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STUDY OF THE ENVIRONMENTAL IMPACT OF WASTE GENERATED DURING POLYETHYLENE PRODUCTION AT THE SOCAR POLYMER PLANT

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Abstract
This paper presents a detailed analysis of the environmental impact of high- and low-pressure polyethylene production processes. The composition of waste generated during the synthesis, polymerization, and granulation stages is investigated. Particular attention is paid to emissions of volatile organic and inorganic compounds, wastewater contamination with heavy metals, and the problem of microplastics in the form of industrial granules. An analysis of the qualitative and quantitative composition of gaseous, liquid, and solid waste was carried out.
Keywords: polyethylene, polymerization, petrochemical waste, volatile organic inorganic compounds, microplastics.

Introduction

The production of synthetic polymers is one of the fastest growing sectors of the global chemical industry. Polyethylene (PE), thanks to its unique physical and chemical properties, low cost, and versatility, occupies a leading position among all plastics produced [1]. Global polyethylene production exceeds 100 million tons per year and continues to grow, driven by demand for packaging materials, pipes, insulation, and consumer goods. In developed countries, per capita consumption was 85-90 kg per person, and this figure continues to grow annually. Along with the growth in polyethylene production, its negative impact on the environment has also increased

[2].

The technological cycle for producing polyethylene includes the processes of hydrocarbon pyrolysis, gas separation, polymerization (at high or low pressure), degassing, and granulation. Each of these stages produces specific types of waste: gaseous emissions containing ethylene and solvents; liquid effluents contaminated with oligomers and catalytic sludge; solid waste in the form of defective polymer, “lumps” and dust. Polymer materials are usually multicomponent systems created using various polymer components. Technological waste in the production of polymer materials arises during their synthesis and processing. They are divided into recyclable materials and technological waste that cannot be recycled. Such waste accounts for 5 to 35%. Based on the insoluble basis of the waste, the raw material is of high quality, not differing from the properties of the original polymer. No special equipment is required to process this waste, which is produced at the same plant. Waste generated during production is used in the processing of various products in addition to various products used as raw materials. In the production of multicomponent polymers, as well as in their practical use, there are processes of separating a number of harmful low-molecular substances from materials [3,4].

Polymer materials with physical, chemical, structural, and technological properties based on various plastics and elastomers are widely used in various areas of the economy and medicine. This is associated with the generation of waste at all stages of the production and processing of polymer materials. Therefore, their disposal is a pressing issue, and their negative impact on human health and the environment has always been a global problem. The solution to environmental problems has led to strict requirements: the production of polymers must be environmentally friendly or at least have a minimal impact on the environment [5].

The purpose of this work is to identify harmful substances emitted into the atmosphere at SOCAR Polymer production facilities, study their concentration in the air, and assess the environmental impact of each of them on the surrounding environment.

Materials and methods

Polyethylene is the most widely used polymer in the world, accounting for more than 30% of the total plastics market [6]. The chemical formula of the monomer is ethylene (CH_2=CH_2).

$$nCH_2 = CH_2 \xrightarrow{P,t,cat} [-CH_2 - CH_2-]_n$$

Despite the chemical inertness of the product itself, the technological processes involved in its production (polymerization, separation, granulation) are associated with the generation of significant amounts of

waste. Technological stages and sources of waste generation Polyethylene production is divided into two main types: LDPE (low-density polyethylene): Radical polymerization at high pressure. HDPE (high-density polyethylene): Ion-coordination polymerization at low pressure using catalysts [7]. Specific types of waste are generated at each stage. The use of organometallic catalysts (Ziegler-Natta, chromium) leads to the formation of toxic sludge containing heavy metals.

In various countries, the production of polyethylene results in the release of many tons of waste into the atmosphere, which severely pollutes the environment. Fig. 1.

Fig. 1. Emissions into the atmosphere during polyethylene production

Industrial pellets (Nurdles): This is one of the most pressing problems. Small granules of raw material (2-5 mm in diameter) often spill during transportation and packaging, ending up in storm drains and from there into rivers and oceans. Fig. 2.

Fig. 2. Emissions of pollutants into the atmosphere during polyethylene production [8]

The ethylene production process and the stages of atmospheric pollutant emissions are shown in Figure 3.

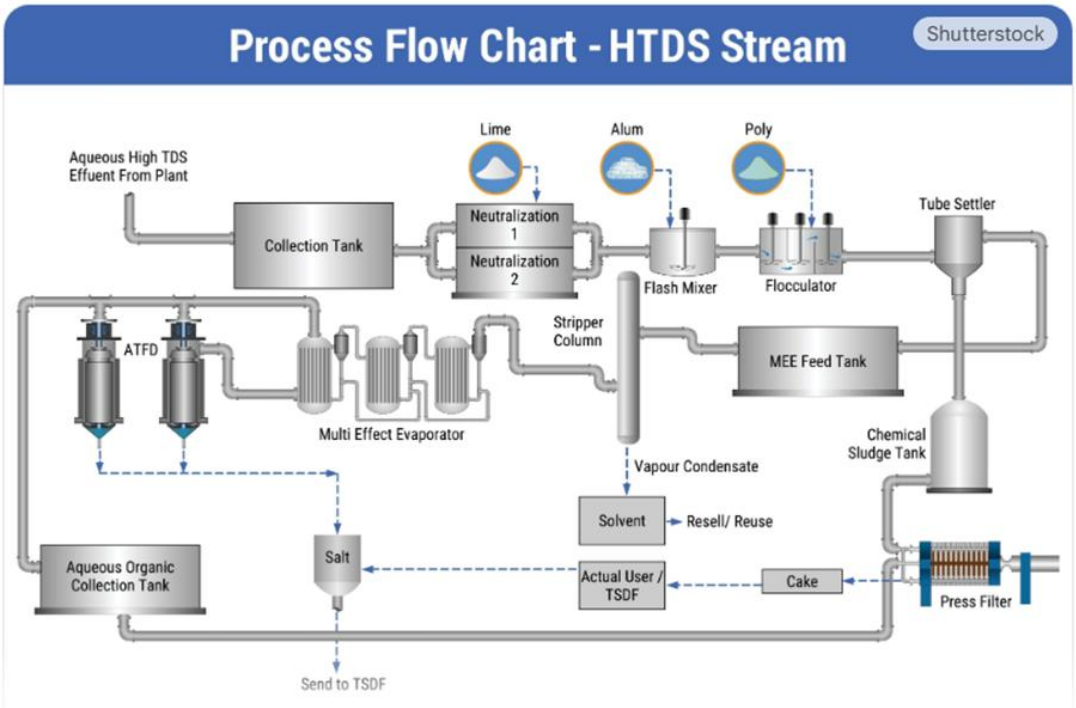

Fig. 2. Schematic diagram of waste generation sources in the process of ethylene suspension polymerization.

We have access to information on the dynamics of polyethylene production from 2009 to 2023 [9]. The graph clearly shows that the growth in the production of plastic materials is increasing significantly year after year. Naturally, this is also a source of environmental pollution.

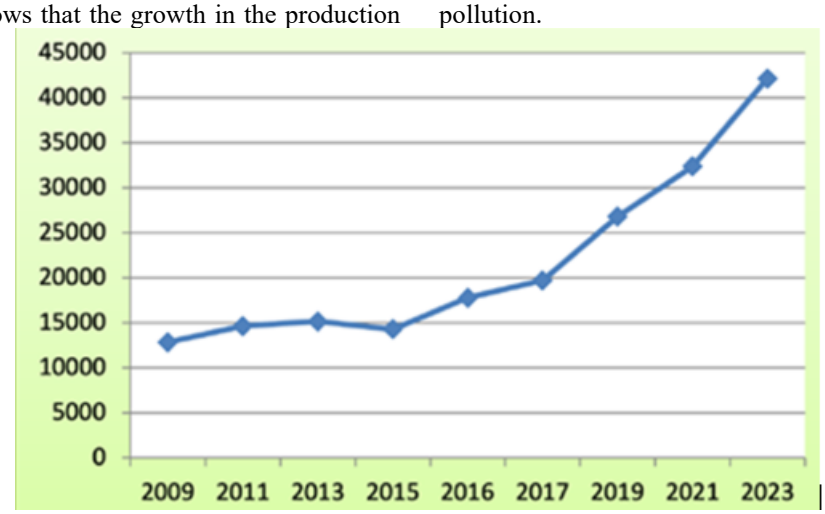

Fig. 3. Dynamics of polyethylene production in Azerbaijan in 2009-2023.

The technological process of polyethylene production consists of three main stages. The first stage involves the preparation of raw materials, namely the purification of raw materials from impurities and contaminants, as well as the regeneration of catalysts used in purification. This stage is characterized by the highest formation of harmful substances that have a negative impact on the environment (Table 1). The data available in the literature on the total amount of pollutant emissions in polyethylene production is shown in table 1 [10].

Table 1.

Emissions of pollutants into the atmosphere during polyethylene production

Pollutant	Hazard class	Mass of pollutant emissions per ton of product, kg/t	
		Minimum value	Maximum value
Suspended solids	-	-	0,072
Ethylene	4	2,45	6,7
Carbon monoxide	4	-	0,93
Butylene	4	0,011	0,053
Aliphatic	3	0,040	0,31
Hydrocarbons C1-C5 (excluding methane)	3	-	0,022
Aliphatic	3	0,0012	0,093
Hydrocarbons C6-C10	3	-	0,00018
Nitrogen dioxide	2	0,00021	0,16
Acetaldehyde	1	-	-

The second stage involves the synthesis of polyethylene in a reactor using initiators and catalysts – this stage is the main stage in the production of polyethylene. During the ethylene polymerization process, ethylene oxide may be formed, which can be purified and sold as a by-product, as well as benz(a)pyrene, which is classified as a Class I hazardous substance. It should be noted that pollutant emissions during the second stage are most often associated with malfunctions in the technological equipment.

At the final stage of production, called "granulation," polyethylene chips may form in the air, which when heated can release organic acids, formaldehyde, and acetaldehyde, as well as ethylene oxide. All these substances, when exceeding the maximum permissible concentration, lead to acute and chronic poisoning [11].

The Polypropylene and High-Density Polyethylene production areas at the SOCAR Polymer plant are designed to produce 200,000 tons of polypropylene and 120,000 tons of high-density polyethylene per year, respectively. Measurements were conducted by our team at 5 selected points in the production area of the SOCAR Polymer plant for PM10 (particulate matter), background radiation, dust, volatile organic compounds (VOC), sulfur dioxide (SO_2), nitrogen oxides (NOx), and noise levels in the ambient air. The coordinates of the measurement points were determined and the corresponding records were kept [12,13].

Environmental monitoring was organized in two phases (active and passive). The results of the studies conducted with mobile devices are presented in Table 2. For the determination of volatile organic compounds, Camsco tubes were used during passive monitoring; the gravimetric method was used for the determination of dust particles; and during active monitoring, a remote sensor "Qrawulf" device was used for the determination of CO, SO_2, NO, and NO_2 [14,15]. The collected samples were analyzed at Azecolab Company LLC, and the results of the laboratory analyses are presented in tables 2 and 3.

Table 2.

Results of laboratory analysis conducted by Azecolab.

Sernumber	**Date**	**06.10.2025**	**Station indicators**					**Mobile device**
1.	**Parameters**	**Unit of measurement**	**Lesson 1. Between zones 02 and 03.**	**Section 2. Between units E-2 and E-5.**	**3. Between zones 01 and 05**	**4. Between object S-3 and zone 05**	**5. Near the nitrogen plant.**	
2.	**NOx (nitric oxide)**	**mq/m³**	**0,02**	**0,02**	**0,0**	**0,0**	**0,02**	**Gas analyzer**
3.	**SO_2**	**mq/m³**	**0,001**	**0,000**	**0,001**	**0,001**	**0,001**	
4.	**CO**	**mq/m³**	**0,07**	**0,07**	**0,07**	**0,07**	**0,07**	
5.	**VOC**	**mq/m³**	**0,02**	**0,02**	**0,02**	**0,02**	**0,02**	
6.	**General dust**	**mq/m³**	**0,001**	**0,005**	**0,071**	**0,001**	**0,001**	**Dust meter**
7.	**Radiation**	**mkR/saat**	**11-13**	**10-12**	**10-11**	**11-13**	**10-11**	**Dosimeter**
8.	**Noise**	**dB**	**56-63**	**60-65**	**76-80**	**80-82**	**90-95**	**Sound measurement**

Table 3

Results of surveys conducted using mobile devices in polymer production areas.

Gas sample								
Act No.	Date of analysis		Note					
	Started	Finished						
Order	06.10.2025	06.11.2025	Sample code					Regulatory document
	Parametrlər	Ölçü vahidi	St. 1. 19/00040	St. 2. 19/00041	St.3. 19/00042	St.4. 19/00043	St. 5. 19/00044	
1.	VOC	ppm	<1.00	<1.00	<1.00	300-990	9-17	İSO 6976 ASTM D1945
2.	CO carbon monoxide	Volume %	<0.01	<0.01	<0.01	<0.01	<0.01	
3.	SO_2 sulfur dioxide	Volume %	<0.01	<0.01	<0.01	<0.01	<0.01	
4.	N_2 (nitrogen)	Volume %	78,08	78,08	78,08	78,08	78,08	
5.	O_2 (oxygen)	Volume %	20,9	20,9	20,9	20,8	20,9	

Tables 4 and 5 show that nitrogen and volatile organic compounds, particulate matter, and nitrogen oxides in the air stream generated during the use and regeneration of catalysts in the technological process, which are mainly formed as a result of fuel combustion and contained in flue gases, are emitted into the atmosphere. If we consider the technological characteristics of the burner and the indicators of internal gas emissions in the process, we will see that they comply with environmental standards.

The tables below present the results of research and monitoring work on the topic “Study of the environmental impact of gas emissions generated during the production of polymers in the petrochemical industry” at SOCAR Polymer plants, which produce SOCAR polymers and are the most environmentally advanced project. An environmental analysis was conducted based on the results of the research work.

Table 4.

Composition of fuel gas (V,%) объемных процентах)) ilə)	
N_2	1,33
CO_2	4,11
CH_4	87,32
C_2H_6	3,22
C_3H_8	1,6
n-C_4H_{10}	1,01
H_2	1,41

Table 5.

The volume of waste gases sent for incineration in October.					
PP			YSPE		
Total (t)	431,67 ton	100%	Total (t)	286,15 т	100%
Propylene (t)	376,79 ton	87,29%	Ethylene, Ethane (t)	156,27 т	54,61%
Propane (t)	28,99 ton	6,72%	Hexene, Hexane (t)	3,81 т	1,33%
Hydrogen (kg)	69,75 kq	0,02%	Isobutane (t)	58,38 т	20,40%
Nitrogen (t)	6,40 ton	1%	Hydrogen (kg)	357,00 кг	0,12%
Ethylene (t)	16,20 ton	4%	Nitrogen (t)	67,05 т	23%
Others (isobutane, pentane, ethane, methane, etc.), (t)	3,22 ton	0,75%	Others (methane, butane, acetylene, etc.), (t)	0,29 т	0,1%

As can be seen from the tables, the measurement results at specified points at the polymer production plant are within acceptable limits for all parameters studied. Noise intensity was recorded at 80-82 dB (slightly above normal). The noise level was recorded at 90-95 dB. The indicators for other measured parameters, including background radiation (10-13 μR/h) and total dust content (0.001-0.071 μg/m^3), are within the norm for the plant's territory. When considering hourly, daily, monthly, and annual indicators at SOCAR Polymer plants, they comply with the environmental standards set by the European Union [16].

The report scientifically substantiates the economic and environmental significance of organizing stationary or continuous environmental monitoring every two hours using a Hi-Flow sampler, personal Drager X2 gas analyzers with infrared cameras during the storage, transportation, and production of raw materials at a polymer manufacturing plant, gas leaks into the atmosphere from tank breathing valves and pipelines (flange connections), as well as the prevention of explosions, fires, and environmental pollution [17].

Conclusion

The composition of harmful gases emitted into the atmosphere from SOCAR Polymer production areas and the concentration of each of them in the air were determined using modern gas analyzers: “Flow Meter,” “Kamsko Tube,” “Arex,” and “Graewulf.” PM10 dust particles, NOx, SO_2, CO, harmful gases, and volatile organic compounds were identified in the waste gases emitted into the atmosphere from the production areas, and environmental analyses were also carried out . It was established that the neutralization of waste gas mixtures produced during technological processes using a regenerative thermal oxidizer (RTO) burner, currently used in polymer plants, at the required level is of great environmental importance for the protection of atmospheric air. The implementation of a “zero emissions” strategy is an achievable goal for companies in the industry by 2030.

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COMPUTER SCIENCES

A MULTIFACTORIAL APPROACH TO THE ANALYSIS OF EDUCATIONAL INSTITUTIONS' EFFECTIVENESS

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Abstract

In the modern educational system, the assessment and prediction of the performance of higher education institutions (HEIs) are closely linked to multifactorial parameters such as students' academic achievements, the competence of instructors, infrastructural resources, and the effectiveness of management. Traditional qualitative approaches often fail to capture the complex interactions among these components, which necessitates the use of computational and mathematical models, as well as the implementation of such a model using the Maple symbolic mathematics software package.

The aim of the article is to develop a mathematical and computational model for achieving success in higher education institutions, a model based on multifactor analysis that integrates student-related, academic, infrastructural, and managerial components. The proposed model provides an objective, data-driven assessment, determines the weights of the indicators, and offers predictive capability. The results obtained may be used both to improve the quality of education and for strategic management processes, thereby enhancing the competitiveness of higher education institutions in the contemporary educational environment.

Keywords: computational model; mathematical model; linear functions; factors influencing the educational process, Maple - symbolic mathematics package.

Introduction.

Education and intellect represent core values in the 21st century-a century defined by knowledge. Education and professional expertise determine the economic strength of a country.

The modern educational space is developing dynamically and requires approaches that ensure systematic analysis and prediction of the success of higher education institutions. The factors determining this success are multifaceted and include both academic achievements and pedagogical competencies, organizational and infrastructural resources and the effectiveness of management. The complex interconnection of these factors requires a scientifically grounded, objective, and quantitative assessment, which is difficult to achieve only by using traditional methods based solely on qualitative evaluation.

In this context, the use of mathematical and computational modeling becomes particularly significant, as it enables the identification of success indicators, the determination of their influence, and the forecasting of the development of educational institutions [1-2], [4-5]. Mathematical and computational models are a solid foundation for optimizing managerial decisions, improving the quality of education, and effectively implementing strategic management processes.

In Western and international practice, various mathematical and computational models and algorithms are employed to optimize the assignment of teachers to positions. These methods include classical and modified Hungarian algorithms, evolutionary algorithms, and multi-objective optimization techniques. The Hungarian method and its variations are commonly applied to teacher–position assignment problems, as reflected in the research of N. Ibrahim (2024). In Romania, at the Technical University of Bucharest, the system developed by Francis Diallo (2024) relies on evolutionary algorithms and multi-objective optimization to refine instructional activity schedules, with the goal of maximizing teachers' preferences and ensuring a more effective and equitable distribution. Similarly, at the University of Edinburgh in the United Kingdom, an

integer programming model has been applied—using the example of the School of Mathematics—to optimize teacher appointments while prioritizing the maximization of teachers' preferences for fair and efficient allocation.

The aim of the given article is the formulation of mathematical and computational models for achieving success in a higher educational institution and the demonstration of their theoretical-practical significance. These models will be based on multifactor analysis, that affects key aspects of educational process management. The article also presents the implementation of the mathematical model using the Maple symbolic mathematics package. This approach enables both researchers and administrators to objectively assess the current situation and identify optimal directions for development.

Main part. In modern literature, the performance of an educational institution is regarded as a complex concept encompassing academic, organizational, social, and infrastructural components. Assessing these components presents a significant challenge, as they are closely interrelated and form a complex system. Research by Tinto (1993) and Astin (1999) demonstrates that student success is directly linked to the quality of the educational environment and the level of institutional support. Furthermore, UNESCO's 2021 report emphasizes that institutional effectiveness should be evaluated not only through academic indicators but also with consideration of socio-economic and cultural contexts.

Mathematical and computational models are widely used in educational research because they provide a data-driven foundation for analysis. Among these models, the following are particularly noteworthy:

- **Statistical models:** Pascarella and Terenzini (2005) indicate that regression analysis is effective for studying the influence of social and academic factors on students' achievements [7].
- **Optimization models:** Johnes (2006) emphasizes that linear programming is useful for optimizing resource allocation in universities [8].
- **Stochastic models:** Bean and Metzner (1985) employed Markov chains to predict student dropout [9].
- **Multifactor indices:** QS (Quacquarelli Symonds) and THE (Times Higher Education) are two leading global rankings that evaluate universities based on multiple criteria, including academic reputation, research quality, and lecturer-to-student ratio, although their methodologies and results differ slightly. The QS ranking focuses on academic reputation, citations, and internationalization, whereas **THE ranking** uses a more complex methodology, giving greater weight to teaching quality, research activity, and international relations.

Many studies have been dedicated to evaluating the performance of educational organizations. For example, OECD's *Education at a Glance* (2023) highlights the need for systemic indicators to assess the quality of education [10].

Hanushek and Woessmann (2015) emphasize that mathematical and statistical modeling is critical for analyzing the relationship between education quality and economic growth [11].

As for our country, Georgia, the National Center for Educational Quality Enhancement (EQE, 2019) uses multifactor evaluation models during the accreditation of higher education institutions (HEIs) [12].

The analysis of these studies indicates that the assessment of success cannot be limited to only one indicator. A comprehensive mathematical model is required, which simultaneously takes into consideration both academic and managerial parameters. Precisely This approach provides the foundation for a systematic and predictable evaluation.

Four main factors affecting the teaching process are discussed in the work [3]; these are:

1."Discipline factor" – this encompasses positive and negative behaviors, the students' personal attitudes, behaviors and habits, and adherence to rules of conduct in the learning environment. It also considers extreme or unregulated behaviors and the presence and management of necessary sanctions. As the disciplinary function increases, it continues to grow simultaneously, $= \boldsymbol{t_1}$, the function can eventually take negative values:

$$\boldsymbol{f(t) = -a_1 t - b_1}$$

The maximal point, where the disciplinary value of the transition from normal discipline to extreme discipline is expressed $\boldsymbol{t = t_j = t_{max}}$. Accordingly,

when $\boldsymbol{t = t_j \in [0, t_v]}$ we have:

$$\max\big(f(t_{max})\big) = a_1 t_{max} + b_1 = c_1$$

where $\boldsymbol{c_1 \in \mathbb{R}}$

2."Teacher factor" – the qualification of teachers, experience, and the use of innovative teaching methods.

This is because, in the interval (0,m] each teacher is expected to have the opportunity to perform at their maximum potential. Accordingly, the maximum value of this factor can be expressed as:

$$\boldsymbol{\max\big(g(t_{max})\big) = a_2 t_{max} + b_2 = m}$$

$\boldsymbol{m \in \mathbb{R}}$. ***Maximum point*** $\boldsymbol{t = t_j = t_{max}}$, ***when*** $\boldsymbol{t = t_j \in [0, t_v]}$

3. "Student factor" – this factor includes attendance, learning motivation, average assessment score, course-completion rate. Taking into account the student's contribution, the maximum value of the educational institution's success will take the form:

$$\boldsymbol{\max\big(S(t)\big) = e^{\frac{(\max(\varphi(t)))(max(f(t)))(max(g(t))}{minh(t)}(t-t_0)} S_0}$$

$$\boldsymbol{= e^{\frac{rc_1 m}{1}(t-t_0)} S_0 =}$$

$$\boldsymbol{= e^{rc_1 m(t-t_0)} S_0.}$$

Here, S(t) and max(s(t)) **)), $\boldsymbol{t_0 = 0}$** in the time interval $[0, t_v]$

If $(t) = S_0$ ლა $0<S(t)<1$ then this is an unsuccessful situation, and in that case, the interval $\boldsymbol{(t - t_0)}$

Should be taken in the form of $\boldsymbol{t_{j+1} - t_j}$

4."Negative Factor"- this factor reflects the influence of the family environment or economic conditions, which negatively affects the student's work,

causing a decrease in the student's motivation to pursue education; the function N=h(t)N which represents the negative factors, is defined as follows:

$\boldsymbol{h}: [\boldsymbol{0}, \boldsymbol{t_v}] \to [\boldsymbol{1}, \boldsymbol{n}), \boldsymbol{h(t)} = \boldsymbol{a_3 t} + \boldsymbol{b_3}, \boldsymbol{a_3}, \boldsymbol{b_3}, \boldsymbol{n} \in \mathbb{R}$

The average contribution of negative factors to student achievement in the time interval $[\boldsymbol{0}, \boldsymbol{t_v}]$

that is, the arithmetic mean of the magnitudes obtained during this time interval, will be:

$$\overline{\boldsymbol{h(t)}} = \frac{\boldsymbol{1}}{\boldsymbol{n}} \sum_{\boldsymbol{j=1}}^{\boldsymbol{n}} \boldsymbol{h(t_j)} = \boldsymbol{\delta}$$

Where: $\boldsymbol{\delta} \in [\boldsymbol{1}, \boldsymbol{n})$

Based on the 4 important factors identified by the model in the article [3], linear **1.** and nonlinear **2.** cases are constructed; the solution [6] of the nonlinear (quadratic) case is carried out using the Maple program (Fig.). Subsequent studies have shown that it is possible to construct higher-order (3rd, 4th) systems, the solutions of which can also be carried out in the Maple program, but these are not presented in this article. The obtained results help in the proper organization and management of the educational process. Below, the linear and quadratic cases of the model are presented.

Let us consider the linear and nonlinear (quadratic) cases.

