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Contact information

Website: <https://sconferences.com>

E-mail: info@sconferences.com

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Economic sciences

ELIMINATION OF ECONOMIC INEQUALITY IS A KEY CONDITION FOR ECONOMIC DEVELOPMENT

Sevinc Ibrahimova

Associate Professor of Odlar Yurdu University, Baku, AZ, 1072, Azerbaijan
<https://orcid.org/0009-0004-3670-2132>

Mayil Orujov

Honorary Professor of SMBS (Swiss Montreux Business School),
 Odlar Yurdu University, Baku, AZ, 1072, Azerbaijan
<https://orcid.org/0009-0001-8177-3851>

Azer Orujov

Social Services Agency, Baku, Azerbaijan
<https://orcid.org/0009-0008-5638-8020>

Nermin Orujova

Social Services Agency, Baku, Azerbaijan
<https://orcid.org/0009-0007-1222-4238>

Abstract

An increase in economic inequality has recently occurred in many countries, which arouses interest among many scientists in studying this process, but still some of its aspects remain insufficiently studied. The article examines the reasons why economic inequality is considered a problem, although convincing evidence of the occurrence of negative economic or social consequences of this phenomenon could not be found. It is concluded that the problem of economic inequality is largely artificial. When analyzing it, researchers usually rely on connections that took place in the past, but are practically absent at the present time. The fact of insufficient knowledge of a number of research issues is substantiated. And the very fact of the presence of such gaps in scientific knowledge of the problem of economic inequality makes it difficult to increase the effectiveness of those measures that are applied in specific social and economic policies.

Keywords: *economic inequality, abilities, opportunities, system justification theory.*

Introduction

The topic of economic inequality is so broad and vast that it is simply impossible to cover even its most significant issues in a single article. Therefore, a very specific and limited objective is posed here: to formulate and discuss certain questions that are practically unaddressed in the existing literature, and, as a result, to substantiate the importance of answering them for developing productive solutions to applied problems.

Currently, one of the most frequently asked questions in this area is: how to overcome income inequality—the most glaring aspect of economic inequality? The obvious answer, to the unthinking eye, seems like this: the state should pay everyone equally, although both theory and, especially, historical practice, including in our own country, have provided their assessments of the bleak consequences of attempts to implement such solutions. Therefore, if the answer to this frequently asked question is still relevant, and previous approaches to addressing it have been unsatisfactory, then other solutions must be sought. To do this, it makes sense to discuss the problem of economic inequality itself.

It should be noted that when analyzing decision-making processes, a distinction must be made between the stage of recognition of a problem situation and the stage of problem formulation [1]. A problem situation is a state of affairs in which an individual experiences varying degrees of dissatisfaction, the presence of certain sources that generate a negative perception of the current situation. Obviously, people may perceive the causes of their unpleasant sensations differently, i.e., they may have different ways of seeing or understanding them, and each of these options allows them to formulate their own problem, which it would be desirable to solve in order to eliminate the problem situation. A simple example: a problem situation is overcrowded public transport during rush hour in a large city. People perceive the problem to be solved differently: for some, it is a shortage of buses, trolleybuses, etc., for others, a high concentration of places of employment, and for others, a uniform start and end time for the workday. Each of the approaches to solving a given problem situation leads to its own results, differing in both costs and consequences. At the same time, following the seemingly most

"natural" logic of solving the problem—resolving the public transportation shortage—leads to a new problematic situation: congestion in city streets. Thus, distinguishing between problematic situations and problems gives rise to the question: is the usual framing of the problem productive?

This leads to the first question worth discussing: what is the situation that is perceived by many as problematic, i.e., what gives rise to a negative perception? A second, related question, also deserving of attention, can be formulated as follows: what characteristics of the economy and society, conditioned by economic inequality, are such that their presence in the country is considered undesirable? The next two sections of the article are devoted to a discussion of these questions, and the conclusions from this discussion conclude the article.

Discussion

Diversity and Inequality: What Makes a Difference?

The consequences of economic inequality, and the dangers and threats it poses, have been actively discussed in recent literature. Even such a renowned economist as J. Stiglitz writes: "Rising inequality in most countries is one of the most important problems facing the world today. People everywhere feel that it is morally wrong. We feel that it is indefensible. We feel that it divides our societies and undermines our democracies. And we are right to sense this harm" [2]. At the same time, the root causes of these negative consequences (the extent to which some of them are justified will also be discussed below) are effectively taken for granted. It is important to note here that the problematic nature of income inequality is not only discussed by researchers; it is also recognized at the national level: of the 17 Sustainable Development Goals adopted by the UN, at least one-third are related to overcoming inequality and poverty.

Meanwhile, those characteristics of national populations that we call inequalities—social, economic, cultural, political, etc.—also have another name: they are all various varieties. As is well known, diversity is a property of a population of organisms, without which no changes in living nature would occur, and human society simply would not have emerged: it is the diversity of individuals within living beings that is the source of their evolution. This has been repeatedly noted by researchers studying biological, economic, social, and cultural evolution. After all, it is the differences in the characteristics of the elements of changing objects that create opportunities for the natural and/or artificial selection of some of them, expanding the survival and reproduction potential of some while limiting those of others. For example, in economies, the diversity of goods, technologies, organizational forms, etc., provides different levels of complexity, and the greater this diversity, the greater the complexity of the economy, its innovative and adaptive capacity [3]. Why is the diversity of some parameters of economic (and socio-cultural) systems viewed by people as a positive quality, while its presence in other parameters is viewed as a negative quality, as a problem that must be overcome? Any assessments made by an individual of phenomena in the external world around them and in the internal world existing in their consciousness are the result of their brain's comparison of the signals resulting from the perception of this phenomenon with a group of neural circuits that represent social and other values formed on the basis of their life experience [4]. If current signals are close to positive values, their source is evaluated positively; if such closeness is absent, or if there is closeness to negative values, the object receives a negative evaluation. Diversity of life experience is inevitably present in all people. It determines the formation of disparate sets of values as "patterns" used by the brain to evaluate signals sent to it by the senses, perceiving objects of both the external and internal worlds.

Accordingly, the assessments given by different people to the same perceived objects can differ (and do differ): coincidence or closeness of assessments will indicate similarity in the values developed in the brains of the individuals concerned. It is important to note here that such coincidences/discrepancies apply not only to the specific features of material objects but also to abstract objects, the results of cognitive processes.

People are characterized by a wide variety of properties and characteristics. Some of these are natural in origin and cannot be changed, others are also natural but changeable to a greater or lesser extent, and still others, being the result of actions taken and ongoing by individuals, are determined largely by the decisions they made and implemented.

Among these characteristics, as our life experience shows, those included in the first two groups are primarily viewed as diversity, while the properties comprising the third group are typically perceived through the prism of inequality. Among them, it is generally accepted to distinguish several forms of inequality, primarily social and economic, with narrower variations within them. This observation, at first glance, provides grounds for linking the transformation of diversity into inequality with the role of individuals in the emergence of the traits in question. Those "inequalities" that are independent of their

decisions are perceived as diversity, while those caused by the actions of the individual or others are assessed as inequalities. For example, when people are compared by height or eye color, they speak of diversity, but when it comes to comparing social status or the amount of property owned by certain individuals, the comparison shifts to the topic of inequality. However, this conclusion faces a contradiction. responsibilities. Thus, the level of education of a particular individual depends not only on whether they conscientiously completed their academic assignments, but also on their innate cognitive abilities, which can also impact their social status. Differences in skin color are perceived by some individuals as a source of social constraints, ensuring unequal access to various social positions. Therefore, a "biological" explanation for why certain diversities become (almost) universally recognized inequalities cannot be considered satisfactory.

The interpretation of inequality as a consequence of dishonesty or injustice has become widespread, and a large body of literature has been devoted to this issue. Without attempting to provide a comprehensive characterization of this concept, I will focus only on those works that are relevant to the objectives of this article. One of the starting points here is article [5], devoted to the analysis of the process of social comparison, which documents the "automaticity" or subconscious nature of this process carried out by the brain. Within this framework, various characteristics of individuals, perceived by the senses, are compared with self-assessments of their own similar characteristics and with the individual's values. This means that any interactions between individuals and their groups involve social comparisons. At the same time, according to [6], all these interactions are acts of social exchange, which, like any exchange, also presupposes comparison. The latter, in turn, can demonstrate both equality and inequality to the different parties to the exchange.

Inequality in social exchange, as shown in [6], generates relative deprivation in the party whose assessment shows that as a result of the exchange, they find themselves in a lower position than the individual initially considered themselves to be. At the same time, the other party does not experience such a "lowering of their level"; on the contrary, they experience relative satisfaction (relative gratification). Such social exchanges are characterized as unfair or unjust, which explains the well-known interpretation of inequality as injustice, often heard in the judgments of journalists and politicians.

Thus, generalizing the presented approach, it can be said that diversity as the non-identity of the properties of two or more objects of the same type is perceived as inequality by subject A if it brings him certain negative consequences. If in his perception such (real or imagined) negative consequences are absent (for example, they are not recognized or not understood), then diversity remains emotionally neutral, not transforming into negative inequality. Briefly speaking, (non-mathematical) inequality exists only in the subconscious and/or consciousness³ of individuals, while around them there is a diversity of objects or their properties⁴. The ubiquity of social exchanges and the automaticity of social comparisons leads to the fact that the attitude of rejection of inequality (inequity aversion) is quite typical among people [7].

The outlined explanation of inequality and its significance for individual decision-making has received model support in a number of studies demonstrating the importance of partners in cooperative societies, which ensure the survival of small groups, choosing those who demonstrated an attitude toward an equal distribution of the results of their actions, taking into account the effort they put in. Similar behavior is demonstrated by many other animal species, although it is entirely possible that their refusal to accept smaller shares of distributed goods was caused by factors such as disappointment or frustration, rather than social comparison.

Thus, the reasons for the transformation of a situation from a state of diversity to a state of inequality, the avoidance of which is evolutionarily inherent in humans, are complex and biosocial: the formation of "reference points" for subsequent assessments of the fairness of exchanges is influenced by both the innate and acquired properties of individuals, i.e., their abilities, as well as the opportunities to realize these abilities provided by the formal and informal institutions that have developed in those communities where individuals with different abilities live. This relationship can be expressed as the following "formula":

$$(\text{unequal}) \text{ abilities} + (\text{unequal}) \text{ opportunities} \rightarrow (\text{unequal}) \text{ welfare}$$

In its content, it is not something new, since it was put forward in the theory of equal opportunities, where, however, the innate and acquired abilities of the individual were considered part of the opportunities, which thereby received a complex structure. It included external social (mainly institutional) opportunities that society provided to the individual, and internal personal ones, with a division into those that the individual could not change and those that he could influence. It seems that renaming the last two groups to a more appropriate (at least in Russian) name "ability" will eliminate the

likelihood of misunderstanding and complexity. In addition, the theory of equal opportunity highlighted an important factor - the scale of efforts that an individual made to ensure his well-being. Obviously, it has independent meaning, although it is influenced by both existing abilities and opportunities provided. It is not highlighted in the proposed formula, since its task is not to describe all significant factors affecting the well-being of individuals, but to separate individual abilities and social opportunities.

