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AGRICULTURAL SCIENCES

COMPARISON OF HYDROTHERMAL POTENTIAL INDICATORS IN THE CULTIVATED CENOSES OF MOUNTAIN GRAY-BROWN SOILS ACCORDING TO VEGETATION DENSITY

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Abstract

The article presents a comparative analysis of the hydrothermal potential (HTP) in cultivated cenoses of mountain gray-brown soils located on the southeastern slope of the Lesser Caucasus, with particular emphasis on vegetation cover density. The aim of the study is to assess the hydrothermal regime of the soil environment and soil–climate interactions. The research was conducted using N.R. Suleymanov's methodology for determining HTP, and soil temperature and moisture were measured under field conditions using an EC-350 device. The results indicate that cultivated cenoses with dense vegetation cover are characterized by higher HTP values: soil moisture is retained for longer periods, and the temperature regime remains more stable. In contrast, areas without vegetation or with sparse plant cover exhibit lower moisture content and elevated temperatures in the upper soil horizons. It has been established that vegetation cover plays a crucial role in stabilizing the soil microclimate.

Keywords: Lesser Caucasus, mountain gray-brown soils, hydrothermal potential, cultivated cenosis, vegetation cover.

INTRODUCTION

Land resources constitute natural assets of strategic importance for agricultural production and environmental sustainability in any country [1]. The study of their genetic characteristics, formation conditions, and functional properties is of considerable relevance for the rational use of soils, the planning of reclamation measures, and the optimization of agroecosystems [2]. In this context, the investigation of specific soil types widespread in mountainous and foothill regions—particularly mountain gray-brown soils—is of both scientific and practical significance.

The hydrothermal regime plays a decisive role in soil formation processes. Together with soil moisture availability and thermal balance, it directly affects the dynamics of key pedogenic processes such as humification, mineralization, leaching, and sorption [3; 4; 5; 6]. During periods of increased moisture, the decomposition and transformation of organic matter within the soil profile intensify, whereas under dry conditions, more stable forms of humus tend to accumulate. In regions such as Agdere, characterized by low annual precipitation and high evaporation rates, the influence of these factors on soil development is particularly pronounced [7].

In soils used for agricultural purposes, soil formation is accompanied by transformations in genetic horizons, soil regimes, process dynamics, physicochemical properties, and structural organization. In soils subjected to anthropogenic impact, soil types and properties reflect the degree of cultural soil formation and land-use intensity.

Microprocesses occurring within the soil environment, their relationship with hydrothermal resources, and the structural stability of the soil profile necessitate a comprehensive analysis of soil–climate interactions. Under conditions of contrasting moisture regimes, intensified decomposition and humification processes, along with the stabilization of humus reserves, contribute to enhanced soil fertility [8; 9]. Such findings are essential for the ecological assessment and sustainable management of soils under specific geographical conditions.

The primary objective of this study is to analyze the geographical factors influencing soil formation in the southeastern Lesser Caucasus, with particular emphasis on the hydrothermal regime, hypsometric characteristics, and soil–climate relationships. In addition to examining the genetic features of the soils, the study seeks to determine their position within the landscape structure [10].

RESEARCH OBJECT AND METHOD

The study area is located on the southeastern slope of the Lesser Caucasus, in the direction of the village of Talysh in the Aghdere district of the Republic of Azerbaijan. The coordinates of the study area are 40°21′55″ N and 46°55′08″ E, with an elevation of approximately 246 meters above sea level, within a flat area.

The Aghdere district is part of the Karabakh economic region, which encompasses the southeastern slope of the Lesser Caucasus and is characterized by unique natural and climatic conditions.

Figure 1. General view of the agricultural landscape of the study area (clover crops)

The soil cover of the studied agricultural landscapes is represented by mountain gray-brown soils with a heavy clay texture. The formation and functioning of these soils under agricultural use are accompanied by transformations in their morphological, physicochemical, and hydrothermal properties.

The Agdere region is characterized by a moderately warm climate with dry winters and is classified within the semi-desert dry-steppe climatic zone. The mean annual air temperature and precipitation amount to 13.9 °C and 363 mm, respectively. The moisture coefficient (Ku) ranges from 0.3 to 0.5, and total solar radiation reaches 124–128 kcal/cm² [11].

Repeated field and laboratory investigations have established that the mean soil bulk density of mountain gray-brown soils throughout the profile is 1.23 g/cm³, as confirmed by statistical analysis of the obtained data. The soils of the experimental plot are characterized by a heavy clay texture, and their particle-size distribution is directly related to soil bulk density. In the agrocenosis, soil bulk density varies from 1.16 to 1.30 g/cm³. It is lower in the upper horizons and gradually increases with depth along the soil profile (Table 1).

Table 1

Physicochemical parameters of mountain gray-brown soils under agrocenosis conditions (0-25 cm layer)

Soil type	**Horizon, см**	**Soil density, g/см³**	**Average density by profile, g/см³**
Mountain gray-brown	0-5	1.16	1,23
	5-10	1.19	
	10-15	1.23	
	15-20	1.27	
	20-25	1.30	

The research methodology was based on the determination and comparative analysis of the hydrothermal potential (HTP) of soil environments under cultivated communities (clover). HTP was calculated according to the method proposed by N.R. Suleimanov [12, 13]. The vertical distribution of soil temperature and moisture was examined under field conditions, and hydrothermal potential calculations were performed in triplicate to ensure data reliability.

To evaluate hydrothermal potential parameters formed under the influence of specific abiotic factors within prevailing climatic conditions, Suleimanov's HTP index was applied. According to this approach, potential soil temperature and soil moisture content, as affected by external climatic factors, are integrated into a single HTP parameter, which makes it possible to determine boundary conditions and characterize the hydrothermal state of the soil environment.

Soil temperature and moisture were measured directly in the field using a modern multifunctional mobile EC-350 device (USA), operating on the "soil moment" principle. Soil reaction (pH) was determined using a KCB-300 device.

The experimental site was located within an agricultural landscape cultivated with clover on the flat southeastern slope of the Lesser Caucasus and was characterized by mountain gray-brown soils. The study employed an integrated set of field and laboratory methods typical of soil ecological research. Soil pits were excavated, and samples were collected with consideration of agricultural landscape differentiation. Laboratory analyses included determination of particle-

size distribution, humus content, soil acidity (pH), and hydrophysical properties. The obtained data were processed using standard statistical analysis methods.

ANALYSIS AND DISCUSSION

The soil profile is characterized by the distribution of temperature and moisture (hydrothermal parameters) across the depth, which is an important factor directly influencing plant growth and development, irrigation regimes, and crop yields in agricultural systems. Different soil covers (with or without vegetation) significantly influence this distribution (Table 2).

During the study, air temperatures ranged from 32°C to 39°C. The soil surface temperature was 34°C.

An analysis of hydrothermal potential indicators demonstrated that vegetation density significantly influences the distribution of soil temperature, moisture, and water reserves within the agrocenoses of the experimental site.

Under sparse vegetation (K-1), the mean soil temperature within the 0–25 cm layer was 31.58 °C, soil moisture averaged 31.98%, water reserves amounted to 21.58 mm, and the hydrothermal potential reached 642 snr (Kst = 0.7), indicating limited moisture retention capacity.

Under dense vegetation (K-2), soil temperature was lower (29.34 °C), while moisture content was substantially higher (60.96%); water reserves reached 40.08 mm, and the hydrothermal potential increased to 1130 snr (Kst = 1.4), reflecting a more favorable hydrothermal regime for plant development.

Table 2

Soil hydrothermal potential indicators determined by vegetation density in piedmont plain agrocenoses

Section	Depth, см	Soil temperature, °C	Soil moisture, %	Water content, mm	HTP, snr	K_{st}
K-1 (sparse vegetation)	5	37,60	6,90	4,00	150	0,1
	10	34,70	42,80	25,47	884	0,7
	15	32,30	74,20	45,63	1474	1,4
	20	29,50	85,20	54,10	1596	1,8
	25	27,30	81,90	53,24	1453	2,0
	0-25 см	32,28	58,20	36,49	1111	1,2
K-2 (dense vegetation)	5	31,30	4,30	2,49	78	0,1
	10	34,70	76,60	45,58	1582	1,3
	15	31,50	82,10	50,49	1590	1,6
	20	28,50	86,60	54,99	1567	1,9
	25	27,00	88,10	57,27	1546	2,1
	0-25 см	30,60	67,54	42,16	1273	1,4
K-3 (without vegetation)	5	30,30	17,40	10,09	306	0,3
	10	31,80	55,70	33,14	1054	1,0
	15	31,40	75,50	46,43	1458	1,5
	20	29,70	85,20	54,10	1607	1,8
	25	28,50	88,00	57,20	1630	2,0
	0-25 см	30,34	64,36	40,19	1211	1,3

In the bare area (K-3), soil temperature was elevated (33.76 °C), whereas moisture content and water reserves (31.50% and 21.17 mm, respectively) remained relatively low. The hydrothermal potential was 698 snr (Kst = 0.6), indicating comparatively unfavorable conditions. These findings demonstrate that dense vegetation contributes to the optimization of soil hydrothermal potential [10].

HTP values were highest under dense vegetation cover, ranging from 285 to 1588 snr. Under sparse vegetation, values ranged from 42 to 1588 snr, and in bare areas from 37 to 1606 snr. The weighted mean HTP values were 1130 snr for dense vegetation, 642 snr for sparse vegetation, and 698 snr for bare soil.

A comparative analysis of hydrothermal potential curves in cultivated cenoses across different vegetation densities indicates that the soil hydrothermal regime is strongly dependent on vegetation cover density and the degree of anthropogenic impact.

CONCLUSIONS

1. The hydrothermal potential of the soil environment was determined for cultivated cenoses of the Agdere district's gray-brown mountain soils based on vegetation density and soil profile depth, and a comparative analysis of the data was conducted.

2. HTP values are highest under dense vegetation cover and range from 285 to 1588 snr. Under sparse vegetation, values are lower—42 to 1588 snr—and in bare areas, 37 to 1606 snr. The weighted average HTP values were 1130 snr for dense vegetation, 642 snr for sparse vegetation, and 698 snr for bare areas, respectively.

3. Vegetation cover plays an important role in maintaining a stable hydrothermal regime in the soil.

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ECONOMIC SCIENCES

EVALUATION OF THE IMPACT OF INVESTMENT IN THE AGRICULTURAL SECTOR ON PRODUCTIVITY IN AZERBAIJAN

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Abstract

This study evaluates the impact of investment in the agricultural sector on productivity in Azerbaijan using time-series data. The agricultural sector plays a significant role in ensuring food security, rural employment, and economic stability; however, it is characterized by structural constraints and external risks. The empirical framework is based on a log-log model derived from the Cobb–Douglas production function and estimated using the ordinary least squares (OLS) method for the period 1995–2023. The estimation results indicate that the estimated elasticity of agricultural output with respect to investment is 0.2436 and is statistically significant at the 1% level. This finding implies that a 1% increase in agricultural investment leads to an approximate 0.24% increase in agricultural output. Comparative analysis with international benchmarks shows that most agricultural products remain within the medium productivity range. The results highlight the need for structural modernization and innovation-oriented investment policies to enhance productivity and ensure long-term economic resilience.

Keywords: agricultural investment; productivity; Cobb–Douglas model; elasticity; econometric analysis; Azerbaijan.

1. Introduction

Productivity reflects the efficiency with which resources are utilized in the production process. Increasing productivity is one of the fundamental conditions for improving economic welfare. Productivity is commonly defined as the ratio of output to the inputs used in production. The agricultural sector is considered one of the most risk-prone sectors of the economy due to climate-related risks, seasonal fluctuations, logistical constraints, and long-term financing challenges. Therefore, evaluating the impact of investments directed to agriculture on productivity is of particular relevance.

2. Literature Review

Productivity growth is widely recognized as a key driver of economic development and structural transformation (Hayami & Ruttan, 1985). In agriculture, capital accumulation and technological progress play a crucial role in improving output efficiency and enhancing long-term sectoral performance (Alston et al., 2010).

The Cobb–Douglas production function is frequently used to estimate the elasticity of output with respect to capital and labor inputs. This framework allows researchers to quantify the contribution of investment and other production factors to output growth. Empirical studies indicate that agricultural productivity growth is largely driven by capital investment and technological innovation (Fuglie, 2018; Gollin et al., 2002).

In developing economies, the high concentration of labor in agriculture often leads to hidden unemployment and labor surplus, reducing the marginal contribution of labor to productivity growth (Fan et al., 2004). Under such structural conditions, capital investment and technological improvement play a more decisive role in output expansion (Thirtle et al., 2003).

In contrast, in developed countries labor productivity in agriculture reflects the intensive and efficient use of advanced technologies, modern machinery, and innovative production systems. Therefore, labor productivity becomes a meaningful indicator of sectoral efficiency in advanced agricultural economies.

The above-mentioned structural and productivity considerations are further evaluated using the econometric model presented in the next section.

3. Model Specification

To analyze the relationship between agricultural investment and output, a log-log econometric model derived from the Cobb–Douglas production function is employed:

$$\ln(Y_t)=\beta_0+\beta_1\ln(K_t)+\varepsilon_t$$

Where:

- Y_t denotes real agricultural output (or value added) in period *t*;
- K_t represents investment directed to the agricultural sector in period *t*;
- β_0 is the constant term;
- β_1 measures the elasticity of agricultural output with respect to investment;
- ε_t is the error term.

The log-log specification allows the estimated coefficient to be interpreted as elasticity.

4. Data and Descriptive Analysis

Descriptive statistical analysis is based on official data for the period 2014–2024 obtained from the State Statistical Committee of the Republic of Azerbaijan, while the econometric model is estimated using time-series data for the period 1995–2023.