1. Linear case, when functions $\boldsymbol{D}=(\boldsymbol{t})$, $\boldsymbol{T}=\boldsymbol{g}(\boldsymbol{t})$ and $\boldsymbol{N}=\boldsymbol{h}(\boldsymbol{t})$ are linear.

Let D be the set composed of disciplinary values. $\boldsymbol{D_1}, \boldsymbol{D_2}, \boldsymbol{D_3}, \boldsymbol{D_4}, \boldsymbol{D_5}$ **so**

$$\boldsymbol{D} = \{\boldsymbol{D_1}, \boldsymbol{D_2}, \boldsymbol{D_3}, \boldsymbol{D_4}, \boldsymbol{D_5}\}$$

And let the corresponding disciplinary values be real numbers.

$$\boldsymbol{d_{j1}}, \boldsymbol{d_{j2}}, \boldsymbol{d_{j3}}, \boldsymbol{d_{j4}}, \boldsymbol{d_{j5}}\ (\boldsymbol{j} = \boldsymbol{1}, \boldsymbol{2})\ \textit{so}$$

Accordingly In the time interval $t = t_j$ for $t = t_1$ we have

$$\boldsymbol{d_{t_1}} = \frac{\boldsymbol{d_{11}} + \boldsymbol{d_{12}} + \boldsymbol{d_{13}} + \boldsymbol{d_{14}} + \boldsymbol{d_{15}}}{\boldsymbol{5}}$$

For $\boldsymbol{t = t_2}$ we have

$$\boldsymbol{d_{t_2}} = \frac{\boldsymbol{d_{21}} + \boldsymbol{d_{22}} + \boldsymbol{d_{23}} + \boldsymbol{d_{24}} + \boldsymbol{d_{25}}}{\boldsymbol{5}}$$

As $\boldsymbol{f(t_1) = a_1 t_1 + b_1}$ *and* $\boldsymbol{f(t_2) = a_1 t_2 + b_1}$ ***we get the system:***

$$\begin{cases} \boldsymbol{a_1 t_1 + b_1 = d_{t_1}} \\ \boldsymbol{a_1 t_2 + b_1 = d_{t_2}} \end{cases} \quad (1)$$

As a result of solving this system (1), the coefficients a_1 and b_1 will have the form:

$$\boldsymbol{a_1} = \frac{\boldsymbol{d_{t_2} - d_1}}{\boldsymbol{t_2 - t_1}}, \boldsymbol{b_1} = \frac{\boldsymbol{t_2 d_{t_1} - t_1 d_{t_2}}}{\boldsymbol{t_2 - t_1}}$$

The linear equation for the points (t_1, d_{t_1}) and (t_2, d_{t_2}) will take the form:

$$\boldsymbol{f(t_1) = a_1 t + b_1} = \frac{\boldsymbol{d_{t_2} - d_1}}{\boldsymbol{t_2 - t_1}} t + \frac{\boldsymbol{t_2 d_{t_1} - t_1 d_{t_2}}}{\boldsymbol{t_2 - t_1}}$$

The disciplinary, teacher, and negative factors for the points $\boldsymbol{t = t_1}$ **and** $\boldsymbol{t = t_2}$

will be defined, respectively, as:

$\boldsymbol{D} = \{\boldsymbol{D_1}, \boldsymbol{D_2}, \boldsymbol{D_3}, \boldsymbol{D_4}, \boldsymbol{D_5}\}$,

$\boldsymbol{T} = \{\boldsymbol{T_1}, \boldsymbol{T_2}, \boldsymbol{T_3}, \boldsymbol{T_4}, \boldsymbol{T_5}\}$ ҫ $\boldsymbol{N} = \{\boldsymbol{N_1}, \boldsymbol{N_2}, \boldsymbol{N_3}, \boldsymbol{N_4}, \boldsymbol{N_5}\}$

In reality, each factor, as we know, corresponds to real variables, respectively. $(t_j), g(t_j)$ ҫ $h(t_j)$ coefficient for $t = t_j$ will be:

$$k_j = \frac{\varphi(t_j) f(t_j) g(t_j)}{h(t_j)}$$

2. Nonlinear case when functions $\boldsymbol{D}=(\boldsymbol{t})$, $\boldsymbol{T}=\boldsymbol{g}(\boldsymbol{t})$ and $\boldsymbol{N}=\boldsymbol{h}(\boldsymbol{t})$ are nonlinear (specifically, it's quadratic)

$$D = f(t) = at^2 + bt + c$$

Disciplinary values d_{t_1}, d_{t_2} and d_{t_3}, $t = t_1, t = t_2$ and $t = t_1, t = t_2$ for the time points, in this case $t_1 < t_2 < t_3$ the system will look as follows:

$$\begin{cases} \boldsymbol{at_1^2 + bt_1 + c = d_{t_1}} \\ \boldsymbol{at_2^2 + bt_2 + c = d_{t_2}} \\ \boldsymbol{at_3^2 + bt_3 + c = d_{t_3}} \end{cases} \quad (2)$$

Let's solve this system (2) with respect to a, b and c. The solution will be carried out using the Maple software. The program line for solving the system has the following form:

The solution of the system corresponding to the considered model in the Maple software package is shown in Figure 1, where the coefficients are known.

Specifically, if the functions $\boldsymbol{T}=(\boldsymbol{t})$ and $\boldsymbol{N}=\boldsymbol{h}(\boldsymbol{t})$ are quadratic, their coefficients can be determined according to the method described above. Among these functions, two may be quadratic while the third is linear, or one may be quadratic while the remaining two are linear. To determine the coefficients of a quadratic function, we use the data points $(\boldsymbol{t_1}, \boldsymbol{d_{t_1}}), (\boldsymbol{t_2}, \boldsymbol{d_{t_2}})$ **and** $(\boldsymbol{t_3}, \boldsymbol{d_t}\ )$

$$solve\left(\left\{a\cdot(t1)^2+b\cdot(t1)+c=dt1,\ a\cdot(t2)^2+b\cdot t2+c=dt2,\ a\cdot(t3)^2+b\cdot t3+c=dt3\right\},\{a,b,c\}\right)$$

$$\left\{a=\frac{dt1\,t2-dt1\,t3-dt2\,t1+dt2\,t3+dt3\,t1-dt3\,t2}{t1^2\,t2-t1^2\,t3-t1\,t2^2+t1\,t3^2+t2^2\,t3-t2\,t3^2},\right.$$

$$b=-\frac{dt1\,t2^2-dt1\,t3^2-dt2\,t1^2+dt2\,t3^2+dt3\,t1^2-dt3\,t2^2}{(t1-t2)\left(t1\,t2-t1\,t3-t2\,t3+t3^2\right)},$$

$$\left.c=\frac{dt1\,t2^2\,t3-dt1\,t2\,t3^2-dt2\,t1^2\,t3+dt2\,t1\,t3^2+dt3\,t1^2\,t2-dt3\,t1\,t2^2}{(t1-t2)\left(t1\,t2-t1\,t3-t2\,t3+t3^2\right)}\right\}$$

Fig. Solution of system in the Maple software package.

Based on the program results, the disciplinary situation can be determined at the time point $\boldsymbol{t = t_j}$ using the corresponding disciplinary function. The analysis showed that considering the combined effect of various factors provides a more objective assessment of the successful performance of an educational institution.

Conclusion

The computer and mathematical models discussed employ functions representing "disciplinary factors," "teacher performance factors," "student factors," and "negative factors" to determine actual outcomes. When the success value is negative, it becomes possible to identify and improve specific functions that adversely affect the results. For example, in cases of disciplinary failure, the function can be adjusted using average values and disciplinary indicators to construct a linear equation for subsequent stages.

The model is also used to achieve positive outcomes through carefully selected functions, particularly when the management of an educational institution is assessed negatively. A multi-factorial approach ensures that development is informed by comprehensive data, enhancing effectiveness, reducing the risk of subjectivity, and strengthening the accuracy of the analytical process.

Applying a multi-factorial approach in the accreditation of educational institutions allows for an objective and multifaceted assessment of educational quality. Considering only a single criterion cannot capture the overall picture of the system, whereas a combined analysis of factors reveals the full spectrum of strengths and weaknesses.

Thus, this model represents a crucial mechanism in the management of educational quality. Its further refinement, through the integration of modern analytical tools and databases, ensures that higher education in Georgia remains competitive within the international educational landscape.

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ECONOMY

ASSESSING THE ROLE OF FOREIGN TRADE IN AZERBAIJAN'S ECONOMIC DEVELOPMENT

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Abstract

This study investigates the role of foreign trade in the economic development of the Republic of Azerbaijan by analysing the relationship between foreign trade turnover and gross domestic product (GDP) over the period 1995–2023, using annual time series data. Trade turnover in this research is defined as the combined value of exports and imports, which serves as a key indicator of Azerbaijan's integration into the global economy. The primary objective of the study is to determine whether changes in foreign trade activity have a significant impact on the country's economic growth and long-term development.

To achieve this objective, a comprehensive set of econometric and statistical techniques was employed. These include descriptive statistical analysis to examine the historical trends of the variables, unit root tests to assess the stationarity of the data, and regression analysis to evaluate the nature and strength of the relationship between GDP and trade turnover. In addition, the Johansen cointegration test was applied to explore the existence of a long-run equilibrium relationship between the variables, while the Granger causality test was used to determine the direction of causality in the short run. Several diagnostic tests were also conducted to ensure the reliability and validity of the model by checking for problems such as heteroskedasticity and autocorrelation.

The empirical results reveal a statistically significant and positive relationship between foreign trade turnover and GDP in Azerbaijan. The Johansen cointegration test confirms the existence of a stable long-term relationship between these two variables, suggesting that foreign trade is closely linked to the country's economic performance over time. However, the results of the Granger causality analysis indicate that, in the short run, changes in GDP tend to drive changes in trade turnover, rather than trade turnover driving economic growth. This implies that while foreign trade is closely associated with economic development, it may not be the primary short-term catalyst of growth.

Overall, the findings suggest that foreign trade plays an important supportive role in Azerbaijan's economic development. Nevertheless, for sustainable and resilient long-term growth, policymakers should focus on reducing dependence on a limited range of export products and instead implement strategies aimed at export diversification, value-added production, and the expansion of non-oil sectors. Such measures would strengthen Azerbaijan's position in international markets and enhance its ability to withstand external economic shocks.

Keywords: Azerbaijan, trade, export, import, relation.

Introduction

In the era of globalization, foreign trade has become one of the key drivers of economic development, especially for developing and emerging economies. The influence of foreign trade on the growth performance of national economies has increased significantly; however, the mechanisms through which trade affects growth remain complex and in some cases contradictory across different country groups (Bahadurlu, 2021). Through participation in international trade, countries gain access to larger markets, advanced technologies, and higher-quality capital goods. In addition, foreign trade encourages specialization based on comparative advantage, increases export revenues, and attracts foreign direct investment, which in turn contributes to job creation, infrastructure development, and overall economic modernization.

Supporters of export-oriented growth strategies argue that such policies lead to greater economic specialization and positive economies of scale (Helpman & Krugman, 1985). Moreover, for an export sector to remain competitive in international markets, it must be productive and innovative, thereby creating demand for highly skilled labor and facilitating the development and diffusion of new technologies, including technology transfer from abroad (Grossman & Helpman, 1991). Other scholars also emphasize the critical role of exports in generating foreign currency earnings, which are essential for financing imports of capital goods and supporting macroeconomic stability (Yagubov & Aliyev, 2020).

In the case of Azerbaijan, foreign trade not only generates national income through exports but also plays an important role in improving economic diversification and integrating the country into the global economy. However, foreign trade can also present significant challenges and risks, particularly for resource-rich developing countries. One of the most prominent theoretical perspectives highlighting the potential negative effects of foreign trade is the "resource curse" or the phenomenon known as Dutch disease (Yagubov & Aliyev, 2020). According to this theory, continuous reliance on resource exports may lead to the depletion of natural reserves, while an appreciation of the national currency reduces the competitiveness of non-resource sectors, leading to a decline in the efficiency of other export-oriented industries. Several studies have also found that excessive dependence on resource exports may negatively affect long-term economic growth and industrial diversification (Sachs & Warner, 2001).

Given these conflicting theoretical and empirical perspectives, the impact of foreign trade on Azerbaijan's economic development remains a subject of considerable debate. Therefore, the aim of this study is to empirically assess the effect of foreign trade on Azerbaijan's economic growth using annual time-series data covering the period from 1995 to 2023. The research applies a comprehensive econometric framework to

quantify and interpret the trade–growth relationship. Specifically, annual data on real GDP, exports, imports, and a composite trade openness index are used to estimate a Vector Error Correction Model (VECM), which captures both short-run dynamics and long-run equilibrium relationships among the variables. The reliability of the estimations is ensured through stationarity and cointegration tests, including the Augmented Dickey–Fuller (ADF) and Johansen tests, while Granger causality analysis is employed to identify the direction of influence between foreign trade variables and economic growth.

Literature Review

The link between foreign trade and economic development has been extensively examined in the economic literature. In recent years, numerous scholars have focused on assessing how foreign trade components—such as exports, imports, and trade openness—affect economic growth. Most studies rely on econometric models to analyze the relationship between these trade variables and Gross Domestic Product (GDP).

One of the recent contributions is by Ilgar Seyfullayev (2022), who analyzed annual data covering the period from 1995 to 2020. The findings indicate the absence of a long-run cointegration relationship among the selected variables. Nevertheless, in the short run, a unidirectional causal relationship from trade openness to economic growth was identified, while the impact of economic growth on openness was found to be statistically insignificant. These results suggest that Azerbaijan gains economic advantages from openness, primarily through oil exports to the global market. However, the short-term nature of these benefits, combined with the lack of reverse causality, highlights structural challenges related to export diversification and quality.

Similarly, the relationship between foreign trade and GDP was investigated in a thesis by Farman Bahadurlu (2021). The study was grounded in the theoretical and methodological foundations established by both domestic and international researchers in the field of foreign trade and economic expansion. A range of scientific methods was employed, including graphical and comparative analysis, as well as systematic, historical, deductive, and inductive approaches. In addition, statistical, correlation, and regression analyses were conducted. The research data were obtained from official statistical sources, including the State Statistical Committee and the State Customs Committee of Azerbaijan, as well as international publications such as the United Nations Statistical Yearbook and reports from the World Bank. The results of the study reveal that increases in both imports and exports contribute positively to the country's economic development. Reseacher Elman Aghayev (2024) is analyzed statistical evidence of foreign relation of Azerbaijan and found the economic integration plays important role for economic growth of country. Another notable study by Sakit Yaqubov and Ali Aliyev (2020) examined the impact of foreign trade indicators on Azerbaijan's economic growth. The authors first provided a statistical overview of the dynamics of foreign trade over the previous decade and calculated the terms of trade index. They then applied a Vector Error Correction Model (VECM) to analyze the interrelationships among GDP growth, export volume, terms of trade, and oil prices, considering both quarterly and annual data. The analysis confirmed the presence of causal relationships among the time series variables. The findings demonstrated a positive short-run and long-run effect of exports and oil prices on GDP growth, as well as a long-term influence of the terms of trade. However, no evidence of reverse causality from foreign trade to GDP growth was found. Sara Huseynova suggests that foreign trade has a predominantly positive effect on Azerbaijan's economic growth. At the same time, researchers emphasize the need to promote trade openness, export diversification, and foreign direct investment in order to mitigate potential risks. These results underline the strong dependence of the Azerbaijani economy on the external sector and support the export-led growth hypothesis. Consequently, foreign trade, particularly exports, is identified as a major driver of economic growth, making the external sector a critical factor in economic forecasting and policy formulation.

Methodology. This study investigates the impact of foreign trade turnover on the economic development of Azerbaijan over the period 1995–2023. The methodology combines descriptive, econometric, and diagnostic approaches to ensure a comprehensive analysis of the relationship between foreign trade and economic growth.The research utilizes annual time series data obtained from official national and international sources, including the State Statistical Committee of Azerbaijan, the World Bank, and the International Monetary Fund (IMF).Descriptive statistics, including mean, median, standard deviation, minimum, and maximum values, were calculated to examine the historical trends and volatility of GDP and trade turnover. Graphical analysis was also employed to visualize the long-term patterns of economic growth and trade activity in Azerbaijan.The Augmented Dickey-Fuller (ADF) test is employed to determine the stationarity of the time series. Stationarity is a necessary condition for reliable regression and cointegration analysis. A simple linear regression model is estimated to explore the relationship between GDP (dependent variable) and foreign trade turnover (independent variable). The model is tested for statistical significance using t-tests, F-tests, and R-squared values. Diagnostic tests such as the Breusch-Pagan test (for heteroskedasticity) and the Durbin-Watson test (for autocorrelation) are applied to ensure model reliability.

The Johansen cointegration test is used to investigate the existence of a long-term equilibrium relationship between GDP and trade turnover. Cointegration analysis allows us to determine whether the variables move together in the long run, indicating a stable economic relationship.

Emprical analyses and discussion.

This section presents the results of the empirical analysis conducted to examine the relationship between foreign trade and economic development in Azerbaijan over the period 1995–2023. The analysis follows a systematic econometric procedure, including descriptive statistics, stationarity testing, regression analysis, cointegration analysis, and causality testing. The main objective is to evaluate both the short-run and long-run dynamics between foreign trade turnover and real gross domestic product (GDP).

The descriptive analysis of the data shows a clear upward trend in both foreign trade turnover and real

GDP in Azerbaijan during the study period. This growth is particularly noticeable in the early 2000s, coinciding with increased oil production and exports following the development of major energy projects such as the Baku–Tbilisi–Ceyhan pipeline. The rapid increase in export revenues significantly boosted national income and foreign exchange reserves.

However, the data also reveal fluctuations in trade turnover and GDP, especially during periods of global economic instability, such as the 2008–2009 financial crisis and the decline in global oil prices in 2014–2016. These shocks affected Azerbaijan's export revenues and highlighted the country's vulnerability to external factors, reinforcing concerns related to overdependence on natural resource exports.

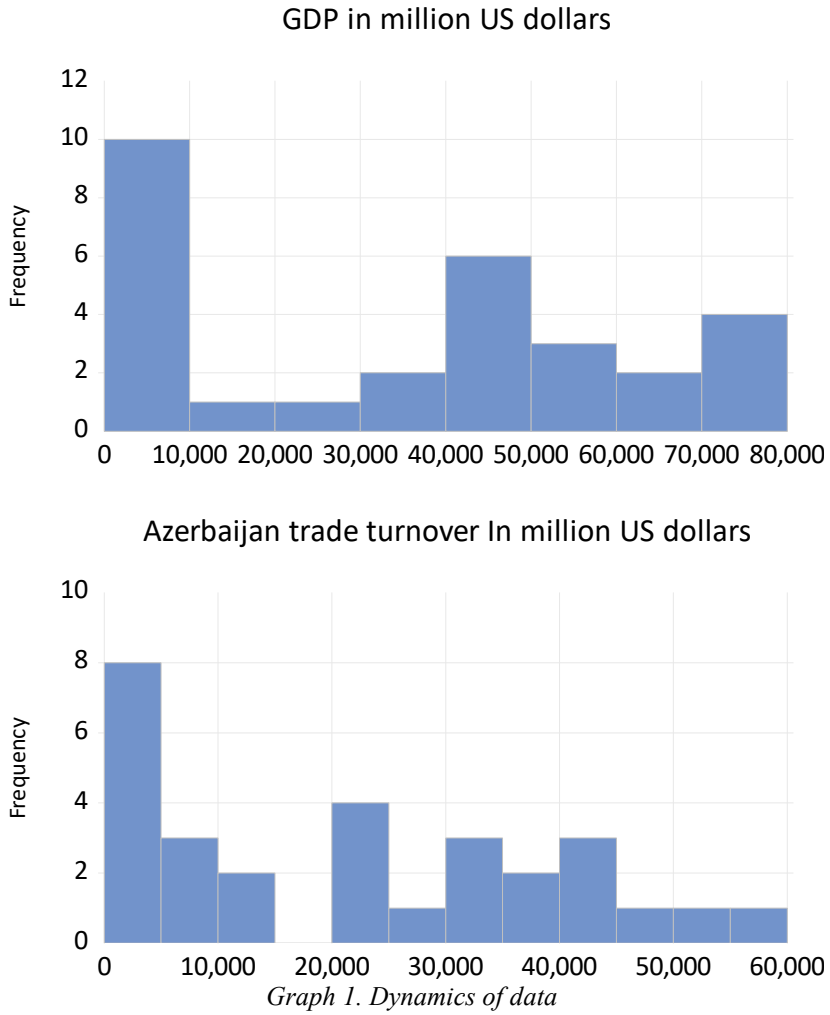
Despite these fluctuations, the long-term trend indicates that Azerbaijan's integration into the global economy through foreign trade has played an important role in its overall economic expansion. Table 1 is showed analyses of descriptive statistics.

Table 1

Descriptive statistics

	GDP	Trade Turnover
Mean	35375.66	22142.27
Median	40867.90	21596.60
Maximum	78807.50	56212.00
Minimum	2415.200	1304.900
Skewness	0.108710	0.343714
Kurtosis	1.577333	1.777118
Jarque-Bera	2.502764	2.377999
Probability	0.286109	0.304526

Basic statistical analysis was carried out to understand the characteristics of the data. Mean, median, minimum, and maximum values were calculated. Values of Skewness of GDP and Trade Turnover equal correspondingly 0.108710 and 0.343714. Distribution of GDP and Trade Turnover is right side according to values of skewness. Furthermore, Kurtosis of GDP and Trade Turnover equal relatively 1.577333 and 1.777118, it means that distribution of GDP and Trade Turnover is peakiness. Probability of Jarque-Bera value for GDP and Trade Turnover is more than 0.05, it means that time series accepted normal distribution.



Graph 1. Dynamics of data

A simple linear regression model was used to examine the effect of trade turnover on GDP. The simple linear regression equation equals:

$$DGDPt = \alpha + \beta \cdot DTRADEt + \varepsilon t$$

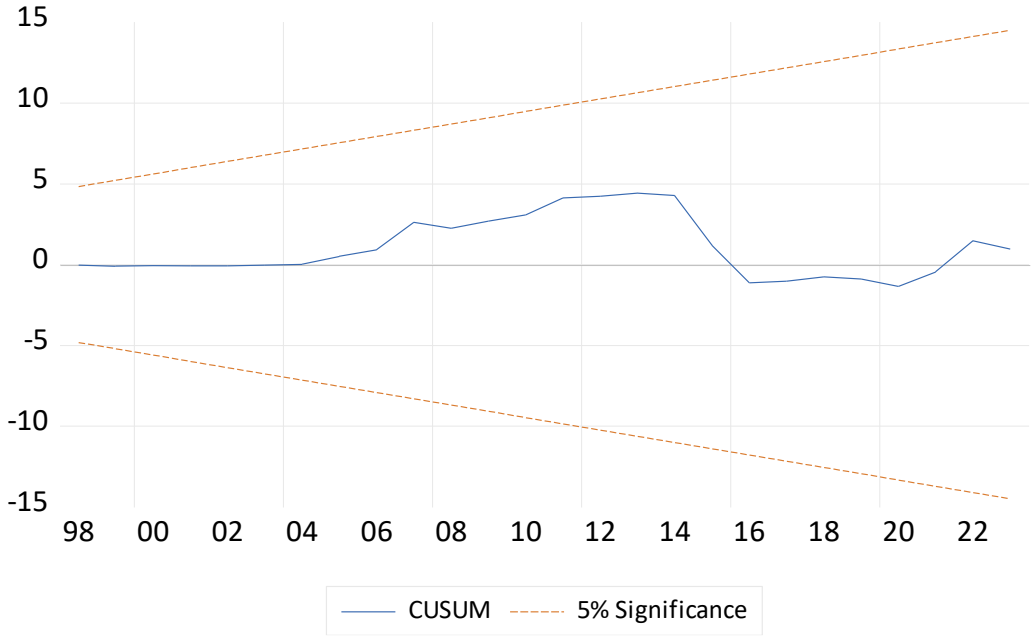
A simple linear regression model is shown on Table 2

Table 2.

Regression model

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DAZTRADE	0.509890	0.098277	5.188307	0.0000
C	1672.452	1221.321	1.369379	0.1826
R-squared	0.508679	Mean dependent var		2500.475
Adjusted R-squared	0.489782	S.D. dependent var		8969.967
S.E. of regression	6407.208	Akaike info criterion		20.43698
Sum squared resid	1.07E+09	Schwarz criterion		20.53214
Log likelihood	-284.1178	Hannan-Quinn criter.		20.46607
F-statistic	26.91853	Durbin-Watson stat		1.682450
Prob(F-statistic)	0.000020			

The regression results show a positive and statistically significant relationship between trade turnover and GDP. R-squared value of 0.51, indicating that about 51% of the variation in GDP is explained by trade turnover. Probability of T-statistic of Trade Turnover (0.0000) is less than 0.05. It means that regression model parameters are important. Probability of T-statistic of C (0.1826) is more than 0.05. It means that regression model parameters are unimportant. The Durbin-Watson statistic (1.68) indicated no serious autocorrelation problem. Stability of parameters is analysed by CUSUM test.



Graph 2. CUSUM test

CUSUM test is defined stability or non-stability of coefficients (parameters) of linear regression model. In test, main line (blue line) of graph doesn't intersect with border lines, it means that regression model parameters are stable.

Breusch-Pagan-Godfrey is defined homos and hetros of errors. F-statistic probability equals 0.3265. When F-statistic probability is more than 0.05, it means that regression model errors are homoscedasticity.

Table 3.

