, replaces certain types of human labor with algorithms and machines. At the same time, digitization and technological innovations create opportunities: new jobs; expanding the fields of employment that reveal the creative potential of a person. This requires new approaches to understanding the processes of transformation of the labor process in the digital economy, determining the advantages of the worker over the machine in the field of labor, and developing measures to strengthen the position of the worker in the digital labor market.

The digital economy can be defined as the use of various innovative digital technologies and cross-domain integration platforms in the new economic environment. Innovative service models to reshape the structure and economic value of buying and selling goods and services for B2B and B2C users. Innovative digital technologies include artificial intelligence (AI), data analytics, cloud computing, virtual reality (VR), augmented reality (AR) and blockchain (Blockchain) and other emerging sciences and technologies.

The digital economy has become increasingly important in recent years. By definition, the digital economy uses digital technologies and the Internet to enable and facilitate business transactions. Products and services are offered online and the buying and selling process takes place digitally. Goods or services are often presented digitally and paid for using virtual means of payment or cryptocurrencies. Interactions between companies and consumers also happen mostly digitally - via web browser, app, email or chat. Digitization of information enables faster and more efficient communication, facilitates access to global markets and helps automate work processes.

As we move from an industrial economy to a digital economy, it is extremely important to pay attention to the theoretical foundations of a modern market economy. Unlike the industrial economy, privacy issues have arisen in the digital economy. Digitization raises various risks, including concerns about the leakage of personal data and corporate data. In addition, the proliferation of malicious cyber-attacks is a problem that continues to this day.

**Keywords:** digital economy, artificial intelligence, digital technologies, oil and gas industry, digital transformation, increasing efficiency.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-102

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# РОЛЬ САМОСТОЯТЕЛЬНОЙ РАБОТЫ В СИСТЕМЕ ПОДГОТОВКИ БУДУЩИХ УЧИТЕЛЕЙ ИСТОРИИ

**[1]Светлана Долецкая, [2]Татьяна Скрябина**
[1]Федеральное государственное автономное образовательное учреждение высшего образования «Крымский федеральный университет имени В. И. Вернадского» Евпаторийский институт социальных наук (филиал) в г. Евпатории, кандидат педагогических наук, доцент, доцент кафедры истории и правоведения, doletskaja@yandex.ru (Крым),
[2]Федеральное государственное автономное образовательное учреждение высшего образования «Крымский федеральный университет имени В. И. Вернадского» Евпаторийский институт социальных наук (филиал) в г. Евпатории, кандидат педагогических наук, доцент, доцент кафедры истории и правоведения, tartanen@yandex.ru, (Крым)

## ABSTRACT

The article reveals the role of independent work in the system of training future history teachers, its features in the preparation and formation of professional qualities of bachelors. The potential of a number of tasks of independent work is emphasized, the conditions for its effective organization are highlighted and justified.
**Keywords:** teacher, history, education, activity, independent work, innovative culture, professional activity.

## РЕЗЮМЕ

В статье раскрывается роль самостоятельной работы в системе подготовки будущих учителей истории, ее особенности в подготовке и формировании профессиональных качеств бакалавров. Подчеркнут потенциал ряда заданий самостоятельной работы, выделены и обоснованы условия ее эффективной организации.
**Ключевые слова:** учитель, история, образование, деятельность, самостоятельная работа, инновационная культура, профессиональная деятельность.

**Постановка проблемы.**
Важная задача высшего образования заключается в подготовке и формировании личности, которая будет способна развиваться, самообразовываться, реализовывать инновационную деятельность и культуру. «Содержательную основу подготовки будущих учителей истории к инновационной педагогической деятельности составляют новшества, применяемые на современном этапе в процессе подготовки обучающихся. Современное образование становится все более динамичным и вариативным. На смену традиционным формам обучения пришло инновационное, что основано на предвидении своего профессионального будущего, активном участии преподавателей в его создании. Наблюдается глубокий разрыв между возрастающим усложнением мира и способностью человека ориентироваться в новых условиях жизни» [6, с. 228]. Обучающийся должен перейти от пассивного потребления знаний к активному анализу исторических проблем, умению находить пути решения и получать оптимальный результат с обоснованными выводами.
Вся система исторического образования ориентирована на фундаментальные теоретические знания, именно поэтому обучающемуся необходимо иметь дело с

множеством информации и выработать новые подходы к ее обработке, которые будут направлены на познавательную самостоятельность, умение отбирать, усваивать актуальную информацию.

Изучение исторического прошлого в условиях реформирования высшего образования приобретает все большую значимость; также это связано с усилением внимания к духовной сфере человечества в условиях развития демократического государства, изучением исходной базы, побуждающей преподавателей вузов к выработке особого подхода к подготовке будущих учителей истории. Высшая школа динамично развивается и направляет обучающегося в самостоятельную учебно-познавательную деятельность.