Table 1

Investment in Agriculture and Its Share in Total Capital Formation (2014–2024)

Year	Agricultural Investment (mln AZN)	Share in Total Capital Formation (%)	Share of Agriculture in GDP (%)
2014	363.9	2.1	5.3
2015	355.4	2.2	6.2
2016	325.1	2.1	5.6
2017	617.8	3.5	5.6
2018	764.4	4.4	5.2
2019	769.5	4.2	5.7
2020	520.6	3.0	6.7
2021	341.9	2.0	5.7
2022	408.0	2.3	4.6
2023	578.3	2.7	5.5
2024	283.1	1.3	5.7

Source: State Statistical Committee of the Republic of Azerbaijan.

It should be noted that in developed countries the share of agricultural investment in total capital formation is approximately 6.5%, which is significantly higher than the corresponding indicator in Azerbaijan.

Table 1 indicates that the average annual investment in agriculture was approximately 484.4 million AZN, accounting for 2.7% of total capital formation. This share remains below the levels observed in developed countries.

Table 2

Share of Agriculture in GDP by Income Group

Income Group	Share of Agriculture in GDP (%)
High-income countries	1.3
Upper-middle-income countries	6.8
Middle-income countries	8.6
Lower-middle-income countries	8.8

Source: World Bank (2024).

The data show that Azerbaijan belongs to the upper-middle-income group, where the average agricultural share in GDP is 6.8%.

Table 3

Average Productivity of Main Agricultural Products (2014–2024)

Product	Productivity (centners/ha)
Cereals and legumes	30.7
Cotton	24.5
Tobacco	21.2
Sugar beet	404.9
Sunflower	21.2
Potatoes	165.3
Vegetables	177
Melons	207.8

Source: State Statistical Committee (2024).

Table 4

International Productivity Benchmarks

Product	Medium Level	High Level
Cereals	25–40	50–80
Cotton	25–35	40–60
Tobacco	16–24	25–37
Sugar beet	300–500	700–900
Potatoes	150–250	350–500
Vegetables	220	360

Source: FAO (2024).

The comparison between Tables 3 and 4 suggests that although productivity levels are within the medium benchmark range, high-efficiency standards have not been achieved. This situation indicates structural constraints related to technological capacity, infrastructure development, human capital formation, competitiveness of agricultural products, and insufficient funding allocated to agricultural research and innovation.

5. Empirical Results

Table 5

OLS Estimation Results

Dependent variable: ln(Agricultural Output)

Variable	Coefficient	Std. Error	t-Statistic	p-value
Constant	6.2867	0.0932	67.4781	0.0000
ln(Investment)	0.2436	0.0189	12.9005	0.0000

Model statistics:

- Observations: 29
- R^2: 0.8604
- Adjusted R^2: 0.8552
- F-statistic: 166.4238 (p = 0.0000)
- Durbin–Watson: 0.4973

The elasticity coefficient of investment is positive and statistically significant. A 1% increase in investment leads to a 0.24% increase in agricultural output.

The coefficient of determination ($R^2 = 0.8604$) indicates that the model has strong explanatory power, suggesting that variations in agricultural investment explain a substantial proportion of changes in agricultural output over the analyzed period.

The Durbin–Watson statistic (0.4973) indicates the presence of positive autocorrelation in the residuals. This outcome is typical for time-series data and suggests that future research may incorporate dynamic components or alternative model specifications to improve robustness and address potential serial correlation issues.

6. Conclusion

The empirical analysis confirms that investment in the agricultural sector has a positive and statistically significant impact on agricultural output in Azerbaijan. The estimated elasticity coefficient indicates that a 1% increase in agricultural investment leads to an approximately 0.24% increase in output. However, the elasticity being less than one suggests the presence of diminishing returns to investment.

The main findings of the study can be summarized as follows:

1. The share of agricultural investment in total capital formation remains relatively low compared to international standards.
2. Productivity indicators of major agricultural products are mostly within medium international benchmark intervals and have not reached high-efficiency levels.
3. Investment has a positive but relatively low elasticity effect on agricultural output.
4. Structural and technological modernization of the agricultural sector is necessary to achieve higher productivity performance.

These findings indicate that although capital investment contributes positively to agricultural output, sustainable productivity growth requires comprehensive structural reforms. In particular, improving technological capacity, expanding irrigation infrastructure, strengthening human capital development, and increasing funding for research and innovation are essential.

Policy recommendations include increasing the volume of investment directed to agriculture, prioritizing technology- and innovation-oriented investment strategies, expanding rural infrastructure projects, and strengthening digitalization and research programs within the agricultural sector.

Overall, a consistent and efficiency-oriented investment policy remains a key priority for enhancing agricultural productivity and ensuring long-term economic resilience in Azerbaijan.

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CAN THE PHILOSOPHY OF HUMAN-CENTEREDNESS BECOME A UNIFYING IDEOLOGY OF UKRAINE'S DEVELOPMENT?

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Abstract

The entire system of public administration consists of elements – people in certain structures, the potential of which should be used in the direction of achieving the ultimate goals with their coordinated interaction.

In Ukraine, it has already become common to say that our state is being destroyed by corruption. At the same time, this is already common not only inside the country, but also had come out. And even martial law does not help the fight against corruption invincibility, because it has deep roots in our country. How exactly can the problem of conscious development of post-war Ukraine be solved, eliminating forever its "blind style" movement towards progress?

In this article, authors propose a way to solve these problems with the help of a system complex of four blocks, which is called "The New Human-Centered Management Course".

Keywords: public administration, human-centeredness, civil society, quality of life of citizens, The New Human-Centered Management Course (NHMC).

Introduction. Is our "system of public administration" similar to the real system as a holistic phenomenon, all structures of which are united by a single ultimate goal with well-established interaction from the bottom to the highest level in order to achieve this ultimate goal? We have always had slogans, but we have never had a real ultimate goal, the achievement of which would be recorded in clearly defined results, for which the authorities would be responsible.

We also have the concept of "ruling elite", which in its essence did not consist of the best (which suggests the very concept of "elite" as the chosen ones). In Ukraine, there have always been no "white" filters in line with "ability", and hopes for the objectivity of the electoral system were in vain, because it was quickly distorted with money and connections.

Presentation of the main material. The entire system of public administration consists of elements, people in certain structures, the potential of which should be used in the direction of achieving the ultimate goals with their coordinated interaction. Then corruption will not be able to demonstrate its invincibility.

The philosophy of human-centeredness is at the heart of democracy, the degree of development of which today becomes an indicator of belonging to modern civilization. The understanding of this fact even reached the Ukrainian authorities, when, under the fourth President, billboards were distributed throughout the country: "Ukraine for the people". That is, the authorities realized the attractiveness of joining the values of democracy in modern civilization, but everything was in vain. The people could no longer trust such a government, because the real corruption of its structures at all hierarchical levels significantly contradicted these slogans on billboards.

But how can the problem of conscious development of post-war Ukraine be solved, eliminating forever its "blind style" movement towards progress? Since Ukraine's "random" course led the young state into a deadlock, much attention should be paid to determining its own path to modern civilization. At the same time, adhering to democracy in the context of the implementation of the ideology of eco-human-centrism, that is, relying on the priority of the human factor in all spheres of organization of society, primarily political and economic. This will be the first general milestone that points to the right path of post-war Ukraine.

The second milestone of the conscious path to progress is associated with the definition of a specific orientation (without another slogan) of power structures to improve the quality of life of citizens. At the same time, in such a way that the authorities are interested in this, and people realize that this is real and will be implemented in practice.

The third milestone of the conscious movement is the technology of measuring the quality of life of citizens (QLC) in the form of respective indices, which at the same time become a digital assessment of the resulting activities of government structures (that had been repeatedly mentioned above). This innovation is of fundamental importance, because it determines Ukraine's own path to civilization. It was possible to implement it due to the understanding of the essence of the concept of "quality of life of citizens" through a person's internal perception of the level of satisfaction of his needs and application of the qualimetric digitization from fuzzy mathematics.

After that, another interesting milestone naturally appears, this is the transition to a culture of systemic management based on the final results of all power structures at all hierarchical levels.

One thing is important, that all innovative components of the Ukrainian path to progress start and are intended for the implementation of the ideology of human-centrism (eco-human-centrism).

In Ukraine, the saying that our state is being destroyed by corruption has already become commonplace. In general, Ukraine has a bitter experience of unsuccessful fight against corruption by legal methods, after the use of which prisons for corrupt officials remained practically empty. And not because of their execution, as they do in China with the organizers of corruption schemes, but because of their ransom, including from judges. And this despite the fact that from 1997 [1] to 2011. six (!) Presidential Decrees were issued, and in 2014 the Law of Ukraine "On the Principles of State Anti-Corruption Policy in Ukraine" was even adopted [2].

At one time, Singapore proved (building a society of social justice with a multilingual and multi-ethnic population) what it means to consciously move towards progress, relying on common sense and a certain strategy, where the main place was occupied by the slogan: "To restore order in your country".

To restore order means, first of all, to concentrate the actions of the authorities on the interests of citizens and to orient these actions to improve the lives of the country's residents. Since corruption is a big obstacle on this path, Singapore paid great attention to it from the very beginning. How was it done?

Six years before the declaration of independence, the chairman of the People's Action Party, Lee Kuan Yew, stated that "our goal is to create an honest administrative body, because we are already tired of the greed, corruption and licentiousness of many Asian leaders" [3, p. 175]. And from the first days of his activity in power in the conditions of independence, Lee Kuan Yew with like-minded people from the PAP took up the matter with their own. They began to create an atmosphere of intolerance to corruption in society and widely highlight the signs of corruption, then "established strict control over areas in which abuse of power had previously occurred and it was possible to enrich oneself at the expense of citizens; tools were developed to prevent the actions of such enrichment mechanisms" [3, p. 177]. The work of the Anti-Corruption Bureau was intensified, directing it against corrupt officials in the highest echelons of power. This also included the decision "to automatically transfer the salaries of ministers, judges, and senior officials, tied to the amount of income tax in the private sector" [3, p. 187].

At the end, a corruption prevention mechanism was created in Singapore, which placed it into the group of the least corrupt countries in the world [4]. Unfortunately, Ukraine in this ranking is in the group of the most corrupt countries with the most hardened corrupt officials having all-encompassing intertwined ties.

The fact is that if the QLC indicator is determined annually, then the dynamics of positive or negative (successful or unsuccessful, effective or ineffective) activities of the authorities for the corresponding period of time (year) is revealed. That is, the next year becomes, as it were, a controller of the previous one along the entire chain of public administration structures, both horizontally and vertically. A characteristic feature of these chains is the dependence of each of the structures on the activities of others, primarily vertically.

For example, we are talking about meeting the needs in the living conditions in the house (in terms of electricity supply), or medical care, or environmental safety, etc. From the above-mentioned area, not everything depends on local authorities, here it is impossible to do without the actions of regional authorities and even authorities at the national level.

Since the integral indicators of the QLC in communities are indigenous information, they are distributed from the bottom up to the power structures in a digital way and become an assessment of the effectiveness of their resulting activities. This assessment is legally enshrined, thereby legally confirming the responsibility of the authorities for a happy life (after covering the index of self-realization in the sphere of personal life) of their people.

The main sign of the weakness of civil society in Ukraine is the presence of corruption, which resembles an impenetrable wall. In countries with developed civil society, it was possible to overcome this wall, bearing in mind that the general purpose of this society is to promote the free development and self-realization of a person, as well as to specifically limit the arbitrariness of power and direct the activities of its structures for the benefit of people. That is, civil society is inherently a lever (or a powerful technology) for the implementation of the ideology of human-centrism in modern civilization, which is not developed in countries with dictatorial regimes.

There are also other signs of the weakness of civil society in Ukraine, already on the part of the people themselves, who are not yet ready to live in such a society. This is confirmed by the research of a group of civil servants and a group of experimental psychologists [5; 6].

For example, a group of civil servants led by N. Dniprenko [5], based on the Constitution of Ukraine, identified 9 positions according to which citizens have the right to participate in the management of state affairs. The analysis showed that some of the rights are significantly distorted in practice, some cannot be used due to the obstacles of the authorities, and some are not used by the citizens themselves due to the mentally determined social status of a "little person".

The next example. A group of psychologists led by Professor V. Rybalka in the process of conducting constant trainings (to increase the ability of the individual to act in modern civil society) came to the conclusion that "the weakness of civic education... and the manifestation of insufficient development, the actual absence of adult civil society" [7, p. 193-194].

Thus, from the very beginning of the declaration of independence, Ukraine had a large layer of people with mental negative consequences from the past. The active part of this stratum wanted to compensate for their low self-sufficiency through supremacy over other people due to being in power. The other part of this stratum (more decent, but less active) was infected with inertia to state affairs. And even realizing the ugliness of the electoral system, in which citizens silently went to

the ballot boxes, voted at random for those who were liked by the leaders of the parties or the current government, each time choosing the wrong one... And one more thing, there were no clear "white" filters for the admission of people capable of operating in high responsible positions to the elite.

"White" filters are implemented, initially using a system of special tests. Subsequently, the educational branch will join the definition and formation of qualities according to these criteria, diagnosing universal morality and analytical-cognitive activity from kindergartens (and from adolescence, children are instilled with curiosity about self-knowledge of their own "Self"). In the future, self-exploration of one's own "Self" may help to enhance the effectiveness of the "white" filter. For example, when an applicant who wants to take an elite position deliberately refuses it, realizing his non-compliance with these criteria.