The result of Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey Null hypothesis: Homoskedasticity			
F-statistic	1.000313	Prob. F(1,26)	0.3265
Obs*R-squared	1.037349	Prob. Chi-Square(1)	0.3084
Scaled explained SS	1.550669	Prob. Chi-Square(1)	0.2130

Time series analysis plays a central role in examining the dynamic behavior of economic and financial variables over time. In this study, time series techniques are applied to investigate the relationships between the selected variables and to identify both short-run and long-run dynamics. The analysis follows several systematic steps: data visualization, stationarity testing, model estimation, and diagnostic checking.Table 2 is shown the unit root test of tome series.

Table 4.

Dickey Fuller test

variable	stage	critical value	1%	5%	10%
GDP	1st difference	-3.621708	-4.339330	-3.587527	-3.229230
Trade Turnover	1st difference	-7.626713	-4.339330	-3.587527	-3.229230

To avoid misleading results in time series analysis, the Augmented Dickey-Fuller (ADF) test was used to check whether the data series are stationary. Both GDP and trade turnover were found to be non-stationary at level but became stationary after taking the first difference. This means the variables are integrated of order one

Table 5.

Granger test

Sample: 1995 2023 Lags: 2			
Null Hypothesis:	Obs	F-Statistic	Prob.
DAZTRADE does not Granger Cause DGDP	26	2.85958	0.0797
DGDP does not Granger Cause DAZTRADE		8.66111	0.0018

The Granger causality test was conducted to examine the directional relationship between the stationary time series of Trade Turnover and GDP. The results indicate that, in the first case, where Trade Turnover is tested as a predictor of GDP, the F-statistic probability value is 0.0797, which is greater than the 5% significance level (0.05). Therefore, the null hypothesis cannot be rejected, suggesting that Trade Turnover does not Granger-cause GDP.

In contrast, in the second case, where GDP is tested as a predictor of Trade Turnover, the F-statistic probability value is 0.0018, which is less than the 5% significance level. In this case, the null hypothesis is rejected, indicating that GDP Granger-causes Trade Turnover. This finding reveals the existence of a unidirectional causality running from GDP to Trade Turnover.

These results imply that changes in economic growth significantly influence trade activity, whereas changes in trade turnover do not significantly predict variations in GDP over the sample period.

Table 6.

Johanssen Cointegration test

Unrestricted Cointegration Rank Test (Trace)				
Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.646227	31.14803	25.87211	0.0100
At most 1	0.186836	5.170572	12.51798	0.5721
Trace test indicates 1 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				
Unrestricted Cointegration Rank Test (Maximum Eigenvalue)				
Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.646227	25.97746	19.38704	0.0048
At most 1	0.186836	5.170572	12.51798	0.5721
Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level * denotes rejection of the hypothesis at the 0.05 level **MacKinnon-Haug-Michelis (1999) p-values				

The Johansen Cointegration Test was applied to check if there is a long-run relationship between GDP and trade turnover. Null hypothesis (None) probability (0.0100) is less than 0.05 and Trace statistics (31.14803) is more than critical value (25.87211). It means that Null hypotthesis can be rejected.

Alternative hypothesis probability (0.5721) is more than 0.05 and Trace statistics (5.170572) is less than critical value (12.798). It means that Alternative hypotthesis can be accepted.

Two conditions are adopted so, It means the between stasionary time series exist cointegration relation.

Conclusion

This research studied the relationship between foreign trade turnover and economic growth in Azerbaijan from 1995 to 2023 using various econometric methods. The results showed that there is a statistically significant and positive relationship between trade turnover and GDP. This means that increases in foreign trade have contributed to the growth of Azerbaijan's economy during the observed period.

The Augmented Dickey-Fuller (ADF) test confirmed that both GDP and trade turnover are non-stationary at level but become stationary at first difference. The Johansen cointegration test showed that there is a long-term equilibrium relationship between the two variables. This confirms that trade and economic growth move together in the long run.

The regression analysis proved that trade turnover has a strong positive effect on GDP, explaining more than half of its variation. The CUSUM test also showed that the model is stable, and the Breusch-Pagan-Godfrey test confirmed that the error terms are homoscedastic.

However, the Granger causality test results indicate that while GDP causes changes in trade turnover, the opposite is not true in the short run. This suggests that the direction of influence mostly runs from economic growth to trade, and not the other way around.

Overall, the findings of this study support the idea that foreign trade is important for economic development in Azerbaijan. Still, the results also suggest that more attention should be given to increasing the quality and diversity of exports to strengthen the long-term benefits of trade. For future policy, it is important to focus on reducing dependency on a few export products and improving the structure of trade to support sustainable economic growth.

Discussion and suggestion.

This study provides empirical evidence of a strong and positive relationship between foreign trade turnover and economic growth in Azerbaijan during the period 1995–2023. The regression results confirm that increases in trade turnover are associated with increases in GDP, indicating that foreign trade has played an important role in supporting the country's economic expansion. This finding is consistent with the theories of export-led growth proposed by Helpman and Krugman (1985) and Grossman and Helpman (1991), who argue that international trade promotes specialization, technological transfer, and productivity growth.

The ADF and Johansen cointegration test results further indicate the existence of a long-run equilibrium relationship between trade turnover and GDP. This implies that despite short-term fluctuations, these variables tend to move together over time, reflecting the structural importance of foreign trade for the Azerbaijani economy. Such a long-term link is particularly expected in a resource-rich country like Azerbaijan, where export revenues—especially from oil and gas—have historically formed a significant part of national income.

However, the Granger causality test reveals a unidirectional short-run causality from GDP to trade turnover rather than the opposite. This result suggests that in the short term, economic growth drives increases in foreign trade activity, rather than trade being the main trigger of growth. One possible explanation is that rising domestic output and income levels increase production capacity and import demand, which in turn expand trade turnover. Another explanation is the heavy dependence on energy exports, meaning that trade volumes are influenced more by global price fluctuations and domestic production levels than by structural trade policies.

Furthermore, the results relate to the concept of the "resource curse" or Dutch disease, which suggests that an economy heavily dependent on a narrow range of export commodities may experience limited diversification and vulnerability to external shocks. Azerbaijan's long-term cointegration with trade, combined with the absence of short-run causality from trade to GDP, may indicate that the quality and structure of trade are just as important as its volume.

Overall, while foreign trade supports Azerbaijan's economic development, the results highlight the need for more balanced and diversified trade to ensure sustainable long-term growth.

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COMPREHENSIVE FINANCIAL ASSESSMENT OF COSTS AND RETURNS IN ESTABLISHING A GRAIN FARM

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Abstract

This study examines the impact of modern irrigation systems and precision agriculture technologies on grain crop productivity in the Agdam region of Azerbaijan, with a particular focus on wheat, barley, and late corn production. Using official agricultural statistics from the State Statistical Committee of Azerbaijan for the period 2015–2024, the research analyzes historical yield trends and regional productivity differences. Time-series forecasting is conducted using the Error–Trend–Seasonality (ETS) model to project crop yields for the period 2025–2035 under baseline conditions. To capture the effects of technological advancement, forecasted results are adjusted based on empirical evidence from international studies and regional pilot projects employing pivot irrigation and precision sowing and fertilization technologies.

The findings indicate that Agdam consistently outperforms national average yields for both wheat and barley, reflecting favorable agro-climatic conditions. The adoption of modern irrigation systems is projected to increase average wheat and barley yields by approximately 25% compared to traditional rain-fed farming practices, with potential yields reaching 6.5–6.8 t/ha for wheat and over 5.3 t/ha for barley by 2035 under optimal conditions. Comparative analysis with real production data from Samukh and Tovuz districts confirms the robustness of these projections, as pivot-irrigated fields demonstrate significantly higher productivity than regional and national averages. For late corn cultivated as a second crop, linear regression forecasts indicate stable yield growth within the range of 3.5–4.7 t/ha over the forecast horizon.

Overall, the results demonstrate that the integration of modern irrigation infrastructure and precision agrotechnologies can substantially enhance grain productivity, mitigate climate-related risks, and improve agricultural efficiency in semi-arid regions. The study provides empirical support for investment in irrigation modernization as a key strategy for sustainable agricultural development and food security in Azerbaijan.

Keywords: Agricultural, development, investment, productivity.

Methodology

This study applies a quantitative, applied research design to evaluate crop productivity and forecast future yields for wheat, barley, and late corn under conventional and modern agricultural practices in the Agdam region of Azerbaijan. The methodology integrates descriptive statistical analysis, time-series forecasting, and scenario-based adjustments reflecting the adoption of modern irrigation and precision agriculture technologies.

The research combines secondary statistical data with empirical field-based observations, ensuring both analytical rigor and practical relevance.

Data Sources

The analysis is based on the following data sources:

- Official agricultural statistics obtained from the State Statistical Committee of the Republic of Azerbaijan (Stat.gov.az), covering crop yields for the period 2015–2024.
- Regional yield data for Agdam, Samukh, and Tovuz districts.
- Climatic indicators, including precipitation and temperature averages, derived from national meteorological records.
- Empirical data and professional observations from pilot pivot irrigation projects implemented in Samukh and Tovuz regions during 2017–2023.
- International benchmark studies from institutions such as the World Bank and FAO, used to estimate the productivity effects of irrigation and precision agriculture technologies.

Variables and Indicators

The key variables employed in the analysis include:

- Dependent variables:
  - Crop yield (t/ha) for wheat, barley, and late corn.
- Independent variables:
  - Precipitation levels (mm)
  - Average growing season temperature (°C)
  - Irrigation availability (rain-fed vs. irrigated)
  - Adoption of modern irrigation systems (pivot irrigation)
  - Use of precision sowing and fertilization technologies
- Control factors:
  - Soil fertility conditions
  - Crop variety characteristics
  - Agronomic practices (planting depth

The productivity of crops planted in the selected Agdam area will vary depending on many different factors. The main data and nuances that will be used in productivity calculations will be the fertility of the soil cover, whether the planted crop is suitable for the soil structure, and the productivity data provided by the Statistics Committee.

Literature Review

Agricultural productivity and structural transformation have long been central themes in development economics, particularly in the context of food security, economic growth, and rural development. Classical contributions by Schultz (1964) laid the theoretical foundation by arguing that traditional agriculture is economically rational but constrained by limited access to modern inputs, technology, and institutional support.

This perspective highlighted the importance of investment in human capital, innovation, and policy reforms to unlock productivity gains in agriculture.

The Green Revolution marked a turning point in global agricultural development. Pingali (2012) provides a comprehensive assessment of its impacts, emphasizing significant yield improvements through the adoption of high-yielding varieties, irrigation, and chemical inputs. While these advances contributed to food security and poverty reduction, the study also underscores environmental degradation, resource overuse, and inequality as critical limitations, calling for a more sustainable and inclusive path forward. Complementing this view, Ruttan (2002) examines the sources of global agricultural productivity growth, identifying technological innovation, institutional change, and public investment as key drivers, while also noting constraints such as land scarcity, environmental stress, and diminishing returns to traditional input intensification.

In developed economies, productivity dynamics are closely linked to innovation systems and policy frameworks. The USDA (2023) highlights the role of research and development, mechanization, and precision agriculture in sustaining long-term productivity growth in the United States. Similarly, Alston et al. emphasize the importance of public agricultural R&D in generating high social returns, reinforcing the argument that productivity growth is not automatic but policy-dependent. In the European context, Pretty (2018) focuses on sustainability and resource efficiency, arguing that future productivity gains must be aligned with environmental objectives through agroecological practices and sustainable intensification.

A substantial body of literature examines agricultural productivity in transition and post-socialist economies. Swinnen and Rozelle (2006) analyze the political economy of agricultural transition from centrally planned systems to market-based structures, emphasizing land reforms, price liberalization, and institutional restructuring. Gorton and Davidova (2019) document mixed productivity outcomes across transition economies, noting that while efficiency gains were achieved, structural fragmentation, limited access to finance, and weak institutions constrained performance in many countries. Henning and von Cramon-Taubadel (2018) further demonstrate that regional disparities and uneven policy implementation significantly influence agricultural development outcomes in Eastern Europe.

Policy interventions, particularly subsidies and rural development programs, play a crucial role in shaping productivity and farm behavior. Matthews (2020) evaluates the impact of agricultural subsidies in Europe, concluding that while they stabilize farm incomes and support rural livelihoods, their productivity effects depend on design and targeting. Pietola and Lansink (2020) analyze farm investment behavior under risk and uncertainty, showing that access to credit, policy stability, and risk management tools significantly influence productivity-enhancing investments.

From a regional perspective, the World Bank and European Union (2021) provide an extensive overview of agriculture and rural development in Europe and Central Asia, identifying low productivity, fragmented landholdings, and limited technological adoption as persistent challenges. These issues are particularly relevant for countries like Azerbaijan, where agriculture remains strategically important for food security and employment.

Empirical studies focusing on Azerbaijan contribute valuable insights into the macroeconomic and sectoral linkages affecting agricultural development. Guliyev and Huseynova (2016) analyze the relationship between imports and GDP using econometric models, highlighting structural dependencies relevant for food security and trade policy. Huseynova's broader work on food security emphasizes agriculture as a complex system encompassing production, transportation, and policy coordination. Related econometric studies by Huseynova and co-authors (2023; 2024; 2025) demonstrate the applicability of advanced quantitative methods in analyzing economic stability, trade dynamics, and policy effectiveness in Azerbaijan, providing a methodological foundation for agricultural productivity analysis.

Overall, the literature suggests that agricultural productivity growth is a multifaceted process influenced by technology, institutions, policy design, and macroeconomic conditions. While global experiences offer valuable lessons, transition economies such as Azerbaijan require context-specific strategies that balance productivity, sustainability, and structural transformation. This study builds on the existing literature by integrating international theoretical perspectives with regional empirical evidence to assess agricultural productivity and its broader economic implications.

The average wheat productivity per hectare for Azerbaijan for the time 2015-2024 ranges around 30-33 centners per hectare, equivalent to 3.0-3.3 t/ha. In contrast, the average productivity for the Aghdam region was a slight improvement, increasing productivity from 32.4 centners per hectare to 41.6 centners per hectare. This suggests that the wheat productivity level for the Aghdam region has surpassed the average for the entire nation by around 6-8 centners per hectare. Variability of productivity over the last ten years is consistent with weather patterns, for example, the average wheat productivity for 2018 declined sharply by around 30.0 centners per hectare because of the drought, which was temporarily offset by a 7.6% increase for the year 2019, when the rainfall patterns picked up.

Climate Factors that Influence Yields. Precipitation is a decisive factor for wheat yield, given the semi-arid climate of Azerbaijan. Wheat is widely grown on rain-fed fields, and drought is the main limiting factor for wheat growth. This affects about one-third of the total wheat area in the country, thus resulting in reduced wheat yields. However, well-irrigated wheat areas during years of sufficient precipitation increase productivity. Studies show that there is a direct correlation between water supply and wheat yield[1]. This is estimated at about 10 kg of grain per 1 mm of water, regardless of whether it is rain or irrigation. This is supported by

[1] https://icarda.org/media/blog/wheat-self-sufficiency-requires-sustainably-closing-yield-gap-cwana#:~:text=Our%20data%20%28Fig,water%20availability%20and%20productivity%20gains

regional data, which shows that the national wheat yield dropped to around 29-30 centners per hectare during the drought of the 2017-2018 growing season, but it returned to above 32 centners per hectare when precipitation improved the following year. Temperature is the other variable used in the regression analysis [2]. Hot weather, especially when it occurs during the growing season, is known to accelerate drought effects, thus lowering crop productivity. In this case, for instance, the summer of 2017 was recorded to be very hot, with the average June-August temperature of 26.6 °C, which is 1.9 °C higher than the average. It is presumed that this condition, therefore, accelerated drought effects on the growing plants. It is also worth noting that lower growing season temperatures or sufficient moisture that compensates for the presence of high temperatures are the keys to higher productivity. It is also found that the regression analysis between the climate and yields reveals that higher rainfall and lower growing season temperatures (averaged around 14-15 °C), which is the average, result in higher productivity, while drought that is accompanied by heatwaves results in lower productivity.

Impact of Modern Irrigation on Yield. The implementation of a modern irrigation system for 2,500 ha of land in the village of Aghdam will positively affect the wheat yield. In that village, the wheat harvest used to come only from rainfed agriculture, also known as "dəmyə əkinçiliyi." By using irrigation, it will make it possible to provide water when it is needed the most. According to the World Bank, the average increase of wheat yield for Azerbaijan farmers that used improved on-farm irrigation systems exceeded 20% [2]. For wheat farming within the Kura-Araz Lowland, where the village of Aghdam lies, the average rainfall is approximated at 406 mm, with irrigation contributing to about 84 mm. Increased irrigation will provide the necessary water for the plant, especially during droughts, when it used not to. This is because the total water requirement for the plant is about 500-600 mm, and this requirement will have been satisfied. Practically, irrigation will help offset reduced yields for irrigation areas that receive lower rainfall annually. Studies among regions of similar climates have shown that the increment of irrigation water by 100 mm will increase wheat yields by about 1 t/ha when other optimal circumstances are provided. Even supplemental irrigation of 28-166 mm after the dry season was shown to raise wheat yields by 2-3 t/ha when timely planting and variety selection are made. Consequently, it is expected that a large increment of wheat yields will result if the initial 2,500 ha irrigation materializes. Nevertheless, it should not be overlooked that soil fertility might become the next limiting progress. The soil of the irrigation area was made better only by the return of the residues (straw) of the previous harvests with only minimal fertilizer use. However, soil fertility will not play the decisive role when water is plentiful. The use of water will then depend on the availability of several nutrients (nitrogen, phosphorus, among others) for the full use of the potential of irrigation for yielding. However, irrigation, even without optimizing fertilizer use, will help bring the average wheat irrigation areas of Aghdam closer to their biological optimum. To give a perspective, new wheat varieties were introduced in Azerbaijan, and they attained as high as 55 centners per hectare or 5.5 t/ha when provided optimal cultivation. This veritably suggests that if irrigation will take on new irrigation systems, it is also possible that average wheat irrigation areas will break the barrier of 50 centners per hectare of average annual actual yields up through new irrigation systems. In other words, irrigation areas will offset the bad effects of lower rainfall. Of note, other inputs will also become important. Overall, other inputs that make wheat reaches optimal growth will also become important.

Smart Sowing and Precision Fertilization Technologies. Irrigation, along with other related activities, such as optimal planting and fertilizer application, also significantly contribute to increased productivity. Under the umbrella of precision agriculture, it has been shown that optimal practices are carried out on a per square meter basis using global positioning systems, sensors, Variable Rate Fertilizer Application (VRT), and other information technology. According to worldwide assessments, the implementation of such technology has a distinct role in increasing productivity. To give a perspective, it has been determined that precision farming techniques are able to increase overall productivity by as much as 30%, in addition to decreasing water use by 20% and fertilizer use by 15%, as per a 2021 evaluation by Food and Agriculture Organization (FAO), [3]which means that smart technologies are able to increase yields by as much as a third from a similar area. The application of innovations in planting and fertilizing has also been shown with concrete examples. A meta-analysis conducted by Chinese scholars, involving 79 studies, revealed that adopting wide-row precision planting technology resulted in a 9.9% increase in yields of winter wheat over conventional planting. This is due to optimized factors like soil preparation, planting depth, and row spacing, because of which around 10% more wheat can be produced per hectare. Furthermore, experience in advanced nations has shown that adopting precise fertilizing and spray technology ensures that no excess as well as deficient fertilizer reaches the plant, hence not only using fertilizer effectively but also increasing yields. Adopting smart fertilizing technology, for example, has been revealed to increase yields by 20% with simultaneous reductions in water and fertilizer use of around 40%.

Impact on Forecasts and Expected Growth Rates. From the above empirical facts, it can be argued that the adoption and implementation of modern pivot irrigation and precision sowing and fertilizing methods have great potential for improving productivity above what would be achieved by conventional methods. To

[2] https://www.worldbank.org/en/results/2019/10/10/azerbaijan-managing-irrigation-systems-through-water-user-associations#:~:text=Jabbar%20Asadov%20is%20a%20farmer,a%20result%20of%20the%20improvements

[3] https://www.coherentmarketinsights.com/industry-reports/precision-farming-market#:~:text=As%20the%20world%27s%20population%20continues,%28FAO%2C%202021

operate within this perspective, a linear regression model based on historical productivity measures, as measured within traditional approaches, can be adapted and shifted upwards based on the adoption and implementation of modern technologies to achieve precision. Based on percentages shown within global experiences, it would be feasible to assume that modern irrigation technologies and related 'smart' agrotechnical solutions greatly improve output forecasts. According to international statistics, pivot irrigation systems, which optimize water feeding for plants, save water and improve outputs up to twice as much as before at once. At the same time, based on exact sowing and fertilizing solutions, it becomes possible to increase production by 20-30% within delimited production territories. Assuming that our forthcoming linear regression model will define a basic scenario based on traditional knowledge, this new reality requires an upgrade on the projection course provided by our model. First, there will be an adjustment on forecast indicators representing an average 25% boosted contribution of modern technologies, based on international scientific and practical facts. It becomes evident that modern irrigation and agrotechnical solutions will enable significantly higher outputs within forthcoming years compared to today's production rates.

Calculation Method. Calculations will start with making forecasting for next 10 years based on data from previous 25 years. There are 3 methods to make forecasting: *linear regression, ETS, and ARIMA.* The calculations were made using the ETS method. The main reasons for this are listed below:

ETS Model (Error, Trend, Seasonal) - The ETS model represents a class of exponential smoothing methods. Error, Trend, and Seasonality are components. The ETS model, which describes a method for representing and decomposing a univariate or multivariate stream of data into three components: error, trend, and seasonality, is widely recognized as an interpretable and flexible model. It was formalized by Hyndman et al. in 2008. The ETS model represents time series observations Y_t using the following decomposition:

$$Y_t = l_{t-1} + b_{t-1} + s_{t-m} + \varepsilon_t$$

Where:

l_{t-1} : Level component

b_{t-1}: Trend component

s_{t-m}: Seasonal component (If applicable)

ε_t: Error term at time *t*

m: Seasonality length

Each component (E, T, S) can be specified as:

- Additive (A): constant magnitude over time,

- Multiplicative (M): Varies proportionally with level,

- None (N): The component is not included.

As a result, there are various ETS model combinations supported by ETS, including ETS(A, A, N), ETS (M, A, N), and ETS (A, M, A).

Advantages of ETS Modeling:

- Flexibility: ETS models fit datasets with or without trend and seasonality and allow a maximum of 30 different model types.

- Recency Weighted Smoothing: Exponential smoothing gives more importance to recent values and thus increases sensitivity to recent changes in the data.

- Effective performance with limited data: ETS performs effectively even with limited data, especially when trend effects are more prominent compared to cyclical components.

- Interpretability and transparency: Unlike some models based on machine learning algorithms, ETS components are interpretable and help explain the underlying dynamics.

Applications in Agricultural Yield Forecasting. Agricultural ETS models are commonly used in agriculture forecasting involving annual or seasonal series with trend or small cyclic components. Examples of crop production datasets, such as wheat or barley production per year, will have trend components due to improvements in farming methods and changes in weather; ETS models can handle these (Makridakis et al., 2020). Within arid and semi-arid regions, such

as Azerbaijan, ETS models will be capable of accounting for the increases due to infrastructural developments like irrigation and better crop seeds. The Python code used for the calculation is as shown in Figure 6.

Table 3.

Actual average wheat and barley yield in Azerbaijan and Agdam, t/ha, 2015-2024

	Wheat			Barley		
Years	Azerbaijan Republic	Agdam Region	Difference %	Azerbaijan Republic	Agdam Region	Difference %
2015	3.15	3.19	2%	2.95	2.98	1%
2016	3.06	3.27	4%	2.69	3.0	12%
2017	2.98	3.87	27%	2.56	3.18	24%
2018	3	3.76	25%	2.79	3.44	23%
2019	3.21	3.9	20%	2.97	3.55	20%
2020	3.18	4.07	28%	2.96	3.64	23%
2021	3.28	4.09	24%	3.07	3.67	20%
2022	3.13	4.11	29%	2.88	3.75	30%
2023	3.3	4.19	24%	2.99	3.9	30%
2024	3.1	4.23	37%	2.93	3.84	31%

Source: Stat.gov.az, https://www.stat.gov.az/source/agriculture/az/2.187.xls

```python
from statsmodels.tsa.holtwinters import ExponentialSmoothing

# Step 1: Take historical yield
yield_series = agdam_df["Yield_t_ha"]

# Step 2: Build ETS Model  – additive trend, no seasonality
ets_model = ExponentialSmoothing(yield_series, trend="add", seasonal=None)
ets_fit = ets_model.fit()

# Step 3: Figure out forecast period
forecast_values = ets_fit.forecast(10)  # Forecast for 10 years

# Step 4: Convert results to DataFrame format
forecast_years = list(range(2025, 2035))
forecast_df = pd.DataFrame({
    "Year": forecast_years,
    "Forecast_Yield_t_ha": forecast_values
})
```

Figure 6. Python ETS Forecast Calculation (Additive Trend, No Seasonality)

Adjusting the obtained productivity results with the effects of modern irrigation technologies and "smart" sowing and fertilization technologies on productivity, the results obtained are reflected in Table 4:

Table 4.

Average forecasted wheat yield in Agdam, t/ha, 2025-2026

	Wheat		Barley	
Years	Forecast_Yield_t/ha	Adjusted Yield, t/ha	Forecast_Yield_t/ha	Adjusted Yield, t/ha
2025	4.38	5.48	3.76	4.70
2026	4.49	5.61	3.81	4.77
2027	4.59	5.74	3.86	4.83
2028	4.69	5.86	3.91	4.89
2029	4.79	5.99	3.96	4.95
2030	4.9	6.12	4.01	5.01
2031	5	6.25	4.06	5.07
2032	5.1	6.37	4.11	5.13
2033	5.2	6.5	4.16	5.19
2034	5.3	6.63	4.20	5.26
2035	5.4	6.75	4.25	5.32

Assumptions. The projections are made based on average climatic conditions every year (no worse-than-worst drought or heatwave on top of existing variability, since irrigation will mitigate the effects of rainfall shortfalls). They also consider improvements in agriculture technology in the irrigated areas, perhaps additional fertilizer uses or better seeds, in the order of improvements that can reasonably be expected within the next ten years. Such improvements will not come about by technological revolution but will result from the better climate. Yields could level off around 48-50 c/ha (since growth cannot exceed nutrient-supplied growth rates, even when irrigation is provided). However, using high-yielding varieties along with judicious fertilizer use, the results could go beyond the estimates, since studies show that it is possible to get 6.5-7.0 tons per hectare.