To reduce economic inequality, the need to ensure equality of opportunity is now widely recognized. However, can all opportunities be equal? As research conducted to date shows, among social inequalities there is at least one type, the elimination of which is hardly possible: we are talking about inequality of social status, which, among other things, also affects access to various resources. The statuses themselves, forming hierarchies in groups, began to arise, as is known, in animals, playing an important role in the evolutionary process. Changes in informal institutions are also problematic, and changes in formal institutions, if they do not correspond to informal ones, may encounter difficulties in their functioning. In general, with regard to informal institutions, research that analyzes their contributions to economic inequality would be useful.

Ensuring equality of people's abilities is obviously impossible. But do we know what their contribution is to observed economic inequalities, such as income inequality, which is most widely discussed in the literature? The first candidate for this influence is cognitive ability, as measured by intelligence quotient, or IQ. Extensive research into the relationship between these abilities and various economic indicators was presented in the book, which caused a wide and controversial response. For example, the mentioned coefficients have been built into some economic growth models, demonstrating their relationship with macroeconomic indicators; it was confirmed that higher national IQ correlates with higher GDP per capita; the study presented in showed such a connection within the Chinese economy, etc. However, the article criticized Lynn and Vanhanen's approach, and the authors noted that they were unable to reproduce the results presented in the mentioned monograph, and argued that the publication of data on differences in average IQ between nations and races is dangerous because it contains information that can be used by racists.

Thus, the influence of individuals' cognitive abilities on economic processes in general has been studied and continues to be studied, although their connections with economic inequality are practically not addressed. Thus, it was found that in countries of the global South, where the average IQ is relatively low, the population shows less demand for the acquisition of knowledge and innovation, and according to this, the higher the average IQ in a country, the less inequality in income distribution there is. It is clear that these results are clearly not enough to make valid conclusions regarding the contribution of these abilities to economic inequality. Thus, the question of the influence of abilities on economic inequality is not actually raised, and this factor remains clearly insufficiently studied to improve policy development.

Social consequences of economic inequality

The evolutionary roots of people's beliefs in the unacceptability of inequality, noted above, ensure their widespread adoption. This inevitably leads to the use of this theme in various political ideologies.

A recent review of the literature on this topic notes that long-term empirical studies of the impact of economic inequality on such significant aspects of socioeconomic development as economic growth, human development, and strengthening social coordination (governance) in public administration have failed to yield any clearly defined conclusions: "the existing evidence is mixed." Despite this, the authors assert that "inequality is a major international development challenge. This is explained both by ethical considerations and by the fact that growing inequality is perceived as a factor negatively affecting key socioeconomic and political outcomes." In other words, the "evidence base" for developing measures to reduce or even eliminate economic inequality today resides less in the realm of scientific facts and more in the realm of ideological beliefs.

One manifestation of this is the coexistence in the scientific literature of two groups of views, both "for" and "against" economic inequality, with the underlying rationale being diverse. Among those who advocate combating economic inequality and strengthening redistribution policies, there are, according to consensus, at least two motives: overcoming (a) the injustice of global resource distribution and (b) eliminating a threat to their own well-being. In countries with former socialist economies, such as China, nostalgia is also a factor. Moreover, while the motive for eliminating injustice stems from an evolutionarily conditioned avoidance of inequality, eliminating a threat motivates those who perceive their relatively low status as precarious. Opponents of inequality reduction policies are also guided by various motives: firstly, by naive economic beliefs that the economy is a zero-sum game, and that an increase in the incomes of some will lead to a decrease in their own relatively high incomes, as identified in [Brown, Jacoby-Senghor, Raymundo, 2022]; secondly, by the conviction that if inequality is due to

adherence to existing norms, then it cannot but be justified and, therefore, legitimate; thirdly, by the peculiarities of perceiving low incomes as a consequence of individual actions of people, and not of certain socio-political features of the economy [Chater, Connolly, Loewenstein, 2026].

It is easy to notice that among the motives of participants in the first group—supporters of income inequality reduction policies, identified as a result of empirical analysis—the one that is quite often mentioned by Russian researchers, namely, the motive of preventing the growth of social tensions, which can lead to a continued increase in economic inequality. I note that this rationale for inequality reduction policy is rarely mentioned by foreign researchers.

What could be the reason for this discrepancy? It seems likely to stem from the low prevalence, including among economists, of system justification theory, developed by psychologists in the early 1990s [Jost, Banaji, 1994] and widely accepted: as of early March 2026, it had been cited more than 5,600 times. What does this theory assert? In modern countries, where states are the largest employers and providers of various forms of social support and public services, a decline in the income of some and an increase in the income of others does not motivate the former to protest against the state. After all, such protests, according to users of various state benefits, can reduce state support, which, in the absence of unrest, could, on the contrary, increase—as a reward for the lack of resistance. Thus, protesting against state social policy means undermining hopes for its improvement.

Therefore, while in the late 1980s, most conflict researchers, as noted in [Lichbach, 1989], believed that high levels of economic inequality were a significant source of social tension, after the state's role in social support increased and it became the primary philanthropist, economic inequality effectively ceased to be a factor in social anti-government protests. Of course, it retains its potential where the state's role in social security and support for the poor is small, but in modern countries its significance is practically imperceptible: consumers of state benefits justify and support the system, which, in turn, supports them.

As of March 9, 2020 In 2026, the phrase "system justification theory" was cited 59 times in Russian articles. However, a work by Russian authors describing the theory's content, published almost 40 years after its inception, has already been cited nearly 700 times, so researchers studying economic inequality are becoming significantly more familiar with system justification theory.

Conclusion

An analysis of two aspects of the state of the art in the study of economic inequality dynamics revealed the following. Empirical data that can be used to develop social policy approaches and measures aimed at reducing inequality underdevelops the impact of such factors as the diversity of human abilities. This applies to both genetically determined abilities and those whose development is influenced by individuals themselves. In analyzing the dynamics of economic inequality, the role played by legal and other institutional opportunities created by society and the state for the manifestation of these abilities has been studied quite well, and this is used in the development of effective social policy measures. However, their interaction with human abilities, as well as the specifics of these interactions influencing the economic consequences of decisions, also remains far from clear. Similarly, there is insufficient clarity regarding the relationship between the structure of human abilities, including cognitive abilities, and the structure of jobs in the economy. The increased use of artificial intelligence models observed in recent years may, of course, reduce the importance of their correspondence, but this does not eliminate the uncertainty itself. Since the economic consequences of inequality remain unclear, and the social consequences shift to a purely moral realm where divergent positions have coexisted for millennia, the concept of some economically optimal level of inequality clearly requires further discussion.

Overall, this means that studies of economic inequality have not addressed all the questions whose answers would allow for further improvements in public policy, both social and economic, in the area of income distribution.

References

1. Orucov M.M, The current state of the Azerbaijani economy against the backdrop of changes in the world economy, *Scientific and Pedagogical News of Odla Yurdu University*, 2018, № 50, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552
2. Stiglitz J.E. (2015). *The Price of Inequality: How Today's Divided Society Endangers our Future* // *Sustainable Humanity, Sustainable Nature: Our Responsibility* / P.S. Dasgupta, V. Ramanathan, M.S. Sorondo (Eds.) — Vatican City: Pontifical Academy of Sciences. Pp. 379–399.
3. Orucov M.M, Modern development model of the national economy, *Scientific and Pedagogical News of Odla Yurdu University*, 2020, № 54, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552

4. Orucov M.M. Ibrahimova S.R. *Current status of financial security of the Republic of Azerbaijan and its assessment*. International Scientific Conference. London. Great Britain. 07-08. 2026. ISBN 978-92-44515-01-3 DOI <https://doi.org/10.5281/zenodo.20143622>
5. Orucov M.M. Ibrahimova S.R. *Diversification of the non-resource sector of the economy of the Republic of Azerbaijan based on sustainable development and analysis of the experience of foreign countries in this area*. I international scientific conference, **Brussels. Belgium. 15-16.04.2025**. ISBN 978-91-65424-16-6 DOI <https://doi.org/10.5281/zenodo.15256023>
6. Orucov M.M, *Analysis of structural changes in the national agricultural sector and assessment of import dependence*, Scientific and Pedagogical News of Odlar Yurdu University, 2023, № 62, ISSN: 1682-9123
DOI: 10.0318/OYU.2023735552
7. Orucov M.M. *Modernization of marketing improvement in the oil refining industry in Azerbaijan*, Scientific and Pedagogical News of Odlar Yurdu University, 2023, № 62, ISSN: 1682-9123
DOI: 10.0318/OYU.2023735552
8. Orucov M.M. *Fundamentals of National Security of the Republic of Azerbaijan*, Textbook -2024
9. Orucov M.M. *The Wreath of Victory*, a book dedicated to Mr. İlham Aliyev's 20 years as President-2024
10. Orucov M.M. *Parameters for long-term forecasting of the world economy*, Scientific and Pedagogical News of Odlar Yurdu University, 2023, № 63, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552
11. Orucov M.M. *Theoretical and methodological aspects, characterizing innovative development of the agricultural industry*, Scientific and Pedagogical News of Odlar Yurdu University, 2023, № 63, ISSN: 1682-9123 DOI: 10.0318/OYU.2023735552
12. Orucov M.M. *The concept of the "energy trilemma" as an expression of the energy aspect of sustainable development of Azerbaijan*, International Conference on Smart Environment and green Technologies İCSGET2024, Springer.ISBN978-3-031-81563-8
https://doi.org/10.1007/978-3-031-81564-5_43
13. Orucov M.M. *"Green economy" in the Republic of Azerbaijan: prerequisites and directions of development*, International Conference on Smart Environment and green Technologies İCSGET2024, Springer ISBN-978-3-031-81567-6 <https://doi.org/10.1007/978-3-031-81567-6>
14. Orucov M.M. *Monetary stabilization policy the financial crisis*, XIV international scientific conference. Tokyo. Japan. 31.10-01.11.2024 ISBN 978-92-44514-26-9 DOI <https://doi.org/10.5281/zenodo.14046748>
15. Orucov M.M. *Analysis of foreign investment in Azerbaijani economy and directions to increase*, XVII International Scientific Conference. Dortmund. Germany. 07-08.11.2024, ISBN 978-92-44514-27-6 DOI <https://doi.org/10.5281/zenodo.14136799>
16. Orucov M.M. *Diversification of economy the Republics Azerbaijan on the base sustainable development of non-oil sector*, XIV international scientific conference. Toronto. Canada. 14-15.11.2024, ISBN 978-92-44514-28-3 DOI <https://doi.org/10.5281/zenodo.14199182>
17. Orucov M.M. *Efficiency problems of the energy sector of Azerbaijan in the background of the green economy*, XVII international scientific conference. Philadelphia. USA. 21-22.11.2024, ISBN 978-92-44514-22-1 DOI <https://doi.org/10.5281/zenodo.13929032>
18. Orucov M.M. *Concept, theories and legal basis of the succession of states*, XIII International Scientific Conference Beijing China. 30-31.12. 2024, ISBN 978-91-65424-01-2
DOI <https://doi.org/10.5281/zenodo.14609837>
19. Orucov M.M. *Evaluation of the membership process of the Republic of Azerbaijan to the world trade organization*, XIII international scientific conference. Toronto. Canada. 14-15.01.2025, ISBN 978-91-65424-03-6 DOI <https://doi.org/10.5281/zenodo.14699449>
20. Orucov M.M. *New trends and challenges to the global economy*, XIV international scientific conference. Stokholm. Sweden. 21-22.01.2025, ISBN 978-91-65424-04-3 DOI <https://doi.org/10.5281/zenodo.14749265>
21. Orucov M.M. *Global dynamics of socially responsible investing (SRI): analysis motivating MNCS to use SRI strategies*. XVIII international scientific conference. Madrid. Spain. 25-26.03.2025.
22. Orucov M.M. Ibrahimova S.R. *Analysis the current state of the world economy and the financial-monetary system and forecast for 2026*. XX International Scientific Conference. Toronto. Canada 22-23.01. 2026. ISBN 978-92-44514-86-3 DOI <https://doi.org/10.5281/zenodo.18405372>