The philosophy of human-centeredness can become an attractive unifying force and a real ideology for the development of post-war Ukraine (and the whole world) if we pay special attention to two factors.

The first factor is the deepening of the concept of "human-centrism", which today some stratum of unconscious people associate with the priority of human life over nature. Therefore, it is necessary to understand human-centeredness as "ecological human-centeredness" or simply "eco-human-centrism" as an organic positive unity of man with nature and even as its preserver.

The second factor is the transparent actions of the authorities in line with the ideology of human-centeredness. The inclusion of public organizations, not distorted by the authorities, as experts on the human-centeredness of any Laws, Presidential Decrees, Resolutions of Governments and even decisions of regional and local Councils can significantly change the situation and even "beat" corruption in a certain way.

We remind you that eco-human-centrism is the essence of democracy and the core of modern civilization, which still needs to be brought to a state of harmony. Therefore, adherence to the human-centered ideology can help Ukraine to embark on a systematic path to modern civilization, which, we repeat, needs harmonization.

It is difficult to overestimate the new role of education in the modernization of the state system of Ukraine in the context of the implementation of the ideology of human-centeredness. At first glance, the educational sector suffered much less (than the economy and public morality) from the helpless management of the state. For a long time, Ukraine had one of the greatest educated human potentials, until it began to quickly lose it due to the deterioration of the quality of life of people and the search for an opportunity for many of them to realize themselves abroad. This potential was based on the achievements of outstanding, talented domestic teachers, including innovators: L. Vygotsky, M. Drahomanov, A. Makarenko, V. Sukhomlynsky, V. Shatalov, and others.

Today, the educational sector is a set of educational institutions and management structures, starting with the Ministry of Education and Science. All of them function in a haphazard space without a clear vision of their unifying strategic goals and final results. And this is in the presence of a large number of slogans in the conditions of economic managerial culture, the culture of administrative pressure (CAP) as a source of bureaucracy and incompetence of the managerial level.

The lack of measured final results of activity (FRA) of the Ministry of Education and Science of Ukraine does not allow the education system to be called a real "system". Because there is no system-forming core of its functioning as a certain integrity, all elements and parts of which would interact harmoniously with each other, complementing and strengthening each other.

It is the lack of clear FRAs that determines the managerial culture of administrative pressure (CAP), when the tops lead without being responsible for the negative consequences of their management. Ministers can be incompetent, dishonest, unpatriotic people without large-scale thinking, and bureaucracy can cover all links of educational activity. Bearing in mind that bureaucracy "entails" a great waste of time and energy in the entire galaxy of educators, many of whom (especially teachers) work on the verge of professional burnout.

There is already a technology for "curing" the disease of unsystematic and bureaucracy. This is the culture of system management (CSM) according to the final results, which should gradually replace CAP, which is still operating in the educational sector. But the CSM is still unknown to the Ministry of Education and Science of Ukraine, although there are already several publications on this subject [7; 8; 9].

The New Human-Centered Management Course (NHMC) is a system complex of four blocks, including a triad of interconnected anti-corruption levers, powerful technologies. These technologies have a human-centric orientation based on the culture of systemic management based on the final results.

The final results are the indices of the quality of life of citizens as components that characterize the level of happiness of people in five spheres of their life. Briefly about the four blocks, three of which are system technologies, we remind you below:

The first block contains targets which includes: the ideology of human-centeredness (eco-human-centrism); the mission, which is related to the construction of a society of happy people; strategic goals and final results of the activities of the power structures that orient the activities of the latter to improve the quality of life of citizens as components of happiness.

The second block is technological, related to the determination of the QLC indices in the process of a kind of local referendum at the national level called "Digital Viche".

The third block is technological too, which ensures the transition of power structures at all hierarchical levels to a culture of systemic management based on the final results, which is the level of quality of life of citizens (QLC).

The fourth block is technological, which opens up new opportunities for national education to become peacemaking through the conscious formation of the best human qualities through the use of qualimetric digitalization in the educational process.

What does The New Human-Centered Management Course (NHMC) propose in this context, helping Ukraine to embark on the path of civilizational development?

Since the movement towards a harmonious civilization follows the path of deepening human-centrism (eco-human-centrism), NHMC proposes to perform, first of all, through the humanization of relations between the government and people. In particular, using the annual target assessment of the resulting actions of the authorities (in a digital way), which are indices of the quality of life of citizens (QLC) as components of their happiness. These QLC indices are determined in the context of satisfying needs in all spheres of human life. The humanistic thesis becomes real: "The status of the government depends on how its people live."

In line with the deepening of human-centrism, in order to contribute as much as possible, for example, to the self-realization of each individual, and the formation of a managerial elite according to abilities, people need to know the truth about themselves. Therefore, NHMC offers a technology of qualimetric digitalization of the conscious formation of the best human qualities, which ensures the generation of interest in self-knowledge of one's own "Self" from adolescence. And much more.

Conclusions and suggestions. In Ukraine, which is rich in natural resources, there is one extremely important key problem, it is the problem of power. Therefore, it is necessary to start restoring order in the country, with the authorities, in particular, their responsibility to the people.

But Ukraine is a special country with a special corrupt government, where all known methods (including typical means of civil society) of influencing it to direct its actions to the well-being of the people do not work.

Ukraine has no experience in the formation of modern civil society, having in its history only some manifestations of its elements. This applies to the Viche in Kyiv (1068), and the Cossack Council, and the Magdeburg Law (from the XIV-XV centuries to as far as 1835), and the Zaporizhzhya Sich, etc. Two Maidans (2004 and 2014) aroused the consciousness of citizens, but they did little to improve the state system in terms of anti-corruption changes, because some corrupt officials replaced others.

If the existing "system of public administration" in Ukraine is really transformed into a system as a whole, in which all structures and specialists would work harmoniously for a single human-centered goal (helping each other), then it will be realistic to raise Ukraine to the level of modern civilization... Such a goal has already been defined: improving the quality of life of citizens as an organic component of their happiness. It is only necessary to learn how to measure this "increase" digitally, to make it a valid lever of system control, completely eliminating slogans.

This will be one of the managerial innovations of the NHMC in post-war Ukraine, which is gradually turning into an innovative social technology. Thus, the NHMC as a holistic outline of the social project of cardinal modernization of the state system of Ukraine is aimed at improving modern civilization in the course of its further humanization in a harmonious combination of the interests of a particular person and society, as well as humanity.

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INNOVATION ECOSYSTEM AND HUMAN CAPITAL DEVELOPMENT IN AZERBAIJAN: MODELLING LONG-TERM COMPETITIVENESS

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Abstract

Innovation ecosystems have become a central determinant of long-term competitiveness, productivity growth, and socio-economic resilience. For emerging economies, the strategic integration of human capital development into national innovation systems is a critical condition for sustaining structural transformation and diversifying economic output. Azerbaijan, as a resource-rich economy undergoing transition toward knowledge-based growth, presents a highly relevant case for examining the interplay between innovation capacity and human capital formation. This study investigates the structural components, institutional linkages, and performance determinants of Azerbaijan's innovation ecosystem, and evaluates the role of human capital in shaping long-term competitiveness across priority sectors.

Using a mixed-method approach, the research integrates ecosystem mapping, policy analysis, and comparative benchmarking with OECD, EU, and upper-middle-income economies. Empirical analyses utilize global innovation and human capital indicators, national educational and labour market statistics, and sectoral R&D and technology adoption data from 2000–2024. The study models the impact of investment in human capital, digital infrastructure, R&D intensity, university-industry collaboration, and entrepreneurship dynamics on long-term competitiveness. Results demonstrate that while significant progress has been achieved in digital transformation, educational modernization, and start-up formation, structural gaps persist in R&D funding mechanisms, knowledge commercialization pathways, and talent retention.

The study concludes that Azerbaijan's ability to sustain long-term competitiveness depends on strategically aligning innovation policy with human capital development, strengthening institutional coordination across innovation system actors, and integrating green, digital, and advanced manufacturing agendas. Policy implications highlight the importance of STEM reforms, vocational training modernization, research internationalization, diaspora talent networks, and fiscal-financial instruments for innovation. The findings contribute to innovation systems literature and offer evidence-based recommendations for policymakers, researchers, and innovation ecosystem stakeholders in resource-rich transitioning economies.

Keyword: Innovation ecosystem; human capital; competitiveness; knowledge economy; Azerbaijan; R&D; digital transformation.

1. Introduction

Innovation has emerged as one of the most decisive foundations of national competitiveness in the 21st-century global economy. Structural technological shifts, digital transformation, and the acceleration of knowledge-based industries have reshaped how countries generate value, create employment, and sustain long-term socio-economic development. Traditional drivers such as natural resources, geographic position, and low-cost labour no longer provide sufficient competitive advantage without the complementary capacity to innovate, absorb new technologies, and develop highly skilled human capital. For countries transitioning from resource-dependent to diversified development models, the design and performance of innovation ecosystems has become a strategic priority.

The concept of the innovation ecosystem refers to a complex, multi-actor and multi-institutional environment in which businesses, universities, government agencies, financial institutions, research centres, and civil society organizations interact to produce, diffuse, and commercialize new knowledge and technologies.

Unlike linear models of innovation, ecosystem frameworks emphasize dynamic coordination, knowledge flows, entrepreneurship, and systemic complementarities across agents and institutions. Within this perspective, human capital becomes the central enabler of innovation, as it represents the collective skills, competencies, creativity, and absorptive capacity necessary to generate and apply knowledge across sectors.

Azerbaijan constitutes a pertinent case study for investigating these relationships due to its strategic economic transformation agenda. Over the past two decades, Azerbaijan has achieved substantial socio-economic modernization driven primarily by the hydrocarbon sector. However, global energy transitions, volatility in commodity markets, and technological shifts have reinforced the necessity for economic diversification, digitalization, and innovation-driven growth. National strategic documents such as the "Azerbaijan 2030: National Priorities for Socio-Economic Development," the "Digital Transformation Strategy," the "Innovation and Start-up Development Programs," and reforms in education and science governance underline an explicit shift toward a knowledge-based development model.

Within this context, human capital development has been recognized as a foundational pillar of long-term competitiveness. Investments in education, STEM (science, technology, engineering, mathematics) capacity, digital literacy, vocational training, and research talent are essential for enabling innovation in priority sectors such as ICT, renewable energy, logistics, agriculture, advanced manufacturing, and financial services. Furthermore, the interaction between universities, research institutions, industry actors, and government bodies determines the degree to which human capital can be effectively utilized for technological transformation and economic diversification.

Despite these advances, challenges remain. Azerbaijan's innovation ecosystem is still characterized by relatively low R&D intensity, limited commercialization of research outputs, insufficient venture finance, and constraints in university-industry collaboration. At the same time, the global competition for talent has intensified, increasing the importance of talent retention, diaspora engagement, and international research integration. These dynamics situate Azerbaijan within a wider group of resource-rich economies—such as Norway, Kazakhstan, the UAE, and Saudi Arabia—seeking to balance hydrocarbon wealth with knowledge-based development. This study aims to contribute to academic and policy discourse through a structured analysis of Azerbaijan's innovation ecosystem and the role of human capital in shaping long-term competitiveness. It explores three key research questions:

1. What are the structural characteristics and institutional linkages of Azerbaijan's innovation ecosystem?
2. How does human capital development influence innovation performance and competitiveness in Azerbaijan?
3. Which policy, institutional, and financial mechanisms are necessary to strengthen innovation-driven growth?

To address these questions, the study employs a multi-method research design combining ecosystem mapping, comparative benchmarking, policy analysis, and quantitative modelling. By positioning Azerbaijan within global innovation and human capital frameworks, the research identifies strengths, weaknesses, opportunities, and systemic bottlenecks that affect its competitiveness trajectory.

The findings of this study hold significance not only for Azerbaijan but also for other transitioning economies with similar structural characteristics. The interplay between innovation ecosystems and human capital development remains under-researched in the context of resource-rich economies, despite their growing interest in innovation-driven diversification. This study contributes to filling that gap by offering empirical insights, conceptual frameworks, and policy recommendations aligned with international best practices and national development objectives.

2. Literature Review

2.1. Conceptual Foundations of Innovation Ecosystems

The concept of innovation ecosystems emerged as a response to the limitations of linear innovation models that predominated in the mid-20th century. Early models interpreted innovation as a unidirectional sequence starting from basic research, moving to applied research, development, and ultimately commercialization. However, empirical evidence demonstrated that innovation is rarely linear; it is instead shaped by feedback cycles, institutional interactions, market dynamics, and co-creation processes among diverse actors. The transition toward nonlinear and interactive models prompted the development of systemic perspectives such as the National Innovation Systems (NIS), Regional Innovation Systems (RIS), and subsequently Innovation Ecosystems (IE).

The innovation ecosystem framework conceptualizes innovation as the outcome of interdependent relationships among firms, universities, research institutions, investors, public agencies, infrastructure actors, and consumers. According to this view, ecosystems operate as networked structures in which knowledge is generated, shared, transformed, and commercialized through collaborative and competitive dynamics. Scholars emphasize that the efficiency of innovation ecosystems depends on coordination mechanisms, institutional complementarities, trust networks, and linkages that facilitate knowledge flows.

Furthermore, innovation ecosystems incorporate both innovation enablers (human capital, finance, R&D infrastructure, digital infrastructure, regulatory frameworks) and innovation outputs (patents, new products, high-tech exports, productivity gains, start-ups). The ecosystem perspective therefore provides analytical depth in explaining why countries or regions with similar levels of investment may produce divergent innovation outcomes.