Comparison with real “Pivot” data. In this part, a comparative analysis will be presented in relation to empirically observed production figures, which have been derived from the author's personal working experience, in addition to the wider production trends based on regional and national levels in Azerbaijan. In recent years, pilot projects with a focus on ‘pivot irrigation systems and improved fertilization methods have been initiated in the Samukh and Tovuz regions. Such local projects have recorded higher production trends compared to regional and national production levels. As presented in Table 5, in Samukh district, wheat production in Pivot irrigations since 2017 has an average production level of 4.31 t/ha during 2017-2023, which is higher than the regional average of 3.71 t/ha by 15%. In Samukh, based on the national average, wheat production in pivot irrigations is higher by 35%. Furthermore, in the Tovuz district, wheat production via pivot

irrigation is higher than regional and national averages by 19% and 39%, respectively. Thus, barley plantings were also carried out in both regions using the pivot irrigation method during 2019-2023, and the results exceeded the regional averages by 58% and the national average by 86%, which is an example of how pivot irrigation and proper fertilization and technical maintenance increase productivity. Moreover, Table 5 above highlights interesting dynamics in barley production in Samukh in the early years of research. A reduction in production occurred from 2019 to 2021. However, based on professional research observations by the researcher, this situation reversed in 2022 with an enhanced approach in carrying out technical maintenance and fertilization work. Therefore, a nearly two-fold increase in production occurred. From a research perspective, a more conservative approach has been taken in adjusting these real data for productivity results. As an alternative to real increases, a 25% increase in the results of previous periods has been considered, although in Samukh district, for example, over a 7-year period, the productivity indicator at the end of the period showed a 46% increase compared to the beginning.

Table 5.

Comparison of actual barley and wheat yield results with averages, 2017-2023

Years	Region	Crop	Harvested area, ha	Actual quantity,T	Actual yield,T	Average yield in region,	Average yield in Azerbaijan,	% in region	% in Azerbaijan
2017	Samukh	Wheat	2,696	7,549	2.80	2.62	3.05	7%	-8%
2018	Samukh	Wheat	2,614	11,765	4.50	3.53	3.01	28%	50%
2019	Samukh	Wheat	2,275	6,839	3.01	3.26	3.24	-8%	-7%
2020	Samukh	Wheat	2,423	12,638	5.22	4.32	3.17	21%	65%
2021	Samukh	Wheat	2,089	9,011	4.31	3.8	3.29	14%	31%
2022	Samukh	Wheat	2,416	12,268	5.08	4.23	3.19	20%	59%
2023	Samukh	Wheat	2,015	10,590	5.26	4.23	3.38	24%	55%
2019	Samukh	Barley	148	720	4.86	3.46	2.97	41%	64%
2020	Samukh	Barley	221	1,054	4.77	3.6	2.96	32%	61%
2021	Samukh	Barley	222	1,044	4.71	3.67	3.07	28%	53%
2022	Samukh	Barley	222	1,673	7.55	3.72	2.88	103%	162%
2023	Samukh	Barley	495	1,947	3.93	3.61	2.99	9%	32%
2017	Tovuz	Wheat	6,938	13,183	1.90	3.23	3.05	-41%	-38%
2018	Tovuz	Wheat	4,180	18,808	4.50	3.24	3.01	39%	50%
2019	Tovuz	Wheat	4,799	17,755	3.70	3.3	3.24	12%	14%
2020	Tovuz	Wheat	4,705	25,900	5.50	3.83	3.17	44%	74%
2021	Tovuz	Wheat	4,522	23,656	5.23	3.71	3.29	41%	59%
2022	Tovuz	Wheat	5,177	26,759	5.17	4.37	3.19	18%	62%
2023	Tovuz	Wheat	5,215	26,883	5.16	4.19	3.38	23%	53%
2019	Tovuz	Barley	377	1,715	4.55	2.73	2.97	67%	53%
2020	Tovuz	Barley	409	2,523	6.18	3.95	2.96	56%	109%
2021	Tovuz	Barley	466	2,908	6.24	3.79	3.07	65%	103%

2022	Tovuz	Barley	613	4,018	6.55	3.8	2.88	72%	128%
2023	Tovuz	Barley	540	3,235	5.99	2.93	2.99	104%	100%

Late Corn. It is planned to plant corn as a second crop to wheat and barley fields. This decision has both agronomic and economic aspects. So, Corn is an important grain and forage crop. This plant has a wide range of applications and high productivity. Canned products such as flour, starch, grits, ethyl alcohol, oil, and others are obtained from corn kernels. Paper, linoleum, activated carbon, synthetic resin, and other products can be obtained from the stalks, leaves, and petioles. The high content of feed units and digestible protein in corn kernels allows its use as valuable forage, and transplanting is considered an important method for increasing forage production. At present, in global agriculture, all kinds of resources and the implementation of cost-effective technologies are allocated to this purpose. The key elements of these technologies include minimal and zero-tillage techniques, also known as No-Till. Considering the fact that a strong root system is formed in a corn plant, during re-sowing, the field must be covered immediately after harvest to a depth of 8-12 cm, and organic and mineral fertilizers must be applied to the field at a rate determined in accordance with the results of soil analysis and tilled to a depth of 25-28 cm. The top layer of the soil must be loosened with a trowel or rotor tines. This will make the soil soft, granular, even, remove weeds, and will provide an even depth of seed burial. The application of soil herbicides for weeds must be applied and mixed in the fields 2-3 days before sowing. Cultivation, thinning, and re-filling operations must be performed 2-3 times during re-sowing of the corn. The first cultivation operation among the rows must be performed at a depth of 8-10 cm, the second operation at a depth of 6-8 cm, and the third operation at a depth of 5-6 cm.

Calculation Method. Because of the constrained nature of available government statistics with respect to late corn (as a second crop) yield in the Agricultural Statistics of Azerbaijan, this research work utilizes solely on the expertise of the researcher in their professional field to predict future production in the next decade. As shown in Table 6 below, variability in the level of production of late corn in terms of yield shows a level of variability, but with no major fluctuation. The average production level over this period is therefore approximately 4.05 t/ha. Hence, taking into consideration these elements in projecting future production levels, a good estimate in this research work to project production level in the first year of forecasting, namely 2025, will be 3.5 t/ha, which is a level taking into consideration the lower bound of early-year production levels in empirical research work. With a linear regression mathematical model established using a Python programming tool, future production levels in this next 10-year period have a projected potential capacity ranging from 3.5 to 4.66 t/ha.

Table 6.

Actual yields of late corn in Samukh and Tovuz, 2017-2022

Years	Region	Area Harvested, Ha	Actual Quantity, T	Yield, T/Ha
2017	Samux	1,766	5,298	3.00
2018	Samux	2,663	12,915	4.85
2019	Samux	2,033	7,500	3.69
2020	Samux	2,311	10,537	4.60
2021	Samux	2,069	4,671	2.26
2022	Samux	1,680	6,867	4.09
2017	Tovuz	2,946	11,107	3.77
2018	Tovuz	2,713	10,715	3.95
2019	Tovuz	2,033	7,500	3.69
2020	Tovuz	5,260	28,943	5.50
2021	Tovuz	4,208	21,021	5.00
2022	Tovuz	3,405	14,267	4.19

Other Crops. These 3 crops are considered as the main crop area and the main calculations were made on these crops. The other 3 crops are planned to be planted more for crop rotation and enrichment of the soil cover with a fertile humus layer obtained from plant residues. Thus, sugar beet, soybean and alfalfa are high-protein crops, when the plant residues remaining after harvesting are mixed with the soil during the tillage stage, the minerals collected in the residues will be mixed with the soil and ultimately form a more productive and fertile soil layer for the main crops in the next plantings. A standard agronomic approach has been put forward for the yield forecasts of these crops. Thus, the yield results obtained with traditional technical maintenance rules will be taken into account for the next 10-year period with a stable and slightly positive increase in all years. Planting these crops in small plots will minimize the risks of yield loss that may arise from them. The results are also strengthened and justified by the author's professional experience and outputs obtained as a result of agronomic consultations.

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INCOME TRENDS AND STATISTICAL EVALUATION OF AZERBAIJAN'S TRANSPORT SECTORS

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Abstract

This study presents a statistical assessment of revenue generated from cargo transportation in Azerbaijan's sea transport sector. By applying descriptive statistical methods, the research investigates long-term patterns, variability, and distributional characteristics of maritime income from 2000 to 2024. The analysis indicates considerable fluctuations influenced by cargo volume shifts, economic developments, and sector-specific changes. Measures such as average income, variance, skewness and kurtosis outline the fundamental properties of income distribution, offering deeper insight into the operational dynamics of maritime transport. These results confirm the enduring significance of sea transport as a major contributor to national transport revenues.

The research also conducts a statistical evaluation of income derived from freight transportation in Azerbaijan's railway sector during 2000–2024. It explores the strategic importance of railway transport in the modern economy and its central role within Azerbaijan's logistics network. The analysis includes freight income trends, descriptive indicators, covariance and correlation outcomes, and factors shaping revenue—such as cargo volume, tariff regulations and infrastructure progress. Furthermore, the study emphasizes the influence of key international transport corridors, including the Trans-Caspian International Transport Route (Middle Corridor), the Baku–Tbilisi–Kars line, the North–South Corridor and the TRACECA initiative. Overall, the findings provide a detailed overview of income behavior in the railway sector and underline its relevance for national economic growth and global transport integration.

Additionally, the study investigates income patterns in Azerbaijan's air transport sector using statistical data. It compares total transport revenue with income derived specifically from air transportation and evaluates income from both air cargo and passenger services. The research applies various statistical techniques such as graphical analysis, descriptive statistics, covariance, correlation and standard deviation to measure variability across income categories. A two-sample t-test is used to compare mean differences among income groups. The results reveal that air transport revenue rises in parallel with total transport income, while strong positive relationships exist between air passenger and air cargo earnings. Overall, the analysis demonstrates that the air transport sector represents a vital and growing component of Azerbaijan's transport economy.

The sea transport sector represents a strategically important component of Azerbaijan's overall transport and logistics system. Situated along the western coast of the Caspian Sea, the country combines modern port facilities—particularly the Baku International Sea Trade Port and several specialized oil terminals—with an expanding fleet of commercial and technical vessels that operate on domestic, regional, and international routes. Maritime transport supports both general cargo and energy-related shipments and plays a vital role in Azerbaijan's plans to strengthen transit connections between Europe and Asia.

Keywords: Azerbaijan, Sea transport, logystic system, air transport, railway transport, economic growth, incomes.

Introduction. In recent years, the performance of Azerbaijan's maritime industry has been mixed. While port revenues and transit-related shipments have grown during many periods, cargo volumes and other operational indicators have fluctuated due to global energy market dynamics, seasonal conditions, and regional infrastructure limitations. Official statistics show steady increases in port income across certain years, alongside variable levels of maritime cargo tonnage depending on segment type, such as international cargo, coastal shipments, and oil-related transshipment. Revenue in the maritime sector is drawn from diverse sources, including port fees, terminal handling charges, freight and charter services, bunkering operations, marine support activities, and petroleum logistics. Despite its strong contribution to national transport earnings and foreign exchange inflows, the sector faces ongoing structural and environmental challenges such as port congestion, fluctuating Caspian Sea water levels, dredging requirements, and geopolitical uncertainties that influence future investments and income stability. These risks must be assessed together with opportunities arising from new transit initiatives and the expansion of port capacity.

Railway transport is another core element of Azerbaijan's transport system and plays an essential role in the national economy. Railways offer a cost-effective and efficient means for moving large quantities of goods, making them a central pillar of the country's logistics network. Continuous investment in rail infrastructure, modernization of rolling stock, and improvements in passenger services have strengthened the sector and enhanced its long-term financial performance. The development and upgrading of the railway network have also contributed significantly to balanced regional

growth and the broader expansion of Azerbaijan's economic potential.

Income generated from railway operations depends on multiple variables, including freight volume, passenger numbers, tariff policies, infrastructure development, and overall operational efficiency. Seasonal trends, logistical challenges, and fluctuations in fuel prices further shape yearly revenue levels. The recent modernization of the network and expansion of major lines have contributed to rising income from both freight and passenger services. Statistical tools such as descriptive indicators, trend analysis, covariance, and correlation help identify revenue patterns, assess performance, and forecast income dynamics. Consistent upward trends reflect improvements in network accessibility and operational capability, supporting domestic economic development and the growth of foreign trade.

Azerbaijan's railway system is also deeply integrated into international transport routes such as the Trans-Caspian International Transport Route (Middle Corridor), the Baku–Tbilisi–Kars Railway, the North–South Transport Corridor, and TRACECA. These corridors establish multimodal links between Europe and Asia, attract additional freight flows, and strengthen Azerbaijan's position within global logistics chains. Examining income trends in the railway sector therefore offers valuable insight into its strategic role in economic development and international connectivity.

The development of air transport in Azerbaijan also has a long historical trajectory that continues to shape the country's aviation sector today. Aviation activities began as early as 1910, initially in experimental form, but gradually evolved into organized air services by the 1920s, including cargo transportation. Over time, and particularly during the Soviet era, technological advancements and expanding airport capacity increased the ability to handle air freight. Airports in Baku, Ganja, and Nakhchivan grew into important hubs for both domestic and international cargo flows.

Following independence, Azerbaijan made substantial investments in airport infrastructure, aircraft modernization, and specialized cargo facilities. The establishment of the Baku Cargo Terminal significantly enhanced the country's capacity to process large volumes of freight. Today, air cargo transport plays a key role in facilitating trade and connecting Azerbaijan to global markets, enabling the fast movement of machinery, electronics, medical supplies, perishable goods, and other critical products.

Income from air cargo operations now constitutes an essential part of the aviation sector's earnings, reflecting both domestic demand and the increasing use of Azerbaijan as a regional transit center. Continuous improvements in aviation infrastructure and logistics services further strengthen the competitiveness of the country's air transport industry. Examining income generated from air transport therefore provides important insights into the broader economic impact of aviation and its contribution to national development.

Recent publications. In recent years, researchers have published several studies analyzing the income dynamics of railway freight transport through statistical and econometric methods. Railway transport is recognized as a key driver of economic development and trade efficiency, linking industrial production with regional and international markets. Recent publications relevant to the income structure of Azerbaijan's sea transport sector mainly originate from official state institutions and industry bodies. The State Statistical Committee of Azerbaijan annually publishes data on transport revenues, cargo volumes, and sectoral indicators.

Literature Review

The development of freight transportation systems, logistics regulation, and the relationship between macroeconomic indicators and sectoral growth has been extensively examined by international and local scholars. Existing studies reveal that transportation infrastructure and freight coordination play a vital role in economic performance, while economic shocks, pricing mechanisms, and regulatory frameworks significantly influence sector efficiency.

Gao et al. (2020) emphasize the regional differentiation in freight mode coordination in China, arguing that efficient multimodal freight integration depends on the economic development level, industrial structure, and geographical conditions of regions. Their findings highlight that integrated logistics corridors increase transport efficiency and reduce costs, especially in regions with advanced infrastructure.

Ko et al. (2022) conduct a data-driven assessment of short-distance freight rail transportation potential within the U.S. Lake Superior region. The study identifies log movements as a key indicator for estimating rail demand and concludes that optimizing short-haul freight can reduce road congestion and environmental load. This complements Gao et al. (2020), indicating the need for regional adaptation in freight planning rather than uniform nationwide strategies.

The COVID-19 outbreak brought significant volatility to freight volumes worldwide. Saxena and Yadav (2022) apply an ARIMA model to analyze rail freight volume and revenue during the pandemic, establishing that freight transport experienced short-term decline followed by gradual stabilization. The study underscores the importance of forecasting tools for crisis management in the transport sector.

Ng et al. (2024) extend this discussion by applying econometric modeling to evaluate pandemic-driven disruptions and recovery patterns in the U.S. rail freight industry. Their results suggest a nonlinear recovery trajectory, influenced by policy responses and supply chain resilience measures. Together, these studies show that pandemic shocks have high short-term impact but long-term adaptability is achievable through strategic planning.

Li and Wu (2024) investigate dynamic pricing in rail freight transport under carbon emission penalties. Their results demonstrate that carbon pricing influences freight operator behavior, pushing them toward environmentally sustainable strategies. The study contributes to the emerging literature on green logistics and provides a quantitative basis for environmental policy evaluation in transport markets.

A group of studies focuses on the macroeconomic relationship between sectors and economic development, with particular emphasis on Azerbaijan.

Huseynova (2023) examines economic growth parameters in Russia and Azerbaijan using cointegration analysis and finds long-run relationships between macroeconomic indicators, reflecting shared economic trends shaped by energy markets.

Huseynova & Hajizada (2024) analyze the stability of Azerbaijan's banking sector under crisis conditions using econometric models. The findings confirm the resilience of financial institutions, though external shocks remain influential. Complementing this, SM & SS (2025) demonstrate a long-run link between the tourism sector and Azerbaijan's economic growth, stressing tourism as a growth-enhancing industry.

Alirzayev & Huseynova (2025) evaluate the J-curve effect and Marshall-Lerner condition for Azerbaijan, providing evidence of export–import elasticity effects and confirming currency depreciation impacts on trade balance in the short and long run. Similarly, Huseynova & Gambarli (2023) investigate the cointegration and causality between the U.S. stock market and global markets, revealing significant transmission mechanisms of financial shocks.

Collectively, these works demonstrate that economic growth in Azerbaijan is closely interconnected with external trade, tourism, and financial,transport integration.

Several studies address regulatory aspects and modernization trends in transport policy. Huseynova & Qurbanova (2025) discuss the state's role in regulating transport and logistics services for foreign trade development, arguing that infrastructure investment and policy harmonization are essential for enhancing transit capacity.

The regulatory basis is reinforced by national documents such as the Law "On Transport", which establishes operational and safety rules, and the Assessment of regulatory framework readiness in international trade (economy.gov.az), which highlights current gaps in legal harmonization with global trade standards. Additionally, the 2024−2026 Action Plan prioritizes expansion of international transit corridors and strengthening Azerbaijan's role as a regional logistics hub.

Yusifov et al. (2019) also stress strategic development directions in Azerbaijan's logistics sector, noting the potential for digitalization, diversification of cargo routes, and structural reforms aimed at improving competitive positioning in Eurasian transport Limited research exists on digital logistics ecosystems and AI-driven optimization in Azerbaijan.

Overall, the literature suggests that efficient freight coordination, resilient transport systems, and robust policy frameworks are central to economic performance. International studies highlight advanced modeling and forecasting tools, while regional research on Azerbaijan focuses on economic integration, banking stability, tourism, and logistics regulations. Future research may benefit from integrating digital transformation, sustainability, and multimodal optimization strategies into transport and trade studies.

Methodology. This study conducts a statistical analysis of railway transport income in the Republic of Azerbaijan, covering both cargo and passenger services from 2000 to 2024. Descriptive statistics are applied to summarize key variables, including cargo volume, passenger numbers, revenue. Trend analysis, covariance, and linear correlation methods are used to explore relationships between these variables and assess their impact on income. Official data sources, including the State Statistics Committee of Azerbaijan and transport reports, are utilized, while EXCEL is employed for calculations, tables, and graphical representations. This methodology provides a concise, reliable framework for understanding the financial and operational dynamics of Azerbaijan's railway sector and supports forecasting of future trends.

The research applies a quantitative descriptive statistical approach based on secondary data obtained from official transport sector reports. Data for total transportation income, income from sea transport, and income specifically from sea transportation of goods were processed using standard statistical tools. Indicators such as mean, median, mode, standard deviation, sample variance, skewness, kurtosis, and confidence intervals were calculated to summarise the income structure and distribution. Graphs and comparative tables were used to identify long-term trends between 2000 and 2024. The analysis focused on identifying distribution patterns (right-skewness, peakness or softness), variability levels, and the comparative behaviour of different income categories within the transport sector. No primary data collection was carried out; all analysis is based on documented statistical sources.

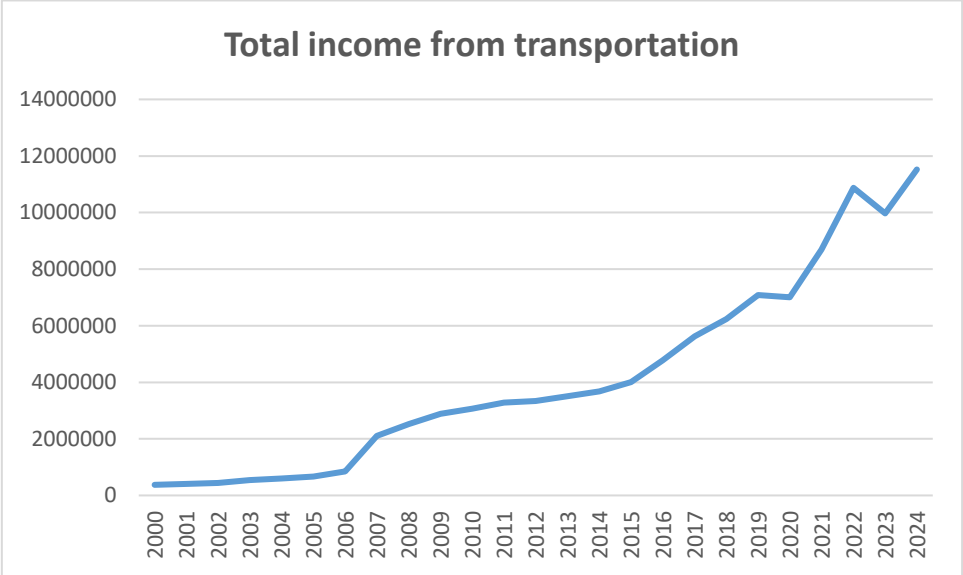

Figure 1.1

Figure 1.1 shows the general income from all transportation services in Azerbaijan from the early 2000s to 2024.

- At the beginning (2000-2005), the income was low and stable, showing slow development in the transport sector.
- Around 2006, the income started to increase more noticeably, meaning overall transport activities (road, rail, air, sea) were growing.
- From 2010 to 2017, the graph shows a steady upward trend, which reflects improvements infrastructure, higher demand, and growing transit activities.
- After 2018, the rise becomes faster. This period shows strong expansion, especially due to new logistics projects, transit corridors, and more trade passing through Azerbaijan.
- Around 2020, there is a small dip, possibly connected to global disruptions (like the pandemic), but the income quickly rises again.
- By 2023-2024, the income reaches its highest level showing that Azerbaijan's transport sector has grown significantly and continues to expand.

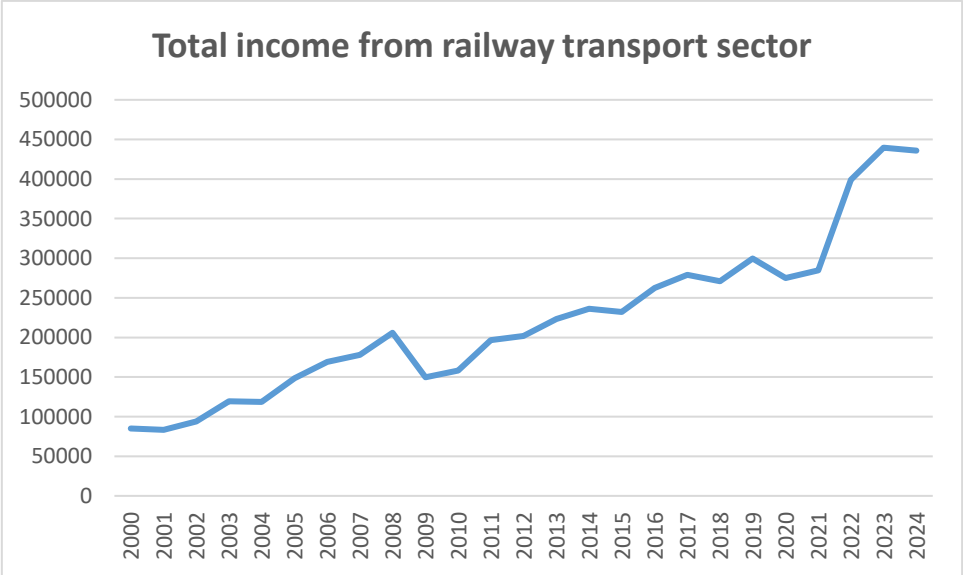

Figure 1.2

Figure 1.2 shows income specifically from railway services in Azerbaijan from 2000 to 2024.

- From 2000 to 2005, the income was low and increased slowly, reflecting limited railway activity at that time.
- Between 2006 and 2014, the line rises steadily, meaning the railway sector was gradually becoming more active and efficient.
- After 2015, the income contributes to grow, showing improvements linked to modernization projects, new wagons, and better railway services.
- There are small ups and downs, but the overall direction is positive.
- The most significant jump happens around 2021-2023, where income rises sharply. This relates to:
  - Increased transit through Azerbaijan,
  - The Middle Corridor becoming important,
  - Rising trade flows from Asia to Europe.

- In 2024, the income remains very high compared to earlier years.