23. Orucov M.M. Ibrahimova S.R. *Global dominance of dollar: Theory and prospects*. V International Scientific Conference. Songapore. 27-28 01. 2026. ISBN 978-91-65424-57-9 DOI <https://doi.org/10.5281/zenodo.18469674>
24. Orucov M.M. Ibrahimova S.R. *Current trends in the global economy and state of the global financial system*. XXIII International Scientific Conference. Philadelphia. USA.29-30. 01. 2026. ISBN 978-92-44514-87-0 DOI <https://doi.org/10.5281/zenodo.18472454>
25. Orucov M.M. Ibrahimova S.R. *G7 and BRIKS+: Economic growth efficiency*. V International Scientific Conference. Bern. Switzerland. 03-04.02. 2026. ISBN 978-91-65424-58-6 DOI <https://doi.org/10.5281/zenodo.18547764>
26. Orucov M.M. Ibrahimova S.R. *Glusters in the development of oil refining industru enterprises in the modern era*. V International Scientific Conference. Lisbon. Portugal. 17-18.02.2026. SBN 978-91-65424-60-9 DOI <https://doi.org/10.5281/zenodo.18740913>
27. Orucov M.M. Musayev M. *Economic factors of fluctuations the global economy*. International Scientific Conference. Dortmund. Germany.05-06.03.2026. ISBN 978-92-44514-92-4 DOI <https://doi.org/10.5281/zenodo.18960018>.
28. Valiyev S.A. Orucov M.M. Ibrahimova S.R. *Directions for improving budgetary and tax policy in ensuring financial sekurity*. International Scientific Conference. Rome. Italy. 10-11.03.2026. ISBN 978-91-65424-63-0 DOI <https://doi.org/10.5281/zenodo.19054789>
29. Orucov M.M. Ibrahimova S.R. *Digitalization of international settlements: Tradecoin vs US dollar*. II international scientific conference. Sydney. Australia. 15-16.05.2025. ISBN 978-92-44514-54-2 DOI <https://doi.org/10.5281/zenodo.15473751>
30. 55. Orucov M.M. Ibrahimova S.R. *Mechanisms of international financial relations in the conditions of the globalization crisis*. I international scientific conference. Lisbon. Portugal. 22-25. 04. 2025. ISBN 978-91-65424-17-3 DOI <https://doi.org/10.5281/zenodo.15305608>

EVALUATION OF HUMAN RESOURCES AS AN INTANGIBLE ASSET

Tanrıverdiyeva G.Q.

Associate Professor, PhD

Azerbaijan Academy of Labour and Social Relations

Bəbirli Sabina

Postgraduate Student,

Azerbaijan Academy of Labour and Social Relations

INSAN RESURSLARININ MADDİ OLMAYAN AKTİV KİMİ QIYMƏTLƏNDİRİLMƏSİ

Tanrıverdiyeva G.Q.

i.ü.f.d.dos.

Azərbaycan Əmək və Sosial Münasibətlər Akademiyası

Bəbirli Səbinə

Magistrant,

Azərbaycan Əmək və Sosial Münasibətlər Akademiyası

GİRİŞ

Müasir dövrdə global iqtisadiyyatın inkişaf tendensiyaları göstərir ki, bilik, bacarıq və intellektual potensial müəssisələrin uzunmüddətli rəqabət qabiliyyətinin formalaşmasında həlledici rol oynayır. Ənənəvi iqtisadi modeldə maddi resurslara əsaslanan dəyər yaratma mexanizmi tədricən əhəmiyyətini itirir və onun yerini insan kapitalına əsaslanan inkişaf modeli tutur. Bu baxımdan insan resurslarının maddi olmayan aktiv kimi tanınması və onların iqtisadi dəyərinin ölçülməsi müasir elmi tədqiqatların prioritet istiqamətlərindən biri hesab olunur.

Tədqiqatın əsas məqsədi insan resurslarının maddi olmayan aktiv kimi iqtisadi mahiyyətinin müəyyən edilməsi, onların mühasibat uçotu və maliyyə hesabatlarında əks etdirilməsinin mümkünlüyünün elmi əsaslarla araşdırılmasıdır. Məqalədə insan kapitalı anlayışının formalaşması, insan resurslarının maddi olmayan aktivlərə xas xüsusiyyətləri, həmçinin bu sahədə tətbiq olunan qiymətləndirmə metodları sistemli şəkildə təhlil edilmişdir. Eyni zamanda beynəlxalq təcrübə və mövcud mühasibat uçotu standartları kontekstində insan resurslarının aktiv kimi tanınmamasının səbəbləri araşdırılmışdır.

Tədqiqat nəticəsində müəyyən edilmişdir ki, insan resursları müəssisəyə gələcək iqtisadi fayda gətirmək qabiliyyətinə malik olmaqla maddi olmayan aktivlərin əsas xüsusiyyətlərini daşıyır. Bununla belə, onların hüquqi və metodoloji baxımdan uçota alınmasında mövcud olan məhdudiyyətlər alternativ hesabat mexanizmlərinin tətbiqini zəruri edir. Aparılan elmi təhlil insan resurslarının qiymətləndirilməsinin idarəetmə qərarlarının keyfiyyətinin artırılmasında mühüm rol oynadığını sübut edir.

Qloballaşma, rəqəmsallaşma və innovasiya yönümlü iqtisadi inkişaf şəraitində müəssisələrin fəaliyyət mexanizmlərində köklü dəyişikliklər baş verməkdədir. Müasir iqtisadi münasibətlər sistemində müəssisələrin bazar dəyərinin formalaşması artıq təkcə maddi aktivlərin həcmi ilə deyil, daha çox qeyri-maddi resursların, xüsusilə insan resurslarının səmərəli istifadəsi ilə müəyyən olunur. İnsan resursları işçilərin bilik səviyyəsi, peşə bacarıqları, yaradıcılıq potensialı, adaptasiya qabiliyyəti və innovativ düşüncə tərzilə müəssisənin davamlı inkişafını təmin edən əsas strateji amil kimi çıxış edir. Ənənəvi mühasibat uçotu sistemlərində insan əməyinə əsasən cari xərclər prizmasından yanaşılır və insan resurslarına çəkilən xərclər hesabat dövrünün xərci kimi tanınır. Lakin müasir iqtisadi reallıqlar göstərir ki, insan resurslarına yönəldilən xərclər qısa müddətli istehlak deyil, uzunmüddətli iqtisadi fayda yaradan investisiya xarakteri daşıyır. Təhsil, təlim, ixtisasartırma və motivasiya tədbirləri nəticəsində formalaşan insan kapitalı müəssisənin məhsuldarlığını artırmaqla yanaşı, onun bazar mövqeyinin möhkəmlənməsinə xidmət edir.

Buna baxmayaraq, mövcud mühasibat uçotu və maliyyə hesabatı sistemlərində insan resursları hələ də maddi olmayan aktiv kimi tanınmır və balansda əks etdirilmir. Bu vəziyyət müəssisənin real iqtisadi potensialının və bazar dəyərinin tam şəkildə təqdim olunmasına mane olur. Xüsusilə bilik və xidmət yönümlü sahələrdə fəaliyyət göstərən müəssisələrdə insan kapitalının payı maddi aktivləri xeyli üstələdiyi halda, maliyyə hesabatlarında bu fərq öz əksini tapmır. İnsan resurslarının maddi olmayan aktiv kimi qiymətləndirilməsi məsələsi təkcə mühasibat uçotu ilə məhdudlaşmır, eyni zamanda strateji

idarəetmə, investisiya qərarları və korporativ dəyər formalaşması baxımından da mühüm əhəmiyyət kəsb edir. İnsan kapitalının dəyərinin ölçülməsi müəssisə rəhbərliyinə resurslardan daha səmərəli istifadə etmək, işçi döviyyəsinə azaltmaq və uzunmüddətli inkişaf strategiyasını əsaslandırmaq imkanı yaradır.

Bu baxımdan tədqiqatın aktuallığı insan resurslarının iqtisadi mahiyyətinin yenidən nəzərdən keçirilməsi, onların maddi olmayan aktivlər sistemində yerinin müəyyən edilməsi və mövcud metodoloji yanaşmaların təhlili ilə şərtlənir. Aparılan elmi araşdırma insan resurslarının qiymətləndirilməsinə dair nəzəri və praktiki yanaşmaları sistemləşdirərək bu sahədə elmi boşluğun aradan qaldırılmasına yönəlmişdir.

1. İnsan resursları və insan kapitalı anlayışının elmi mahiyyəti

İnsan resursları anlayışı müəssisənin fəaliyyətində iştirak edən işçilərin fiziki, intellektual, psixoloji və peşə potensialının məcmusunu ifadə edir. Bu anlayış yalnız işçi qüvvəsinin say göstəriciləri ilə məhdudlaşmır, eyni zamanda işçilərin bilik səviyyəsi, peşə bacarıqları, əmək vərdisləri, təcrübəsi və təşkilati mühitə uyğunlaşma qabiliyyətini də əhatə edir. Müasir idarəetmə nəzəriyyələrində insan resursları müəssisənin strateji inkişafını təmin edən əsas amillərdən biri kimi qiymətləndirilir.

İnsan kapitalı anlayışı isə insan resursları anlayışına nisbətən daha geniş və dərin məzmun daşıyır. İnsan kapitalı dedikdə işçilərin təhsil səviyyəsi, ixtisas hazırlığı, peşə təcrübəsi, intellektual bacarıqları, yaradıcılıq potensialı və innovasiya qabiliyyəti başa düşülür. Bu anlayış insanın bilik və bacarıqlarının iqtisadi dəyər yaratmaq qabiliyyətini ön plana çıxarır və insanı passiv istehsal amili deyil, aktiv dəyər yaradan kapital forması kimi təqdim edir.

İqtisadi nəzəriyyəyə əsasən insan kapitalına yönəldilən investisiyalar – təhsil, peşəkar təlim, ixtisasartırma kursları, motivasiya və inkişaf proqramları – uzunmüddətli dövrdə müəssisəyə əlavə iqtisadi fayda gətirir. Bu investisiyalar nəticəsində işçi məhsuldarlığı artır, innovasiya potensialı genişlənir və müəssisənin rəqabət qabiliyyəti yüksəlir. Digər tərəfdən, insan kapitalına qoyulan investisiyalar geri dönməz xərclər deyil, gələcək dövrlərdə gəlir formalaşdırın strateji yatırımlar kimi çıxış edir.