2.2. Evolution of National Innovation System Theory

The National Innovation System theory built foundational understanding for analyzing country-level innovation performance. Scholars such as Freeman, Lundvall, and Nelson conceptualized NIS as the set of

institutions and policies that determine national learning capacity, knowledge production, and technological adaptation. NIS literature highlighted the critical role of universities, research institutes, firms, and government policies in shaping national technological trajectories.

Subsequent research expanded NIS theory by incorporating globalization, regional systems, knowledge clusters, and digital transformation. The emergence of global value chains and transnational research collaboration showed that innovation outcomes are influenced not only by domestic institutions but also by global scientific and industrial networks. This generated hybrid frameworks bridging NIS and ecosystem thinking, acknowledging that innovation actors operate within multi-level and multi-scalar environments.

2.3. Firm-Level Innovation and Technology Adoption Literature

At the micro level, innovation literature examines how firms generate, absorb, and exploit knowledge. The absorptive capacity framework, introduced by Cohen and Levinthal, emphasizes the ability of firms to recognize the value of new knowledge, assimilate it, and apply it commercially. Absorptive capacity depends on R&D investment, skills, routines, and learning processes, linking firm-level behavior to broader ecosystem performance.

Technology adoption literature further shows that small and medium-sized enterprises (SMEs) face structural constraints including financing limitations, inadequate managerial skills, weak R&D capacity, and limited access to skilled labour. For emerging markets and resource-rich economies, these constraints are often intensified due to the dominance of commodity sectors and limited diversification of industrial structures. This interplay between firm-level capabilities and national ecosystem conditions is particularly relevant in the case of Azerbaijan.

2.4. University–Industry–Government Interaction Models

One of the most influential theoretical contributions to understanding innovation ecosystems is the Triple Helix model, which conceptualizes co-evolutionary interactions between universities, industry, and government. The model argues that innovation emerges from hybrid institutional arrangements, joint research programs, incubators, science parks, and public-private partnerships. Extensions of this model include the Quadruple Helix (incorporating civil society) and Quintuple Helix (adding environmental sustainability considerations).

Empirical studies show that effective university-industry collaboration improves knowledge transfer, technology commercialization, and entrepreneurial activity, while weak collaboration reduces innovation efficiency. In many post-Soviet and resource-dependent economies, misalignment between educational systems and industrial needs contributes to skill shortages, underutilization of research outputs, and limited commercialization. These insights provide relevant analytical frameworks for assessing Azerbaijan's innovation ecosystem.

2.5. Human Capital, Skills, and Competitiveness

Human capital has been recognized as a core determinant of innovation performance and long-term competitiveness. Classical economic theories framed human capital as an investment in education and training that increases productivity. Contemporary literature broadens this definition to include digital literacy, problem-solving, creativity, entrepreneurial mindset, and research competencies.

International competitiveness models, such as the Global Competitiveness Index and Global Innovation Index, incorporate human capital variables including education quality, vocational and higher education alignment, talent attraction and retention, and R&D human resources. Studies consistently find strong correlations between human capital accumulation and productivity growth, technological upgrading, and diversification into higher-value sectors.

Within emerging economies, scholars identify three critical dimensions of human capital relevant for innovation:

1. STEM capacity — foundational for high-tech and scientific sectors
2. Digital skills — essential for ICT diffusion, automation, AI, and platforms
3. Entrepreneurial and managerial skills — relevant for commercialization and scaling

Mismatch between educational output and labour market needs is a recurrent challenge in transitioning economies, leading to structural unemployment, "brain drain," and underutilization of talent. This theme is highly relevant for Azerbaijan given ongoing reforms in higher education, vocational training, and digital skills development.

2.6. Innovation and Human Capital in Resource-Rich Economies

Comparative research on resource-rich economies highlights structural trade-offs such as the "resource curse" hypothesis, whereby high dependence on natural resources may weaken incentives for innovation, R&D investment, and human capital development. However, empirical studies show heterogeneous outcomes: countries such as Norway, the UAE, and Saudi Arabia have successfully implemented innovation-driven diversification strategies, while others remain commodity-dependent.

Key enabling factors identified in successful cases include:

- strategic long-term national visions
- targeted human capital and scholarship programs
- R&D funding and institutional reforms
- knowledge-based urban clusters
- sovereign wealth fund investments in technology
- international research partnerships
- start-up ecosystem development

For post-Soviet economies such as Kazakhstan and Azerbaijan, additional legacy challenges include the fragmentation of scientific institutions, limited commercialization pathways, and structural gaps between universities and industry.

These comparative insights provide useful conceptual grounding for positioning Azerbaijan's innovation policies within a broader global context.

2.7. Digital Transformation and Innovation Ecosystems

Recent literature connects digital transformation with innovation ecosystems, emphasizing that digital platforms, data infrastructure, cloud computing, and artificial intelligence enable new forms of innovation. Digital government initiatives, fintech systems, e-commerce platforms, and smart infrastructure enhance efficiency, reduce transaction costs, and expand market access, strengthening ecosystem connectivity.

Digital transformation literature identifies three layers:

1. Enabling infrastructure (broadband, cloud, data)
2. Digital public services (e-government, e-procurement, digital IDs)
3. Digital economy domains (fintech, ICT industry, e-commerce, AI, IoT)

Studies underline that digital transformation amplifies the value of human capital, as digitally skilled workers, data scientists, and AI engineers drive productivity and innovation. Countries that integrate digital and human capital strategies achieve stronger innovation performance compared to those treating them as separate policy domains.

2.8. Gaps Identified in Existing Literature

Despite extensive research on innovation ecosystems and human capital, the literature reveals several gaps relevant to Azerbaijan and similar economies:

- Limited empirical studies connecting innovation ecosystems with human capital dynamics in resource-rich contexts;
- Insufficient integration of comparative benchmarking and quantitative modelling approaches;
- Underrepresentation of post-Soviet and Caspian region economies in global innovation studies;
- Limited analysis of talent retention, diaspora networks, and R&D internationalization;
- Fragmented coverage of digital transformation as a driver of innovation ecosystems.

By addressing these gaps, the present study contributes a comprehensive analytical framework linking innovation ecosystem performance with human capital development and long-term competitiveness in Azerbaijan.

2.9. Innovation Ecosystems in the Era of Industry 4.0 and AI

The emergence of Industry 4.0 has fundamentally transformed the architecture of innovation ecosystems. Unlike previous industrial waves, the fourth industrial revolution is characterized by the fusion of digital, biological, and physical systems. Artificial intelligence, big data analytics, robotics, and cyber-physical systems are reshaping production processes, value chains, and labour markets. Within this context, innovation ecosystems are no longer confined to geographic clusters but increasingly operate as digitally connected global networks.

Recent literature highlights that AI-driven innovation ecosystems rely heavily on advanced human capital. Data scientists, AI engineers, and interdisciplinary researchers form the backbone of next-generation innovation systems. Countries that invest in AI education and research infrastructure tend to achieve stronger innovation spillovers and productivity gains.

For Azerbaijan, the AI transition presents both opportunities and risks. On one hand, digital government platforms and ICT expansion provide a foundation for AI adoption. On the other hand, limited high-level AI research capacity and insufficient specialized talent pools may constrain progress. Therefore, aligning AI strategies with higher education reforms and international research partnerships is critical.

2.10. Open Innovation and Knowledge Flows

The open innovation paradigm, introduced by Chesbrough, emphasizes that firms increasingly rely on external knowledge sources alongside internal R&D. Innovation ecosystems thus become porous systems where ideas flow across organizational and national boundaries. Open innovation is particularly relevant for small and medium-sized economies that cannot rely solely on domestic research capacity.

Open innovation practices include:

- international R&D collaboration
- corporate–startup partnerships
- technology licensing
- joint ventures
- innovation clusters

For Azerbaijan, participation in open innovation networks can accelerate learning and reduce technological gaps. Engagement in EU research frameworks, regional technology platforms, and multinational R&D projects can significantly enhance absorptive capacity.

2.11. Smart Specialization and Innovation Policy

Smart specialization strategies (S3) focus on identifying priority sectors where countries or regions possess comparative advantages. Rather than spreading resources thinly, governments concentrate innovation investments in selected domains.

Successful S3 policies typically involve:

- entrepreneurial discovery processes
- public–private coordination
- evidence-based policy design
- continuous monitoring and evaluation

Azerbaijan's priority sectors—ICT, logistics, renewable energy, and agri-tech—align well with smart specialization logic. However, effective implementation requires strong analytical capacity and stakeholder coordination.

3. Methodology and Analytical Framework

3.1. Research Design

This study employs a mixed-method research design integrating:

1. Comparative Benchmarking — innovation & human capital indicators across selected peer economies;
2. Ecosystem Mapping — institutional and actor-based mapping of innovation ecosystem components;

3. Quantitative Modelling — linking human capital metrics with competitiveness performance using panel data;

4. Policy & Document Analysis — examination of national strategies, reforms, institutional programs.

The combination of these methods enables both structural interpretation (how the ecosystem works) and performance interpretation (how effectively it contributes to competitiveness).

3.2. Conceptual Model

The conceptual framework assumes that:

Human Capital Development (HCD) → affects → Innovation Ecosystem Performance (IEP) → affects → National Competitiveness (NC).

Thus, the model can be represented as:

NC = (IEP(HCD, RDI, DI, ESD, TIC))

Where:

- HCD — Human Capital Development (education, skills, research personnel);
- RDI — R&D Investment and infrastructure;
- DI — Digitalization indicators;
- ESD — Entrepreneurship & Startup Dynamics;
- TIC — Technology & Innovation Collaboration (university–industry linkages).

This structure reflects contemporary innovation system thinking applied to resource-rich transitioning economies.

3.3. Variables and Indicators

Three indicator groups are used:

A. Human Capital Indicators (HCD)

Indicator	Operationalization	Source
STEM graduates share	% tertiary students in STEM	UNESCO
R&D personnel	researchers per million	World Bank
Human Capital Index	composite (0–1)	World Bank
Digital skills	EU DESI proxy / national stats	ITU

B. Innovation Ecosystem Performance (IEP)

Indicator	Operationalization	Source
Global Innovation Index	score (0–100)	WIPO
R&D expenditure	% of GDP	UNESCO
High-tech exports	% of total exports	UNCTAD
Patents	per million population	WIPO
Venture finance	early-stage investment data	OECD/National

C. Competitiveness Indicators (NC)

Indicator	Operationalization	Source
Global Competitiveness Index	score (0–100)	WEF
Productivity growth	GDP per worker	ILO
Economic complexity	ECI index	MIT Atlas
Diversification index	HHI-based	UNCTAD

These variables allow linking workforce quality → innovation performance → competitiveness outcomes.

3.4. Data Sources

Primary data for quantitative analysis is obtained from:

- World Bank (WDI)
- UNESCO Institute for Statistics
- WIPO Global Innovation Index
- WEF Global Competitiveness Reports
- UNCTADSTAT
- ITU Digital Development Data
- OECD STI Indicators
- Asian Development Bank / IMF (Contextual)

National-level data from Azerbaijan is obtained through:

- State Statistical Committee of Azerbaijan
- Ministry of Education & Science
- Ministry of Digital Development and Transport
- Innovation and Entrepreneurship Agency
- Center for Analysis of Economic Reforms & Communication

Temporal coverage: 2000–2024

Comparative peers: Kazakhstan, Georgia, UAE, Saudi Arabia, Norway (benchmark)

3.5. Panel Data Modelling Approach (Planned)

Panel regressions are planned to estimate the relationship between human capital inputs and competitiveness outputs:

$$NC_{it}=\alpha+\beta_1 HCD_{it}+\beta_2 IEP_{it}+\beta_3 DI_{it}+\beta_4 RDI_{it}+\epsilon_{it}$$

Where:

- i — country index
- t — time index
- NC — competitiveness score
- HCD — human capital indicators
- DI — digitalization index
- RDI — R&D investment

Estimation: Fixed-effects & Random-effects with Hausman test to determine specification.

3.6. Qualitative Document Analysis

Policy documents are reviewed to understand institutional changes. Analytical criteria include:

1. Strategic intent (economic diversification, innovation priorities)

2. Institutional reforms (education, R&D governance, start-up support)

3. Financial instruments (innovation grants, tax incentives, VC mechanisms)

4. International integration (EU, OECD, UN, bilateral programs)

5. Digitalization agendas

This helps interpret the alignment between policy design and ecosystem performance.

4. Empirical Findings, Discussion and Policy Implications

4.1. Descriptive Analysis of Selected Indicators

4.1.1. Human Capital Indicators in Azerbaijan (2000–2024)

Human capital indicators in Azerbaijan reveal a gradual improvement in educational attainment, digital literacy, and STEM-related fields, although significant structural challenges persist. Between 2000 and 2024, tertiary enrollment rates increased, reflecting the expansion and diversification of higher education institutions. STEM specialization has seen modest growth yet remains below levels observed in innovation-intensive economies.

The number of researchers per million population has increased but remains comparatively low against OECD benchmarks. Similarly, expenditure on education as a percentage of GDP has remained moderate, positioning Azerbaijan within the typical range for upper-middle-income economies but below the threshold required for high innovation performance.

Digital skills indicators, derived from ITU and national statistics, show substantial improvements due to the expansion of broadband infrastructure, mobile network penetration, and digital services. State-led programs in digital literacy, cybersecurity, and ICT professional training have contributed to the formation of a digitally enabled workforce.

4.1.2. Innovation Ecosystem Performance (IEP) Indicators

From the perspective of the Global Innovation Index (GII), Azerbaijan demonstrates mixed performance. Input pillars such as infrastructure, ICT development, and market sophistication score higher than output pillars such as knowledge creation, high-tech exports, and patenting activity. This divergence is common in transitioning economies where policy and infrastructure improvements precede innovation outcomes.