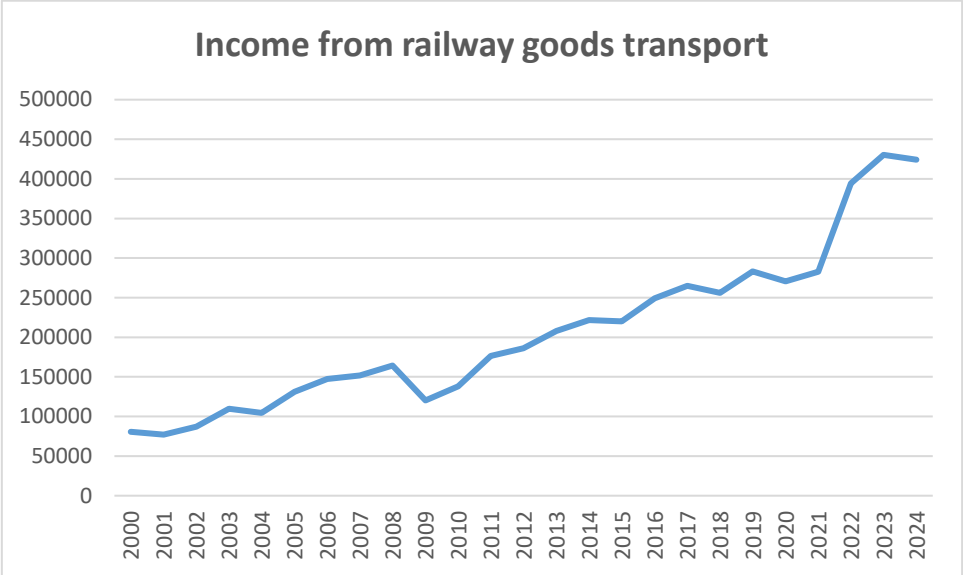

Figure 1.3

Figure 1.3 shows how much income Azerbaijan earns from transporting goods by railway from 2000 to 2024.

- At the start (2000-2004), the income was low but slowly rising, showing limited but increasing goods movement.
- Around 2005-2008, the graph shows a clear increase, meaning more freight activities and more demand for rail cargo services.
- In 2009, there is a small drop, possibly linked to global economic slowdown, but the income quickly recovers.
- After 2010, the line increases steadily and continuously, showing:
  - more transit goods,
  - bigger trade flows through Azerbaijan,
  - modernization of railway infrastructure.
- Between 2020-2023, the income rises sharply. This strong jump reflects:
  - Growth of Middle Corridor,
  - Increased East-West transit,
  - Higher international and domestic freight volumes.
- In 2024, the income slightly decreases but stays very high compared to earlier years.

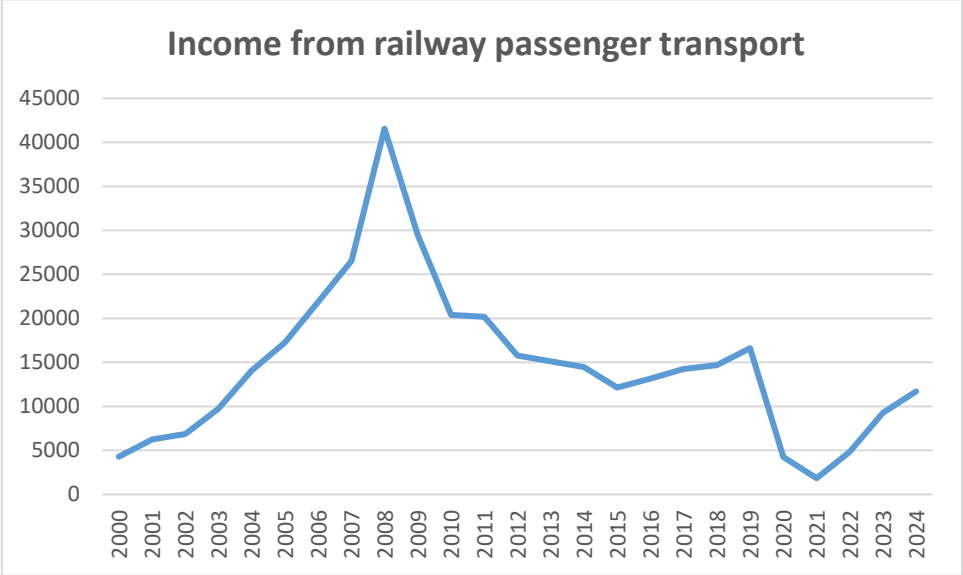

Figure 1.4

Figure 1.4 shows income earned from carrying passengers by railway from 2000 to 2024.

- From 2000 to 2006, passenger income increases quickly, meaning more people were using trains.
- It reaches a strong peak around 2007-2008. This was the highest point in passenger transport income.

- After 2008, the graph shows a sharp decline, which continues for several years. Reasons may include:
  - Modernisation works on rail lines,
  - Growing use of cars and buses,
  - Changes in travel habits.
- Between 2012-2018, the income stays low and stable, with small ups and downs.
- In 2020, income drops significantly again, likely affected by COVID-19 restrictions and reduced travel.
- After 2021, income begins to rise again, showing slow recovery.
- By 2023-2024, the line moves upward, but levels are still much lower than in the early 2000s.

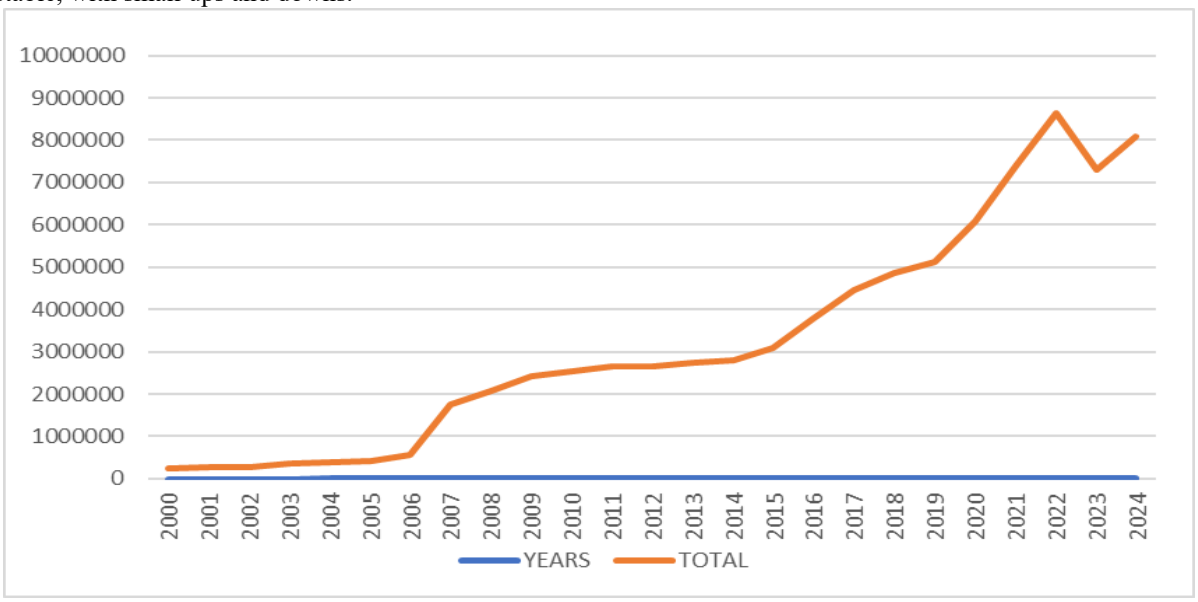

Figure 1.5

Figure 1.5 illustrates the overall revenue generated from all transportation services in Azerbaijan between the early 2000s and 2024.

- From 2000 to 2005, the income remained low and almost unchanged, indicating that the transport sector was developing slowly during this period.
- After 2006, the revenue began to rise more clearly, showing growth across all transport modes, including road, rail, air, and sea.
- Between 2010 and 2017, the graph presents a consistent upward movement, which suggests better infrastructure, increasing demand, and expanding transit operations.
- Post-2018, the increase becomes sharper, reflecting rapid sector expansion supported by new logistics projects, international transport corridors, and a rise in trade flows through Azerbaijan.
- Around 2020, a slight decline appears, likely related to global challenges such as the pandemic, but the income recovers shortly after.
- By 2023–2024, the revenue reaches its peak, demonstrating that Azerbaijan's transportation sector has achieved strong growth and continues to develop.

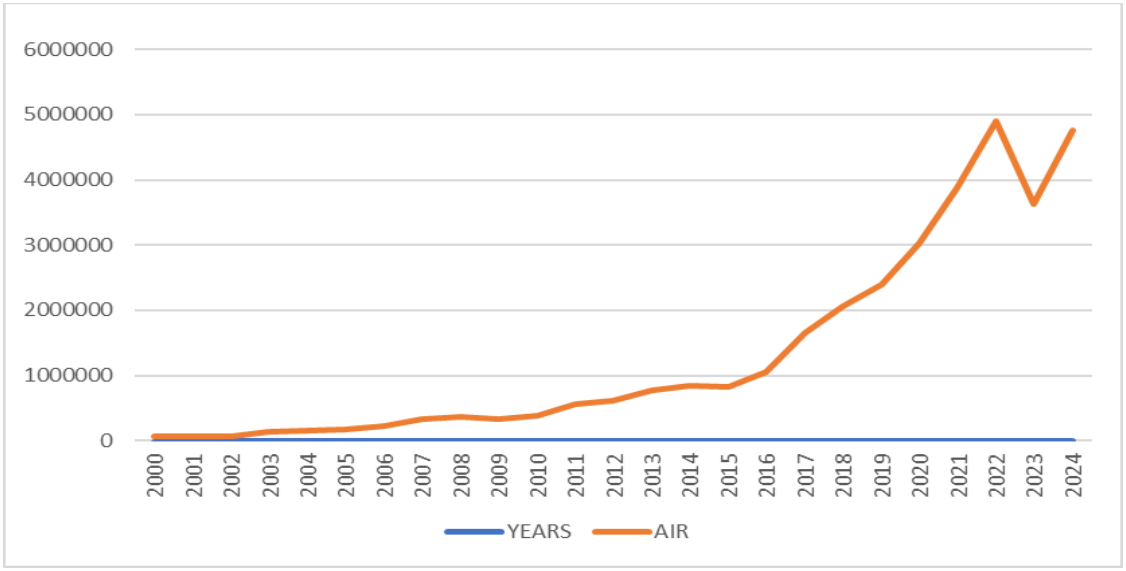

Figure 1.6

Figure 1.6 shows the income from the air transport sector in Azerbaijan from the early 2000s to 2024.

- Between 2000 and 2005, the income was quite low and stable, showing that the aviation sector was still at an early stage of development.
- After 2006, the revenue started to increase gradually, meaning that air travel demand, international flights, and cargo activities were growing.
- From 2010 to around 2017, the graph demonstrates a steady upward trend, reflecting improvements in airport infrastructure, the expansion of national airlines, and higher passenger traffic.
- After 2018, the growth becomes faster. This period shows strong development in the aviation sector, supported by new routes, increased transit flights, and rising air cargo operations.
- Around 2020, there is a noticeable decline, most likely caused by global air travel restrictions during the pandemic. However, the income begins to recover soon after.
- By 2023–2024, the income reaches its highest point, showing that air transportation in Azerbaijan has expanded strongly and continues to grow.

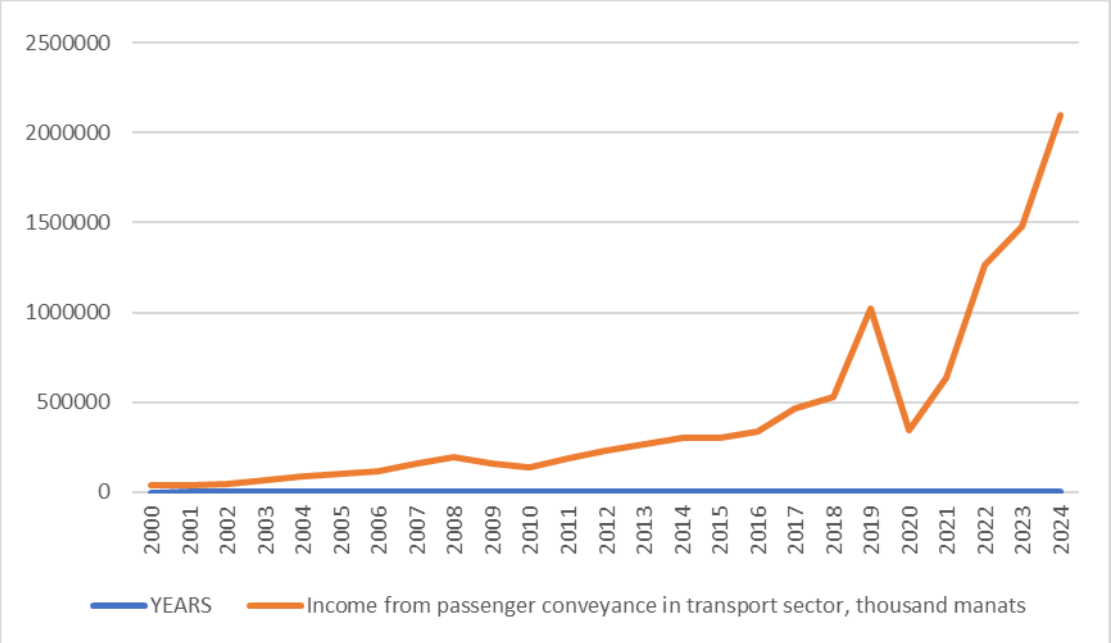

Figure 1.7

Figure 1.7 shows the income from passenger conveyance in the air transport sector in Azerbaijan from the early 2000s to 2024.

- From 2000 to 2005, the income remained low and almost unchanged, which indicates limited passenger traffic and slow development in the aviation market.
- After 2006, the revenue began to rise gradually, reflecting increasing demand for domestic and international flights.
- Between 2010 and 2017, the graph shows a stable upward trend, suggesting improvements in airport services, more flight destinations, and an overall rise in passenger numbers.
- After 2018, the increase becomes more rapid. This period demonstrates strong growth driven by higher transit passengers, expanded airline operations, and improved air travel accessibility.
- Around 2020, the income drops noticeably due to global travel restrictions caused by the pandemic, reducing passenger movements. However, recovery starts shortly after this period.
- By 2023–2024, the income reaches its peak, showing that passenger transportation by air in Azerbaijan has grown significantly and continues to expand.

Figure 1.8

Figure 1.8 shows the income from the transportation of goods in the air transport sector in Azerbaijan from the early 2000s to 2024.

- From 2000 to 2005, the income was low and remained nearly stable, showing that air cargo activities were still limited during this period.
- After 2006, the revenue started to increase gradually, indicating a rise in air freight demand and the development of cargo services.
- Between 2010 and 2017, the graph shows a steady upward trend, which reflects improvements in cargo infrastructure, better logistics systems, and growing international trade.
- After 2018, the growth becomes faster, showing strong expansion in air cargo operations supported by transit routes, new logistics hubs, and higher volumes of imported and exported goods.
- Around 2020, there is a slight decline due to global disruptions and reduced trade activity, but the income begins to rise again soon after.
- By 2023–2024, the income reaches its highest level, demonstrating that air cargo transportation in Azerbaijan has grown significantly and continues to develop.

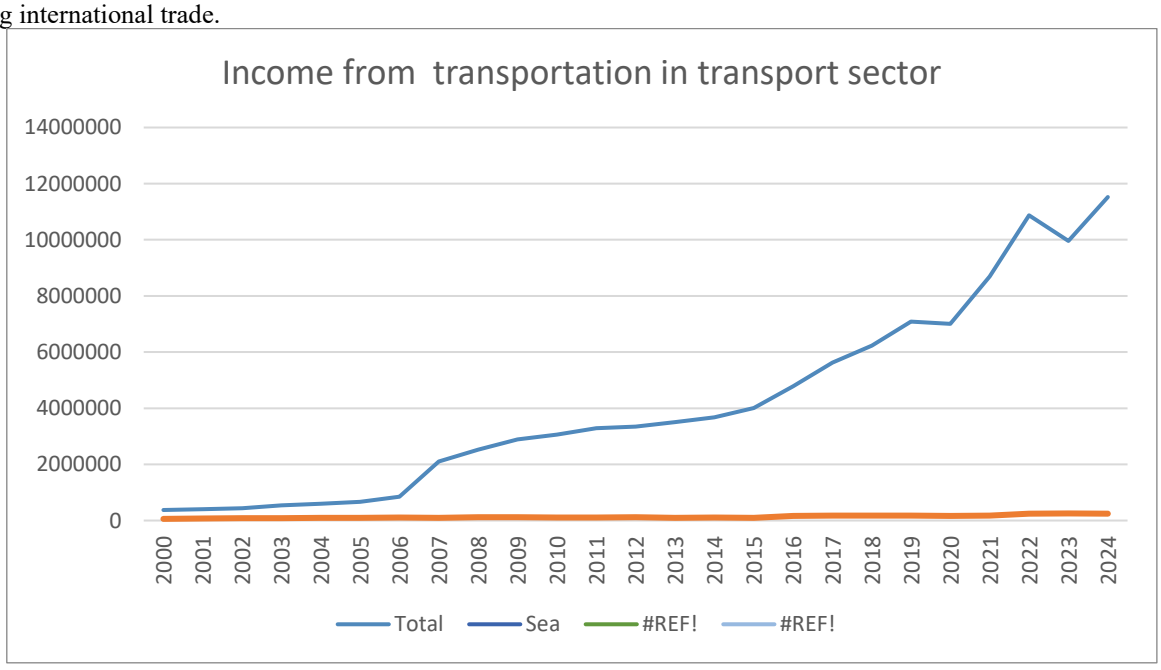

Figure 1.9

Figure 1.9 illustrate how total income from transportation in transport sector, income from sea transportation in transport sector, income from sea transportation of goods in transport sector and income from sea transportation of passenger in transport sector change by the year from 2000 to 2024.

Blue line illustrate total income from transportation in transport sector

Red line illustrate income from sea transportation in trsansport sector

Green line illustrate , income from sea transportation of goods in transport sector

And last one purple line illustrate income from sea transportation of passenger in transport sector.

Key Decline Periods and Causes

1. 2008–2009 Global Financial CrisisA sharp decline is visible around 2008–2009. This corresponds to the global financial crisis, which led to reduced trade volumes worldwide. Maritime cargo turnover in the Caspian Sea region, including Azerbaijan, decreased.

Source: State Statistical Committee of Azerbaijan (SSC) transport reports, 2009.

2. 2014–2016 Oil Price Shock Income from sea transport significantly dropped during 2014–2016. The global oil price collapse reduced both petroleum shipment volumes and related port revenues. Since a large share of Azerbaijan's maritime income is tied to oil logistics, the impact was immediate.

Source: SSC annual transport statistics; ASCO financial report 2015.

3. 2020 – COVID-19 Pandemic The graph shows a distinct fall in 2020. The pandemic caused disruptions in logistics chains, lowered demand for industrial products, and reduced passenger sea transport almost completely.

Sources: Trend News Agency (2020), Report.az maritime overview (2020), SSC transport indicators.

4. 2022–2023 Regional Geopolitical Shifts Some instability is observed in 2022–2023 due to regional transport rerouting caused by international sanctions and shifts in Eurasian trade corridors. Although the Middle Corridor gained importance, short-term fluctuations appeared while logistics systems adapted.

Source: Baku International Sea Trade Port annual report (2023).

Table 1.1

Descriptive statistics of total income from transportation and total income from railway transport sector

Total income from transportation		*Total income from railway transport sector*	
Mean	4162191.32	Mean	221860.52
Standard Error	683116.394	Standard Error	20040.00953
Median	3341800	Median	205828
Mode	#N/A	Mode	#N/A
Standard Deviation	3415581.97	Standard Deviation	100200.0476
Sample Variance	1.1666E+13	Sample Variance	1004004954 6
Kurtosis	-0.30500832	Kurtosis	0.139673363
Skewness	0.79606331	Skewness	0.726624947
Range	11147389	Range	356243
Minimum	375131	Minimum	83348
Maximum	11522520	Maximum	439591
Sum	104054783	Sum	5546513
Count	25	Count	25
Largest(1)	11522520	Largest(1)	439591
Smallest(1)	375131	Smallest(1)	83348
Confidence Level(95.0%)	1409882.94	Confidence Level(95.0%)	41360.54684

Table 1.1 presents the results of the analysis of statistical characteristics. The Skewness value for total income from transportation is positive number, it means that distribution is on the right side. The Skewness value for total income from railway transport sector is positive number, it means that distribution is on the right side. The Kurtosis value for total income from transportation is negative number, it means that distribution is softness. The Kurtosis value for total income from railway transport sector is positive number, it means that distribution is peakness.

Table 1.2

Descriptive statistics of total income from railway transport sector and income from railway goods transport.

Total income from railway transport sector		*Income from railway goods transport*	
Mean	221860.5	Mean	207198.5
Standard Error	20040.01	Standard Error	20434.17
Median	205828	Median	186087
Mode	#N/A	Mode	#N/A
Standard Deviation	100200	Standard Deviation	102170.9
Sample Variance	1E+10	Sample Variance	1.04E+10
Kurtosis	0.139673	Kurtosis	0.073506
Skewness	0.726625	Skewness	0.82625
Range	356243	Range	353224
Minimum	83348	Minimum	77093
Maximum	439591	Maximum	430317
Sum	5546513	Sum	5179963
Count	25	Count	25
Largest(1)	439591	Largest(1)	430317
Smallest(1)	83348	Smallest(1)	77093
Confidence Level(95.0%)	41360.55	Confidence Level(95.0%)	42174.06

Table 1.2 presents the results of the analysis of statistical characteristics. The Skewness value for total income from railway transport sector is positive number, it means that distribution is on the right side. The Skewness value for income from railway goods transport is positive number, it means that distribution is on the right side. The Kurtosis value for total income from railway transport sector is positive number, it means that distribution is peakness. The Kurtosis value for income from railway goods transport is positive number, it means that distribution is peakness.

Table 1.3

Descriptive statistics of total income from railway transport sector and income from railway passenger transport.

Total income from railway transport sector		*Income from railway passenger transport*	
Mean	221860.5	Mean	14661.92
Standard Error	20040.01	Standard Error	1775.138
Median	205828	Median	14240
Mode	#N/A	Mode	#N/A
Standard Deviation	100200	Standard Deviation	8875.689
Sample Variance	1E+10	Sample Variance	78777863
Kurtosis	0.139673	Kurtosis	2.324375
Skewness	0.726625	Skewness	1.193048
Range	356243	Range	39716
Minimum	83348	Minimum	1837
Maximum	439591	Maximum	41553
Sum	5546513	Sum	366548
Count	25	Count	25
Largest(1)	439591	Largest(1)	41553
Smallest(1)	83348	Smallest(1)	1837
Confidence Level(95.0%)	41360.55	Confidence Level(95.0%)	3663.705

Table 1.3 presents the results of the analysis of statistical characteristics. The Skewness value for total income from railway transport sector is positive number, it means that distribution is on the right side. The Skewness value for income from railway passenger transport is positive number, it means that distribution is on the

right side. The Kurtosis value for total income from railway transport sector is positive number, it means that distribution is peakness. The Kurtosis value for income from railway passenger transport is positive number, it means that distribution is peakness.

Table 1.4

Descriptive statistics of income from railway goods transport and income from railway passenger transport.

Income from railway goods transport		*Income from railway passenger transport*	
Mean	207198.5	Mean	14661.92
Standard Error	20434.17	Standard Error	1775.138
Median	186087	Median	14240
Mode	#N/A	Mode	#N/A
Standard Deviation	102170.9	Standard Deviation	8875.689
Sample Variance	1.04E+10	Sample Variance	78777863
Kurtosis	0.073506	Kurtosis	2.324375
Skewness	0.82625	Skewness	1.193048
Range	353224	Range	39716
Minimum	77093	Minimum	1837
Maximum	430317	Maximum	41553
Sum	5179963	Sum	366548
Count	25	Count	25
Largest(1)	430317	Largest(1)	41553
Smallest(1)	77093	Smallest(1)	1837
Confidence Level(95.0%)	42174.06	Confidence Level(95.0%)	3663.705

Table 1.4 presents the results of the analysis of statistical characteristics. The Skewness value for income from railway goods transport is positive number, it means that distribution is on the right side. The Skewness value for income from railway passenger transport is positive number, it means that distribution is on the right side. The Kurtosis value for income from railway goods transport is positive number, it means that distribution is peakness. The Kurtosis value for income from railway passenger transport is positive number, it means that distribution is peakness.

Table 1.5

Descriptive statistics of Income from transportation of air transport sector in Azerbaijan.

YEARS		*TOTAL*		*AIR*	
Mean	2012	Mean	3237867.92	Mean	1332094.52
Standard Error	1.47196	Standard	526746.506	Standard Error	307868.1451
Median	2012	Median	2645666	Median	617870
Mode	#N/A	Mode	#N/A	Mode	#N/A
Standard Deviatio	7.3598	Standard	2633732.53	Standard Devia	1539340.726
Sample Variance	54.1667	Sample V	6.9365E+12	Sample Varianc	2.36957E+12
Kurtosis	-1.2	Kurtosis	-0.57589481	Kurtosis	0.391702127
Skewness	0	Skewness	0.67630001	Skewness	1.285703421
Range	24	Range	8392942	Range	4841155
Minimum	2000	Minimum	241001	Minimum	63655
Maximum	2024	Maximum	8633943	Maximum	4904810
Sum	50300	Sum	80946698	Sum	33302363
Count	25	Count	25	Count	25
Largest(1)	2024	Largest(1	8633943	Largest(1)	4904810
Smallest(1)	2000	Smallest(	241001	Smallest(1)	63655
Confidence Level(	3.03798	Confidenc	1087151.36	Confidence Lev	635408.6219

Based on table 1.5 skewness distribution of total income from transportation of air transport sector is positive number, it means that distribution is right sided and skewness distribution of income from transportation of air transport sector is also positive it means that distribution is right sided. In table kurtosis also mentioned. Kurtosis for Total income from transportation of air transport sector is negative number it means distribution is softness. But kurtosis for income from

transportation of air transport sector is positive number it means our distribution is peakness.