Анализ исходной базы позволил рассмотреть творческую самостоятельную работу обучающихся как деятельность, которая обусловлена самостоятельным поиском будущим специалистом ответа на любую проблему, с целью достижения результатов, имеющих объективную или субъективную новизну и оригинальность, прогрессивность, в условиях владения средствами организации этой деятельности на фоне позитивного отношения к познанию. Главными структурными элементами самостоятельной работы обучающихся являются ее цель и мотивы, которые могут быть как разнообразными, так и противоречивыми. Актуальность и инновационность проблемы самостоятельной работы можно обосновать необходимостью поиска наилучшего решения в форме конкретных моделей и форм.

**Изложение основного материала исследования.**

Главной целью и задачами выполнения самостоятельной работы по получению теоретических и эмпирических знаний является их систематизация, работа с базовыми понятиями, умение решать когнитивные задачи, устные и письменные тесты.

В ходе самостоятельной работы обучающиеся должны усвоить материал закрепить его путём написания контрольных работ, также тестовых заданий для самопроверки, прежде чем применить полученные знания на практике, провести анализ исторической ситуации, выработать правильное решение путём применения различных активных методов обучения таких как дискуссия, диалог и др. На заключительном этапе обучающийся должен уметь применить полученные знания и умения на практике для того, чтобы сформировать собственную теоретическую позицию и выработать модель понимания той или иной темы.

Все количество часов, отведенных учебным планом на изучение определенной дисциплины, разделяют на аудиторную и самостоятельную работу обучающихся. Все виды последней можно поделить на работы репродуктивные, творческие и комбинированные.

Представление учебного материала по любой дисциплине совокупностью модулей обусловлено необходимостью разложения информации на логически связанные модули (порции). Это требование связано с особенностями механизма функционирования кратковременной памяти человека. При этом усвоение учебного материала осуществляется обучающимися самостоятельно в процессе поэтапной переработки информации с последующим ее закреплением в долгосрочной памяти в случае неоднократного повторения [7].

Овладение умениями и навыками самостоятельной работы является необходимой предпосылкой для качественного усвоения модульной учебной программы и успешной профессиональной деятельности будущих учителей истории. Установлено, что логические и специфические приемы умственной деятельности формируются в определенном порядке.

Перед тем как стать умственными, то есть максимально обобщенными и усвоенными, действия проходят несколько этапов: предварительное ознакомление с предметом, этап материального действия, перенос действия к плану гласной речи без опоры на предметы, этап внешней речи о себе, умственный этап. Только при такой последовательности формирования умственных действий обучающийся имеет возможность на высоком уровне овладеть новыми знаниями и приобрести возможности реализовать их на практике [1].

Итак, в организации самостоятельной работы будущих учителей истории важно обратить внимание на: 1) работу с архивными источниками по истории, формирование исходной базы исследования; 2) работу с нормативно-правовыми актами; 3) выявление особенностей развития исторических явлений путем анализа современных научных публикаций; 4) работу со словарями (определение понятий); 5) создание схем, моделей и макетов; 6) выполнение тестовых заданий по темам курса; 7) реферирование исторического материала; 8) создание пакета документов «Портфель студента»; 9) самостоятельную работу студента в сети Интернет и т.д. «Краеведческая работа, таким образом, предоставляет практически все возможности для реализации современного практико-ориентированного обучения в образовательных организациях разного уровня, что делает ее особенно актуальной и влечет за собой необходимость обращать пристальное внимание на краеведческую подготовку будущих учителей истории» [3, с. 305-306].

Историки, преподаватели общественных дисциплин, чаще всего сталкиваются с необходимостью работы с понятиями и терминами, поскольку именно они в концентрированном виде содержат ту информацию, которую необходимо усвоить и могут служить отправной точкой как для приобретения новой информации, так и для извлечения из памяти, усвоенной ранее. В связи с этим в ходе самостоятельной работы необходимо уделять особое внимание работе с терминами, которые должны детально рассматриваться с разных сторон. Одним из эффективных способов работы с терминами является попытка создания собственных формулировок, которые можно предложить обучающимся после усвоения материала темы. Кроме того, работа с терминами требует глубокого понимания и знания предмета, поскольку идёт процесс постоянного обновления содержания терминов и появления новых, ранее не используемых в научной среде.