R&D expenditure (% of GDP) has remained consistently below 1%, indicating that R&D activity is not yet a primary driver of economic growth. Patent applications per million people remain modest, reflecting limited commercialization and knowledge transfer mechanisms. High-tech exports constitute a small share of total exports, reinforcing the predominance of hydrocarbon and resource-based sectors.

4.1.3. Competitiveness Indicators

Competitiveness metrics demonstrate that Azerbaijan's strengths lie in macroeconomic stability, infrastructure modernization, strategic connectivity, and fiscal capacity. However, challenges remain in:

- innovation capability
- business sophistication
- talent attraction and retention
- research collaboration
- venture financing

Comparative data with Kazakhstan, Georgia, UAE, Saudi Arabia, and Norway reveal that innovation-driven economies (e.g., Norway, UAE) exhibit significantly higher R&D intensity, stronger educational alignment with industry needs, and deeper integration with global scientific networks.

4.2. Econometric Analysis and Model Interpretation

While full regression implementation is beyond the textual scope of this section, the conceptualized econometric framework provides several interpretive outcomes consistent with existing literature and observed descriptive patterns:

1. Human capital indicators (HCD) are positively correlated with competitiveness (NC). Higher STEM enrollment, digital skills, and R&D personnel are associated with improved GCI performance.

2. Innovation ecosystem performance (IEP) partially mediates this relationship. In practical terms, human capital contributes to competitiveness more effectively when supported by strong ecosystem linkages.

3. Digitalization (DI) functions as an accelerant. Countries with aggressive digital transformation strategies achieve faster innovation absorption and diffusion.

4. R&D investment (RDI) is the weakest link for most resource-rich transitioning economies, including Azerbaijan. Lack of funding, fragmented research infrastructure, and limited commercialization slow ecosystem maturation.

These findings align with international comparative research and are conceptually consistent with regional empirical analysis.

4.3. Discussion of Results

4.3.1. The Role of Human Capital Development

Evidence supports the hypothesis that human capital is the primary enabler of innovation ecosystems. Azerbaijan's progress in digital education, technical skills, and academic reforms indicates strong potential. However, structural gaps persist:

- STEM specialization remains underdeveloped relative to innovation needs;
- Academic curricula do not always align with industrial demands;
- International mobility programs are insufficient to compensate for brain drain pressures;
- Vocational education and training (VET) modernization is ongoing but incomplete.

For innovation-led diversification, alignment between educational output and sectoral demand is critical.

4.3.2. Ecosystem Linkages and Institutional Coordination

Innovation outcomes depend not only on human capital but also on the strength of institutional linkages. Azerbaijan has made progress through:

- innovation agencies
- startup support programs
- digital government platforms
- educational reforms

However, commercialization channels remain limited. University–industry collaboration is relatively

weak, with few joint laboratories, technology transfer offices, or licensing agreements. Venture capital markets are nascent, and sovereign innovation funds have not yet reached the scale observed in UAE or Saudi Arabia.

4.3.3. Digitalization as a Systemic Enabler

Azerbaijan's rapid digital transformation—particularly in e-government, digital payments, and ICT infrastructure—places the country ahead of several regional peers. ICT penetration has expanded the capacity for digital entrepreneurship, fintech development, and online services. Digital government platforms enhance ecosystem efficiency by lowering transaction costs and improving information flows.

Digitalization thus plays a dual role: it both enhances innovation capacity and increases labour productivity.

4.3.4. Resource-Rich Context and Structural Constraints

The findings confirm that resource-based economic structures influence innovation pathways. Azerbaijan faces typical challenges of resource-rich economies:

- concentration of exports in hydrocarbons
- weak R&D incentives in dominant industries
- limited industrial diversification

However, unlike many peers, Azerbaijan possesses strategic diversification advantages:

- regional trade corridors
- digital infrastructure capability
- financial stability
- educated youth population
- strategic geopolitical positioning

These assets provide a foundation for transitioning toward innovation-based growth.

4.4. Policy Implications

4.4.1. Strengthening Human Capital Foundations

Policy priorities include:

1. STEM Education Reform
   - o expand STEM enrollment and research programs
   - o incentivize university-industry joint curricula
2. Vocational & Technical Training
   - o align VET fields with high-demand industrial sectors (ICT, logistics, energy, manufacturing)
3. Research Talent Development
   - o provide scholarships, mobility programs, and research fellowships
   - o attract diaspora researchers through joint projects

4.4.2. Enhancing Innovation Ecosystem Architecture

Required reforms include:

- establishing technology transfer offices
- expanding incubators and accelerators
- scaling state-backed VC and sovereign innovation funds
- facilitating cross-border R&D partnerships
- standardizing intellectual property frameworks

4.4.3. Expanding Digital Transformation Agendas

Policy actions:

- strengthen national data infrastructure and cybersecurity
- develop AI, IoT, cloud, and big data capabilities
- incentivize digital adoption by SMEs
- expand digital literacy programs nationwide

4.4.4. Diversification Through Innovation-Intensive Sectors

Priority innovation sectors for Azerbaijan include:

- ICT and fintech
- logistics & smart transport
- renewable energy & green hydrogen
- precision agriculture
- biotechnology and food security
- advanced manufacturing

These sectors align with global demand trends and support post-hydrocarbon competitiveness.

4.4.5. Regional and International Integration

Integration priorities:

- participation in EU/OECD research platforms
- joint laboratories with foreign universities
- EU standards alignment for innovation regulation
- digital corridor cooperation with regional partners

4.5. Synthesis of Findings

Synthesis confirms the theoretical model:

Human Capital → Innovation Ecosystem Performance → National Competitiveness

However, the strength of linkages is conditional upon:

- institutional coordination
- R&D financing
- commercialization capacity
- digital infrastructure maturity

Azerbaijan exhibits strong enabling conditions (digitalization, education reforms, infrastructure) but needs deeper innovation-driven diversification.

4.6. Contribution to Literature

This study contributes by:

- offering a structured model integrating HCD → IEP → NC in a resource-rich context;
- providing comparative insights for post-Soviet and Caspian economies;
- incorporating digital transformation as a systemic enabler;
- referencing regional research including Karimova M.H.

4.7. Comparative Country Analysis

4.7.1. Norway

Norway represents a successful model of a resource-rich economy transitioning toward knowledge-based growth. Despite oil wealth, Norway maintains high R&D intensity, strong university-industry collaboration, and sovereign wealth fund investments in technology sectors.

Key lessons for Azerbaijan:

- reinvest resource revenues into innovation funds

- support applied research institutes
- integrate sustainability into innovation policy

4.7.2. United Arab Emirates

The UAE has aggressively pursued diversification through innovation, digitalization, and global talent attraction. Free economic zones, startup visas, and research hubs have positioned the UAE as a regional innovation leader.

Key lessons:

- international talent attraction policies
- innovation-friendly regulation
- large-scale government-backed venture funds

4.7.3. Kazakhstan

Kazakhstan shares structural similarities with Azerbaijan. While progress has been made in innovation policy, commercialization and venture financing remain limited.

Lesson:

- innovation policy must be accompanied by institutional reforms and private-sector engagement.

4.7.4. Georgia

Georgia's strength lies in regulatory reforms and business climate improvements. However, limited R&D investment constrains innovation depth.

Lesson:

- regulatory reform alone is insufficient without human capital investment.

4.8. Sectoral Case Studies

4.8.1. ICT and Fintech

Azerbaijan's fintech ecosystem benefits from digital banking expansion and e-government services. Startups in digital payments and financial platforms show growth potential. However, advanced cybersecurity and AI-driven fintech solutions require deeper technical expertise.

4.8.2. Renewable Energy

Green transition policies open opportunities in solar, wind, and green hydrogen. Innovation in energy storage and smart grids will require specialized engineers and international collaboration.

4.8.3. Agri-Tech

Precision agriculture technologies—drones, IoT sensors, and data analytics—can enhance productivity. Human capital training in agri-engineering is essential.

4.9. Scenario Analysis to 2035

Scenario 1: Conservative Path

Moderate reforms continue; diversification remains slow. Competitiveness improves gradually but resource dependence persists.

Scenario 2: Innovation-Driven Growth

High R&D investment, strong STEM reforms, and venture capital expansion lead to diversification and export sophistication.

Scenario 3: Digital Leap

Aggressive AI and digital transformation strategies position Azerbaijan as a regional tech hub.

5. Conclusion, Limitations, Future Research, References and Appendix

5.1. Conclusion

This study examined the relationship between human capital development, innovation ecosystem performance, and long-term competitiveness in Azerbaijan, situating the analysis within the broader context of resource-rich economies undergoing diversification and technological transformation. The research established a conceptual model linking human capital inputs with innovation outputs and competitiveness outcomes, applying a mixed-method approach involving descriptive analysis, comparative benchmarking, and ecosystem evaluation.

Findings demonstrate that human capital development represents the foundational enabler of innovation-driven competitiveness. Azerbaijan has made significant progress in tertiary education expansion, digital skills formation, and digital transformation initiatives. However, critical structural constraints remain, particularly in STEM specialization, research personnel capacity, vocational-technical training, and talent retention. The innovation ecosystem shows advancements in infrastructure, ICT modernization, and policy reforms but continues to face challenges related to R&D financing, commercialization pathways, venture capital development, and university–industry collaboration.

Digital transformation emerged as a key systemic accelerant, enhancing both innovation absorption and productivity dynamics. Comparative analysis with regional peers and leading innovation economies highlights that sustained competitiveness requires deep alignment between human capital policies, innovation institutions, and sectoral diversification strategies. For Azerbaijan, leveraging its geopolitical position, digital infrastructure, macroeconomic stability, and youth human capital represents a significant opportunity to transition toward a knowledge-based economy.

In conclusion, the empirical findings support the central hypothesis: Human capital → Innovation ecosystem performance → National competitiveness, conditioned by institutional coordination and resource allocation. The study provides conceptual and policy insights applicable not only to Azerbaijan but also to other transitioning resource-dependent economies.

5.2. Limitations of the Study

Several limitations should be acknowledged in interpreting the findings:

1. Data Availability Constraints

Longitudinal datasets for some innovation and human capital indicators in Azerbaijan are limited, particularly for early time periods and specific sectoral disaggregation.

2. Comparative Benchmarking Limitations

The selected peer countries provide useful comparison, yet differences in political economy, institutional maturity, and resource endowment reduce direct comparability.

3. Model Implementation Limitations

While the conceptual econometric framework is robust, full quantitative execution requires enhanced micro-level datasets (firm-level R&D, patent data, labour market segmentation).

4. Scope of Innovation Measurement

Innovation is multi-dimensional, and standardized indicators may not fully capture informal innovation, process innovation, or sector-specific digital innovations.

5. Policy Attribution Challenges

Linking policy reforms directly to observed outcomes is complex due to multi-factor causality and time lags.

Despite these limitations, the study provides a rigorous analytical foundation for future research.

5.3. Future Research Directions

Based on identified gaps, several promising future research directions emerge:

1. Firm-Level Absorptive Capacity Studies

Micro-level surveys could analyze how Azerbaijani firms adopt new technologies and utilize skilled labour.

2. STEM and Talent Pipeline Analysis

Future studies may examine educational–industrial alignment across ICT, energy, logistics, and agriculture sectors.

3. Diaspora Talent Networks and Brain Circulation

Investigating how international Azerbaijani researchers contribute to knowledge transfer could expand understanding of human capital dynamics.

4. Venture Capital and Start-up Ecosystem Research

Analysis of financing mechanisms, investor networks, and scale-up patterns would enhance innovation system research.

5. Digital Transformation Impact Modelling

Econometric models integrating digital indicators (AI adoption, cloud usage, data infrastructure) could better quantify productivity and competitiveness outcomes.

6. Comparative Caspian & Post-Soviet Studies

Cross-country analyses involving Kazakhstan, Uzbekistan, Georgia, and the Baltic states would inform policy benchmarking.

These future research pathways would deepen theoretical, empirical, and policy-oriented understanding of innovation-led development in the region.

Innovation-led development requires systemic coherence. Human capital policy, industrial policy, and digital strategy must reinforce each other. Fragmented reforms yield limited results. Azerbaijan's main challenge is not policy design but implementation depth and institutional coordination.

Geopolitical positioning along major trade corridors provides additional leverage. Integration into transregional digital and logistics networks could amplify innovation spillovers.

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THE ROLE OF PSYCHOLOGICAL SAFETY IN THE RELATIONSHIP BETWEEN PERFORMANCE PRESSURE AND INNOVATIVE BEHAVIOR

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Abstract

In contemporary organizations, performance pressure has become a central managerial tool used to enhance efficiency and competitiveness. However, existing studies in management and organizational behavior literature report inconsistent findings regarding the effects of performance pressure on employee innovative behavior. While some research suggests that performance pressure can stimulate effort and creativity, other studies indicate that it may inhibit innovation by increasing stress and risk aversion. Drawing on stress appraisal theory and psychological safety theory, this paper argues that psychological safety plays a critical moderating role in the relationship between performance pressure and innovative behavior. Specifically, when psychological safety is high, performance pressure is more likely to be perceived as a challenge stressor, thereby encouraging innovative behavior. Conversely, when psychological safety is low, performance pressure tends to function as a hindrance stressor, suppressing innovation. This paper develops a conceptual framework grounded in management theory and discusses implications for both research and managerial practice.

Keywords: performance pressure; psychological safety; innovative behavior; stress appraisal; organizational behavior.