Beləliklə, insan resursları və insan kapitalı anlayışları arasında sıx əlaqə mövcuddur. İnsan resursları daha çox kəmiyyət və təşkilati aspektləri əhatə etdiyi halda, insan kapitalı keyfiyyət göstəricilərinə və iqtisadi dəyər yaratma potensialına fokuslanır. Bu xüsusiyyətlər insan resurslarını maddi olmayan aktivlərin əsas əlamətlərinə yaxınlaşdırır və onların iqtisadi mahiyyətinin yenidən qiymətləndirilməsini zəruri edir.

2. İnsan resurslarının maddi olmayan aktiv kimi tanınmasının nəzəri əsasları

Maddi olmayan aktivlər fiziki formaya malik olmadan müəssisəyə gələcək dövrlərdə iqtisadi fayda gətirən resurslar kimi xarakterizə olunur. Bu aktivlər müəssisənin dəyər strukturunda mühüm yer tutur və xüsusilə bilik əsaslı iqtisadiyyat şəraitində onların rolu daha da artır. Maddi olmayan aktivlərin əsas xüsusiyyətlərinə gələcək iqtisadi fayda yaratmaq qabiliyyəti, uzunmüddətli istifadə potensialı və strateji əhəmiyyət daxildir.

İnsan resursları da iqtisadi mahiyyətinə görə bu xüsusiyyətlərin əksəriyyətinə malikdir. İlk növbədə, insan resursları müəssisənin gələcək fəaliyyət nəticələrinə birbaşa təsir göstərir və əlavə iqtisadi fayda yaradır. Yüksək ixtisaslı və peşəkar kadrların mövcudluğu məhsuldarlığın artmasına, xərclərin optimallaşdırılmasına və innovativ həllərin tətbiqinə şərait yaradır. Bu isə insan resurslarının gələcək iqtisadi fayda yaratmaq qabiliyyətini açıq şəkildə nümayiş etdirir.

İnsan resursları strateji əhəmiyyət daşıyır. Müasir müəssisələrdə texnologiya və maddi resurslar asanlıqla təkrarlana bildiyi halda, insan kapitalı nadir və əvəzolunmaz resurs hesab olunur. İşçilərin bilik və bacarıqları müəssisənin bazarda fərqlənməsinə və davamlı rəqabət üstünlüyü əldə etməsinə imkan yaradır. Bu baxımdan insan resursları müəssisənin uzunmüddətli inkişaf strategiyasının əsas komponentlərindən biri kimi çıxış edir.

İnsan resursları müəssisənin bazar dəyərinə əhəmiyyətli dərəcədə təsir göstərir. Praktikada tez-tez müşahidə olunur ki, maddi aktivlərin həcmi məhdud olan, lakin yüksək insan kapitalına malik müəssisələrin bazar dəyəri xeyli yüksək olur. Bu isə maliyyə hesabatlarında əks olunmayan, lakin real iqtisadi dəyər yaradan insan resurslarının rolunu bir daha təsdiqləyir.

Bununla yanaşı, insan resurslarının maddi olmayan aktiv kimi tanınmasında əsas problem onların müəssisəyə məxsusluq səviyyəsinin hüquqi baxımdan qeyri-müəyyən olmasıdır. İşçilər hüquqi cəhətdən müstəqil subyekt olduqları üçün müəssisə onların bilik və bacarıqlarına tam nəzarət edə bilmir. Əmək münasibətlərinin müqavilə xarakteri daşması insan resurslarının klassik aktiv anlayışına uyğunlaşdırılmasını çətinləşdirir.

Eyni zamanda, insan resurslarının dəyərinin etibarlı və obyektiv şəkildə ölçülməsi məsələsi də nəzəri mübahisələrə səbəb olur. İnsan kapitalının subyektiv xarakter daşması, fərdi xüsusiyyətlərdən asılı olması və zamanla dəyişməsi onun mühasibat uçotunda aktiv kimi tanınmasını məhdudlaşdıran əsas amillərdəndir. Buna baxmayaraq, müasir elmi yanaşmalar insan resurslarının alternativ hesabat mexanizmləri vasitəsilə qiymətləndirilməsinin mümkünlüyünü əsaslandırır.

Nəticə etibarilə, insan resursları iqtisadi mahiyyətinə görə maddi olmayan aktivlərin əsas xüsusiyyətlərinə malik olsa da, onların hüquqi və metodoloji xüsusiyyətləri klassik mühasibat uçotu çərçivəsində aktiv kimi tanınmasını çətinləşdirir. Bu isə insan resurslarının qiymətləndirilməsi üzrə yeni konseptual yanaşmaların və alternativ hesabat modellərinin formalaşdırılmasını zəruri edir.

3. İnsan resurslarının qiymətləndirilməsi metodları

İnsan resurslarının iqtisadi dəyərinin müəyyən edilməsi müasir elmi ədəbiyyatda ən çox müzakirə olunan məsələlərdən biridir. İnsan kapitalının qeyri-maddi və subyektiv xarakter daşması onun ölçülməsini çətinləşdirir. Buna baxmayaraq, müxtəlif elmi yanaşmalar çərçivəsində insan resurslarının qiymətləndirilməsi üçün bir sıra metodlar formalaşdırılmışdır. Bu metodlar əsasən xərc, gəlir və bazar yanaşmalarına bölünür.

1) Xərc yanaşması

Xərc yanaşması insan resurslarının dəyərini onların formalaşdırılmasına və inkişafına çəkilən xərclər əsasında müəyyən edir. Bu yanaşmaya görə insan kapitalı müəssisənin keçmiş dövrlərdə işçilərin hazırlanması üçün sərf etdiyi investisiyaların məcmusu kimi qiymətləndirilir.

Bu metod aşağıdakı xərcləri əhatə edir:

- ✓ təhsil və peşə hazırlığı xərcləri;
- ✓ təlim və ixtisasartırma proqramları;
- ✓ işə qəbul və seçim xərcləri;
- ✓ adaptasiya və inkişaf tədbirləri;
- ✓ motivasiya və sosial paket xərcləri.

Cədvəl 1. Xərc yanaşması üzrə insan resurslarının dəyərinin formalaşması

Xərc elementləri	İqtisadi məzmunu	Uçotda əks olunması
Təlim xərcləri	Bacarıqların artırılması	Cari xərc
İşə qəbul xərcləri	Kadr seçimi və yerləşdirmə	Cari xərc
Adaptasiya xərcləri	İşə uyğunlaşma	Cari xərc
Sosial paketlər	Motivasiya və saxlanma	Cari xərc

Müsbət xüsusiyyətləri:

1. Hesablama sadəliyi:

Xərc yanaşması əsasən müəssisənin insan resurslarının formalaşdırılmasına çəkdiyi xərclərin toplanması üzərində qurulduğundan, onun hesablanması nisbətən sadədir. Təlim, ixtisasartırma və işə qəbul xərcləri kimi maliyyə məlumatları müəssisənin mövcud uçot sistemində asanlıqla mövcuddur. Bu sadəlik, yanaşmanın xüsusilə kiçik və orta sahibkarlıq subyektləri üçün praktik tətbiqinə imkan yaradır.

2. Məlumatların asan əldə olunması:

Bu metodda əsas mənbələr müəssisənin daxili maliyyə və personal hesabatlarıdır. Beləliklə, əlavə sorğular, bazar araşdırmaları və ya proqnoz hesablama ehtiyacı olmur. İşçi xərclərinin dəqiq uçotu və hesabatlılıq mexanizmləri mövcud olduqda, metodun tətbiqi sürətli və effektiv olur.

3. Kvantitativ nəticələrin əldə olunması:

Xərc yanaşması işçi kapitalının dəyərini rəqəmlərlə ifadə etməyə imkan verir, bu da mühasibat və maliyyə hesabatlarında əlavə göstərici kimi istifadə oluna bilər. Bu xüsusiyyət planlaşdırma və büdcə təhlili prosesində əlavə dəstək təmin edir.

Mənfi cəhətləri:

1. Gələcək iqtisadi faydanı nəzərə almır:

Xərc yanaşması yalnız keçmişdə və ya cari dövrdə həyata keçirilmiş xərcləri nəzərə alır. İşçinin gələcəkdə yaratacağı əlavə dəyər və məhsuldarlıq artımı bu yanaşmada əks olunmur. Bu, insan kapitalının strateji və uzunmüddətli rolunu tam əks etdirməməsinə gətirib çıxarır.

2. İnsan kapitalının real bazar dəyərini əks etdirmir:

Metod işçilərin potensial bazar qiymətlərini, bacarıqlarının rəqabətçi üstünlüyünü və əmək bazarındakı tələbi nəzərə almır. Bu səbəbdən, müəssisənin balansında göstərilən dəyər real bazar dəyərindən fərqli ola bilər.

3. İnnovasiya və keyfiyyət göstəricilərini nəzərə almır:

Xərc yanaşması yalnız maliyyə göstəricilərinə əsaslanır, işçilərin yaradıcılıq və innovasiya qabiliyyətləri kimi keyfiyyət amillərini qiymətləndirmir. Bu isə müasir bilik əsaslı iqtisadiyyatda metodun əhəmiyyətini məhdudlaşdırır.

2) Gəlir yanaşması

Gəlir yanaşması insan resurslarının dəyərini onların gələcəkdə yaradacağı iqtisadi faydanın diskontlaşdırılmış məbləği kimi müəyyən edir. Bu metod insan kapitalını aktiv kimi dəyərləndirməyə daha yaxın yanaşma hesab olunur.

Gəlir yanaşmasına əsasən:

İnsan kapitalının dəyəri = gələcək əlavə gəlirlərin cari dəyəri

Cədvəl 2. Gəlir yanaşması üzrə insan kapitalının qiymətləndirilməsi (şərti nümunə)

Göstəricilər	Məbləğ
İllik əlavə gəlir	300 000 AZN
Diskont dərəcəsi	10 %
Gözlənilən istifadə müddəti	5 il
İnsan kapitalının dəyəri	1 137 000 AZN

Səmərəli tərəfləri:

1. Gələcək iqtisadi faydanı nəzərə alır: Gəlir yanaşması işçinin və ya insan kapitalının gələcəkdə gətirəcəyi əlavə iqtisadi faydanın diskontlaşdırılmış dəyəri üzərində qurulur. Bu metod müəssisənin insan resurslarından əldə edəcəyi real maliyyə və strateji nəticələri proqnozlaşdırmağa imkan verir.

2. Strateji qərarlar üçün uyğundur: Metod işçi kapitalının qiymətini gələcək dövrlərə əsasən hesabladığı üçün, menecerlər və rəhbərlər üçün investisiya planlaması, ixtisasartırma strategiyaları və kadr seçim qərarlarında etibarlı göstərici rolunu oynayır.

3. İnsan kapitalının qiymətləndirilməsinin bazar yönümlü modellərlə birləşdirilməsi mümkündür: Gəlir yanaşması həm daxili, həm də xarici iqtisadi göstəricilərə əsaslanaraq strateji analizlərdə istifadə oluna bilər. Məsələn, diskontlaşdırılmış gəlir dəyərləri əmək bazarındakı məvaciblərlə müqayisə edilə bilər.

Mənfi cəhətləri:

1. Proqnozların subyektivliyi: Gəlir yanaşması işçinin gələcəkdə yaradacağı əlavə dəyəri proqnozlaşdırmağa əsaslandığından, nəticələr müəyyən dərəcədə subyektiv olur. İşçinin performansı, bazar şərtləri və iqtisadi amillər dəyişikliyə məruz qaldıqda, qiymətləndirmə də dəyişir.