Как известно, история содержит огромное количество дат, имён, фактов и их наиболее интересных и занимательных подробностей. С одной стороны, увлечение подробностями может повысить интерес обучающихся к предмету, увлечь, дать пищу для размышлений и привести к серьезной исследовательской работе; с другой же –огромное количество информации может привести к тому, что будет потеряна основная канва событий, возникнут трудности в понимании закономерностей исторического процесса. В этой ситуации необходимо придерживаться определенного баланса, использовать карты, схемы, а также таблицы сравнительно-сопоставительного характера. «Обучающиеся, при составлении сравнительных хронологических таблиц решают еще одну немаловажную задачу – выделение главных дат, позволяющих создать периодизацию, и служащих своеобразным костяком исторического процесса. Конечно, подбор дат зависит от масштабности периода, объема избранной тематики, цели задания; но в любом случае предполагается их разделение на основные и вспомогательные, которое необходимо осуществить самостоятельно и обосновать, предварительно проанализировав обширный материал» [4, с. 78].

Собственно заполнение таблиц требует достаточно обширных знаний, причём не просто фактического материала, а чаще всего уже проработанного и аналитически осмысленного, поскольку для того, чтобы сравнить необходимо глубоко знать и понимать материал. Наиболее сложным заданием является сравнение не по уже заданным критериям, а выделение собственных критериев, направленных на поиск общего и особенного.

Исторические карты традиционно используются для самостоятельного извлечения материала, на современном этапе их возможности существенно расширились за счет применения компьютерных технологий: «…карта является серьезным подспорьем в получении профильных исторических знаний, а также может выступать средством развития критического мышления; позволяет воспринимать события прошлого и настоящего в тесной связи не только с их локализацией, но и способствовать определению их роли в историческом процессе» [2, с. 296].

Обоснованно популярной является работа с тестами. Если решение большей части тестовых заданий рассчитано на воспроизведение материала, то составление тестов с выполнением всех необходимых требований можно назвать довольно сложной задачей, в ходе которой нужно выделить вопросы, которые охватывают основное содержание темы и могут проверить уровень знаний. Выполнение такой работы необходимо контролировать и проводить тогда, когда обучающиеся уже имеют определённый опыт и обладают суммой знаний.

Отдельного внимания заслуживает подготовка рефератов, а затем курсовых и выпускных работ в ходе подготовки которых студенты осуществляют результативную самостоятельную работу. Особенно плодотворными выступают рефераты или доклады, связанные с изучением исторических источников, трактовка которых, как правило, носит неоднозначный характер, требует изучения мнения различных исторических школ и формирования собственного мнения. Более углублённым макетом этой же деятельности являются курсовые и выпускные работы соответствующей тематики.

Контроль выполнения самостоятельной работы студента-историка выступает неотъемлемой составляющей учебного процесса, одной из основ организации и повышения его эффективности.

Задачей, требующей творческого решения, является проверка заданий самостоятельной работы. Без систематической проверки и обязательной корректировки система самостоятельной работы не будет эффективной, поскольку обучающиеся, особенно младших курсов обучающиеся как правило не обладают достаточной мотивацией и сталкиваются с дефицитом времени, так как на них обрушивается поток непривычных разнообразных заданий. Если система проверки самостоятельной работы не будет организована, обучающиеся могут просто отложить выполнение заданий она неопределённое время.

Частично контроль можно осуществлять в ходе практических занятий, подготовка к которым тоже составляет часть самостоятельной работы. Каждая практическая работа должна быть направлена, с одной стороны, на воспроизведение пройденного материала и его преобразование, то есть осуществляться на репродуктивном и творческом уровнях. На практике каждое занятие кроме стандартных вопросов для обсуждения и практических задач, может сопровождаться целым набором заданий на выделение наиболее важных дат, терминов, персоналий. Важно включать вопросы для самоконтроля, которые формулируются для того, чтобы обучающийся при подготовке не упустил каких-то важных

событий или деталей; и в случае, если это произошло, имел возможность вернуться к теме и проработать необходимый материал.

Отдельный жанр практического занятия – это проблемные вопросы, постановка которых вызывает ряд трудностей, особенно у обучающихся первых курсов. Именно стремление увидеть проблемность в той или иной тематике как раз-таки и формируют исследовательские навыки, которые в дальнейшем используются в студенческой научной деятельности.

Если система проверки самостоятельной работы налажена и ни одно задание не остается без внимания преподавателя, у обучающегося постепенно складывается привычка выполнения самостоятельной работы, он осознает ее необходимость и значимость. Кроме того, на старших курсах контроль постепенно может заменяться мотивацией на глубокое изучение необходимых профессиональных знаний, умений, навыков, поскольку обучающийся осознаёт, что в ближайшей перспективе все это предстоит применять на практике.