Table 1.6

Descriptive statistics of Income from sea transportation in transport sector in Azerbaijan

Total		Sea	
Mean	4162191.32	Mean	134266.76
Standard Error	683116.394	Standard Error	10978.75374
Median	3341800	Median	110778
Mode	#N/A	Mode	# N/A
Standard Deviation	3415581.97	Standard Deviation	54893.76868
Sample Variance	1.16662E+13	Sample Variance	3013325840
Kurtosis	-0.305008323	Kurtosis	0.014025188
Skewness	0.796063313	Skewness	0.962746538
Range	11147389	Range	193870
Minimum	375131	Minimum	59051
Maximum	11522520	Maximum	252921
Sum	104054783	Sum	3356669
Count	25	Count	25
Largest(1)	11522520	Largest(1)	252921
Smallest(1)	375131	Smallest(1)	59051
Confidence Level(95.0%)	1409882.943	Confidence Level(95.0%)	22659.03404

Based on table 1.6 skewness distribution of total income from transportation in transport sector is positive number it means that distribution is right sided and skewness distribution of income from sea transportation in transport sector is also positive it means that distribution is right sided. In table kurtosis also mentioned. Kurtosis for Total income from transportation in transport sector is negative number it means distribution is softness. But kurtosis for income from sea transportation in transport sector is positive number it means our distribution is peakness.

Table 1.7

Descriptive statistics of income from sea transportation of goods in transport sector

Income from sea transportation of goods in transport sector	
Mean	132779.52
Standard Error	10800.26632
Median	110047
Mode	#N/A
Standard Deviation	54001.33158
Sample Variance	2916143813
Kurtosis	-0.03757408
Skewness	0.948912941
Range	190371
Minimum	58627
Maximum	248998
Sum	3319488
Count	25
Largest(1)	248998
Smallest(1)	58627
Confidence Level(95.0%)	22290.65412

Based on table 1.7 skewness distribution for Income from sea transportation of goods in transport sector is positive number it means that distribution is right sided. And kurtosis for Income from sea transportation of goods in transport sector is negative number it means distribution is softness.

Table 1.8

Descriptive statistics of income from passenger conveyance in seaway transport sector

Income from passenger conveyance in seaway transport sector	
Mean	1487.24
Standard Error	282.593355
Median	940
Mode	#N/A
Standard Deviation	1412.966775
Sample Variance	1996475.107
Kurtosis	4.479895441
Skewness	2.14711409
Range	5778
Minimum	401
Maximum	6179
Sum	37181
Count	25
Largest(1)	6179
Smallest(1)	401
Confidence Level(95.0%)	583.2440188

Based on table 1.8 skewness distribution for Income from sea transportation of passenger in transport sector is positive number it means that distribution is right sided. And kurtosis for Income from sea transportation of goods in transport sector is peakness number it means distribution is peakness.

Table 1.9

Correlation matrix of total income from transportation and total income from railway transport sector.

	Total income from transportation	*Total income from railway transport sector*
Total income from transportation	1	
Total income from railway transport sector	0.960556	1

Table 1.9 Presents the results of the analysis of statistical characteristics.

The relationship between total income from transportation and total income from railway transport sector is strong linear.

Table 1.10

Correlation matrix of total income from railway transport sector and income from railway goods transport.

	Total income from railway transport sector	*Income from railway goods transport*
Total income from railway transport sector	1	
Income from railway goods transport	0.996342283	1

The relationship between total income from railway transport sector and income from railway goods transport is strong linear.

Table 1.11

Correlation matrix of total income from railway transport sector and income from railway passenger transport.

	Total income from railway transport sector	*Income from railway passenger transport*
Total income from railway transport sector	1	
Income from railway passenger transport	-0.179927139	1

Table 1.11 presents the results of the analysis of statistical characteristics.

The relationship between total income from railway transport sector and income from railway passenger transport is weak linear.

Table 1.12

Correlation matrix of income from railway goods transport and income from railway passenger transport.

	Income from railway goods transport	*Income from railway passenger transport*
Income from railway goods transport	1	
Income from railway passenger transport	-0.263326501	1

Table 1.12 presents the results of the analysis of statistical characteristics. The relationship between income from railway goods transport and income from railway passenger transport is weak linear.

Table 1.13

Correlation matrix of total income from transportation and total income from seaway transport sector.

	Total	Sea
Total	1	
Sea	0.945835422	1

Table 1.13 shown that total income from transportation in transport sector and income from sea transportation in transport sector has strong relation.

Table 1.14

Correlation matrix of total income from seaway transport sector and income from seaway passenger transport.

	Sea	Income from passenger conveyance in seaway transportation
Sea	1	
Income from passenger conveyance in seaway transportation	0.639340993	1

Table 1.14 shown income from sea transportation in transport sector and income from passenger conveyance in seaway transportation has middle relation.

Table 1.15

Correlation matrix of total income from seaway transport sector and income from seaway goods transport.

	Sea	Income from transportation of goods
Sea	1	
Income from transportation of goods	0.999797589	1

Table 1.15 shown income from sea transportation in transport sector and income from transportation of goods in seaway transportation has strong relation.

Table 1.16

Correlation matrix of income from seaway goods transport and income from seaway passenger transport.

	Income from goods in seaway transportation	Income from passenger conveyance in seaway transportation
Income from goods in seaway transportation	1	
Income from passenger conveyance in seaway transportation	0.623741467	1

Table 1.16 shown Income from passenger conveyance in seaway transportation and Income from transportation of goods in seaway transportation has middle relation.

Table 1.17

Correlation matrix of total income from transportation and income from air transport sector in Azerbaijan.

	TOTAL	***AIR***
TOTAL	1	
AIR	0.96523	1

Table define that relation between total income from transportation and income from air transport sector in Azerbaijan is **strong**.

Table 1.18

Correlation matrix of income from air transport sector and Income from passenger conveyance in transport sector in Azerbaijan.

	AIR	*ncome from passenger conveyance in air transport sector, thousand manats*
AIR	1	
Income from p	0.88698	1

Table define that relation between income from air transport sector and Income from passenger conveyance in transport sector in Azerbaijan is **strong**.

Table 1.19

Correlation matrix of income from air transport sector and Income from transportation of goods in transport sector in Azerbaijan.

	AIR	*ncome from transportation of goods in air transport sector, thousand manat*
AIR	1	
Income from tr	0.97668	1

Table define that relation between income from air transport sector and Income from transportation of goods in transport sector in Azerbaijan is **strong**.

Conclusion. The analysis of income dynamics in Azerbaijan's railway sector shows that railway transport plays an essential strategic role in national development and international connectivity. Azerbaijan's railway network functions not only as a domestic logistics system but also as an important component of several major regional and global transport corridors. The country participates in the Trans-Caspian International Transport Route (Middle Corridor), the Baku–Tbilisi–Kars Railway, the North–South Transport Corridor, TRACECA, and other international logistics routes. These corridors increase the volume of transit cargo passing through Azerbaijan and strengthen the country's role as a key transport hub between Europe and Asia. As a result, the railway sector gains higher freight income, attracts new transit flows, and diversifies its economic revenue sources.

Modernization of infrastructure, digitalization of cargo operations, expansion of logistics centers, and integration with regional platforms have improved operational efficiency. The increase in cargo turnover along the Middle Corridor has been especially significant, since global supply chains increasingly rely on alternative Eurasian routes. The Baku–Tbilisi–Kars Railway also supports growing trade between Turkey, Georgia, Central Asia, and Europe, contributing to stable long-term income growth. Passenger transport has benefited from improved service quality and stronger regional mobility.

Despite these positive trends, revenue stability is still affected by both internal and external factors, such as geopolitical risks, seasonal fluctuations, changes in global trade demand, and the need for continuous infrastructure investment. Improving tariff competitiveness, strengthening institutional capacity, and expanding international cooperation will remain important for maintaining sustainable growth.

Overall, Azerbaijan's railway sector has strong potential to further improve its financial performance by using its geographic advantages, strengthening its participation in international transport corridors, and continuing modernization efforts. As global supply chains continue to transform, Azerbaijan's strategic railway network is well-positioned to support national economic development and reinforce the country's role as a major regional transport and logistics hub.

The statistical analysis of income from sea transportation in Azerbaijan's transport sector between 2000 and 2024 demonstrates clear links between economic conditions, global market shifts, and sector-specific developments. The data reveal that sea transport continues to be an essential contributor to national transport revenues, particularly due to its integration with oil logistics, cargo transit, and increasing regional trade flows.

Fluctuations in income—especially during periods such as the 2008–2009 financial crisis, the 2014–2016 oil price decline, and the 2020 COVID-19 pandemic—show that the maritime sector is sensitive to global economic disruptions. Meanwhile, recent geopolitical shifts highlight both risks and opportunities for Azerbaijan, as the Middle Corridor expands and international transport routes evolve.

Descriptive statistics indicate right-skewed distributions, suggesting that peak-income years significantly exceed average performance, mainly driven by oil-related activity. Variance and standard deviation values confirm that income streams remain highly variable, reflecting the dynamic nature of maritime trade.

Overall, the analysis underscores the importance of continued investment in port infrastructure, fleet modernization, and diversification of maritime services. Strengthening these areas will enhance the resilience of Azerbaijan's sea transport sector and support sustainable revenue growth in the years ahead.

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HYDROLOGY

DEVELOPMENT OF NOVEL POLYAMINE COAGULANTS FOR WASTEWATER AND DRINKING WATER

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Abstract

The purpose of the research work is to purchase new types of coagulants, which are more efficient, easy to produce and relatively cheaper than the coagulants used in the treatment of waste and drinking water.

In the laboratory, new types of coagulants were synthesized from the reaction of various diamines such as ethylenediamine, diethylenetriamine, hexamethylenediamine with propylene oxide and epichloridine. During the synthesis, 4 types of coagulants were obtained. The effectiveness of coagulants in different doses was studied using the "Jar test" method and the Turbidometer device. By comparison, the most ideal type of coagulant was determined. The amount of nitrate and ammonium in the water treated with a new type of coagulant was measured and analyzed. Properties, structure and quality of the obtained coagulant were determined by IR spectrum.

Keywords: coagulant, water treatment, polyamine polymer, turbidity removal, sustainable water.

Introduction Water resources are increasingly strained by population growth and environmental pressures. Globally, over 40% of people experience water scarcity, and more than 700 million lack access to clean drinking water. In this context, efficient water purification is critical. Suspended solids, organic matter, and inorganic salts released during industrial and household wastewater generation degrade water quality and threaten human health. Coagulation–flocculation (C/F) is a key treatment process: adding a coagulant destabilizes colloidal particles and organic matter, forming flocs that can be sedimented or filtered out. Traditional coagulants (e.g. aluminum sulfate, ferric chloride) have long been used in drinking-water treatment. However, drawbacks include high chemical dosage needs, the generation of large quantities of sludge, and residual metal ions in treated water. For example, excessive aluminum from alum or polyaluminum chloride has been linked to health risks, prompting strict WHO limits on Al in drinking water. Similarly, iron and aluminum salts can cause pH shifts and are toxic at high levels.

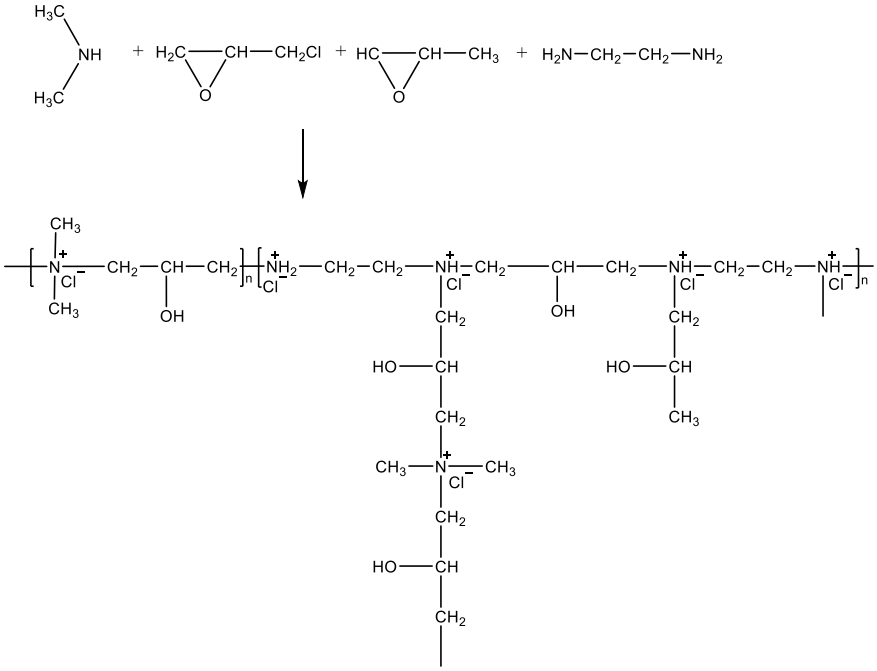
These issues motivate the search for new, more sustainable coagulants. In recent years, research has explored both natural coagulants (e.g. plant extracts) and synthetic organic polymers. In particular, cationic polyamine coagulants – polymers built from amines and epichlorohydrin – have shown excellent performance in removing turbidity and colloids. Such polymers carry high positive charge density and can rapidly neutralize negatively charged particles over a wide pH range. They are also easier to handle and dose than metal salts. Nevertheless, many existing polyamine flocculants require complex synthesis or costly monomers. The goal of this study was to synthesize and evaluate new polymeric coagulants that are easy to produce, cost-effective, and highly efficient in turbidity removal for wastewater and potable water treatment.

Materials and Methods

Synthesis of Coagulants: Four novel polyamine coagulants were prepared via stepwise polymerization. Following literature methods for epichlorohydrin condensation, epichlorohydrin (ECH) and propylene oxide were first reacted with a diamine (e.g. diethylenetriamine, DETA) under stirring for ~6 hours at elevated temperature. The reaction mixture was then split into portions; to each portion, additional diamines (such as ethylenediamine or hexamethylenediamine) were added and reacted for ~5 hours. This condensation yields a viscous, water-soluble polymer rich in amine and quaternary ammonium groups. The product mixtures were then heated (≈70 °C) under reduced pressure (rotary evaporation) to remove unreacted monomers and water, yielding concentrated coagulant solutions. * Jar-Testing: Coagulation efficiency was assessed by standard jar tests. Turbid suspensions were prepared by dispersing clay into distilled water (initial turbidity ~100 NTU). Each synthesized coagulant (at 0.1% concentration) was dosed at 2.5, 5.0, and 10.0 mL into separate jars of the turbid water. Gentle mixing was applied, and the mixture was allowed to settle. Water turbidity was measured after 15 and 30 minutes using a turbidimeter to quantify flocculation performance (lower NTU indicates better clarity).

Name	Chemical formula	Molar mass (g\mol)	Density (g\cm3)	Boiling point (o C)	Melting point (o C)
Epixlorhidrin	C_3H_5Cl	78.11	1.18066	117.9	-48
Propilen oksidi	C_3H_6O	58.080	0.859	35	-111.9
Etilendiamin	$C_2H_4\ (NH_2)_2$	60.100	0.90	116	8
Dietilenetriamin	$C_4H_{13}N_3$	103.169	955	204	-39
Heksametilendiamin	$C_6H_{16}N_2$	116.208	0.84	204.6	39-42

The initial synthesis was carried out with epichlorohydrin, propylene oxide and diamine for 6 hours.



The resulting compound was divided into 3 equal parts, and a 3:1 part was reacted with ethylenediamine for 5 hours. The resulting 4-part mixture was boiled in an R-210 Rotavapor for 1 hour and separated from the water contained in the diamine.

Water Quality Analysis: After coagulation, key water-quality parameters were measured. pH and electrical conductivity (EC) were measured with a multiparameter meter; total dissolved solids (TDS) were calculated from EC. Ammonium and nitrate concentrations were determined by standard colorimetric methods. These values were compared to drinking-water standards (e.g. WHO limits) to ensure treatment safety.

Characterization: The chemical structure of the new coagulants was confirmed by Fourier-transform infrared (FTIR) spectroscopy. Characteristic absorption bands (–NH, –C–N, epoxy-derived linkages) were identified, confirming successful polymer formation and functional group presence.

Results and Discussion

Among the four synthesized polymers, the coagulant containing diethylenetriamine (DETA) as one component – designated EXH-DMA-PO-DETA – exhibited the highest flocculation efficiency. Table 1 summarizes the jar-test results for this coagulant at different dosages.

Turbidity removal: The EXH-DMA-PO-DETA coagulant achieved the greatest turbidity reduction at the lowest dose (2.5 mL). Specifically, the turbidity fell from ≈100 NTU to 32.6 NTU after 15 min and to 12.96 NTU after 30 min (approximately 87% removal at 30 min). Higher doses were less effective: at 5.0 mL the 30-min turbidity was 46.5 NTU, and at 10 mL it was 29.0 NTU. This indicates an optimal dosage of ~2.5 mL under these conditions. (Overdosing can lead to re-stabilization of particles, a known effect in jar tests.)

Table 1. Turbidity (NTU) after coagulation with EXH-DMA-PO-DETA (initial ≈100 NTU). ·

2.5 mL dose: 15 min – 32.64 NTU; 30 min – 12.96 NTU · 5.0 mL dose: 15 min – 63.84 NTU; 30 min – 46.54 NTU

10.0 mL dose: 15 min – 41.15 NTU; 30 min – 29.01 NTU

These results demonstrate that EXH-DMA-PO-DETA is a highly effective coagulant: at optimal dose it removed nearly all turbidity within 30 minutes, comparable to or better than many conventional coagulants. The superior performance at low dose suggests that the polyamine polymer has very high charge density and floc-forming ability.

2,5 ml		5 ml		10 ml	
15 minute	30 minute	15 minute	30 minute	15 minute	30 minute
32,64	12,99	63,85	46,54	41,16	30
32,64	12,99	63,83	46,54	41,15	29,01
32,65	12,96	63,83	46,54	41,12	29,01
32,64	12,96	63,83	46,54	41,12	29,01

Treated water quality: After flocculation with EXH-DMA-PO-DETA (2.5 mL dose), the water pH shifted slightly from 7.5 to about 8.5. This pH (within the 6.0–9.0 range recommended for drinking water) is acceptable for potable supply. The EC and TDS values showed only minor increases, indicating negligible addition of dissolved salts. Nitrate concentrations decreased slightly (perhaps due to adsorption on flocs), while ammonium increased marginally (possibly from residual amine groups). Crucially, both analytes remained well below regulatory limits (e.g. WHO guideline of 50 mg/L for nitrate), so the treated water quality meets drinking-water standards.

Structural confirmation: FTIR spectra of the EXH-DMA-PO-DETA polymer showed broad –NH and –OH stretching bands and characteristic C–N and epoxy-derived linkages, consistent with a polyamine–epichlorohydrin copolymer. The presence of quaternary ammonium peaks confirmed successful polymerization, in agreement with the intended structure.

Overall, the DETA-based coagulant (EXH-DMA-PO-DETA) outperformed the other variants (EDA- or HMDA-based) under the test conditions. Its high efficiency at low dosage suggests it could significantly reduce chemical usage in treatment processes. Moreover, because these polyamine coagulants can be synthesized from readily available industrial chemicals (epichlorohydrin, propylene oxide, common amines), production costs should be relatively low. By replacing or supplementing aluminum- or iron-based coagulants, such polymers can reduce sludge generation and health risks. Conclusions New polyamine-based coagulants were successfully synthesized via epichlorohydrin-condensation chemistry and tested for water purification.

Key findings include: - Four novel coagulant polymers were obtained by reacting epichlorohydrin, propylene oxide, and various diamines (EDA, DETA, HMDA). - Jar-test evaluations showed that the DETA-containing polymer (EXH-DMA-PO-DETA) achieved the greatest turbidity removal, reducing ~100 NTU to ~13 NTU in 30 minutes at a 2.5 mL dose. (Turbidity removal exceeded 85% under optimal conditions.) - Treated water quality (pH, TDS, nitrate, ammonium) remained within safe limits for drinking water. The coagulant did not impart any unacceptable residue and actually lowered nitrate levels. - Structural analysis (FTIR) confirmed the expected polymer composition with abundant amine and quaternary groups.

These results indicate that EXH-DMA-PO-DETA is a promising new coagulant for both wastewater and potable water treatment. Its high charge density and effective flocculation are comparable to leading commercial polyamine coagulants, while potentially offering easier synthesis and lower chemical cost. The fact that drinking-water parameters were largely unaffected suggests safe applicability (with conventional post-treatment). For practical application, combining this polymer with coagulant aids or standard multi-step treatment may further enhance performance. Future work should explore scale-up of synthesis, longer-term stability, and cost–benefit analysis, with the goal of delivering an industrially viable, sustainable water-treatment reagent. Coagulants with 5 different compositions were obtained through syntheses. Each of these coagulants was tested using the “jar test” method and their effectiveness was measured. Based on the results obtained during the analyses, a comparison was made between the coagulants based on the turbidity results they showed in the first 2.5 ml of the solution within 30 minutes. The data obtained showed that the coagulant with the best coagulation effect was the diethylenetriamine-based coagulant called EXH-DMA-PO-DETA. Later, we determined that the EXH-DMA-PO-DETA coagulant did not seriously affect the drinking water standards in the analyses of ammonium, pH, TDS, total hardness. When looking at the safety analyses conducted, it was concluded that after using the diethylenetriamine-based coagulant, the water will go through other purification stages and that its use is safe, taking into account the parameters of the raw water itself. It is proposed that the coagulants be used with a coagulant additive to increase the effectiveness of the coagulation process. Let's hope it will contribute to progressive solutions for the industry.

Sources: This work builds on established knowledge of coagulation processes and polyamine coagulant chemistry. All experimental results and interpretations are original to the current study.

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NEUROBIOLOGY

POST-COVID-19 VISUAL IMPAIRMENTS: PATHOPHYSIOLOGY AND CLINICAL MANIFESTATIONS

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Abstract
SARS-CoV-2 infection is increasingly recognized as a multisystem disorder affecting not only the respiratory system but also neural, vascular, and sensory pathways. Among post-infectious complications, visual impairments have gained attention due to their multifactorial origins. This review synthesizes current evidence regarding the pathophysiological mechanisms underlying visual dysfunctions following COVID-19, emphasizing direct viral effects, immune-mediated inflammation, vascular alterations, and hypoxia. Clinical manifestations, including retinal abnormalities, optic neuritis, and central visual pathway dysfunction, are discussed, alongside implications for diagnosis and monitoring.
Keywords: COVID-19, SARS-CoV-2, visual disorders, retina, optic nerve

Introduction

The SARS-CoV-2 virus, identified in late 2019, quickly escalated into a global pandemic, resulting in severe medical, social, and economic consequences. Initially considered primarily a respiratory pathogen, subsequent studies have highlighted its systemic involvement, affecting multiple organs including the nervous system and sensory pathways [1,2].

Evidence indicates that SARS-CoV-2 exhibits neuroinvasive and vasculotropic properties, which, along with systemic inflammatory responses and endothelial dysfunction, can contribute to neurological and sensory deficits [3,4]. The visual system is particularly vulnerable to such direct and indirect viral effects.

Expression of ACE2 receptors in the retina, vascular endothelium, optic nerve, and brain structures suggests that SARS-CoV-2 may directly affect the visual apparatus [5]. Additionally, COVID-19-associated hypercoagulability and microcirculatory dysfunction can compromise retinal perfusion, potentially leading to ischemic injury and neuronal damage [6]. Clinical and imaging studies have observed retinal microhemorrhages, cotton wool spots, thickening of the retinal nerve fiber layer, optic neuritis, and cortical-origin visual deficits [7,8]. These findings underscore the multifactorial impact of COVID-19 on the visual system.

Pathophysiological Mechanisms of Visual Dysfunction

Direct Viral Infection

SARS-CoV-2 enters host cells via its S-spike protein binding to ACE2 receptors. These receptors are expressed in the retina, choroid, vitreous body, photoreceptors, Müller cells, and retinal vascular endothelium [9]. Viral entry can initiate endothelial injury, cytokine production, and vascular dysfunction, resulting in direct cellular damage in ocular tissues [10].

Endothelial Injury and Thrombotic Events

COVID-19 is associated with endothelial dysfunction and a procoagulant state, which can compromise retinal vascular structures. This may result in vessel occlusions, edema, hypoxia, and microinfarcts, leading to visual loss [11]. Microvascular events also contribute to structural retinal pathology.

Immune and Inflammatory Mediated Damage

The systemic immune response, including cytokine storms, can cause ocular inflammation such as uveitis, retinitis, and optic neuritis. Autoimmune responses may arise due to molecular mimicry between viral and host proteins, e.g., MOG-IgG and AQP4-IgG associated optic neuritis [12].

Hypoxia and Systemic Oxygen Deficiency

Severe COVID-19 may induce prolonged hypoxia, affecting high oxygen-demand tissues like the retina. Atrophic changes in the outer plexiform layer (OPL) have been observed, likely resulting from hypoxic injury [13]. Retinal hypoxia compromises vascular and neural layers, leading to functional visual impairment.

Optic Nerve and Central Visual Pathway Involvement

SARS-CoV-2 can infiltrate the CNS, impacting the optic nerve and visual pathways. Viral entry may disrupt the blood-brain barrier, resulting in inflammation and demyelination. Clinical reports describe optic neuritis, ischemic optic neuropathy, and retinal vascular events [14,15]. Both direct and indirect effects contribute to significant visual dysfunction.