2. Diskont dərəcəsinin seçimi riski: Gələcək iqtisadi faydanın indiki dəyərə çevrilməsi üçün diskont dərəcəsi seçilməlidir. Diskont dərəcəsinin yanlış seçilməsi insan kapitalının dəyərinin az və ya çox qiymətləndirilməsinə səbəb ola bilər.

3. Hesablama mürəkkəbliyi: Gəlir yanaşması daha mürəkkəb maliyyə hesablamaları tələb edir və yüksək dəqiqlik üçün ətraflı məlumatların mövcudluğu vacibdir. Bu isə kiçik və orta müəssisələr üçün çətinlik yarada bilər.

4. Ətraf mühit və bazar dəyişkənliyinə həssaslıq: Makroiqtisadi dəyişikliklər, tələbatın azalması və ya işçi kadrların digər müəssisələrə köçməsi kimi amillər gəlir yanaşmasının nəticələrinə birbaşa təsir göstərir.

3) Bazar yanaşması

Bazar yanaşması oxşar bilik və bacarıqlara malik işçilərin əmək bazarındakı dəyərinə əsaslanır. Bu metodda insan resurslarının dəyəri əmək bazarında formalaşan maaşlar, bonuslar və kompensasiya paketləri əsasında müəyyən edilir.

Cədvəl 3. Bazar yanaşmasının əsas xüsusiyyətləri

Göstərici	Məzmun
Əsas meyar	Əmək bazarı qiymətləri
Məlumat mənbəyi	Əmək bazarı statistikasısı
Tətbiq sahəsi	Nəzəri və müqayisəli təhlil
Əsas məhdudiyyət	Standart bazarın olmaması

Bu metod əsasən nəzəri xarakter daşıyır və praktiki tətbiqi məhduddur.

4. Beynəlxalq mühasibat uçotu standartları və insan resursları

Hazırda Beynəlxalq Maliyyə Hesabatı Standartları Şurası tərəfindən qəbul edilmiş standartlara əsasən insan resursları maddi olmayan aktiv kimi tanınmır. Bunun əsas səbəbləri aşağıdakılardır:

- ✓ insan resursları üzərində tam nəzarətin mümkün olmaması;
- ✓ dəyərin etibarlı və obyektiv ölçülməsində çətinliklər;
- ✓ hüquqi mülkiyyət hüququnun olmaması.

Cədvəl 4. İnsan resurslarının aktiv kimi tanınmamasının səbəbləri

Meyar	İnsan resursları	Maddi olmayan aktivlər
Fiziki forma	Yoxdur	Yoxdur
Gələcək fayda	Var	Var
Nəzarət	Qismən	Tam
Hüquqi mülkiyyət	Yox	Var

Buna baxmayaraq, bir sıra inkişaf etmiş ölkələrdə intellektual kapital hesabatları, insan kapitalı göstəriciləri və qeyri-maliyyə hesabatları tətbiq edilməkdədir.

5. İnsan resurslarının aktiv kimi tanınmasının üstünlükləri və riskləri

Üstünlüklər

Cədvəl 5. İnsan resurslarının aktiv kimi tanınmasının üstünlükləri

Üstünlük	İqtisadi təsiri
Real dəyərin əks etdirilməsi	Şəffaflıq artır
Strateji idarəetmə	Qərarların keyfiyyəti yüksəlir
İnvestisiya cəlb edilişi	Etibar artır

Risqlər

Cədvəl 6. İnsan resurslarının aktiv kimi tanınmasının riskləri

Risk	Məzmun
Subyektivlik	Ölçmədə qeyri-dəqiqlik
Etik problemlər	İnsan faktorunun obyektləşdirilməsi
Hesabat qeyri-sabitliyi	Maliyyə göstəricilərində dəyişkənlik

6. Azərbaycanda insan resurslarının maddi olmayan aktiv kimi qiymətləndirilməsi

Azərbaycanda insan resurslarının maddi olmayan aktiv kimi qiymətləndirilməsi məsələsi son illərdə iqtisadi inkişaf strategiyaları çərçivəsində daha çox diqqət mərkəzinə çevrilmişdir. Ölkədə iqtisadiyyatın şaxələndirilməsi, qeyri-neft sektorunun inkişafı və innovasiya yönümlü fəaliyyətin genişləndirilməsi insan kapitalının əhəmiyyətini artırmışdır. Xüsusilə xidmət, informasiya texnologiyaları, maliyyə və təhsil sektorlarında fəaliyyət göstərən müəssisələr üçün yüksək ixtisaslı əmək resursları əsas rəqabət üstünlüyü hesab olunur.

Buna baxmayaraq, Azərbaycanda fəaliyyət göstərən müəssisələrin böyük əksəriyyətində insan resurslarının iqtisadi dəyərinin sistemli şəkildə qiymətləndirilməsi və hesabatlarda əks etdirilməsi hələ geniş yayılmamışdır. Ənənəvi mühasibat uçotu praktikalarında işçi qüvvəsinə çəkilən xərclər əsasən cari xərclər kimi qəbul edilir və onların uzunmüddətli iqtisadi fayda yaradan investisiya kimi qiymətləndirilməsi məhdud səviyyədə həyata keçirilir. Bu vəziyyət müəssisələrin real iqtisadi potensialının maliyyə hesabatlarında tam şəkildə əks olunmamasına səbəb olur.

Son illərdə ölkədə insan kapitalının inkişafına yönəlmiş dövlət proqramları, təhsil islahatları, peşə hazırlığı və kadrların ixtisasartırma proqramları insan resurslarının keyfiyyətinin yüksəldilməsinə mühüm töhfə verir. Xüsusilə ali təhsil müəssisələrində və iri şirkətlərdə insan resurslarının idarə olunması sahəsində müasir yanaşmaların tətbiqi genişlənməkdədir. Bununla yanaşı, beynəlxalq şirkətlərin və transmilli korporasiyaların Azərbaycanda fəaliyyəti insan kapitalının qiymətləndirilməsi və idarə olunması üzrə yeni idarəetmə standartlarının tətbiqinə də stimül yaradır.

Bununla belə, insan resurslarının maddi olmayan aktiv kimi qiymətləndirilməsi sahəsində metodoloji yanaşmaların formalaşdırılması, qeyri-maliyyə hesabatlarının tətbiqi və insan kapitalının ölçülməsi üzrə vahid göstəricilər sisteminin yaradılması hələ də aktual məsələlərdən biri olaraq qalır. Bu istiqamətdə elmi tədqiqatların genişləndirilməsi, müəssisələrdə strateji insan resursları idarəetmə modellərinin tətbiqi və beynəlxalq təcrübənin öyrənilməsi Azərbaycanda insan kapitalının daha səmərəli istifadə olunmasına və iqtisadi inkişafın dayanıqlığının artırılmasına mühüm töhfə verə bilər.

NƏTİCƏ

Aparılmış elmi-nəzəri və empirik tədqiqatların nəticələri göstərir ki, insan resursları müasir iqtisadi şəraitdə müəssisələrin fəaliyyətinin əsas hərəkətverici qüvvələrindən biri olmaqla yanaşı, iqtisadi mahiyyətinə görə maddi olmayan aktivlərin fundamental xüsusiyyətlərinə malikdir. İşçilərin bilik səviyyəsi, peşə bacarıqları, təcrübəsi, innovativ düşüncə qabiliyyəti və yaradıcılıq potensialı müəssisənin uzunmüddətli rəqabət üstünlüyünün formalaşmasında həlledici rol oynayır. Bu xüsusiyyətlər insan resurslarını ənənəvi istehsal amili çərçivəsindən çıxararaq, strateji kapital kateqoriyasına yaxınlaşdırır.

Tədqiqat nəticəsində müəyyən edilmişdir ki, insan kapitalına yönəldilən investisiyalar – təhsil, peşəkar təlim, ixtisasartırma, motivasiya və inkişaf proqramları – müəssisələr üçün qısa müddətli xərc deyil, uzunmüddətli iqtisadi fayda yaradan strateji investisiya xarakteri daşıyır. Bu investisiyalar işçi məhsuldarlığının artmasına, innovativ fəaliyyətin genişlənməsinə, əmək resurslarından istifadənin səmərəliliyinin yüksəlməsinə və nəticə etibarilə müəssisənin maliyyə göstəricilərinin yaxşılaşmasına

səbəb olur. Empirik təhlillər göstərir ki, insan kapitalına daha çox sərmayə qoyan müəssisələr bazar şəraitində daha dayanıqlı mövqe tutur və risklərə qarşı daha davamlı olur.

Bununla yanaşı, tədqiqat sübut edir ki, mövcud mühasibat uçotu və maliyyə hesabatı standartları insan resurslarının maddi olmayan aktiv kimi rəsmi şəkildə tanınmasına imkan vermir. İnsan resursları üzərində tam mülkiyyət hüququnun olmaması, dəyərin etibarlı və obyektiv ölçülməsində yaranan çətinliklər, həmçinin etik və hüquqi məhdudiyyətlər onların balansda aktiv kimi əks etdirilməsini əngəlləyən əsas amillər sırasındadır. Nəticədə, müəssisələrin maliyyə hesabatlarında real iqtisadi potensialı tam əks etdirməyən vəziyyət formalaşır.

Bu baxımdan tədqiqatın əsas nəticələrindən biri ondan ibarətdir ki, insan resurslarının iqtisadi dəyərinin ölçülməsi və qiymətləndirilməsi üçün mövcud uçot mexanizmləri kifayət etmir və alternativ yanaşmaların tətbiqi zəruridir. İnsan kapitalının qiymətləndirilməsi üzrə vahid metodoloji yanaşmaların formalaşdırılması, qeyri-maliyyə göstəricilərinə əsaslanan hesabatların, intellektual və insan kapitalı hesabatlarının tətbiqi müəssisələrin iqtisadi şəffaflığının artırılmasına mühüm töhfə verə bilər. Bu cür yanaşmalar idarəetmə qərarlarının daha əsaslandırılmış şəkildə qəbul edilməsinə, resursların daha səmərəli bölüşdürülməsinə və strateji planlaşdırmanın təkmilləşdirilməsinə imkan yaradır.

Eyni zamanda, insan resurslarının qiymətləndirilməsinin institusional və normativ əsaslarının inkişaf etdirilməsi milli mühasibat uçotu sisteminin beynəlxalq təcrübəyə uyğunlaşdırılması baxımından da əhəmiyyətlidir. Xüsusilə bilik və xidmət yönümlü iqtisadiyyat şəraitində insan kapitalının rolunun artması bu sahədə elmi tədqiqatların davam etdirilməsini və yeni konseptual yanaşmaların formalaşdırılmasını aktuallaşdırır.

Nəticə etibarilə, aparılan tədqiqat göstərir ki, insan resurslarının maddi olmayan aktiv kimi qiymətləndirilməsi yalnız nəzəri əhəmiyyət daşıyır, eyni zamanda müəssisələrin idarəetmə səmərəliliyinin yüksəldilməsi, investisiya cəlb ediliyinin artırılması və davamlı inkişaf strategiyasının formalaşdırılması baxımından mühüm praktiki əhəmiyyətə malikdir. Gələcək tədqiqatlar bu sahədə metodoloji boşluqların aradan qaldırılmasına və insan kapitalının uçot və hesabat sistemlərində daha dolğun əks etdirilməsinə yönəldilməlidir.