При этом преподаватель должен соблюдать педагогические требования объективности, систематичности, дифференцированности проверки и тому подобное. Объективно определить уровень усвоения материала позволит применение модульно-рейтинговой оценки выполнения самостоятельной работы. «В зависимости от ситуации, иногда необходимо практически мгновенно принять решение (проявить оперативность мышления), активизировать имеющиеся знания и на их основе вывести новое суждение (проявить системность мышления), изменить что-то в своих словах или действиях (проявить пластичность мышления), иногда неожиданно для себя найти необычный ход размышлений, неизвестный ранее способ обучения (проявить креативность мышления), воспринимать аргументы оппонента с точки зрения их убедительности, научности, признавать их целесообразность (проявить толерантность, сдержанность, тактичность, мобильность мышления)» [5, с. 210].

Эффективная организация самостоятельной работы нуждается в соблюдении определенных условий.

Прежде всего, ее цели и задачи должны обязательно сопрягаться с содержанием образовательных программ того ВУЗа, где обучаются студенты.

Следующий фактор, который определяется потребностями современного мира – это те требования, которые предъявляет работодатель и рынок труда в целом. Навыки, полученные в ходе самостоятельной работы, должны соответствовать этим требованиям.

Важным условием является целостность, непрерывность самостоятельной работы, которая должна осуществляться постоянно от одного предмета к другому, имея при всём её разнообразии определённую преемственность.

Задания самостоятельной работы должны быть дифференцированы таким образом, чтобы каждый обучающийся мог достичь успеха, чтобы они не представляли неразрешимых задач для обучающихся, давали возможность применения и развития полученных умений и навыков.

Кроме того, необходимо учитывать уровень развития интересов обучающихся, их личностные особенности, в соответствии с которыми, в случае если предоставляется такая возможность, определять актуальные для студентов виды самостоятельной работы.

**Выводы**

Таким образом, самостоятельная работа способствует: углублению и расширению знаний по истории; формированию интереса к познавательной деятельности; овладению приемами процесса познания; развитию познавательных способностей; выработке собственной позиции, способности применить изученное на практике, творчески переосмысливать, соотносить полученные результаты деятельности с перспективами своей будущей профессии. Поэтому, при условии создания оптимальных условий, она становится главным резервом повышения эффективности подготовки будущих учителей истории и дает возможность поднять уровень готовности к успешной профессиональной деятельности.

**Декларации**

Рукопись не была представлена в какой-либо другой журнал или на конференцию.

**Ограничения исследования**

Ограничений, которые могли бы повлиять на результаты исследования, нет.

**Подтверждение**

Автор хотел бы выразить благодарность работникам службы поддержки и пожилым людям, которые приняли участие в этом исследовании, поделившись своими бесценными знаниями и опытом. Их сотрудничество и открытость в значительной степени способствовали глубине и богатству результатов исследований.

**ЛИТЕРАТУРА**

1. Vyazemskiy, Ye. Ye. Teoriya i metodika prepodavaniya istorii. – M.: VLADOS, 2003. – 384 s.
2. Doletskaya, S. V. Nekotoryye vozmozhnosti ispol'zovaniya kartograficheskoy naglyadnosti v protsesse obucheniya istorii / S. V. Doletskaya // Realizatsiya kompetentnostnogo podkhoda v sisteme professional'nogo obrazovaniya pedagoga: Sbornik materialov IX Vserossiyskoy nauchno-prakticheskoy konferentsii (s mezhdunarodnym uchastiyem), Yevpatoriya, 14–15 aprelya 2022 g. – Simferopol': OOO «Izdatel'stvo Tipografiya «Arial», 2022. – S. 296-300.
3. Doletskaya, S. V. Podgotovka budushchikh uchiteley istorii i obshchestvoznaniya k istoriko-krayevedcheskoy deyatel'nosti / S. V. Doletskaya // Realizatsiya kompetentnostnogo podkhoda v sisteme professional'nogo obrazovaniya pedagoga: sbornik materialov X Vserossiyskoy nauchno-prakticheskoy konferentsii, Yevpatoriya, 14–15 aprelya 2023 g. – Simferopol': OOO «Izdatel'stvo Tipografiya «Arial», 2023. – S. 305-309.
4. Doletskaya, S. V. Spetsifika kursa istorii Drevnego Vostoka kak sostavnoy chasti istorii Drevnego mira i osobennosti yego prepodavaniya / S. V. Doletskaya // Problemy sovremennogo pedagogicheskogo obrazovaniya. – 2023. – № 79-2. – S. 77-79.
5. Skryabina T.O. Metodicheskiye aspekty razvitiya kriticheskogo myshleniya u obuchayushchikhsya vysshey shkoly / T. O. Skryabina // Problemy sovremennogo pedagogicheskogo obrazovaniya – 2022. – № 74-2. – S. 210-212.