Clinical Manifestations

Conjunctival Involvement

Conjunctivitis is common post-COVID-19, presenting with hyperemia, tearing, foreign body sensation, and mild burning. Red eye is attributed to direct viral action, inflammatory responses, and immune activation [16].

Retinal Alterations

Optical coherence tomography (OCT) reveals post-COVID retinal changes including thickened retinal nerve fiber layers, microhemorrhages, cotton wool spots, and vascular alterations. Long-term thinning of

the ganglion cell layer suggests potential neurodegeneration [17,18].

Optic Neuritis

Post-COVID optic neuritis manifests as reduced visual acuity, impaired color vision, and headaches. These effects are likely mediated by immune activation and cytotoxic effects on neural tissue [19].

Central Nervous System-Origin Visual Symptoms

Blurred vision, photophobia, delayed visual information processing, and functional visual deficits may arise from central visual pathway dysfunction, particularly in the visual cortex and associative areas [16].

Conclusion

SARS-CoV-2 impacts the visual system via multiple mechanisms: direct infection of retinal and endothelial cells, endothelial dysfunction, thrombosis, immune-mediated inflammation, hypoxia, and CNS involvement. These pathophysiological processes lead to retinal vascular occlusion, microinfarcts, optic neuritis, uveitis, and central visual pathway dysfunction, resulting in visual impairments such as blurred vision, photophobia, and delayed visual processing. Understanding these multifactorial effects is essential for the clinical management and monitoring of post-COVID-19 visual complications.

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PEDAGOGY

NEW ERA TEACHING TOOLS FOR BIOLOGY TEACHERS: ARTIFICIAL INTELLIGENCE

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Abstract

This article explores the possibilities of using artificial intelligence (AI) technologies in the teaching process for biology teachers. In the modern era, digital transformations have become one of the primary directions of educational development, necessitating the renewal of teachers' pedagogical approaches. Specifically, AI tools in biology education enhance the relevance, interactivity, and scientific basis of lessons, bringing new content to students' learning processes. The article explains the role of AI in lesson planning, improving assessment mechanisms, and creating adaptive learning environments tailored to students' individual characteristics. Research indicates that using AI not only helps optimize teachers' workloads but also significantly improves students' inquiry-based learning skills and interest in the subject. Tools such as virtual laboratories, 3D modeling software, and simulations enable a clearer and deeper understanding of abstract biological concepts. At the same time, the article highlights the technological, methodological, and ethical challenges that arise when implementing AI, emphasizing the particular importance of enhancing teachers' digital competencies for contemporary education.

Keywords: artificial intelligence, adaptive learning, interactive teaching, simulation software, virtual laboratories, educational technologies.

Introduction

The rapid innovations observed in the global education system today require teachers to expand their professional competencies and demonstrate a more flexible and modern mindset. "Currently, artificial intelligence is developing rapidly and is remarkably spreading across all spheres of the world" (Tahiru, 2021). The penetration of AI technologies into all areas of society has created conditions for education to keep pace with this process. A modern teacher no longer serves merely as a knowledge transmitter but acts as a facilitator who organizes the learning environment and fosters students' research and creative abilities. In this context, integrating AI into teaching not only opens up extensive methodological opportunities for educators but also presents certain adaptation challenges. Modern youth - including school students, university students, and new-generation teachers-show high interest in innovative educational technologies and observe the outcomes of their application in the learning process. These technologies enhance learning efficiency while increasing students' motivation and enabling more purposeful lesson organization. "The application of new educational technologies in biology lessons allows students to acquire a large volume of cognitive and scientific information, makes the lessons more engaging and interesting, and promotes learners' active participation in the educational process. This, in turn, improves the quality of instruction and retention" (Babayeva, 2023, p. 18).

Since biology studies the structure, functioning, and interactions of living organisms, the application of new technologies in this field is particularly significant. AI tools enable teachers to present lesson materials in a more visual, interactive, and application-oriented manner. Applications such as virtual laboratories, simulation software, and 3D modeling allow students to observe complex biological processes in conditions close to real-life experiences, facilitating deeper understanding. By observing abstract biological concepts through virtual laboratories and simulation tools, students can grasp complex processes in a more tangible and comprehensible way. This not only enhances lesson quality but also significantly increases students' interest in biology and nature.

"The most immersive systems are those that use virtual reality (VR) technology. This technology allows the user to view a virtual environment from their own perspective. Because the scene is continuously updated with head or body movements, the user feels as if they are inside the environment, and the realism of the virtual world is stronger" (Pagliai et al., 2021). At the same time, AI supports teachers in pedagogical processes such as lesson planning, formative assessment, and monitoring students' individual developmental dynamics. However, effective utilization of these opportunities requires the development of teachers' digital competencies. This article systematically examines the practical applications of AI for biology teachers, its impact on the teaching process, and future perspectives.

The Role of Artificial Intelligence in Education

In the modern era, the development of artificial intelligence (AI) technologies has led to the emergence of new approaches in the education system. AI has become a crucial tool in the teaching process, enhancing both teachers' performance and students' learning experiences. The primary function of AI is to analyze large volumes of data in a short time, personalize learning, and create adaptive mechanisms within the educational process. These capabilities represent the key scientific advantages that distinguish AI from traditional teaching approaches.

AI in education primarily enables the establishment of adaptive learning models. Such models provide instructional materials tailored to each student's knowledge level, learning pace, and individual characteristics. Data on students' prior activities are analyzed

by AI systems, resulting in the automatic personalization of the learning process. This increases learner engagement in line with constructivist approaches and facilitates more sustainable knowledge acquisition. Additionally, AI supports teachers' activities through intelligent tutoring systems, offering assistance in lesson planning and instructional decision-making.

Intelligent assessment tools, automated test analysis, monitoring of student achievements, and lesson planning functions reduce teachers' workloads and enable the management of the pedagogical process on a more scientific basis. Therefore, AI is not only a technical tool but also serves as an analytical assistant in pedagogical decision-making. "A methodology based on fuzzy logic, combining both quantitative and qualitative indicators, has been proposed to measure the quality of education" (Ismayilov et al., 2024).

Moreover, AI holds particular significance in teaching subjects like biology, which require experimental and visual explanations. Modeling biological phenomena, creating 3D representations of cell structures, virtually observing ecosystems, and simulating real laboratory conditions allow students to gain a deeper understanding of complex topics. These technologies contribute both to concretizing abstract concepts and expanding practical learning opportunities. The use of virtual reality (VR) in education not only impacts academic outcomes but also enhances retention and recall of learned information. Research indicates that "students learning in fully immersive VR environments retain information better and for longer periods compared to traditional educational settings" (Ahmadov & Osmanli, 2025; İsmayılov et al., 2024).

Overall, AI makes teacher-student interactions more efficient, structures the learning process, and increases objectivity in education. Its analytical, adaptive, and interactive functions make AI an essential component of 21st-century educational environments and provide a significant contribution to the development of innovative pedagogical models.

Applications of AI in Various Fields of Biology

Biology as a subject is rich in abstract, microscopic, and often directly unobservable processes for students. Consequently, AI and virtual laboratories are particularly effective in certain areas of biology. Below are the areas where AI is most frequently applied and generates high educational value.

1. **Microbiology**

Microbiology deals with the structure, behavior, and reproduction of microorganisms, which are often difficult for students to observe in real laboratory settings. In this field, AI enables:

- the creation of 3D models of microorganisms,
- simulation of their reproduction in various nutrient media,
- step-by-step visualization of infection processes.

Thus, students begin to understand abstract theoretical information visually.

2. **Cytology (Cell Biology)**

The structure of cells and the functions of organelles are among the most abstract topics for students. AI and virtual laboratories in this area:

- present interactive 3D models of cells,
- explain the functions of organelles through animations,
- sequentially and clearly visualize the stages of cell division (meiosis and mitosis).

This method also reinforces memory by "animating" intracellular processes.

3. **Histology**

Histology requires extended laboratory practice with microscopes. AI in this field:

- provides high-resolution virtual microscope images of tissue samples,
- teaches automatic recognition of cell and tissue types,
- enables comparison of healthy and diseased tissues.

This is especially advantageous in schools with a limited number of microscopes.

4. **Genetics**

Genetic processes, DNA structure, and inheritance mechanisms pose abstract challenges. AI in genetics:

- visually demonstrates DNA replication and transcription processes,
- allows simulations of genetic combinations,
- models the effects of mutations on organisms.

5. **Ecology and Environment**

Ecological modeling is challenging due to the high variability in real-world conditions. AI in this area:

- creates 3D models of ecosystems,
- calculates the impact of environmental changes on living organisms,
- simulates population growth and decline processes.

"Artificial intelligence can recommend appropriate learning resources, identify areas needing development, and adjust the difficulty level of learning tasks" (Harry, 2023).

Observations from the virtual laboratories we conducted indicate that AI-based simulations play a significant role in mastering the abstract concepts of biology. In particular, virtual experiments in microscale and theoretically complex fields such as cytology, microbiology, and histology substantially enhance students' observation, analysis, and critical thinking skills. "Artificial intelligence can support the enhancement of students' knowledge and skills in education through personalized learning opportunities, intelligent tutoring systems, and simulation-based instructional tools" (Zhao et al., 2018).

Stepwise modeling of cell structures, microorganism behaviors, and tissue changes in virtual environments allows students to comprehend processes that are difficult to observe in real laboratories in a visual and interactive manner. Additionally, in anatomy lessons, virtual laboratories enable visualization of the internal structure of organs, which is particularly valuable when direct observation of real organs presents certain challenges. Observations show that virtual laboratories organized with AI support increase students' motivation to learn, strengthen their interest in biology, and facilitate a deeper and more systematic understanding of topics.

Challenges in AI Implementation

Although the use of AI in biology lessons significantly enriches the teaching process, practical observations indicate that its implementation encounters certain challenges. "To advance the development of next-generation AI systems in the field of biology, it is necessary to overcome a number of critical scientific and technological barriers" (Hassoun et al., 2025). Timely consideration of these limitations is essential for both teachers and schools.

1. Insufficient Material and Technical Resources

Observations indicate that AI tools require powerful computers, tablets, stable internet, and modern technical infrastructure to function effectively. Many schools do not fully possess these resources, limiting teachers' ability to utilize virtual laboratories and other AI-based programs to their full potential. In particular, virtual simulations are resource-intensive, and school equipment often cannot support them. This constitutes a major factor restricting the implementation of these technologies.

2. Concerns Among Parents

The extensive use of technology by students raises concerns for some parents. They worry that AI may lead to excessive dependence on technology and weaken practical laboratory skills. Many parents consider AI-based lessons to be "too digital" and believe that traditional learning methods are safer. Such concerns can sometimes hinder teachers from integrating technology into their lessons.

3. Methodological Adaptation Challenges

Using AI in lessons requires teachers to adopt new planning strategies and teaching approaches. Preparing assignments for virtual laboratories, tracking student outcomes on AI platforms, and adapting lessons to these technologies demand additional time and preparation. This can create extra workload for teachers.

4. Social and Psychological Effects

Widespread use of technology may cause distraction and excessive screen time for some students. Conversely, students who use technology less frequently may feel left behind. This imbalance can create psychological obstacles within the learning process.

Conclusion and Recommendations

The integration of artificial intelligence (AI) into biology education in the modern era provides new opportunities for both teachers and students. Virtual laboratories and AI-based simulations enable the visual and interactive presentation of abstract and microscopic biological concepts. Observations conducted in this study indicate that the use of virtual laboratories in fields such as cytology, microbiology, histology, and anatomy enhances students' observation, analysis, and critical thinking skills, increases interest in the subject, and facilitates a deeper understanding of the topics. AI also serves as an important support tool for teachers in lesson planning, assessment, and the organization of individualized learning. However, the implementation of this technology faces certain challenges. High demands for material resources, limited access to technological infrastructure, and students' excessive reliance on technology make AI utilization difficult in some schools. Additionally, parental concerns require teachers to apply technology in a balanced manner. Leveraging the large volumes of data generated by virtual technology environments allows for more reliable predictions of the effectiveness of teaching and learning activities. As a result, "decisions necessary for quality improvement can be made more quickly and based on more accurate information" (Abbasova & Aliyeva, 2023).

Based on these considerations, the following recommendations can be proposed for the effective use of AI in biology education:

1. Organize professional development programs to enhance teachers' digital and AI competencies;
2. Improve technological infrastructure in schools and expand access to virtual laboratories;
3. Integrate virtual laboratories and AI tools into lesson plans purposefully and in a balanced manner;
4. Ensure proper supervision and guidance by teachers and parents during students' use of technology;
5. Apply the STEAM approach in biology lessons to strengthen students' creative and inquiry-based learning skills.

Thus, AI and virtual laboratories make biology education more interactive, practical, and personalized, enriching the learning experience for both teachers and students and contributing significantly to increasing future interest in the subject.

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PHILOLOGY

A HOLISTIC APPROACH TO INPUT IN SECOND LANGUAGE ACQUISITION

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Abstract

This paper examines the role of input in second language acquisition in the light of theoretical and empirical studies. The role of input in language acquisition is examined within the theoretical frameworks of the Input Hypothesis of Krashen, Interaction Hypothesis of Long and the Output Hypothesis of Swain in the present study. This study, which is based on the literature review, reveals that input alone is not sufficient; it should be handled together with attention, interaction and cognitive processes.

In the field of second language acquisition, input is considered one of the key components of the language learning process. In this context, the study aims to examine the function and limits of input in language acquisition. The research was conducted with a qualitative literature review method. The literature review reveals that comprehensibility of input is necessary for language acquisition but not sufficient on its own. Studies show that input yields more effective results when supported by cognitive and interactional processes such as attention, awareness, interaction, and output production. As a result, this study emphasizes that the qualitative characteristics of the input in second language teaching should be organized consciously and purposefully and provides a holistic perspective between theoretical approaches and pedagogical practices in the literature.

Keywords: second language, language input, comprehensible input, learner interaction, cognitive processes.

1. INTRODUCTION

Second Language Acquisition (SLA) is a major area of research as it examines how people learn a language that is not their native language. This field, which is related to many disciplines, especially linguistics and educational sciences, aims to explain the cognitive and environmental factors affecting the language learning process. Among these factors, input is accepted as one of the basic concepts at the center of second language acquisition theories.

The input involves all language contents that the learner is exposed to the target language. This is in the field of reading, listening and the language teachers in the classroom make use of, and the daily example of communication. The concept has been given theoretical sensitivity by Krashen in his "Input Hypothesis" where he argues that intelligible input is the main requirement in language acquisition (Krashen, 1985). However, subsequent research has raised the question of whether the input alone is sufficient; it has been suggested that processes such as output, interaction and noticing also play a role in acquisition. This necessitated a more detailed consideration of the function of the input in second language acquisition.

The concept of input is important not only in terms of theoretical discussions, but also in terms of second language teaching practices. The effectiveness of learning process directly depends on quality and level of linguistic materials given to students. Therefore, the type of input and how it is processed by the learner remains an important topic of study for researchers and teachers.

The aim of this study is to examine the basic theoretical approaches and related research that address the role of input in second language acquisition. In this article, which is based on the literature review, the place and importance of the input in second language acquisition will be evaluated in the light of current studies. The study aims to provide a general framework on the subject by summarizing the discussions in the field.

1.1 Theoretical Background

The role of input in second language acquisition has been discussed within the framework of different theoretical approaches in the literature. One of the most effective of these approaches is the "Input Hypothesis" developed by Krashen. Krashen argues that the process of learning a language occurs when the learner is exposed to comprehensible input that can be referred to as i+1 that is just slightly higher in level than the current level of the learner. According to this school of thought, language acquisition is to a large extent an unconscious process, and that the grammar structures will be acquired without compulsion so long as one supplies enough input (Krashen, 1985).

Over time, however, there have been criticisms that mere exposure to input is not enough for second language acquisition. In this regard, the Interaction Hypothesis developed by Long is based on the idea that input is made easier to understand once it is interacted with by the learners and that acquisition can use this as a process. The meaning negotiations that take place in the process of interaction allow learners to identify their deficit in linguistic abilities and to input more fruitfully (Long, 1996).

In addition, Swain's Output Hypothesis lays stress on the fact that the process of language production by learners is crucial to the acquisition process. Swain suggests that understanding of linguistic constraints in the generation of output is cognisant amongst learners and the knowledge of these constraints enables the input to be handled with more conscious deliberation (Swain, 1985). These theoretical approaches show that input

alone is not enough; it should be handled together with processes such as interaction, output and awareness.

As a result, although the theoretical framework for second language acquisition accepts input as a basic element, it reveals that the acquisition process has a multidimensional structure.

2. METHODOLOGY OF THE LITERATURE REVIEW

This study is a qualitative literature review aimed at evaluating research examining the role of input in second language acquisition. No original data collection process was carried out in the study; instead, previously published theoretical and empirical studies on the subject were systematically examined. In this respect, the study aims to bring together the existing information in the literature and provide a general framework.

Within the scope of the literature review, basic theoretical approaches and frequently cited studies focusing on the concept of second language acquisition and input were selected. The studies examined have been evaluated within the framework of theoretical models explaining the role of input in second language acquisition, especially Krashen's Input Hypothesis, Long's Interaction Hypothesis and Swain's Output Hypothesis. Sources have been determined on the basis that they are directly related to the subject and reflect the discussions in the field.

The selected studies were analyzed comparatively in terms of the type of input, its comprehensibility, and its contribution to the acquisition process. In this analysis process, the common findings and differing opinions of the studies were tried to be revealed. In the literature review, mainly peer-reviewed academic articles, basic theoretical works and widely used sources in the literature were taken into account.

As a result, this methodological approach aims to summarize the existing literature on the role of input in second language acquisition and to reveal general trends on the subject.

3. LITERATURE REVIEW

3.1 Types and Features of Input

In the literature on second language acquisition, the concept of "input" has raised the question not only of the learner's exposure to language, but also of what characteristics this input has. Initial empirical studies assumed that linguistic input intelligibility is a pre-requisite to a successful language acquisition. The later studies however, have established that variables such as type of input, presentation modality and learner processing strategy have a conclusive effect on the results of acquisition. It is argued that intelligible input is structured specifically through interaction, and negotiation processes make input learnable (Long, 1983, p.130). In this context input has been thought of as a dynamic element, which is actively constructed by communicative exchange, and not as an archive (of linguistic information).

However, the view that only understandable input exposure is not enough has gradually gained strength in the literature. It was noticed that the learner must consciously recognize certain linguistic features in order for the input to turn into acquisition (Schmidt, 1990, p.132). This approach deepened the discussions about the nature of input around the concepts of attention and consciousness. As a matter of fact, many studies have revealed that acquisition is limited when the input is not made "noticeable" by the learner (Schmidt, 1990, p.140).

The input enhancement approaches developed in this direction aim to attract attention by visually or formally highlighting certain features of the input. emphasized that input enhancement can increase recognition in instructional contexts, but this will not automatically result in acquisition (Smith, 1993, p.167). Subsequent empirical studies show that the consequence of this method depends on the characteristics like the target linguistic system, genre of the task, and the level of proficiency of the learner.

Another important dimension related to the characteristics of the input is its relationship with the output. It is revealed that when output production and input enhancement are considered together, learners pay more attention to linguistic forms and this supports acquisition (Izumi, 2002, p.545). These findings show that input is more explanatory when evaluated together with interaction and production processes, not alone.

The broad meta-analyses indicate that the results of studies on textual input enhancement are not homogenous and effects become strongly context-sensitive. It was stated that the effects of the type and characteristics of input on acquisition are not universal, but dependent on conditions (Han, Park, & Combs, 2008, p.161). Therefore, the current literature reveals that instead of explaining the effect of input through a single feature, intelligibility, attention, interaction and production processes should be handled holistically.

3.2 Input in Different Language Skills

Although the role of input in second language acquisition research has been discussed in a general framework for a long time, later studies have revealed that the effects of input on different language skills are not the same. Especially receptive skills such as listening and reading and productive skills such as speaking and writing require different cognitive processes in terms of the way the input is processed. Therefore, skill-based examination of input has become an important area of research in the SLA literature.

Empirical studies on listening proficiency have also found out that the meaning-oriented and contextualized inputs can help in acquiring a language. It was stated that learners process input through both bottom-up and top-down strategies in the listening process, and that quality input plays a central role in this process (Vandergrift, 2007, p.193). Similarly, it was emphasized that input in listening is not only auditory data, but also carries discursive and pragmatic cues (Rost, 2011, p.59).

In terms of reading skills, it has been suggested that written input offers a more favorable environment for the recognition of linguistic forms. It was argued that reading provides learners with intensive and repetitive input, which in particular supports the acquisition of vocabulary and syntactic structures (Grabe, 2009, p.88). Moreover, when the written input is maintained, the recognition is also enhanced as a learner is able to

work with the material with a personalized temporal focus.

When it comes to productive skills, it seems that input plays an indirect but critical role. In speaking skills, learners use the input they are exposed to as a model and reconstruct that input during interaction. Meaningful speech input supports the development of fluency and accuracy, but this is often effective in combination with interaction and feedback (Bygate, 2001, p.17). In writing skills, input is decisive, especially in the acquisition of text type knowledge and discourse structures. Learners internalize academic writing norms and linguistic patterns through the texts they read (Hyland, 2003, p.21).

As a result, the current literature reveals that input does not have a uniform effect on different language skills, but on the contrary, input functions in different ways according to the specific cognitive and pedagogical needs of each skill. As a result, systematic manipulation of the quality of input in the skill-based models of pedagogy becomes the issue that should be addressed urgently by educators.

3.3 Empirical Studies on Input and Language Acquisition

The input provided to the second language acquisition has been discussed in a more concrete manner especially using experimental and quasi-experimental studies. The empirical investigation has examined how the amount and quality of input influences acquisition in various situations; therefore, disrupting the validity of current theoretical presumptions in passing through methodology. These studies have answered the questions since whether input alone is sufficient and how it can facilitate acquisition assuming it is sufficient or not.

Empirical research carried out earlier has shown that learners who have been exposed to intensive medium that describes meaning make significant gains in language development. In experimental study on vocabulary acquisition, it was found that learners who received interactionally modified input achieved higher levels of vocabulary acquisition compared to those who received simplified input (Ellis, Tanaka, and Yamazaki, 1994, p.176). The above result highlights the importance of simplifying input besides the importance of reconfiguring it by means of interaction.

Empirical investigations that directly aim at the aspect of input recognition show that form-based interventions help in facilitating acquisition. It was reported that form-focused instruction applied during reading tasks significantly increased learners' awareness and use of relative sentence structures (Doughty, 1991, p.441). These results show that meaning-based input can be enriched pedagogically in terms of target structures.

In contrast, other empirical research claims that the effectiveness of the input interventions is limited and strongly dependent on circumstances. In the study examining the relationship between conscious awareness levels and acquisition, stated that being noticed does not always result in long-term gains (Leow, 1997, p.481). This shows that cognitive individual differences should also be taken into account when explaining the effect of input.

More recent empirical research has addressed input along with output and feedback. The learners who received feedback during the interaction showed significant improvement in their question structures, and this improvement was more pronounced compared to the groups exposed to input only (Mackey, 1999, p.580). Therefore, these results have been consistent with the fact that input is most effective, empirically speaking, when applied within interactional settings.

In general, empirical literature confirms that input is an indispensable element for language acquisition, but suggests that it must be supported by factors such as attention, interaction, and cognitive processing for acquisition to occur. These findings reveal the importance of adapting theoretical input approaches to pedagogical practices on an empirical basis.

4. DISCUSSION

The literature discussed in this study clearly reveals that the role of input in second language acquisition cannot be evaluated as a one-dimensional phenomenon. The theoretical and empirical studies examined show that input does not only mean the learner's exposure to language; on the contrary, the type of input, the way it is presented, and how it is processed by the learner determine the acquisition process.

The most basic point that the literature points out in common is that understandable input is necessary for acquisition, but not sufficient on its own. Although early approaches have emphasized the quantity of input, later studies have shown that cognitive processes such as attention, recognition and interaction play a central role in the transformation of input into intake. Empirical research, particularly following the noticing hypothesis, demonstrates that students can fail to learn language irreversibly when exposed to intensive language input including forms of language that they do not consciously notice. This implies that input only takes place when the learner processes it, but not just being exposed to it.

When skill-based studies are examined, it is seen that the effects of input on different language skills are not homogeneous. With receptive skills, listening and reading, meaning-driven, contextually-rich information directly facilitates learning. Input plays a more constructive role of being indirect in productive skills like speaking and writing. In productive skills, input usually gains meaning with interaction, feedback and output production. Therefore, production practice must be available in correspondence with the input, and not separately.

A significant portion of empirical studies have revealed that interactionally enriched input supports acquisition. Negotiations of meaning that occur during interaction allow learners to restructure language at both the form and meaning levels. Nonetheless, other studies show that input changes of instruction interventions are small or vary depending on the context. This situation reveals that the effect of input cannot be explained by universal rules; variables such as individual differences, task types and learning context should be taken into account.

Such findings demonstrate how an input design in language teaching should be conscious and purposeful.

Rather than simply offering intensive input to learners, providing attention-grabbing, interactive, and production-promoting inputs can make acquisition more effective. Especially in skill-based teaching approaches, it is clear that the type of input required by each skill should be different. In this context, it can be said that curricula should move away from the understanding of "uniform input".

Input as found in literature is critical but not conclusive in language acquisition. The effect of input on acquisition becomes more meaningful when considered together with attention, interaction, and cognitive processing processes. These findings suggest that both theoretical models should be re-evaluated and pedagogical practices should be designed from a more holistic perspective. Therefore, there is a need to revisit both theoretical models and teaching practices in a more holistic approach.