İstifadə olunmuş ədəbiyyat

1. Azərbaycan Respublikasının Maliyyə Nazirliyi. Mühasibat uçotu haqqında qanunvericilik. Bakı: Rəsmi nəşrlər.
2. Həsənov, E. A. Mühasibat uçotunun nəzəri əsasları. Bakı: İqtisad Universiteti nəşriyyatı.
3. Quliyev, T. Ə. Müasir mühasibat uçotu və maliyyə hesabatı. Bakı: Elm və Təhsil.
4. Məmmədov, R. S. İnsan resurslarının idarə olunması. Bakı: Azərbaycan Dövlət İqtisad Universiteti nəşriyyatı.
5. Becker, G. S. *Human Capital: A Theoretical and Empirical Analysis*. Chicago: University of Chicago Press, 1993.
6. Edvinsson, L., Malone, M. S. *Intellectual Capital*. New York: Harper Business, 1997.
7. Flamholtz, E. G. *Human Resource Accounting*. Boston: Kent Publishing Company, 1985.
8. Lev, B. *Intangibles: Management, Measurement, and Reporting*. Washington: Brookings Institution Press, 2001.
9. OECD. *The Well-being of Nations: The Role of Human and Social Capital*. Paris: OECD Publishing, 2001.
10. Schultz, T. W. *Investing in People: The Economics of Population Quality*. Berkeley: University of California Press, 1981.
11. Stewart, T. A. *Intellectual Capital: The New Wealth of Organizations*. New York: Doubleday, 1997.
12. III. Türk dilində
13. Acar, A. C. *İnsan Kaynakları Yönetimi*. İstanbul: Beta Yayınları.
14. Eren, E. *Stratejik Yönetim ve İşletme Politikası*. İstanbul: Beta Yayınları.
15. Sabuncuoğlu, Z. *İnsan Kaynakları Yönetimi*. Bursa: Alfa Aktüel Yayınları.
16. Добрынин, А. И. *Человеческий капитал в современной экономике*. Москва: Инфра-М.
17. Капелюшников, Р. И. *Экономика человеческого капитала*. Москва: Высшая школа экономики.
18. Милгрот, П., Робертс, Д. *Экономика, организация и управление*. Москва: Экономическая школа.
19. Смит, А. *Исследование о природе и причинах богатства народов*. Москва: Соцэкгиз.

STUDY ON THE LEVEL OF BUSINESS DIGITALIZATION**Vusal Bahadir Kasymov**

Master program student

Department of Economic and Technological Sciences

Azerbaijan State University of Economics (UNEC)

STUDY ON THE LEVEL OF BUSINESS DIGITALIZATION**Вусал Бахадир Касымов**

Магистрант,

Кафедра экономических и технологических наук,

Азербайджанский государственный экономический университет (UNEC)

Abstract

In the modern era, digitalization serves as one of the main drivers of economic development and has a significant impact on the activities of business entities. In particular, for small and medium-sized enterprises (SMEs), the application of digital technologies is of strategic importance in terms of enhancing competitiveness, increasing operational efficiency, and expanding market opportunities. The article also examines the level of digitalization among SMEs operating in Azerbaijan, the existing opportunities and challenges in the digital transformation process, as well as the impact of digital technologies on business operations. The study employed theoretical and empirical approaches, and the data obtained from a structured survey were analyzed using statistical methods. The results of the study show that digitalization increases the productivity and competitiveness of SMEs; however, financial constraints, low levels of digital literacy, and problems with technological infrastructure hinder the development of this process. The article also presents practical recommendations for increasing the level of digitalization among SMEs.

Аннотация

В современную эпоху цифровизация выступает одним из основных факторов экономического развития и оказывает существенное влияние на деятельность хозяйствующих субъектов. В частности, для малых и средних предприятий (МСП) применение цифровых технологий имеет стратегическое значение с точки зрения повышения конкурентоспособности, увеличения операционной эффективности и расширения рыночных возможностей. В статье рассматриваются уровень цифровизации МСП, функционирующих в Азербайджане, существующие возможности и проблемы процесса цифровой трансформации, а также влияние цифровых технологий на деятельность предприятий. В исследовании были использованы теоретические и эмпирические подходы, а данные, полученные в результате структурированного опроса, были проанализированы с применением статистических методов. Результаты исследования показывают, что цифровизация способствует повышению производительности и конкурентоспособности МСП; однако финансовые ограничения, низкий уровень цифровой грамотности и проблемы технологической инфраструктуры сдерживают развитие данного процесса. В статье также представлены практические рекомендации по повышению уровня цифровизации малых и средних предприятий.

Keywords: digitalization, SMEs, digital transformation, digital economy, innovation, Azerbaijan.

Ключевые слова: цифровизация, МСП, цифровая трансформация, цифровая экономика, инновации, Азербайджан.

Introduction. One of the main trends in the development of the modern global economy is the process of digitalization. The rapid development of information and communication technologies has led to the transformation of business models, the modernization of management mechanisms, and the integration of economic relations into the digital environment. Digitalization is not only about technological changes but also a strategic factor that ensures increased economic efficiency and competitiveness.

Small and medium-sized enterprises (SMEs) not only constitute the bulk of the economy but also play a vital role in providing employment, fostering innovation, and developing the entrepreneurial environment. In today's environment of intensifying global competition, the integration of SMEs into

digital technologies takes on particular significance in terms of ensuring their sustainability in the market.

In recent years, Azerbaijan has implemented significant measures aimed at developing the digital economy. The expansion of e-government services, the development of digital financial systems, and increased investment in information technology have accelerated the country's digitalization process. However, the level of digitalization in the SME sector and its effectiveness have not yet been fully studied.

From this perspective, the main objective of this article is to assess the level of digitalization among SMEs in Azerbaijan, examine the impact of digital technologies on business operations, and identify existing challenges.

Literature Review. *The essence of small and medium-sized enterprises (SMEs) is defined by the multifaceted functions they perform within the economic system. SMEs are entities that, compared to large enterprises, are more flexible, make decisions more quickly, and are able to adapt rapidly to market changes. Their main characteristic lies in their tendency to seek innovative solutions despite limited resources and in their ability to fill gaps in various sectors of the economy.*

The essence of small and medium-sized enterprises lies primarily in the diversification of economic activity. Enterprises of this type are widespread in manufacturing, services, trade, agriculture, and other sectors, and contribute to the balanced development of the country's economy. Their activities lead to the formation of new markets, the efficient use of local resources, and the strengthening of the entrepreneurial ecosystem.

At the same time, one of the most important characteristics of SMEs is their social function. These enterprises provide the bulk of employment in most countries, help reduce regional unemployment, and facilitate the integration of young people into the labor market. Creating a closer and more transparent environment in relations between workers and enterprises has a positive impact on the development of human capital.

The European Union (EU) recognizes that small and medium-sized enterprises (SMEs) are one of the main drivers of economic growth and has therefore been developing SME policies at the strategic level for many years. With the aim of enhancing the competitiveness of SMEs, expanding their financial opportunities, and creating conditions for more sustainable operations in the European market, the EU adopted a framework document in 2008 titled "Small Business Act for Europe" (SBA). This document effectively serves as the constitution of European policy regarding SMEs and sets out general principles for all member states.

The SBA's activities are guided by the "Think Small First" principle. This approach holds that the interests of small and medium-sized enterprises must be given priority when developing public policy and adopting new regulations. This entails both eliminating additional burdens on the administration and minimizing administrative barriers that weaken the competitiveness of SMEs. The "Small Business Act" sets forth 10 key principles that promote the development of SMEs, and these principles serve as a guide for shaping SME policy in EU countries.

The development of an entrepreneurial culture in ASEAN countries, support for entrepreneurial initiatives among youth, and the commercialization of innovative ideas are identified as key principles of the SBA. The SBA establishes effective legal mechanisms to facilitate the return of SME owners to the economic system following business failure. The goal is for business closure to be viewed not as a long-term punishment for the entrepreneur, but as a fresh start.

When drafting new laws and regulations, the AI strives to avoid imposing an additional administrative burden on SMEs. The "Think Small First" approach serves precisely this purpose. The user-friendly use of e-government services by SMEs and the digitization of licenses and permits form the basis of this principle. The AI encourages the active participation of SMEs in public procurement. Special quotas and simplified tendering mechanisms are applied.

Thanks to programs such as COSME, InvestEU, and Horizon Europe, SMEs have greater access to loans, guarantee funds, and venture capital. The European Investment Fund provides SMEs with grants for research and development (R&D), opportunities for technology transfer, and support for integration into innovation clusters. Reducing the carbon footprint of SMEs, transitioning to green technologies, and improving resource efficiency are supported by special incentive mechanisms.

Single Market requirements have been simplified and harmonized to enable SMEs to operate freely across the 27 EU member states. The EU supports the expansion of SMEs' export potential through international trade networks, market research services, and EU offices abroad.

Digital transformation in small and medium-sized enterprises (SMEs) is a key factor in competitiveness in today's economic environment. This process contributes both to improving a

company's internal efficiency and to strengthening its position in global markets. SMEs that successfully adopt digital technologies achieve a more flexible, rapid, and sustainable growth trajectory. For this reason, digital transformation is no longer a choice for SMEs but an inevitable strategic necessity.

Digital transformation is viewed as a phase of both development and restructuring for small and medium-sized businesses. This process affects all stages of business operations and involves a shift from traditional business practices to digital approaches. Although the opportunities created by digitalization enable SMEs to become more flexible, resilient, and competitive, implementing this process comes with a number of challenges. For this reason, digital transformation is a complex process based on balancing both opportunities and risks.

One of the key benefits of digital transformation is the improvement of operational efficiency. Electronic document management, automated management systems, and cloud technologies enable small and medium-sized businesses to accomplish more with fewer resources. Digital solutions streamline workflows, reduce time wasted, and minimize human error. Additionally, these technologies improve decision-making within organizations and enable real-time access to information. At the same time, digitalization expands organizations' market opportunities. E-commerce channels, online sales platforms, and social media marketing opportunities create conditions for SMEs to expand beyond the local market, attract a new customer base, and participate in the global market.

Research Methodology. The main objective of this study is to assess the level of digitalization among small and medium-sized enterprises (SMEs) operating in Azerbaijan, analyze the extent to which digital technologies are used, and determine the impact of this process on business operations. The study included both a description of the current situation and a statistical analysis of the relationships between variables.

A quantitative approach was used in the study. A survey method was chosen to collect empirical data, and information was obtained using a structured questionnaire. The questionnaire questions addressed the level of digital technology adoption by SMEs, the impact of digitalization on business outcomes, and the challenges encountered in this process.

The main hypotheses of the study are formulated as follows:

H1: There is a positive relationship between the level of digitalization and a company's revenue growth.

H2: There is a statistically significant relationship between the level of digital technology adoption and operational efficiency.

H3: The level of digital skills has a direct impact on the degree of digitalization of SMEs.

The SPSS software package was used for data analysis. The statistical analysis included descriptive statistics, correlation analysis, and comparative tests.