6. Skryabina T.O. Razvitiye innovatsionnoy kul'tury budushchego uchitelya istorii v protsesse obucheniya / T. O. Skryabina // sbornik trudov Í-y mezhdunarodnoy nauchno-prakticheskoy konferentsii «Psikhologo-pedagogicheskoye soprovozhdeniye obrazovatel'nogo protsessa». – Simferopol': IT «ARIAL», 2022. – S. 228-231.
7. Studenikin, M. T. Metodika prepodavaniya istorii v shkole. – M.: VLADOS, 2003. – 240 s.

Publication history

Article received: 20.12.2023
Article accepted: 10.01.2023
Article published online: 10.02.2024
DOI: 10.36962/CESAJSC58012024-113

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# EDITORIAL BOARD & INTERNATIONAL ADVISORY

**Bahrain**



**Bangladesh**



**Bosna & Hercegovina**



**Brazil**



**Bulgaria**

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



## AIMS AND SCOPE

**ESIF NGO The Southern Caucasus Scientific Journals** publishes peer-reviewed, original research and review articles in an open-access format. Accepted articles span the full extent of the social and behavioral sciences and the humanities.

ESIF NGO The Southern Caucasus Scientific Journals seeks to be the world's premier open-access outlet for academic research. As such, unlike traditional journals, ESIF NGO The Southern Caucasus Scientific Journals does not limit content due to page budgets or thematic significance. Rather, ESIF NGO The Southern Caucasus Scientific Journals evaluates the scientific and research methods of each article for validity and accepts articles solely on the basis of the research. Likewise, by not restricting papers to a narrow discipline, ESIF NGO The Southern Caucasus Scientific Journals facilitates the discovery of the connections between papers, whether within or between disciplines.

ESIF NGO The Southern Caucasus Scientific Journals offers authors quick review and decision times; a continuous-publication format; and global distribution for their research via ESIF NGO The Southern Caucasus Scientific Journals Online. All articles are professionally copyedited and typeset to ensure quality.

Those who should submit to ESIF NGO The Southern Caucasus Scientific Journals include:

- Authors who want their articles to receive quality reviews and efficient production, ensuring the quickest publication time.
- Authors who want their articles to receive free, broad, and global distribution on a powerful, highly discoverable publishing platform.
- Authors who want their articles branded and marketed by a world-leading social science publisher.
- Authors who want or need their articles to be open access because of university or government mandates.

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



## TOPICS OF JOURNAL

Agricultural, environmental & natural sciences
Social, pedagogy sciences & humanities
Medicine and biology sciences
Regional development and infrastructure
Economic, management & marketing sciences
Legal, legislation and political sciences
Art and Film Studies
Cinematography
History of Science and Technics
Information, Computing and Automation
Innovative Technologies
Mathematics & Applied Mathematics

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



**NGO Education Support & Investment Fund (Georgia, Tbilisi)** is publishing scientific papers of scientists on Website and in Referred Journals with subjects which are mentioned below:



ISSN: 2613-5817; E-ISSN: 2613-5825; UDC: 0 (0.034);
DOI PREFIX: 10.36962/PIRETC
Proceeding of The International Research Education & Training Center.
http://bsj.fisdd.org/index.php/piretc

ISSN: 2674-4562, E-ISSN: 2674-4597, UDC: 620.9 (051) (0.034);
DOI PREFIX: 10.36962/ENECO
Proceedings of Energy Economic Research Center. ENECO
http://bsj.fisdd.org/index.php/eneco-peerc

ISSN: 1609-1620, E-ISSN: 2674-5224; UDC: 62 (051) (0.034);
DOI PREFIX: 10.36962/PAHTEI
Proceedings of Azerbaijan High Technical Educational Institutions. PAHTEI
http://bsj.fisdd.org/index.php/pahtei

ISSN: 2663-8770, E-ISSN: 2733-2055; UDC: 672, 673, 67.01-67.02
DOI PREFIX: 10.36962/ETM
ETM Equipment, Technologies, Materials
http://bsj.fisdd.org/index.php/etm

ISSN: 2733-2713; E-ISSN: 2733-2721; UDC: 33
DOI PREFIX: 10.36962/SWD
SOCIO WORLD-SOCIAL RESEARCH & BEHAVIORAL SCIENCES
http://bsj.fisdd.org/index.php/swd

E-ISSN: 2587-4713; UDC: 620.9 (051) (0.034)
DOI PREFIX: 10.36962 / ECS
Economics
https://scsj.fisdd.org/index.php/esc

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

**NGO Education Support & Investment Fund (Georgia, Tbilisi)** is publishing scientific papers of scientists on its Website and in Referred Journals with subjects which are mentioned below:



ISSN: 2346-8068; E-ISSN: 2346-8181; UDC: 611-618
DOI PREFIX: 10.36962/ALISJMSC
Ambiance in Life-International Scientific Journal in Medicine of Southern Caucasus.
http://scsj.fisdd.org/index.php/ail