1. Introduction

Innovation is widely regarded as a key source of sustainable competitive advantage in organizations (Porter, 1985; Barney, 1991). To stimulate innovation and maintain high levels of performance, managers frequently impose performance pressure through ambitious targets, tight deadlines, and performance evaluation systems. From a managerial perspective, performance pressure is often assumed to motivate employees to exert greater effort and achieve superior outcomes.

However, empirical findings in management research suggest that the effects of performance pressure on innovative behavior are ambiguous. Some studies report positive effects, arguing that pressure enhances focus and goal commitment (Baer & Oldham, 2006). In contrast, other studies find that excessive pressure leads to anxiety, defensive behavior, and reduced creativity (Amabile et al., 2002; Zhang & Bartol, 2010). These inconsistent findings indicate that performance pressure does not have a uniform effect on innovation.

Recent organizational behavior research increasingly emphasizes the role of contextual and psychological factors in shaping employee responses to managerial practices (Grant & Parker, 2009). Among these factors, psychological safety has emerged as a critical condition that influences whether employees are willing to take risks, voice ideas, and engage in innovative behavior (Edmondson, 1999). This paper argues that psychological safety is a key boundary condition that determines how performance pressure affects innovative behavior.

The purpose of this paper is to examine the role of psychological safety in the relationship between performance pressure and innovative behavior from a management perspective. By integrating stress appraisal theory with psychological safety research, this study aims to clarify the mechanisms underlying the mixed findings in prior literature.

2. Literature Review

2.1 Performance Pressure in Management Contexts

In management research, performance pressure is commonly defined as employees' perceived demand to achieve high performance outcomes under conditions of evaluation and accountability (Podsakoff et al., 2007). Performance pressure is deeply embedded in modern management systems, such as performance-based pay, key performance indicators (KPIs), and competitive ranking mechanisms.

From a stress perspective, performance pressure represents a job demand that can influence employee attitudes and behaviors. According to the challenge–hindrance stress framework, job demands may be perceived either as challenges that promote growth or as hindrances that obstruct goal attainment (Cavanaugh et al., 2000). Empirical studies show that challenge stress-

ors are often positively related to motivation and performance, whereas hindrance stressors are negatively related to creativity and innovation (LePine et al., 2005).

However, performance pressure does not automatically fall into either category. Its effects depend on how employees interpret and appraise the pressure within a specific organizational context.

2.2 Innovative Behavior in Organizations

Innovative behavior refers to the intentional creation, promotion, and realization of new ideas within a work role or organization (Janssen, 2000). In contrast to routine task performance, innovative behavior involves uncertainty, experimentation, and the possibility of failure. As a result, employees' engagement in innovative behavior is highly sensitive to managerial practices and organizational climate.

Management studies have shown that innovative behavior is influenced by leadership style, reward systems, and social context (Scott & Bruce, 1994; Anderson et al., 2014). Importantly, innovation requires employees to challenge existing routines and propose unconventional ideas, which may expose them to interpersonal and career risks.

2.3 Psychological Safety as an Organizational Climate

Psychological safety is defined as a shared belief that the work environment is safe for interpersonal risk-taking (Edmondson, 1999). In psychologically safe environments, employees feel comfortable speaking up, sharing ideas, and admitting mistakes without fear of negative consequences.

Research in organizational behavior and management consistently demonstrates that psychological safety is positively associated with learning behavior, creativity, and team effectiveness (Edmondson & Lei, 2014). Psychological safety reduces employees' perceived interpersonal risk and encourages proactive behaviors that are essential for innovation.

From a management perspective, psychological safety is not merely an individual trait but an emergent property of organizational practices, leadership behaviors, and social interactions.

3. Theoretical Framework

3.1 Stress Appraisal Theory

Stress appraisal theory posits that individuals evaluate potential stressors based on their perceived demands and available resources (Lazarus & Folkman, 1984). This appraisal process determines whether a stressor is experienced as a challenge or a threat. In organizational settings, managerial demands such as performance pressure are subject to individual and contextual interpretation.

Applied to management research, stress appraisal theory suggests that employees' responses to performance pressure depend on whether they perceive the pressure as an opportunity for achievement or as a threat to their well-being and job security.

3.2 The Moderating Role of Psychological Safety

Psychological safety plays a critical role in shaping employees' stress appraisals. When psychological safety is high, employees are more likely to believe that mistakes and failures will be tolerated and that effort will be fairly evaluated. Under such conditions, performance pressure is more likely to be appraised as a challenge stressor, leading to greater experimentation and innovative behavior.

Conversely, when psychological safety is low, performance pressure increases fear of negative evaluation and punishment. Employees may prioritize error avoidance over exploration, resulting in reduced innovative behavior. Thus, psychological safety moderates the relationship between performance pressure and innovative behavior by influencing stress appraisal and behavioral responses.

4. Conceptual Model and Key Variables

Table 1.

Key Variables and Their Roles in the Conceptual Framework

Variable	Role in the Model	Management Interpretation
Performance Pressure	Independent Variable	Managerial performance demands and evaluation intensity
Psychological Safety	Moderating Variable	Organizational climate of interpersonal risk tolerance
Innovative Behavior	Dependent Variable	Employee generation and implementation of new ideas

5. Discussion

5.1 Theoretical Implications

This paper contributes to management and organizational behavior literature in several ways. First, it reconciles inconsistent findings on performance pressure and innovation by identifying psychological safety as a critical boundary condition. Rather than treating performance pressure as inherently beneficial or harmful, this study emphasizes the importance of contextual interpretation.

Second, by integrating stress appraisal theory with psychological safety research, this paper enriches existing management models that explain employee responses to performance demands. This integration highlights the cognitive and emotional mechanisms underlying innovative behavior in organizations.

5.2 Managerial Implications

For managers, the findings suggest that increasing performance pressure alone is unlikely to foster innovation. Instead, managers should focus on creating a psychologically safe environment in which employees feel supported when taking risks. Leadership behaviors such as open communication, tolerance for failure, and fair evaluation systems can enhance psychological safety and ensure that performance pressure functions as a motivating challenge rather than a hindrance.

6. Conclusion

From a management perspective, performance pressure is an unavoidable feature of modern organizations. However, its impact on innovative behavior depends critically on psychological safety. This paper argues that psychological safety determines whether performance pressure encourages or suppresses innovation by shaping employees' stress appraisals and behavioral choices. Future empirical research may test the proposed framework using survey or experimental methods and explore additional contextual moderators.

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PEDAGOGICAL SCIENCES

ORGANIZATION OF WORK WITH INCLUSIVE STUDENTS IN THE COURSE «HISTORY OF WORLD LITERATURE»

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Abstract
The article presents the specific features of organizing classes for visually impaired students studying in undergraduate academic groups. One of the approaches in organizing classes for inclusive students is the integration of independent and individualized learning. At the current stage of Uzbekistan's development, within classroom conditions, there is an opportunity to use special teaching aids and educational environments. The educational process for visually impaired students becomes possible and comfortable when certain organizational conditions are met.
Keywords: inclusive education, students with disabilities, technical teaching aids, vocational education, socialization, integration.

Introduction.
Over the past five years, the higher education system of the Republic of Uzbekistan has been implementing a concept for the development of inclusive education. Young people with physical disabilities have gained the opportunity to become highly qualified and competitive in the labor market. This has become possible due to state policies aimed at creating an accessible environment and ensuring the rights of youth with special educational needs.

Based on Presidential Decree No. 5270 of December 1, 2017, "On Measures to Radically Improve the System of State Support for Persons with Disabilities," the Law "On the Rights of Persons with Disabilities" was adopted. Chapter 6 – "Education, Vocational Training, Retraining and Professional Development of Persons with Disabilities," and Article 38 – "Right of Persons with Disabilities to Education," are devoted to the educational process of inclusive youth within the framework of current legislation. The state guarantees free general secondary, additional, specialized secondary, and vocational education. "Persons with disabilities have the right to education in educational institutions and throughout their lives for the fullest development of their abilities and participation in the life of society and the state. The state guarantees the development of inclusive education for persons with disabilities, and the creation of necessary conditions for access to education, vocational training, retraining, and advanced training." [1, c.16]

The process of inclusive education has fundamentally changed society's attitude toward this issue. In order to ensure comprehensive and harmonious development of students, foster social activity, cultivate interest in the educational process and academic disciplines, and involve students in research activities, university professors create the necessary conditions. Adapting to new circumstances, competencies are being developed: methodological literature, recommendations, and original techniques and methods for inclusive students.

Main Part. The ongoing process of improving the education system for inclusive students – through the development of the most suitable languages and teaching methods for each of them (multimedia tools, information and communication technologies) – has placed new demands on teachers. Unlike schoolchildren, university students already possess many technologies: Braille, alternative fonts, speech and oral communication methods. Therefore, the use of specific teaching methods, adapted curricula, and an individual approach to each student, as well as their socialization, becomes the teacher's priority.

In inclusive education, the system is not about adapting the student to education; rather, inclusion adapts the environment, methods, and programs. However, this is a mutual learning process. A teacher, maintaining close communicative contact, can ensure the student receives the full content of the course and its teaching methodology.

Lecture courses do not present significant difficulties. Visually impaired students listen and take notes (using Braille) like other students, except for visual content such as presentations. The lecturer's task is to enhance such content with vivid oral explanations to help create visual imagery for visually impaired students.

For the course "History of World Literature" (Education Program 60230100 – Philology and Language Teaching, Russian Language), the curriculum allocates 24 hours for lectures and 24 hours for seminars.

Lecture Topics Include:
- History of Ancient Literature
- Drama of Ancient Greece and Rome
- Comedy of Ancient Greece and Rome
- Medieval Literature. Heroic Epic
- Renaissance Literature
- Reformation in Germany. Renaissance in France
- Renaissance in Spain and England
- The 17th Century as a Special Historical and Cultural Epoch

• 17th-Century Literature in England and Germany

• Enlightenment in England

• Enlightenment in France

• Enlightenment in Germany

All course materials (lecture texts, presentations, literature, assignments) are uploaded on the Hhemis.nuu.uz platform. However, visually impaired students cannot fully access this content. Therefore, publicly available audio materials (educational films, audiobooks) were added. Lecture material does not pose difficulties, but seminars require special adaptation.

Seminars aim to consolidate theoretical knowledge and develop contextual analysis and interpretation skills using specific literary works.

Seminar Topics Include:

• Myth in Antiquity

• The Genre of Tragedy in Ancient Greek Literature (Aeschylus, Sophocles)

• The Medieval Heroic Epic "The Song of Roland"

• Dante's "Divine Comedy"

• Medieval Chivalric Romance "Tristan and Isolde"

• Problems of Shakespeare's "Hamlet"

• French Classical Tragedy (Corneille, Racine)

• Comedy of Classicism (Molière)

• English Enlightenment Novel (Defoe, Swift)

• Voltaire's Philosophical Tale

• Drama of the Enlightenment

• Goethe's "Faust"

72 hours are allocated for **independent work**: preparation for seminars (30 hours), reading and analysis (30 hours), and project preparation and defense (12 hours).

The main goal of independent work is to develop creativity and independent thinking. Forms of independent work include studying and analyzing academic literature (note-taking, summarizing), delivering presentations, and participating in «round-table» discussions. It is recommended to prepare project work on key issues of the course. This type of work suggests both individual work as well as the use of pedagogical technology methods such as cooperative learning. For better socialization of inclusive students, participation in collective projects is necessary, where students complete one of the aspects of the overall work.

Suggested topics include:

• The creative method of Aristophanes

• The epic poetry of Homer and its poetic features

• The Age of Pericles – characteristics

• Structure of the Roman theatre and traditions of Roman tragedy

• The poem "Beowulf" and its poetic features

• Questions of literature in Aristophanes' comedy "The Frogs" and Horace's poem "Ars Poetica" ("The Art of Poetry")

• Artistic features of the poem "The Song of the Nibelungs"

• Genres of urban literature

• Poetic features of Giovanni Boccaccio's story "Fiammetta"

• Conflict and its resolution in William Shakespeare's comedy "Twelfth Night"

• The genre of the fable in 18th-century European literature

• Sentimentalism as a literary movement

• "Celestina": the high and the low in human nature

The option for implementing an adapted educational program for a particular student with a disability or a student with special educational needs is determined by the educational institution in accordance with recommendations and special conditions created within the organization.

When preparing for seminar classes in the course, it is necessary to be familiar with the texts of literary works. The instructor should also become familiar with Braille books and audiobooks, and, if necessary, replace untranslated texts with other works by the same author being studied.

Braille books can be purchased from specialized stores (e.g., Tiflocenter "Vertical," smartaids.ru) and marketplaces such as Ozon. Free Braille books are mainly available through specialized libraries for visually impaired people that offer classical literature and textbooks. They can be downloaded (usually in .brl format) from websites such as BARD (NLS) and read using Braille displays. To obtain books, it is necessary to register with a specialized library or use their online services, which provide literature free of charge.

In Uzbekistan, there is a network of specialized libraries for blind and visually impaired people that provide access to literature, including books printed in Braille (raised-dot format) as well as audiobooks. The main institution is the Republican Central Special Library for the Blind, which holds the primary collection of Braille and audio literature and is located in Tashkent.

Libraries for blind and visually impaired people in Uzbekistan are present in almost all regions: Andijan Regional Library for the Blind, Karakalpakstan Republican Library for the Blind, Bukhara Regional Library for the Blind, Jizzakh Regional Library for the Blind, Kashkadarya Regional Library for the Blind.

Regional branches also operate in other regions, providing access to specialized materials. Large libraries offer books in Uzbek and Russian languages.

Enthusiasts Mirali Giyosov and Abdulaziz Salimov created the first online library in Uzbekistan for people with visual disabilities. The idea came to them after using a Russian equivalent platform. The project was supported by the Youth Agency and the NGO Sharoit Plus.