To collect empirical data for the study, a survey method based on a quantitative approach was used. For this purpose, a structured questionnaire was developed and a survey was conducted among small and medium-sized enterprises (SMEs) operating in Azerbaijan. The survey collected data on the level of digitalization of enterprises, the technologies they use, the impact of digital transformation on business results, as well as the main difficulties they face.

The questionnaire consists of several sections. The first section identifies the general characteristics of the respondent organizations (field of activity, number of employees, duration of operation, etc.). The second section is aimed at assessing the level of digital technology adoption by enterprises. The third section assesses the impact of digitalization on economic indicators, specifically on revenue growth and operational efficiency. The final section identifies the main obstacles and constraints in the digitalization process.

The survey included 250 participants from 50 small and medium-sized enterprises. The sample was selected to represent various sectors of activity, with particular emphasis placed on the participation of businesses in the retail, services, agriculture, manufacturing, and other sectors. This approach allowed for more generalizable and objective results.

Data collection was conducted primarily through online platforms (Google Forms and email) and partially through personal contact. To ensure the reliability of the collected data, the survey questions were pre-tested during a pilot phase, and any unclear or imprecise questions were corrected.

Research Results and Analysis. As part of this study, a survey was conducted among 250 respondents to assess the level of digitalization of small and medium-sized enterprises operating in Azerbaijan. Statistical analysis of the survey results was performed using SPSS, and the results are presented below in a systematic format.

According to the survey results, the level of digital technology adoption in organizations is rated as high. Most respondents reported using digital technologies in their day-to-day operations (average score ≈ 4.12). This indicator suggests that SMEs are in the process of transitioning from traditional business models to digital approaches.

In particular, the use of digital systems for accounting and financial transactions has become widespread. This is considered an important factor in terms of improving business efficiency and ensuring transparency. At the same time, the high level of use of social media and digital marketing tools indicates that digitalization plays an important role in the market-oriented strategies of SMEs.

To determine the characteristics of the respondent enterprises that participated in the study, data were collected on their field of activity, number of employees, and duration of operation. The results are presented in the table below.

Table 3.1. Demographic indicators of respondent enterprises

Indicator	Category	Number (N)	Share (%)
Field of activity	Trade	85	34.0
	Services	70	28.0
	Agriculture	35	14.0
	Industry / Manufacturing	40	16.0
	Other	20	8.0
Number of employees	1–10 (micro)	110	44.0
	11–50 (small)	85	34.0
	51–250 (medium)	55	22.0
Duration of activity	0–3 years	60	24.0
	4–7 years	70	28.0
	8–15 years	65	26.0
	Over 15 years	55	22.0

The results presented in Table 3.1 show that the majority of enterprises participating in the study operate in the trade (34%) and services (28%) sectors. This indicates that SMEs are primarily concentrated in service-oriented and market-oriented sectors. Although the share of agriculture and industry is relatively small, there is also some presence in these sectors.

In terms of the number of employees, the majority of respondents are microenterprises (44%). This result confirms that the structure of SMEs in Azerbaijan consists mainly of small enterprises. Small enterprises account for 34%, and medium-sized enterprises for 22%, which indicates a balanced structure of the sector, albeit with a predominance of microenterprises.

In terms of years in operation, the data show that a significant proportion of businesses have been in operation for 4–7 years (28%) and 8–15 years (26%). This indicates that the respondents are primarily business entities with some experience. The share of recently established enterprises (0–3 years) is also quite large (24%), which indicates continued dynamism in the entrepreneurial environment.

As part of the study, descriptive statistical indicators for the main variables were calculated based on respondents' answers. These indicators allow for an assessment of the general trend and distribution of the variables.

Table 3.2. Descriptive statistical indicators for key variables

Variable	N	Minimum	Maximum	Mean	Standard deviation
Digitalization level (Q4–Q8)	250	2.40	5.00	4.12	0.68
Impact of digitalization (Q9–Q13)	250	2.20	5.00	4.05	0.72
Mathematical skills (Q14–Q16)	250	2.00	5.00	3.98	0.75
Barriers and difficulties (Q17–Q20)	250	1.80	4.80	3.10	0.81

The results presented in the table show that the level of digitalization among the responding organizations is high. The average digitalization score of 4.12 confirms that the majority of enterprises actively use digital technologies. This result indicates that SMEs have already achieved a significant level of integration into the digital transformation process.

The average digitalization impact score (Mean = 4.05) indicates that digitalization has a positive impact on business operations. In particular, outcomes such as revenue growth, reduced operating costs, and accelerated business processes were highly rated by respondents.

The average level of digital skills was rated at 3.98, indicating that staff generally possess the ability to use digital technologies. At the same time, the relatively high standard deviation suggests that these skills are underdeveloped in some organizations.

The average score for obstacles and challenges, which stands at 3.10, confirms the existence of certain problems in the digitalization process. These problems are primarily related to limited financial resources, a lack of technical expertise, and infrastructure issues.

Cronbach's alpha was used to assess the internal consistency and reliability of the scales employed in the study. This analysis determines whether the items within each group of variables measure the same construct.

Table 3.3. Scale reliability indices (Cronbach's alpha

Scale	Items	Cronbach's alpha	Reliability level
Quantitative rating level	Q4–Q8	0.88	High
Impact of digitalization	Q9–Q13	0.91	Very high
Digital skills	Q14–Q16	0.86	High
Barriers and challenges	Q17–Q20	0.82	High

The results presented in the table show that Cronbach's alpha coefficients for all scales exceed 0.80. This indicates a high level of reliability for the survey instrument used.

The highest level of reliability was observed when assessing the impact of digitalization ($\alpha = 0.91$). This result indicates that the items included in this variable are strongly correlated with one another and measure the same phenomenon.

The results for the level of digitalization ($\alpha = 0.88$) and digital skills ($\alpha = 0.86$) also confirm high reliability. This indicates the stability and consistency of respondents' answers in these areas.

On the scale measuring problems and difficulties, Cronbach's alpha was determined to be 0.82, which corresponds to a satisfactory and high level of reliability. This result shows that this indicator is useful for analysis.

As part of the study, a Pearson correlation analysis was conducted to determine the relationship between the main variables. This analysis allows us to determine the direction (positive/negative) and strength of the relationship between variables.

Table 3.4. Correlation matrix by variables

Variables	1	2	3	4
1. Level of digitalization	1			
2. Impact of digitalization	0.65**	1		
3. Digital skills	0.58**	0.62**	1	
4. Obstacles and difficulties	-0.41**	-0.48**	-0.44**	1

Note: $p < 0.01$

The correlation results presented in the table show that there are statistically significant relationships between the variables.

Based on the results obtained, a strong positive correlation was identified between the level of digitalization and the impact of digitalization ($r = 0.65$, $p < 0.01$). This result indicates that as the level of digital technology use in an organization increases, so does its impact on business outcomes.

A positive and moderately strong correlation was also found between digital skills and the level of digitalization ($r = 0.58$, $p < 0.01$). This indicates that the technological knowledge and skills of staff play an important role in the effective implementation of digitalization.

At the same time, there is a positive correlation between digital skills and the impact of digitalization ($r = 0.62$, $p < 0.01$). This result reaffirms that human capital is a key factor in the digital transformation process.

A negative correlation was found between the "barriers and challenges" variable and all other variables. In particular, there is a moderate negative correlation between obstacles and the impact of digitalization ($r = -0.48$, $p < 0.01$). This means that as financial, technical, and institutional challenges increase, the effectiveness of digitalization decreases.

As part of the study, a multiple regression analysis was conducted to determine the impact of digitalization on the activities of institutions. The impact of digitalization () was used as the dependent variable in the analysis, while the level of digitalization (Q14–Q16), digital skills (Q17–Q20), and barriers and challenges (Q18–Q20) were included as independent variables.

Table 3.5. General indicators of the regression model

Statistic	Value
R	0.75
R ²	0.56
Adjusted R ²	0.55
F-statistic	48.3
Significance (p)	0.000

Table 3.6. Regression examples

Variable	Standardized beta	t	Significance (p)
Significance level	0.42	6.85	0.000
Digital skills	0.35	5.90	0.000
Obstacles and difficulties	-0.28	-4.75	0.000

The results of the regression model show that the model is statistically significant overall ($F = 48.3$, $p < 0.001$). The model has a high explanatory power ($R^2 = 0.56$), meaning that the independent variables account for 56% of the variation in the dependent variable. This result indicates that the model is sufficiently robust.

Based on the results obtained, the level of digitalization is the factor with the strongest positive impact on business performance ($\beta = 0.42$, $p < 0.001$). This result indicates that as the level of digital technology use in organizations increases, their efficiency grows significantly.

Digital skills also have a significant positive effect ($\beta = 0.35$, $p < 0.001$). This confirms that the technological knowledge and skills of staff play a key role in ensuring the effectiveness of digitalization.

The "barriers and challenges" variable, on the other hand, has a negative effect ($\beta = -0.28$, $p < 0.001$). This result shows that as financial constraints, technical incompatibilities, and infrastructure problems increase, the impact of digitalization on the organization decreases.

The results of the regression analysis were used to test the hypotheses proposed in the study. The hypotheses were formulated to determine the direction and significance of the relationships between the variables.

Table 3.7. Results of the hypothesis test

Hypothesis	Variable	Beta (β)	p-value	Result
H1	Level of digitalization $\rightarrow$ Effect	0.42	0.000	Accepted
H2	Digital skills $\rightarrow$ Impact	0.35	0.000	Accepted
H3	Barriers $\rightarrow$ Impact	-0.28	0.000	Accepted

According to the results of the analysis, all hypotheses were statistically significant ($p < 0.01$).

In accordance with the first hypothesis, it was found that the level of digitalization has a positive and strong impact on the company's performance ($\beta = 0.42$). This result shows that the use of digital technologies significantly increases the efficiency of SMEs.

The results for the second hypothesis show that digital skills also have a positive impact on the company's operations ($\beta = 0.35$). This confirms that human capital plays an important role in digital transformation.

According to the third hypothesis, it was found that barriers and challenges have a negative impact on organizational performance ($\beta = -0.28$). This result indicates that financial constraints, technical issues, and organizational resistance reduce the effectiveness of digitalization.

The t-test for independent samples tests for a difference between two groups (for example: micro- and small businesses).

H0: There is no difference between the groups

H1: There is a difference

Table 3.8. Results of the T-test

Group	N	Mean (score)	Medium
Micro (1–10)	110	3.95	0.72
Small/Medium	140	4.25	0.60
Test	t	p	
T-test	-2.85	0.005	

The results show that there is a statistically significant difference in the level of digitalization between microenterprises and other enterprises ($p < 0.05$). The level of digitalization is higher in small and medium-sized enterprises

Comparative Analysis (in a Regional and International Context)

To more fully assess the results of the empirical analysis, the obtained indicators were compared with the results of regional and international studies. This approach allows us to determine the position of the level of digitalization of SMEs in Azerbaijan against the backdrop of global trends.

Based on the results of the empirical analysis, the average level of digitalization among SMEs operating in Azerbaijan was determined to be high (average value ≈ 4.12). This result indicates that a significant proportion of these enterprises already use digital technologies in their day-to-day operations and are actively engaged in the process of digital transformation. However, to more accurately assess the nature of this level, it is necessary to compare it with international indicators.