**Representation of the International Diaspora Center of Azerbaijan in Georgia. NGO (Georgia Tbilisi)** and **NGO Education Support & Investment Fund (Georgia, Tbilisi)** are publishing scientific papers of scientists on its Website and in Referred Journals with subjects which are mentioned below:



ISSN: 2298-0946, E-ISSN: 1987-6114; UDC: 3/k-144
DOI PREFIX: 10.36962/CESAJSC
The Caucasus-Economic and Social Analysis Journal of Southern Caucasus
http://scsj.fisdd.org/index.php/CESAJSC

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



# Title of the Paper (14 point, Bold, Times New Roman)

**First Author's Name[1], Second Author's Name[2] , Third Author's Name[3],** .....
[1]Affiliation (Department, Faculty/College, Institution/University)
[2, 3]Affiliation of other authors, if different (Department, Faculty/College, Institution/University)
Corresponding author's email:
(Affiliation1,2,3 Times New Roman, 10)

Article Type: Refer to the section policy of journal for acceptable article types.

**ABSTRACT**
(Times New Roman, 12)
The manuscript should contain an abstract within 300 words. The manuscript should have a self-contained, citation-free abstract and state briefly the purpose of the research, methodology, key results and major conclusions. Abstract should be in a single paragraph with running sentences. Do not use any subheading or point list within the abstract. Also, non-standard or uncommon abbreviations should be avoided, but if essential they must be defined at their first mention in the abstract itself.
**Keywords:** Authors are advised to writes 3-5 keywords related to the article, separated by comma. These keywords will be used for indexing purpose.

## Introduction (Times New Roman, 12)

Mostly Papers starts with introduction. It contains the brief idea of work, requirement for this research work, problem statement, and Authors contribution towards their research. Sufficient recent reference citation [1] from last 2 years should be included for showing the existing challenges and importance of current work. This section should be succinct, with no subheadings unless unavoidable [2, 3]. State the objectives of the work and provide an adequate background related to your work, avoiding a detailed literature survey or a summary of the results.

## Research Methodology (Times New Roman, 12)

This part should contain sufficient detail to reproduce reported data. It can be divided into subsections if several methods are described. Methods already published should be indicated by a reference [4], only relevant modifications should be described. Methodology should be written concisely in detail by maintaining continuity of the texts.

## Theory and Calculation (Times New Roman, 12)

A Theory section should extend, not repeat, the background to the article already dealt with in the Introduction and lay the foundation for further work. In contrast, a Calculation section represents a practical development from a theoretical basis. Do not add extensive basic definitions or well-known theories, instead highlight theoretical background and its specific usages in view of your work only.

## Mathematical Expressions and Symbols (Times New Roman, 12)

Mathematical expressions and symbols should be inserted using **equation tool** of Microsoft word. References may be added for used equations to support its authenticity, e.g. this result has been analysed using Fourier series [5].

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



$$f(x) = a_0 + \sum_{n=1}^{\infty} \left( a_n \cos \frac{n\pi x}{L} + b_n \sin \frac{n\pi x}{L} \right) \quad (1)$$

**Results and Discussion** (Times New Roman, 12)

This section may each be divided by subheadings or may be combined. A combined Results and Discussion section is often appropriate. This should explore the significance of the results of the work, don't repeat them. Avoid extensive citations and discussion of published literature only, instead discuss recent literature for comparing your work to highlight novelty of the work in view of recent development and challenges in the field.

**Preparation of Figures and Tables** (Times New Roman, 12)

Authors are supposed to embed all figures and tables at appropriate place within manuscript. Figures and tables should neither be submitted in separate files nor add at the end of manuscript. Figures and Tables should be numbered properly with descriptive title. Each Figure/Table must be explained within the text by referring to corresponding figure/table number. Any unexplained or unnumbered Figure/Table may cause rejection of the paper without being reviewed.

**Formatting Tables** (Times New Roman, 12)

Table should be prepare using table tool within the Microsoft word and cited consecutively in the text. Every table must have a descriptive title and if numerical measurements are given, the units should be included in the column heading. Formatting requirement has been summarized in the Table 1.