4.1 Limitations

This study is not a research based on original data collection, but a theoretical and empirical synthesis of the existing literature. Therefore, the results obtained cannot be interpreted as causal inferences. In addition, the fact that the studies examined include different contexts, learner profiles, and methods limits the generalizability of the findings. Individual learner differences are not discussed in detail in this study.

4.2 Suggestions for Future Research

It is reasonable to assume that future studies need to examine the long-term implications of the different kinds of input on certain language skills by applying the experimental and longitudinal designs. In addition, research addressing the cognitive underpinnings of attention and recognition processes will more clearly explain the mechanisms of transformation of input into acquisition. Input in the technology-supported learning contexts is an important field that warrants future academic investigation.

5. CONCLUSION

This study discussed the role of input in second language acquisition from a multidimensional perspective in the light of theoretical and empirical literature. While the researchers confirm that input is an indispensable component for language acquisition, it clearly reveals that it is not an element that guarantees acquisition alone. On the contrary, the effect of input is closely related to the learner's attention, recognition processes, interaction possibilities, and cognitive processing mechanisms. This fact suggests that input is to be evaluated as an active learning experience but not like a passive exposure.

Findings from the literature revealed that the type of input and the form of presentation have different effects on different language skills. While meaning-oriented and enriched input directly contributes to receptive skills such as listening and reading, it is seen that input functions together with interaction, feedback and output production in productive skills such as speaking and writing. This indicates that input should be organized in a conscious and purposeful way in skill-based language teaching.

Empirical research synthesis demonstrates that interactive and attention-catching input can be used to ease acquisition but this can be affected by contextual factors and characteristics of learners. Therefore, instead of explaining the effect of input with universal rules, context-sensitive and flexible models need to be developed.

In conclusion, while this study confirms the central position of input in second language acquisition, it reveals that acquisition is only possible by integrating input with cognitive and interactional processes. These findings also enhance the reconsideration of the theoretical frameworks and the planning of educative practice that concentrate on a more comprehensive view on the subject.

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ДЕНЬ ЗИМНЕГО СОЛНЦЕСТОЯНИЯ В РАЗНЫХ КУЛЬТУРАХ

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WINTER SOLSTICE DAY IN DIFFERENT CULTURES

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Аннотация

Зимнее солнцестояние — это момент, когда Солнце находится на минимальной высоте над горизонтом. Наклон оси, по которой вращается Земля, в дни солнцестояния оказывается максимальным, в сторону или Северного, или Южного полушария. Поэтому солнцестояние бывает два раза год: в июне, когда день становится самым длинным, и в декабре, когда ночь оказывается самой продолжительной.

Явление получило свое название, потому что за несколько дней до и после этого момента положение Солнца в небе в полдень почти не меняется.

В ночь с 21 на 22 декабря – день зимнего солнцестояния, когда астрономический годовой цикл завершается, когда нужно расстаться со старым и не брать с собой в новый год. Это начало астрономической зимы. Самая длинная ночь и самый короткий день в году. Это праздник начала зимы у древних тюрков, день обновления времени. В пространстве царит воздушный шар. По этой причине первый месяц зимнего сезона называется у казахов «желтоқсан» (декабрь). 25 декабря – День Нартугана – это то же, что это Рождество Христово в Европе, т.е. день рождения пророка Иса (Иисуса).

Казахи называли день зимнего солнцестояния «қаратүн» (черная ночь). Для кочевого народа қаратүн имел глубокое символическое значение и воспринимался как момент перехода, когда тьма достигает своего пика, а затем в День Нартугана начинается обновление и рост. Этот период считался временем размышлений, внутреннего очищения и подготовки к новым жизненным этапам.

Многие народы отмечали день зимнего солнцестояния. У древних славян зимнее солнцестояние знаменовало собой праздник Коляды, один из самых важных праздников года, посвященный солнцу, его возрождению и победе света над тьмой.

Считалось, что в этот день берет свою власть грозный Карачун – божество смерти, подземный бог, повелевающий морозами, злой дух. Древние славяне верили, что он повелевает зимой и морозами и укорачивает светлое время суток.

Abstract

The winter solstice is the moment when the Sun is at its minimum height above the horizon. The inclination of the axis along which the Earth rotates is at its maximum during the solstice, towards either the Northern or Southern Hemisphere. Therefore, the solstice occurs twice a year: in June, when the day becomes the longest, and in December, when the night turns out to be the longest. The phenomenon got its name because a few days before and after this moment, the position of the Sun in the sky at noon hardly changes. On the night of December 21-22 is the winter solstice, when the astronomical annual cycle ends, when you need to part with the old and not take it with you in the new year. This is the beginning of the astronomical winter. The longest night and the shortest day of the year. This is the holiday of the beginning of winter among the ancient Turks, the day of the renewal of time. A balloon reigns in space. For this reason, the Kazakhs call the first month of the winter season "zheltoksan" (December). December 25 is Nartugan Day, which is the same as Christmas in Europe, i.e. the birthday of the prophet Isa (Jesus).

Kazakhs called the day of the winter solstice "karatun" (black night). For the nomadic people, karatun had a deep symbolic meaning and was perceived as a moment of transition when darkness reaches its peak, and then on the Day of Nartugan renewal and growth begin. This period was considered a time of reflection, inner purification and preparation for new life stages.

Many nations celebrated the winter solstice. Among the ancient Slavs, the winter solstice marked the holiday of Kolyada, one of the most important holidays of the year, dedicated to the sun, its rebirth and the victory of light over darkness.

It was believed that on this day the terrible Karachun, the deity of death, the underground god who commands frosts, and the evil spirit, took power. The ancient Slavs believed that he commanded winter and frost and shortened the daylight hours.

Ключевые слова: Солнцестояние, свет, тьма, каратун, нартуган, карачун.

Keywords: Solstice, light, darkness, karatun, nartugan, karachun.

Время циклично. Главные солярные точки года – два равноденствия и два солнцестояния были известны человеку ещё много тысяч лет назад. Наши предки жили в гармонии с природными и космическими ритмами, а потому отлично знали законы природы и руководствовались ими себе во благо.

Так, они вычислили в сутках время, когда в природе создаются оптимальные условия для определенных ритуалов.

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Великая Ночь Қаратүн – праздник Нұртуған. Казахи называли день зимнего солнцестояния «қаратүн» (черная ночь). Для кочевого народа қаратүн имел глубокое символическое значение и воспринимался как момент перехода, когда тьма достигает своего пика, а затем в День Нартугана начинается обновление и рост. Этот период считался временем размышлений, внутреннего очищения и подготовки к новым жизненным этапам [7].

Обряд, который в сегодняшних реалиях рекомендуется провести перед закатом накануне Қаратүна: обращаясь в сторону Солнца произнести фразы на расставание с чем-либо или удалением чего-либо из своей жизни. Фразы должны звучать в будущем времени. Желательно это делать на открытом воздухе. Если не получается выйти, то, хотя бы, сделать это в помещении (дома, в офисе). Например: «Я расстанусь с болезнью», «Я брошу курить», «Я рассчитаюсь с долгами» (про себя) или «Анара перестанет болеть», «Иван перестанет курить», «Берик рассчитается с долгами» (про других), и так далее.

Если есть такая возможность, при свете уходящего солнца будет хорошо зажечь свечу или костёр. Гореть огню лучше вплоть до рассвета, но можно затушить его через полчаса после заката и снова разжечь за полчаса до рассвета. Таким образом, мы символизируем присутствие солнечного света даже в самую тёмную ночь в году.

С наступлением Қаратүн семья собирается перед огнем (будь то костер или зажженные свечи). Необходимо проговорить или вспомнить всё, что было у вас хорошего и плохого за прошедший год. Написать на бумажках вещи или ситуации, с которыми хотите расстаться и сжигайте их в огне [3].

Ночью можно заняться установкой елки и заготовкой лент, с которыми можно загадать желания.

Перед рассветом, при наступлении второго пограничного состояния суток, необходимо обращаясь на восход произносить фразы на прибытие, увеличение чего-либо, каждую фразу проговаривая вслух по несколько раз и закрепить своё желание, завязав ленточку [3].

Нужно помнить, что привязывая ленты на живое растение всегда следует использовать только простую белую хлопковую ткань и не вязать фиксирующий узел. Нужно сложить ленту вдвое, перекинуть её через ветку, и пропустить два свободных конца через образовавшуюся петельку. Вы так же можете использовать искусственное дерево.

Фразы также произносятся в будущем времени. Например: «Я найду себе хорошую работу», «Мои способности усилятся», «Я буду здоров» (про себя) или «Владислав будет здоров», «Нұрлан выгодно продаст квартиру», «Айнұр удачно устроится на новом месте» (про других) и так далее. Одно пожелание на одну ленту.

После этого можно приступать к праздничной трапезе по случаю наступления Нұртуған (Зарождение Света).

Смысл Великого зимнего праздника, конечно же, основан на возрождении отмеченного выше зимнего сезона и времени, прославление необходимых им обрядов.

Праздник нартуган – это сезон зимы, мероприятие, чтобы выиграть самый короткий день и самую длинную ночь, чтобы осветить сумерки дня и ночи. Нартуган – это церемония празднования девяноста солнечных зим под названием «Желтоксан»; начало привития человеческих ценностей, таких как уважение к воздуху, почитание Солнца, Света, желание гармонии огня и воздуха. В последний месяц зимы Великие степи наводнены белой метелью, которая также является зимним характером воздуха. Месяц называется «ақпан» (февраль) [7].

Следует обратить внимание на одну историческую ценность, свидетельствующую о содержании праздника нартуган. Мы должны признать, что восходящая корова, изображенная в петроглифе на скале на горе Аңырақай, является живым воплощением этого зимнего сезона.

В казахском понимании зимний сезон означает признак старения времени [7].

Праздник нартуган имеет первостепенное значение, чтобы показать увековечивание времени в образе солнца через воскресение из мертвых. Скорее всего, день рождения назвали бы «Красная Шапочка". Это образ новорожденного, и слово «Шака» – древнетюркское понятие «ребенок". Одним из производных этого Нартуганского ритуала следует считать и прославление обряда «красное яйцо» с тюрками в составе польской нации.

Нартуган – это познавательный великий праздник зимнего сезона, основанный на древних тенгрианских знаниях тюркских народов. Древнее

слово «нар», обозначающее понятие солнца, послужило основой для названия этого праздника [10].

Кочевой народ создал этот праздник в эпоху Солнца и света. Однако сегодня этот праздник, состоящий из нескольких этапов ритуалов и обрядов, характерен для оседлых национальностей и народностей. Он является ценностью, которая знаменует космогоническое познание евразийских народов на древних пространствах. Однако он сегодня почти забыт и постепенно превратился в возвращение к своему прежнему характеру с объединенным восстановлением нескольких народов. Нартуган – это не только праздник, но это историческая ценность, скрывающая свои древние исторические понятия и знания, это историческая ценность, скрывающая свои древние исторические понятия и знания, а также собственное имя человека, например, современные казахские имена, такие как Нуртуган, Кунтуган, Айтуган. Также были известны казахские жырауи с именами Нартуган и Нуртуган. Казахи обычно связывают это с явлением, приуроченным ко дню рождения человека [7].

Но в наше время мы с сожалением говорим, что общетюркский характер стал отстраненным и забытым. Именно поэтому в этнографии многих народов трудно встретить этот праздник. Этот праздник сегодня сохранился у тюркского народа чувашей – нартукан. В последнее время начали восстанавливаться и татарские, башкирские народы [3]. Наряду с этим венгерский народ также празднует «корачун»/ «карачун»/Каратун, не забывая традиции.

Мажарлар ежелгі түркілердің Нартуған (Карачун) мерекесін атап өтті

2018 жылғы 22 желтоқсан, 20:06

Жаңалықтарды telegram арнамыздан оқыңыз!

ТЕМЕРИН. ҚазАқпарат - Мажарстандық «Мадияр-Тұран» қоры ежелгі түркінің Карачун мерекесін атап өтті. Бұл мейрам Қазақстанда Нартуған деген атпен танымал, деп хабарлайды ҚазАқпарат RTV арнасына сілтеме жасап.

В этой картинке сообщается, что в Венгрии фонд «Мадияр-Туран» отметил древний тюркский праздник Карачун, который в Казахстане называется Нартуган (мадьяры – самоназвание венгров [6, с. 331]).

Сегодня Карачун, празднование, организуемое фондом "Мадияр-Туран", традиционно отмечается в венгерской стране. Они говорят «Карачон», основываясь на древнетюркском слове. По программе праздника венгры зажигают большой факел по всей стране и поют шаманские песни. Суть этого ритуала в том, что свет способствует тому, чтобы луч быстрее преодолел самую длинную ночь в году и снова засиял.

Мы не можем скрыть тот факт, что праздник был отмечен по-разному под влиянием многовековой идеологии и носил разный характер. Более того, такие народы, как поляки, отмечают День «красного яйца», приуроченный к этому празднику. Учитывая, что многие этнографические ценности казахского народа неразрывно связаны с этой знаменательной датой [3].

Известно, что тюркские народы почитали четыре стихии, стихии как великого творца. Это вода, огонь, почва и воздух. В тюркском понимании эти четыре стихии совпадают с четырьмя сезонами времени: весна – Водный, лето – огненный, осень – почвенный, зима – воздушный, поэтому окружающая природа впадает в четыре различных состояния. В весеннее время поверхность земли покрывается водой, весь мир смешивается с водой, которую казахи называют «бурной»; в летний сезон днем на земле не остается ни травы, ни растительности, ни человека, ни насекомого, ни животного, которые не выходят на поверхность, но при этом накапливают энергию. Отсюда и название «Огненной» Земли,

т.е. испепеляющая жара, зной, трава выгорает, суховей. Когда наступает осень, весь летний «огонь» увядает, осыпается, падает на землю и превращается в почву. Осенью пространство служит почвенным покровом. А с наступлением зимы, когда царствование стихии Воздуха и закрепилось на земле, девяносто дней называют «декабрем». Весна, начало года «Су дүлейі – «водная» лето – «От» оттоксан», т.е. «огненная», осенний сезон – Топырақ «почва». Только слово «желтоқсан» Ауа «воздушная» от слова «жылға» – «жылтоқсан», декабрь" стало названием первого месяца зимы и перестало использоваться [3].

Время прихода каждой четверти признано в соответствии с днем и ночью: весеннее равноденствие – Наурыз, осеннее равноденствие – Сабантуй, летнее солнцестояние – Сабатой, а зимнее солнцестояние – в соответствии с праздниками Нартуган, открыты и отмечаются стихийные времена года.

Нартуган – один из четырех великих праздников, основанных на таком историко-философском познании, и, несмотря на то, что он является символом зимнего сезона, он начинает восхождение к источнику великого познания, наряду с присвоением древнего названия солнцу. В древнетюркском понимании Солнце – это вечность, и поэтому оно умирает и воскрешается каждый год. Дата его смерти совпадает с Днем самого короткого дня в году в ночь с 21на 22 декабря. Через три святых дня солнце-луч возрождается. Дата – 25 декабря. Это то, что тюрки называют Нартуган/ Нартукан [7].

Что здесь означает слово «нар»? В казахском языке в наше время слово «Нур» обозначает священный свет, но это было древнее понятие «солнце», которое было названо «нар»: в прошлом он заменен исламским словом «Нур». Мангистауский народ в Казахстане, принадлежащий к единой алтайской языковой группе, до сих пор называет «нар». В общем, слово нар – «это всечеловеческое название дня, и только каждый на свой язык говорил «нар или» «Нур» [10].

Наши предки начинали декабрь с войны. Но сегодня это превратилось в короткую кампанию по сохранению мяса. А древний вариант – источник света, ставший источником великой жизни, – был принесен в жертву в честь Солнца. Бедные, у которых не было или мало крупного рогатого скота, объединялись, чтобы забить один крупный рогатый скот, разделив его на 12 человек и разделив жеребьевку. Это было божественное мировоззрение. 12-я часть может символизировать структуру глобального пространства, имеющего прямое влияние на Солнечную систему, состоящую из 12 созвездий на небе, и пожелать благополучия этому пространству [7].

Этот день сохранился у многих как знаменательный праздник, и каждый народ олицетворяет свое познание этим днем: у венгерского народа – «карачун»/Каратун; у польского – «день красного яйца", у чувашей – нартукан и т.д. А в казахской культуре он не является знаменательным праздником, приспособлен к бытовым обычаям, смысл ритуала был забыт с приходом ислама. Что касается нартугана, то среди тюркских народов наиболее полно обычаи и традиции сохранились у чувашей. Давайте возьмем ритуал Сурхури, чтобы убедиться.

Сурхури – начало праздника, связанного с Солнцем (22 декабря). Сур хури (плевать на черного) означает отрицать печаль. Иначе местные называют "нартукан". За три дня до этого момента девушки гуляют по деревне и кружат вокруг дома с невесткой. Затем собирают солод и урожай, чтобы приготовить бозу и кашу. Все собираются и готовят эту еду в уединенном доме, вечером в этом доме молодежь празднует наедине. Это похоже на казахскую «головную» скамью. На следующее утро в основном собираются отцы молодых людей. Их сажают на четвереньки, дают бозу, шутят и веселятся. Смысл этого праздника чувашей – конец года и рождение нового года [3].

День сета – основа разрушения старого и темного. Самый короткий день в году. Этот день считается моментом усиления темных сил. В этот день читается молитва по отношению к одомашненным. Оказывается, в жертву забивают гусей. А у казахов соғым, т.е. забивают крупный рогатый скот.

Кашарни (Кэшарни) – недельное продолжение Нартугана/ Сурхури. Главный напиток этой недели – боза, ферментированная специальным ритуалом. Это делается с помощью ритуала и молитвы, которые специально соблюдаются во время брожения. Кэшарни начинается после 21-22 декабря [7].

В местности Мары в Туркмении также имеется достаточно обычаев, непосредственно относящихся к Нартугану. Так, игры «Шорыкйол» (овечья нога) проводятся после короткого зимнего дня и долгой ночи в течение недели. Овца изображена как одна проекция Солнца на землю. А в основе казахского орнамента из бараньих рогов, скорее всего, изображен один и тот же жизненный путь Солнца. Поэтому он стал уважаемым и почитаемым символом. Эта игра характерна также для шувашей, татар, башкир и удмуртов. У туркменских мары также есть игра под названием «Соқыртаға», которая является аналогом, версией казахской игры «Соқыртеке» (слепой баран). В казахском фольклоре аймусин Ак серке играет символ ночи, а рог играет роль Луны. Игра в шуршание, повышение статуса дня, мера поддержки [7].

Атрибутивные символы праздника нартуган ускоряют усвоение, принятие праздника в сознании, повышают его ценность.

Рогатый баран – главная языческая фигура Нартугана, с рогами, идущими по траектории движения Солнца.

Петух – символ Стихии Воздуха, предвестник времени. Он объявляет каждое утро и объявляет о возобновлении дня.

Солнечное вечнозеленое дерево, которое выдерживает воздушные порывы и не меняет цвета, вечный символ времени, пути в природе, то есть путь желания. Атрибутивные символы праздника

елки ускоряют усвоение, принятие праздника в сознании, повышают его ценность. Елку также можно использовать в виде колышков.

Баурсак (пышные, жаренные в масле хлебные изделия) в казахской традиции изображает образ жаркого солнца, поддерживает новорожденный нар огнем и энергией, – это аромат, который излучает продукт.

У каракалпаков – Келсеңе ярым Жұлдызым. У туркменов – Нұртуған [7].

Многие народы отмечали день зимнего солнцестояния. У древних славян зимнее солнцестояние знаменовало собой праздник Коляды, один из самых важных праздников года, посвященный солнцу, его возрождению и победе света над тьмой [11].

В этот день славяне чествовали солнце, которое, казалось, замирало, чтобы потом начать свой новый путь. Главным символом солнца в этот период было Коло, огромное колесо, которое обвязывали соломой и поджигали, а затем скатывали с горы, провожая уходящий год и встречая новый. Люди пекли круглые караваи, символизирующие солнце, и угощали друг друга.

Коляда включала в себя обряд колядования. Молодежь, нарядившись в яркие костюмы, ходила по домам, распевая колядки — песни с пожеланиями добра, здоровья и благополучия хозяевам и их семьям. Взамен колядующие получали угощения и подарки. Этот обычай был не только веселым развлечением, но и способом распространения добрых пожеланий и укрепления общины.

Сейчас, хотя древние традиции изменились, день зимнего солнцестояния, продолжает оставаться временем для размышлений, философствования, подведения итогов и загадывания желаний. Вот несколько простых ритуалов: наведение порядка в своем доме, избавление от ненужных вещей, чтобы освободить пространство для новой энергии и позитивных перемен; запись и сжигание желаний.

Скандинавы в древности отмечали Йоль, означавший возвращение света. Популярным обычаем было сжигание большого полена, которое должно было тлеть несколько дней. Оно символизировало продление солнечного света [10].

У инков (древнего высококультурного племени индейцев, жившем в Южной Америке в бассейне реки Амазонки [6, с. 242]) был праздник Инти Райми, посвящённый богу Инти, зимнему солнцестоянию и Новому году. Церемония шла девять дней, с музыкой и танцами, люди надевали разноцветную одежду и маски.

В Иране в кругу близких отмечают Шаб-е Ялда — праздник, который выпадает на 20, 21 или 22 декабря. В самую длинную ночь в году люди угощаются орехами, гранатами и арбузами: красный цвет олицетворяет оттенки рассвета и символ жизни. Есть те, кто не ложится спать до самого утра, чтобы увидеть наступление рассвета [1].

Карачун (сущ. м. и нар.) – капут, конец, смерть, гибель, извод; допячение кого-либо до конца, например, такие обороты: «Дать кому карачун, задать карачуна» – убить, уничтожить кого-либо, что; «Пришёл ему карачун». Симб. Злой дух. «Солнцеворот, день 12 (25) декабря Спиридонов день – день языческого бога Карачуна. Карачунить» – уничтожить, изводить, убивать. [2, с. 312].

Карачун (Корочун) – День зимнего солнцестояния 21-22 декабря.

Карачун – (внезапная смерть – устар.) Общеслав. Образовано, вероятно, с помощью суф. -ун от основы *kork, связанной этимологически с корок – «нога, шаг». См. карачим, окорок. Написание и произношение А вместо О – в результате аканья и закрепления его в орфографии [12, с. 188]

В славянской мифологии злой дух, сокращающий жизнь и олицетворяющий смерть в раннем возрасте. По мнению ряда исследователей, Карачун – божество нижнего мира, повелитель морозов, холода и мрака [4].

В источнике [8] приведены такие предположения о происхождении слова «Карачун»:

1. В карпато-балканском этнолингвистическом ареале слово «Карачун» обозначало рождественский календарный цикл и его обрядовые реалии.

2. По гипотезе астронома Д.О., в Древней Руси словом «Корочюн» называли день зимнего солнцестояния.

3. По мнению В.В Иванова и В.Н. Торопова, в славянской мифологии Карачуном назывался зимний солнцеворот и связанный с ним праздник.

Карачун [5] – это день подведения итогов, прославления предков, родовых богов, духовное и физическое очищение через огонь, т.е. в течение недели до этого дня должны гореть свечи [10].

Слеующий день – каляда – избавление от ненужного, старого, возрождение, начало нового, прибавление света, зачинание нового цикла, почитание предков (на столе должна быть кутья), прирастания силы, света.

Лада – великая прародительница рожана, праматерь божия (появление младенца из темноты: пещера, вертеп, где всё вертится, крутится. 25 декабря – Рождество, чтили предков, славили богов (щедровечер) [4].

Арина Никитина [11] отмечает, символами карачуна считали птицу сирин, богиню кара (чёрная волчица). В этот день положено расстаться с эго, со старым, отпустить, не обманывать себя, покормить собачек.

Карачун (Корочун) – дата события уникальна для каждого года. В 2025 году эта дата – 21 декабря. Один из самых холодных дней зимы и самый короткий день в году. День языческого почитания Карачуна (второе имя Чернобога) приходится на день зимнего солнцеворота (отмечаемого в зависимости от года 21 или 22 декабря). Считалось, что в этот день берет свою власть грозный Карачун – божество смерти, подземный бог, повелевающий морозами, злой дух. Древние славяне верили, что он повелевает зимой и морозами и укорачивает светлое время суток [8].

Слуги грозного Карачуна – медведи-шатуны, в которых оборачиваются бураны, и метели-волки. Считалось, что по медвежьему хотению и зима студеная длится: повернется медведь в своей берлоге на другой бок, значит, и зиме ровно половину пути до весны пройти осталось. Отсюда и поговорка: «На Солнцеворота медведь в берлоге поворачивается с одного бока на другой» [11].

В народе понятие «карачун» в смысле погибели, смерти используется до сих пор. Говорят, например: «пришел ему карачун», «жди карачуна», «задать карачуна», «хватил карачун». С другой стороны, слово «карачить» может иметь следующие значения – пятиться задом, ползком, «скорячило» – скорчило, свело. Возможно, Карачуна так называли именно потому, что он как бы заставлял дневное время идти в обратную сторону, пятиться, ползти ползком, уступая ночи.

Постепенно в народном сознании Карачун сблизился с Морозом, который сковывает стужей землю, как бы погружая ее в смертный сон. Это более безобидный образ, чем суровый Карачун. Мороз – просто повелитель зимних холодов [11].

Итак, на огромном пространстве Евразии отмечают день зимнего солнцестояния, в самый короткий день и самую длинную ночь года подводя итоги перед огнем костра или свечи, прощаясь со старым, ненужным. Затем встречают рассвет, появление нового дня с надеждой и верой в прибавление света. Также древние инки и скандинавы праздновали этот день у пламени костра, сопровождая определенными ритуалами.

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