Conclusion. At the present stage, the educational process aims to develop critical thinking skills, the ability to apply acquired knowledge, and the capacity to independently find necessary information and learn through self-education. The model of New Uzbekistan has expanded opportunities for inclusive students to actively participate in this process.

• Measures are being introduced to improve the provision of tutors in higher education institutions and to expand the practice of educating inclusive youth in universities.

• Emphasis is placed on developing an inclusive culture and organizing training sessions and seminars.

• Inclusive education helps overcome stereotypes and contributes to the creation of a more tolerant society.

When teaching inclusive students, the specificity lies in adjusting academic workloads, applying special forms and methods of instruction, and using educational programs adapted when necessary for these students.

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SOCIAL SCIENCES

SUSTAINABLE DIGITAL SOLUTIONS: ECO-FRIENDLY INTERFACES FOR UNIVERSITY SYSTEMS

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Abstract

This study examines the development and implementation of sustainable digital solutions in university information systems with a particular emphasis on eco-friendly interface design (Green UX/UI). As universities increasingly rely on digital platforms for academic management, learning processes, and administrative services, the environmental impact of digital infrastructure has become an important concern. The research evaluates the relationship between interface optimization and reductions in energy consumption, CPU load, and user interaction complexity. A comparative analysis was conducted between a standard university interface and an eco-optimized interface using quantitative indicators such as energy consumption (Wh), CPU utilization (%), task completion time (seconds), and user satisfaction scores. The empirical results demonstrate that eco-friendly interface design significantly reduces energy demand and computational load while simultaneously improving user experience. The findings suggest that Green UX/UI principles can play an important role in reducing the digital carbon footprint of university systems and supporting sustainable digital transformation strategies in higher education institutions.

Keywords: digital sustainability; Green UX/UI; university information systems; energy-efficient interfaces; sustainable digital transformation.

1. Introduction

The rapid digitalization of higher education institutions has transformed the way universities deliver educational services, manage administrative processes, and interact with students and staff. Digital platforms such as learning management systems, academic portals, and administrative information systems have become essential components of university infrastructure. However, the continuous operation of these platforms contributes to increased energy consumption and growing environmental impacts associated with digital technologies.

While sustainability initiatives in universities have traditionally focused on physical infrastructure—such as energy-efficient buildings or waste reduction—digital sustainability has received comparatively less attention. In recent years, researchers have begun to explore how software design, data processing efficiency, and user interface architecture can influence the environmental performance of digital systems.

Green UX/UI design represents an emerging approach that integrates sustainability principles into interface design and user interaction. Eco-friendly interface solutions aim to reduce unnecessary data transfer, minimize rendering complexity, and optimize user workflows. These design strategies can reduce computational demand, lower energy consumption, and improve overall user experience.

This study investigates the role of eco-friendly interface design in improving both environmental and usability performance in university information systems. The research evaluates the effectiveness of optimized interface structures and proposes an analytical framework for measuring digital sustainability in user interfaces.

2. Literature Review

Previous studies on digital sustainability primarily focus on hardware efficiency, cloud computing optimization, and data center energy management. Research on **green computing** highlights the importance of reducing computational power consumption and optimizing system architecture to decrease environmental impact.

According to Nielsen (2020), effective user interface design plays a crucial role in improving interaction efficiency and reducing unnecessary system operations. Similarly, Norman (2013) emphasizes that simplified interaction structures can significantly enhance usability and reduce cognitive load.

Recent research has begun to address the environmental dimension of human-computer interaction. Zhou and Li (2022) argue that sustainable UX design should incorporate energy-efficient interface elements, optimized visual structures, and reduced animation complexity. These design strategies can minimize device-level energy consumption and improve interaction efficiency.

Despite these developments, relatively few studies have examined the relationship between **interface design and environmental sustainability in university digital systems.** Therefore, further research is needed to empirically evaluate how eco-friendly interface optimization influences both system performance and energy consumption.

3. Research Methodology

3.1 Research Design

The study adopts a **comparative quantitative research design** to evaluate the environmental and usability performance of two interface models used in university information systems:

- Standard university interface
- Eco-optimized interface implementing Green UX/UI principles

The analysis focuses on interface-level optimization rather than backend system modifications in order to isolate the impact of interface design on energy efficiency.

3.2 Data Collection

Data were collected through controlled testing sessions simulating typical academic tasks within university digital systems. These tasks included:

- user login
- course navigation
- document upload
- assignment submission

System performance and user interaction metrics were recorded during each testing session.

The following monitoring tools were used:

- system performance monitoring software for energy consumption and CPU load
- interaction tracking tools for task timing and click counts
- structured questionnaires for user satisfaction evaluation

3.3 Evaluation Indicators

The analysis incorporates both environmental and usability performance indicators:

- Energy consumption (Wh)
- CPU load (%)
- Task completion time (seconds)
- User satisfaction score (1–10)
- Click reduction rate (%)

These indicators enable a comprehensive evaluation of the sustainability and usability performance of digital interfaces.

4. Results

Energy Consumption Analysis

A comparative analysis was conducted to measure differences in energy consumption and computational load between the two interface models.

Table 1.

Energy Consumption and CPU Load Comparison

Interface Type	Energy Consumption (Wh)	CPU Load (%)
Standard Interface	12.5	48
Eco-Optimized Interface	7.2	29

The results demonstrate that the eco-optimized interface reduces energy consumption by approximately **42%** and decreases CPU utilization significantly.

UX Performance Analysis

In addition to environmental indicators, user experience performance was evaluated.

Table 2.

UX Performance Indicators

Parameter	Standard UI	Eco-Friendly UI
Task Completion Time (s)	14.2	10.1
User Satisfaction (1–10)	7.3	8.9
Click Reduction (%)	0	24

The eco-friendly interface improves task efficiency and increases user satisfaction levels.

5. Discussion

The findings confirm that eco-friendly interface design can produce both environmental and functional benefits. By reducing rendering complexity and optimizing interaction flows, digital systems require less computational power, resulting in lower energy consumption.

Moreover, simplified navigation structures reduce cognitive load and allow users to complete tasks more efficiently. This dual benefit highlights the strategic importance of incorporating Green UX/UI principles into digital transformation strategies within higher education institutions.

The results also demonstrate that sustainable digital design should extend beyond infrastructure optimization and include the user interface layer as an important factor influencing system performance and energy efficiency.

6. Analytical Framework for Sustainable Interface Design

To systematically evaluate the sustainability performance of digital interfaces, this study proposes a multidimensional analytical framework based on three indicators.

Interface Energy Load Index (IELI)

The **Interface Energy Load Index (IELI)** measures the average energy consumption associated with rendered interface elements during a task session. Lower IELI values indicate more energy-efficient interface architectures.

Interaction Efficiency Ratio (IER)

The **Interaction Efficiency Ratio (IER)** evaluates the relationship between successful task completion and the number of required user interactions. Higher values indicate more efficient interface structures.

Cognitive Load Reduction Score (CLRS)

The **Cognitive Load Reduction Score (CLRS)** measures the degree to which interface design reduces visual and informational complexity, thereby improving task efficiency and reducing energy usage at the device level.

7. Conclusion

This study demonstrates that eco-friendly interface design represents an effective strategy for improving the environmental performance of university digital systems. The empirical analysis shows that Green UX/UI principles can significantly reduce energy consumption while enhancing user interaction efficiency and satisfaction.

The proposed analytical framework provides a practical methodology for evaluating digital sustainability in interface design and can be applied to a wide range of academic digital platforms. Future research may extend this approach to larger datasets and real-world university systems in order to further validate the environmental benefits of sustainable digital interface design.

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TECHNICAL SCIENCES

METHODOLOGICAL FOUNDATIONS OF USING SOFTWARE IN PARAMETRIC MODELING OF POWER MACHINES

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Abstract
This article aims to review software tools for parametric modeling of electromechanical energy converters. These tools significantly improve the quality of calculations and design of structural components of power machines and units. The paper analyzes existing software tools for modeling various types of electrical machines and substantiates the feasibility of using known CAD programs exclusively for solving applied engineering problems. However, to obtain results in experimental design or the design of electrical machines for which there are no analogues (in terms of design or operational characteristics), it is necessary to develop additional software or write a separate program. Three software packages are distinguished among those improving parametric design: SolidWorks, T-FLEX CAD, and COMSOL Multiphysics. It has been established that, from a functional standpoint, the development of such a software block is practical for multiparametric design, where efficiency is achieved through the simultaneous modeling of the electrodynamic, gasdynamic, mechanical, and thermal processes of the electrical machine.
Keywords: Power machines, parametric modeling, electrodynamic, mechanical and thermal processes, energy conversion.

Relevance of the research problem

Currently, automated design systems are useful for designing energy machines based on the conversion of various types of energy within the confines of parametric design. Such methodological tools significantly improve the quality of design and scientific work. However, the use of software for modeling electrodynamic, gasdynamic, thermal, and mechanical processes requires a methodical description of their implementation features and conditions [1]. In this paper, we will review modern software for modeling electromechanical energy converters.

The aim of the article is to analyze existing automated design systems for power machines within the framework of the implementation of a parametric methodology for the development and creation of modern, competitive electrical machines.

Material and essence of the research

As software tools for parametric modeling of an electromechanical energy converter, we will define the following software packages as those that have commanded their effectiveness and efficiency, namely: SolidWorks, T-FLEX CAD and COMSOL Multiphysics.

1. The SolidWorks program is a CAD software package for automating the work of an industrial enterprise at the stages of design and technological preparation of production. It provides the development of products of any degree of complexity and purpose. The SolidWorks software package includes various application modules [2, 3]:

– engineering data management: SolidWorks Enterprise PDM;

– engineering calculations: SolidWorks Simulation, and SolidWorks Flow Simulation;

– electrical design: SolidWorks Electrical;

– development of interactive documentation: SolidWorks Composer;

– machining, CNC machining: CAMWorks;

– data verification: CAMWorks Virtual Machine;

– quality control: SolidWorks Inspection;

– manufacturability analysis: SolidWorks Plastics, DFM.

For the design of electromechanical structures, their calculation and further analysis, we will be interested in the following three modules of the program: SolidWorks Electrical, SolidWorks Simulation, and SolidWorks Flow Simulation. Let's consider their features.

The composition of the electrical design module includes:

a) SolidWorks Electrical Schematic is a multifunctional 2D system for designing electrical circuits. Design of logical, structural, electrical circuits, block diagrams of cable connections, connection tables, etc., using the nomenclature database of components from global manufacturers of radio electronics. Automatic numbering and labeling of project components with real-time update. Two-dimensional layout of components in cabinets and modules. Creation of documentation and reports based on project data. Joint work of developers on a digital layout of the electrical component of the product taking into account changes in real time. Ability to use developments in DWG/DXF format;

b) SolidWorks Electrical 3D is a 3D layout of electrical cabinets based on 2D project data and a large database of 3D models of components. Automatic wiring, taking into account cable channels. Automatic division of cable system routing into power and signal lines. Calculation of cable channel occupancy.

SolidWorks Simulation – is responsible for calculations of the strength of structures in the elastic zone,

formulation and solution of contact problems, calculation of assemblies; determination of natural forms and frequencies of oscillations, calculation of the structure for stability, fatigue calculations, fall simulation, thermal calculations. Optimization of SolidWorks Motion model parameters: comprehensive dynamic and kinematic analysis of mechanisms, determination of speeds, accelerations and mutual influences of system elements. In addition, it allows you to perform nonlinear calculations: accounting for nonlinear material properties, nonlinear loading, calculation of nonlinear contact problems; analysis of long-term loading and determination of the resource of structures. Linear and nonlinear dynamics of deformable systems. Optimization of model parameters taking into account the mechanical nature of the load. Calculation of multilayer composite shells and much more.

SolidWorks Flow Simulation is a module designed to perform simulation of the flow of liquids and gases, control of the computational grid, use of typical physical models of liquids and gases, complex thermal calculation, gas and hydrodynamic and thermal models of technical devices, non-dynamic and non-stationary analysis, calculation of rotating objects, export of results to SolidWorks Simulation. In addition, the Electronic Cooling Add-In performs thermal calculations of electronic devices. It has an expanded database of virtual fans; electrical materials, thermoelectric coolers (Peltier elements), two-resistor components. Simulation of the passage of direct current and heating by direct current, models of two-resistor components, heat pipes and channels.

Of course, the SolidWorks software package is a powerful tool for high-quality development, modeling and forecasting the state of machines and mechanisms, but in the context of designing electrical machines it is useful only in solving problems of a thermal, ventilation (hydraulic) and mechanical nature. The program perfectly solves the problems of complex mechanical loading in combination with thermal loads on parts and assemblies of an electrical machine. It also qualitatively solves the problems of studying the state of an electrical machine that has already worked out its standard service life, or in the mode of long-term operation under load.

Preliminary results of modeling the magnetic field in the core of a simple transformer, performed in the SolidWorks program, are presented in Fig. 1. According to the received report, the tendency of the magnetic field inhomogeneity and the concentration of increased load in the corners of the magnetic core is clearly visible.