**Table 1:** Summary of formatting requirement for submitting paper in this journal.
(Times New Roman, 12)

| **Layout** | **Size** | **Margin (Normal)** | **Header** | **Footer** | |
|---|---|---|---|---|---|
| Single column | A4 (8.27" X 11.69") | Top=1"<br>Bottom=1"<br><br>Left=1"<br>Right=1" | Do not add anything in the header | So not add anything in the footer | |
| **Font** | **Article Title** | **Headings** | **Subheadings** | **Reference list** | **Text** |
| | Times New Roman, 16 pt, Bold, centred | Times New Roman, 11 pt, Bold, Left aligned | Times New Roman, 10 pt, Bold, Left aligned | Times New Roman, 8 pt, Justified | Garamond, 11 pt, Justified |
| **Line Spacing** | 1.15 | 1.15 | 1.15 | 1.15 | 1.15 |
| Page number | We will format and assign page numbers | | | | |

(Times New Roman, 10)

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



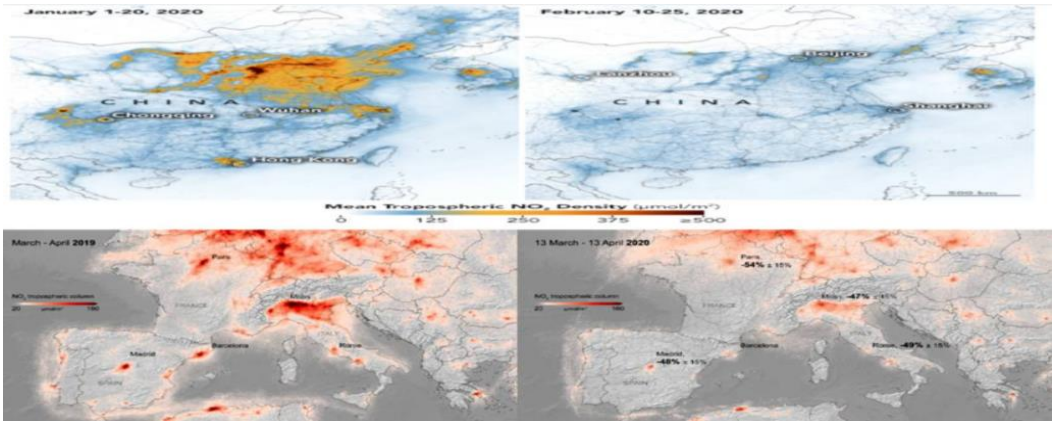



**Figure 1:** Logo of the IRETC Publisher (Times New Roman, 12)

**Formatting Figures** (Times New Roman, 12)
All figures should be cited in the paper in a consecutive order, author may be asked to provide separate files of the figure. Figures should be used in bitmap formats (TIFF, GIF, JPEG, etc.) with 300 dpi resolution at least unless the resolution is intentionally set to a lower level for scientific reasons. If a bitmap image has labels, the image and labels should be embedded in separate layer. Figure 1 shows the logo of AIJR Publisher.

**Conclusions** (Times New Roman, 12)
Each manuscript should contain a conclusion section within 250-450 words which may contain the major outcome of the work, highlighting its importance, limitation, relevance, application and recommendation. Conclusion should be written in continuous manner with running sentences which normally includes main outcome of the research work, its application, limitation and recommendation. Do not use any subheading, citation, references to other part of the manuscript, or point list within the conclusion.

**Declarations** (Times New Roman, 12)

**Study Limitations** (Times New Roman, 12)
Provide all possible limitation faced in the study which might significantly affect research outcome, If not applicable write, none.

**Acknowledgements** (Times New Roman, 12)
All acknowledgments (if any) should be included in a separate section before the references and may include list of peoples who contributed to the work in the manuscript but not listed in the author list.

**Funding source** (Times New Roman, 12)
Provide funding source, supporting grants with grant number. The name of funding agencies should be written in full, if no funding source exist, write, none.

**Competing Interests** (Times New Roman, 12)
Declare any potential conflict of interest exist in this publication.

**Human and Animal Related Study** (Times New Roman, 12)
If the work involves the use of human/animal subjects, each manuscript should contain the following subheadings under the declarations section-

**Ethical Approval** (Times New Roman, 12)
Provide ethical approval authority name with the reference number. If ethical approval is not required, provide an ethical exemption letter of not required. The author should send scan copy (in pdf) of the ethical approval/exemption letter obtained from IRB/ethical committee or institutional head.

**Informed Consent** (Times New Roman, 12)
Write a statement of informed consent taken from the participants to publish this research work. The editor may ask to upload scan copy if required.

**References** (Times New Roman, 12)
Author(s) are responsible for ensuring that the information in each reference is complete and accurate. **Do not use grey literature (unauthentic website, news portal, social media, Wikipedia etc) as reference, only scholarly literature (Journal, online books, proceedings, patents, authentic websites with permanent archival policy) are acceptable references.** Author should include sufficient recent (last 2 years) references in the article. All references must be numbered consecutively and citations of references in the text should be identified using numbers in square brackets (e.g., “as explained by AIJR [1]”; “as discussed in many reports [2]-[6]”). All references should be cited within the text correctly; do not add only list of references without citation within the text. All cited references should be listed after declarations section in the following style-

1. W. S. Author, “Title of paper,” Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. https://doi.org/10.21467/ajgr
2. Bahishti, “Peer Review; Critical Process of a Scholarly Publication”, J. Mod. Mater., vol. 2, no. 1, pp. 1.1-1.2, Oct. 2016. https://doi.org/10.21467/jmm.2.1.1.1-1.2
3. Bahishti, “A New Multidisciplinary Journal; International Annals of Science”, Int. Ann. Sci., vol. 1, no. 1, pp. 1.1-1.2, Feb. 2017. https://journals.aijr.in/index.php/ias/article/view/163
4. W. S. Author, “Title of paper,” Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. Access online on 20 March 2018 at https://www.aijr.in/journal-list/advanced-journal-graduate-research/
5. W. S. Author, “Title of paper,” Name of Journal in italic, vol. x, no. x, pp. xxx-xxx, Abbrev. Month, year. Access online on 5 March 2018 at https://www.aijr.in/about/publication-ethics/
6. M. Ahmad, “Importance of Modeling and Simulation of Materials in Research”, J. Mod. Sim. Mater., vol. 1, no. 1, pp. 1-2, Jan. 2018. DOI: https://doi.org/10.21467/jmsm.1.1.1-2

Main features of citation style are given as-

- The author name format is, "first name (Initial), middle name (Initial) and last name". This differs from other styles where author's last name is first.
- The title of an article (or chapter, conference paper, patent, etc.) is in quotation marks.
- The title of the book or journal is in italics.
- Online link of the original paper. If any reference is not available online, it should be modified with available online reference

Complete Detail of Each Author
Provide complete detail of each author in the following format as well as add each author with complete detail during online submission (step 3) in the same order as appears in the manuscript.

First Author's Full Name: (Times New Roman, 12)
Highest Qualification:
Department:
Post/Rank (If a student, provide course name and course year):
Affiliation (College/University/Institute) with postal address:
email id:
ORCID:
Mobile:

Second Author's Full Name: (Times New Roman, 12)
Highest Qualification:
Department:
Post/Rank (If a student, provide course name and course year):
Affiliation (College/University/Institute) with postal address:
email id:
ORCID:
Mobile:

Third Author's Full Name: (Times New Roman, 12)
Highest Qualification:
Department:
Post/Rank (If a student, provide course name and course year):
Affiliation (College/University/Institute) with postal address:
email id:
ORCID:
Mobile:

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online)
THE CAUCASUS
ECONOMIC AND SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS



## NOTES

## JOURNAL INDEXING

ISSN: 1987-6521; E-ISSN:2346-7541; DOI prefix: 10.36962/CESAJSC; UDC: 3/k-144
©Publisher: Representation of Azerbaijan International Diaspora Center in Georgia.
©Editorial office: 0165 Georgia. Marneuli municipality. Village Takalo.
©Typography: Representation of Azerbaijan International Diaspora Center in Georgia.
Registered address: 0165 Georgia. Marneuli municipality. Village Takalo.
Telephones: +994 55 280 70 12; +994 55 241 70 12 (Whatsapp),
Website: https://scsj.fisdd.org/index.php/CESAJSC
E-mail: gulustanbssjar@gmail.com; sc.mediagroup2017@gmail.com

©Publisher: ESIF NGO, I/N: 404619864
©Typography: ESIF NGO, I/N: 404619864
Registered Address / Service Address: Georgia, Tbilisi, Mtatsminda district, Jorjadze Street N 5, floor 1
Director & Shareholder: Namig Isazade
Telephones: +994 55 280 70 12; +994 55 241 70 12 (Whatsapp),
Website: https://scsj.fisdd.org/index.php/CESAJSC
E-mail: gulustanbssjar@gmail.com; sc.mediagroup2017@gmail.com

ISSN: 2298-0946 (Print), ISSN: 1987-6114 (Online); DOI PREFIX:10.36962/CESAJSC

VOLUME 58 (12) ISSUE 01 2024



# THE CAUCASUS

## ECONOMIC & SOCIAL ANALYSIS JOURNAL OF SOUTHERN CAUCASUS

MULTIDISCIPLINARY JOURNAL
REFEREED & REVIEWED JOURNAL

AGRICULTURAL, ENVIRONMENTAL & NATURAL SCIENCES
SOCIAL, PEDAGOGY SCIENCES & HUMANITIES
MEDICINE AND BIOLOGY SCIENCES
REGIONAL DEVELOPMENT AND INFRASTRUCTURE
ECONOMIC, MANAGEMENT & MARKETING SCIENCES
LEGAL, LEGISLATION AND POLITICAL SCIENCES
ART AND FILM STUDIES
CINEMATOGRAPHY

Platform & workflow by OJS/PKP

https://scsj.fisdd.org/index.php/CESAJSC

SCAN ME