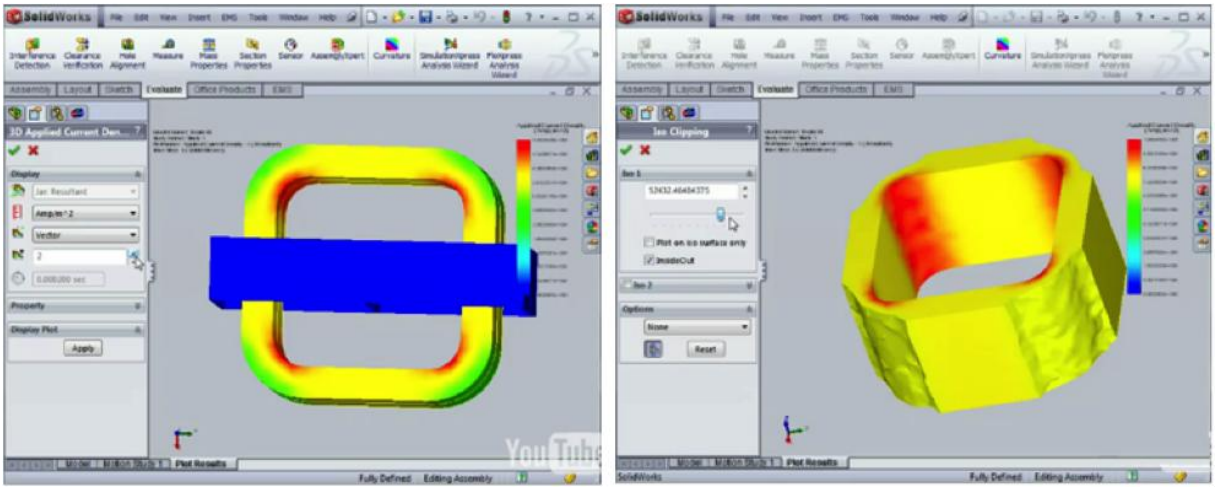

Figure 1. Results of modeling the magnetic field in the core of a simple transformer, performed in SolidWorks

The main advantages of using the SolidWorks program are as follows:

– clear, classic program interface, as for any solid-state design program of the CAD family;

– logical construction of both geometric and mathematical models is implemented, according to the "step-by-step" principle;

– a sufficiently large library of template geometric models, a large library of materials (metals and non-metals), well-developed interaction when working with national and industry standards (DSTU, ISO, DIN, ASME);

– sufficiently high-quality implementation of modeling of mechanical, thermal and ventilation processes in combination with relatively low requirements for computer resource power (depends on the number of parts in the assembly and the detail of the calculation grid);

– allows several designers to work on the development simultaneously;

– there are enough sources of information in free access to answer questions of a narrow specialty, or to solve "single-case" problems.

The main disadvantages of the program include:

– there is not enough functionality for deeper work with the electromagnetic component of modeling, modeling of the mechanical and thermal state of the machine is implemented much better;

– when building a geometric model, it requires a more detailed definition of the initial data, with an insufficient amount of initial data (unfortunately, this is sometimes dictated by reality) the modeling results will be incorrect and unsuitable for further use;

– to obtain high-quality development results, the developer's qualification level is higher than average.

2. T-FLEX CAD is an engineering computer-aided design system that combines parametric capabilities of 2D and 3D modeling with tools for creating and designing drawings and design documentation in accordance with the ESKD and foreign standards (ISO, DIN, ANSI). The scope of application is general mechanical engineering, including the construction of power machines and mechanisms and aircraft. The main functionality of the program is the following [4, 5]:

– parametric 2D sketching and parametric 2D/3D design using hybrid parameterization, which combines classical parameterization based on construction elements and dimensional parameterization based on constraints and control dimensions;

– direct reading and import of formats of various CAD systems; export to formats of other CAD systems;

– full associative relationship between the 3D model and its drawing;

– a set of tools for preparing design documentation in accordance with the ESKD, ISO, DIN and ANS standards;

– the ability to combine the methods of work "bottom-up" (from part to assembly) and "top-down" (from assembly to part);

– work with reference geometry with the ability to manage the update process;

– there are tools for collective work with projects;

– engineering express analysis of parts by means of finite elements;

– API interface for developing your own programs;

– variable editor using multi-line expressions and syntax highlighting;

– support for working with internal and external databases;

– libraries of parametric 2D and 3D standard elements.

As in the above-mentioned software complexes and individual modules, in

T-FLEX CAD, the modeling process of various types of tasks and engineering studies using MSE tools is implemented at a high level. T-FLEX CAD is a relatively young development tool, but quite effective for solving problems of the mechanical and thermal state of an electric machine. The calculation component of aerodynamic processes is excellently performed, and allows you to calculate all possible flow losses, which, for example, are necessary to remove excess heat from the slot channel of the stator winding. The parameterization of the models is performed according to the hybrid type (geometric, tabular). Fig. 2 shows a part of the electromechanical energy converter, made in the T-FLEX CAD program.

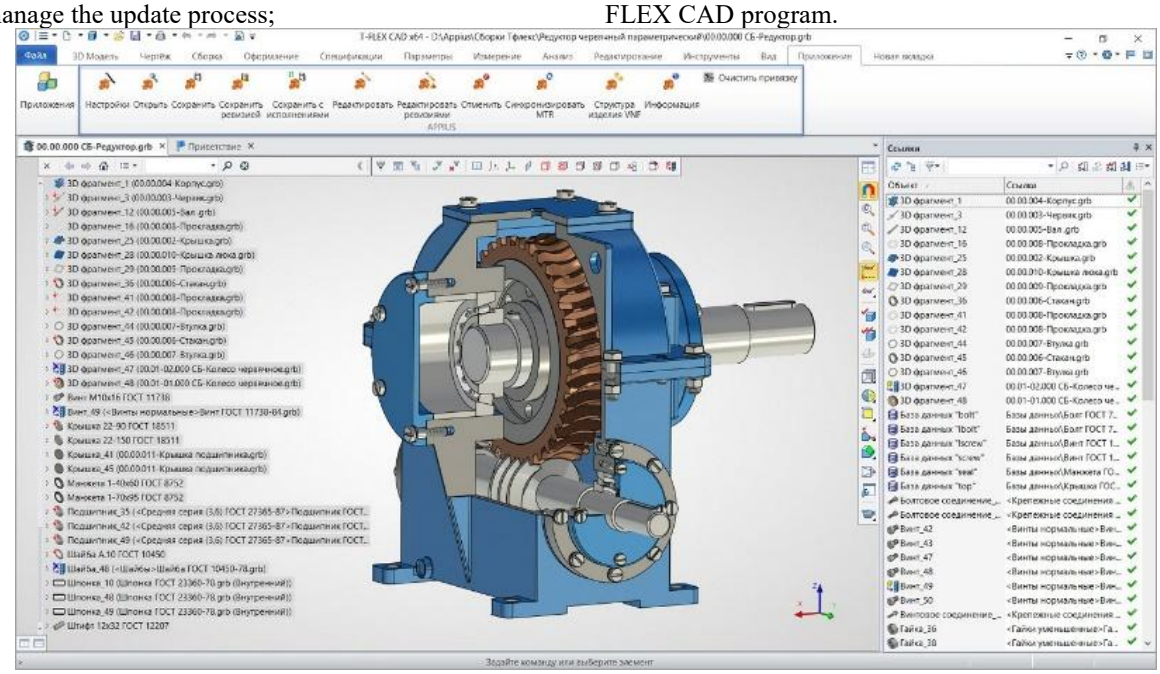

Figure 2. Part of an electromechanical energy converter (reducer) made in the T-FLEX CAD program

The main advantages of using the T-FLEX CAD program are as follows:

– an intuitive set of tools for designing and building a geometric structure;

– the mathematical apparatus of calculations is based on the foundations of the MFE, and is not limited to it;

– the program provides wide opportunities for developing drawings, which significantly speeds up the design work on the project

The main disadvantages of the program include:

– insufficient functionality for better work on modeling and research of the electromagnetic component of the unit, modeling of the mechanical and thermal state of the machine is implemented somewhat better;

– the program requires constant monitoring and analysis of intermediate results of the calculation stages from the developer.

3. COMSOL Multiphysics is a general-purpose modeling software used in all areas of design, manufacturing, and research. This software suite provides fully integrated multiphysics and single-physics modeling capabilities, model management, and easy-to-use tools for creating simulation programs. Additional software modules provide specialized functionality in the fields of electromagnetics, structural mechanics, acoustics,

fluid flow, heat transfer, and chemical engineering. All additional products in the product suite easily connect to COMSOL Multiphysics for a modeling workflow that remains the same no matter what you are modeling.

The functionality of the program is very extensive, covering almost all areas of design, and is described in more detail in [6, 7]. COMSOL Multiphysics performs its work using the following program components:

– Electromagnetics module;
– Structural mechanics and acoustics module;
– Fluid flow and heat transfer module;
– Chemical engineering module;
– Multipurpose products module;
– Interface products module.

To implement the design and optimization of electrical machines, an electromagnetic module is used. To develop and evaluate the mechanical and thermal state of an electrical machine, a structural mechanics and acoustics module, and a fluid flow and heat transfer module are used. The mathematical apparatus used to perform calculations is MSE. Parameterization is implemented in a hybrid type.

The available functionality of the electromagnetic module for rotating machines simplifies the modeling of motors and generators. For example, you can study the behavior of induction or permanent magnet motors, in particular, by recording the eddy current losses that arise inside the magnets. In any model used to model electromagnetic motion, you can study the dynamics of a rigid or flexible body under the influence of magnetic forces and moments, induced currents, as well as mechanical loads and configurations of the structural parts of an electrical machine. A universal moving grid allows you to model linear motion. This is important for understanding the operation of components that include plungers, such as magnetic power switches, solenoids, and general drives. Modeling losses in laminated iron cores and yokes of electric motors and transformers is necessary to predict their efficiency and performance. In particular, for laminated iron (electrical steel), empirical models of electromagnetic losses are important because macroscale Joule heating or induction heating cannot fully describe the effect that causes losses. At the same time, modeling laminates separately is often impractical. Fig. 3 shows a geometric model for studying losses in an electric motor.

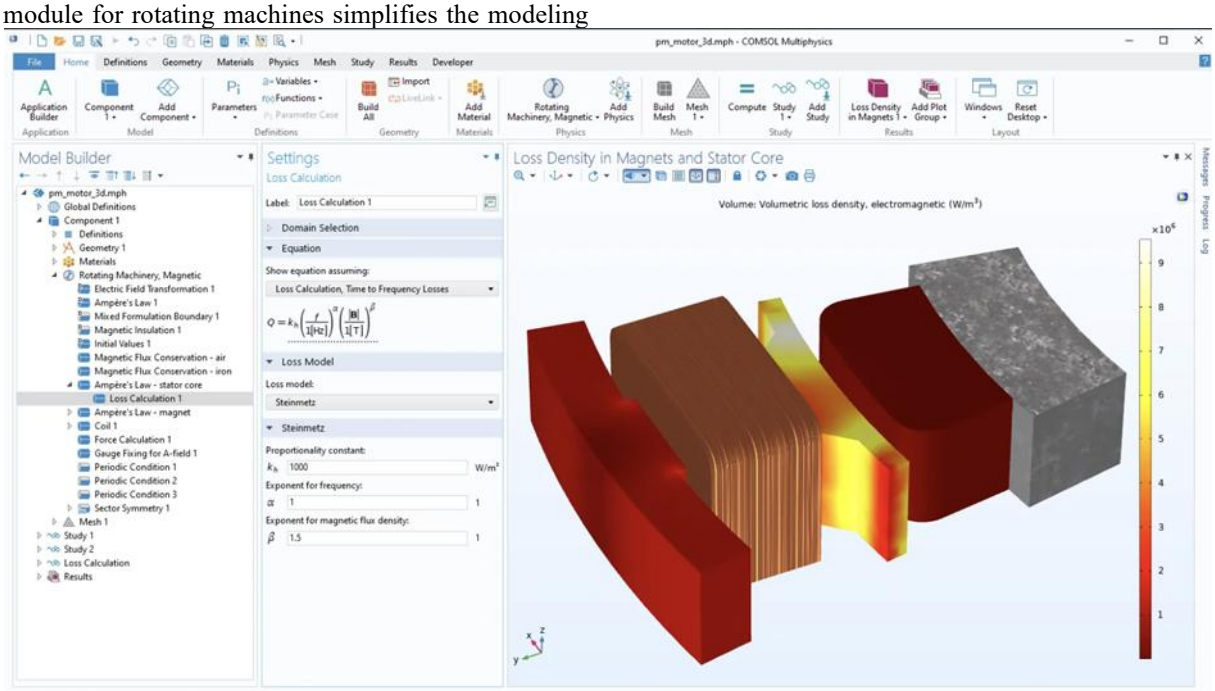

Figure 3. Geometric model for studying losses in an electric motor, made in the COMSOL Multiphysics program

The main advantages of using the COMSOL Multiphysics program are:

– results of modeling a wide range of multiphysical phenomena and processes are obtained, combined with a high degree of adequacy and accuracy of calculations;

– accurate multiphysical models take into account a wide range of operating conditions and a large set of materials and templates, which qualitatively increases the speed and efficiency of using the program;

– in comparison with the research functionality, COMSOL Multiphysics shows the best result among all CAD system programs;

– a set of tools for designing and building a research model is accessible to mastering;

– the main disadvantages of the program include:

– it is extremely important for the developer to have confident programming skills;

– requires powerful computer equipment and accompanying modern software;

– to obtain high-quality development results, the developer's qualification level is above average.

Conclusion

As a result of the analysis of existing software tools for modeling electromechanical energy converters, it has been proven that the use of well-known CAD programs is advisable only for solving applied engineering problems, but to obtain results in experimental design or design of power machines for which there are no analogues (in terms of design or operating conditions), it is necessary to develop an additional software

block or write an individual program. It has been established that writing such a software block is advisable, from a functional point of view, to be performed within the framework of multiparametric design, where efficiency is achieved due to the simultaneous modeling of electromagnetic, electromechanical and heat-ventilation processes of a power machine.

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