In developed countries, particularly in OECD countries, the level of SME digitalization is more structured and technologically advanced. According to OECD data (2024), the majority of SMEs in these

countries use not only basic digital tools but also advanced technologies such as ERP systems, cloud technologies, big data analytics, and artificial intelligence. In contrast, the digitalization of SMEs in Azerbaijan is largely limited to entry-level technologies—online banking, electronic accounting, and marketing activities on social media.

Studies conducted in the European Union show that approximately 59% of businesses have reached a “basic level of digital intensity,” and among large enterprises, this figure exceeds 90%. Although this figure is lower for SMEs, compared to the situation in Azerbaijan, there is a higher degree of structure in the digital transformation process. In particular, e-commerce, cloud services, and the adoption of digital management systems are more widespread among European SMEs.

Compared to developing countries, Azerbaijan is in a more advantageous position. According to reports by the World Bank and the World Economic Forum, in most developing regions, a significant portion of SMEs still lack access to basic digital infrastructure—reliable internet or modern technological tools. In Azerbaijan, however, high internet penetration ($\approx 85\text{--}90\%$) and the widespread availability of e-government services significantly expand SMEs’ opportunities for digitalization.

The differences become even more apparent when compared to East Asian countries, particularly China and South Korea. In these countries, SMEs are more deeply integrated into the digital platform economy, and solutions in the fields of e-commerce, fintech, and artificial intelligence are widely adopted. In Azerbaijan, however, this process is still in its early stages, and the use of platform-based business models is limited.

The results of the empirical analysis showed that digitalization has a significant positive impact on the economic performance of small and medium-sized enterprises (SMEs) operating in Azerbaijan. According to the results of the regression analysis, the impact of the level of digitalization on business performance is statistically significant ($\beta = 0.42$, $p < 0.001$). This result indicates that the use of digital technologies creates conditions for increasing business revenue, reducing operating costs, and optimizing work processes.

These findings are generally consistent with data from international studies. Reports by the OECD (2024) and the World Bank also note that digitalization is one of the key factors driving productivity growth in SMEs. In particular, thanks to the adoption of digital technologies, businesses can access market information more quickly, optimize decision-making processes, and develop customer-centric strategies. Studies conducted in developed countries show that the impact of digitalization is not limited to the operational level but also leads to innovation and the formation of new business models.

Conclusions and Recommendations. Based on the results of the study, the level of digitalization among small and medium-sized enterprises operating in Azerbaijan was analyzed, and the impact of this process on business operations, as well as existing opportunities and limitations, were comprehensively examined. The empirical and theoretical findings obtained allow us to formulate the following main conclusions.

First and foremost, it was found that the level of digitalization among SMEs in Azerbaijan is generally high, and most businesses actively use digital technologies in their day-to-day operations. This indicates that the country’s digital transformation has already passed the initial stage and has entered the phase of practical implementation. At the same time, it was found that digitalization is mainly concentrated at the level of fundamental technologies, while the implementation of advanced systems remains limited.

The research results show that digitalization has a significant positive impact on business operations. In particular, the implementation of digital technologies leads to such important outcomes as increased operational efficiency, reduced costs, accelerated workflows, and higher customer satisfaction. The results of the regression analysis also confirmed the statistical significance of this impact.

At the same time, it has been established that digital skills play a crucial role in the digitalization process. As the level of technological knowledge and skills among staff increases, the effectiveness of digital transformation also rises. This finding demonstrates that digitalization is not merely the adoption of technology, but a complex process directly linked to the development of human capital.

Since research findings indicate that digital skills play a significant role, strengthening measures aimed at developing human capital takes on particular importance. From this perspective, it is necessary to organize continuing education programs for owners and employees of small and medium-sized enterprises, improve digital literacy, and formalize practical technological skills. Expanding cooperation between universities, training centers, and business entities can yield effective results in this regard.

In addition, it is necessary to formalize a strategic approach to digitalization at the organizational level. SMEs should view digital technologies not only as a means of streamlining day-to-day operations, but also as a key component of their long-term development strategy. The use of digital marketing tools, integration with e-commerce platforms, and the application of modern technologies in customer relationship management can significantly strengthen companies' market positions.

Another important area is the removal of existing barriers to digitalization. Comprehensive measures are needed to reduce financial constraints, address gaps in technical knowledge, and minimize resistance to change within organizations. To this end, both the government and the private sector should establish advisory services, technical support platforms, and innovation centers.

In the long term, digitalization should be viewed as an integral part of the country's overall economic development strategy. To integrate SMEs into the global digital economy, it is particularly important to expand international cooperation, strengthen the innovation and startup ecosystem, and promote technology-driven business models.

References

1. Bharadwaj, A., El-Sawy, O., Pavlu, P., & Venkatraman, N. (2013). *Digital business strategy: Toward a new generation of ideas*. *MIS Quarterly*, 37(2), 471–482.
2. Eurostat. (2024). *Statistics on the Digital Economy and Society*.
3. Kane, G. C., Palmer, D., Phillips, A. N., & Kiron, D. (2018). *Growing Up in the Digital Age: Learning, Leadership, and Legacy*. MIT Sloan Management Review.
4. McKinsey & Company. (2022). *Digital SMEs: Global Trends and Insights*. McKinsey Global Institute.
5. Nadirov, A. A. "Some Aspects of the Transition to a Market Economy and the Integration of the Republic of Azerbaijan into the Global Economy." *Bulletin of the Azerbaijan Academy of Sciences: "Economics" Series*, No. 1, 1998.
6. Nambisan, S., Wright, M., and Feldman, M. (2019). *The Digital Transformation of Innovation and Entrepreneurship*. *Research Policy*, 48(8), 103773.
7. Niftullaev, V. M. *Fundamentals of Entrepreneurship*. Baku, 2004.
8. OECD. (2022). *The Digital Transformation of SMEs*. *OECD SME Studies*.
9. OECD. (2024). *The Digitalization of SMEs: Enhancing the Contribution of SMEs to the Digital Economy*. OECD Publishing.
10. Porter, M., and Happelmann, J. (2015). *How Smart, Connected Products Are Transforming Companies*. *Harvard Business Review*.
11. United Nations. (2024). *Global Report on MSMEs*.
12. Vial, G. (2019). *Understanding Digital Transformation: An Overview and Research Agenda*. *Journal of Strategic Information Systems*, 28(2), 118–144.
13. World Economic Forum. (2023). *Report on the Digital Transformation of Small and Medium-Sized Enterprises*.

Jurisprudence

THE LEGAL PRINCIPLE OF THE RULE OF LAW AND EQUALITY

Endri Balla

Department of Public Administration, Faculty of
Political Science and Law, "Aleksandër Moisiu" University of Durrës, Albania

Abstract

The aim of this paper is to examine the features of the legal principle, which is one of the most crucial components of the legal system and law overall. Legal principles are fundamental rules that possess a stable nature and a deep philosophical foundation. They constitute the legal fabric and arise from influences that predate positive law, connecting to timeless concepts such as truth, justice, proportionality, correctness, and accuracy in actions overall. Legal principles are embedded within the normative hierarchy, which encompasses legal principles, legal norms, legal doctrine, and legal practice. This paper will explore the distinctions between principle and rule, or principle and norm, through various criteria, including logical and source-based criteria. Utilizing these criteria, the authors analyze and clarify the differences between these concepts. After outlining a general overview of the legal principle, we will concentrate on specific principles such as the principle of the rule of law, and the principles of equality and solidarity. The principle of the rule of law can be viewed as a foundational principle in Europe, intricately tied to the very essence and evolution of the concept across various European nations and, concurrently, with the law of the European Union. The principle of equality, encompassing equality before the law (equality in law enforcement) and equality in law (equality in legislative creation), is a shared European principle of the rule of law that frequently manifests as a ban on arbitrariness. These principles are interrelated and do not exist in isolation but are fundamentally connected to one another.

Keywords: legal principle, rule, norm, rule of law, equality, solidarity

1. Introduction

Legal principles hold significant importance in the logical dimension of interpretation. Their primary characteristic lies in the guidelines that shape the definition of legal rules concerning both the rules themselves and the manner in which they are executed. The constitution contains legal principles primarily within the description of certain fundamental rights and, to a lesser extent, in other sections that provide general directions for regulations to follow. To summarize somewhat, constitutional legal principles are crucial for interpreting statutes in alignment with the constitution. On one hand, they indicate the importance assigned to specific principles; on the other hand, they represent the goals of the statutory system's values and the broader legal system, while also delineating the scope of meaning within which the statutory framework operates.

Legal principles can be traced back to Roman law. In the academic discourse following World War II, scholars such as Esser, Larenz, and F. Bydlinski highlighted this topic, and since Dworkin's seminal work "Model Rules I," it has frequently been a subject of theoretical debate in both Anglo-American and European legal scholarship. Alexy is one of the authors who adds a distinctive perspective to these discussions. The essential distinction between rules and principles is that rules are constructed in an "all or nothing" manner. From the perspective of interpreting statutory provisions in accordance with the constitution, a difference exists between the notion that human dignity is the common denominator of fundamental rights and the principle that general legal actions cannot apply retroactively. They cannot be directly executed but must first be operationalized through statutory rules that honor human dignity. In this regard, legal principles serve as measures of values that can vary in intensity and whose application is necessitated by specific behavioral types. The value measure that can be practically implemented is neither absolute nor diluted in its essence, such as with the principle of human dignity or the principle of freedom of expression. If it were absolute, it would imply the principle serves as the pinnacle from which necessary solutions relevant to a particular case can be mechanically derived. Conversely, if it were diluted, it would suggest that the application depends solely on how the relevant law enforcer interprets and applies it.

Therefore, a legal principle is neither an absolute standard in content nor a criterion that relies solely on the authority of the enforcer; it is a foundational value that necessitates acting "proportionally" and "in a balanced way." This value foundation can be applied with such intensity as allowed by the

content norms that are legally established in a specific legal realm and as dictated by the characteristics of the case being adjudicated.

II. Literature Review

In modern legal theory, the differentiation between rules and principles has been significant, particularly regarding legal interpretation. Some theorists have argued that principles are not part of the law under the positivist view, or at least not within Hart's understanding of law. This stems from Dworkin's well-known critique of legal positivism, particularly Hart's version, which, according to Dworkin, saw law merely as a set of rules. Dworkin begins by asserting that law contains standards that do not operate as rules: these are principles. Both principles and rules lead to specific decisions, but rules apply in a categorical manner. When the facts align with a rule, it is either valid, and the answer it produces should be accepted, or it is invalid and thus does not aid in the decision-making process. Principles operate quite differently; they possess a dimension of weight, "do not impose legal outcomes that automatically arise when specified conditions are met," and the existence of counter-examples does not negate the validity of a principle. Dworkin believes that Hart's rule of recognition, which asserts that legal rules are valid due to approval from a competent authority, does not apply to principles, or at least not to some of them, because their source does not stem from a distinct decision by a legislature or court, but rather from a sense of appropriateness that has evolved within the profession and the public over time. Dworkin contends that no one can alter the rule of recognition to encompass principles, nor can the principles themselves be regarded as the rule of recognition.

Dworkin combines two distinct criteria to differentiate between rules and principles: a logical criterion and a "source" criterion identified by Raz. The logical criterion pertains to the structure of the standard. As previously discussed, he claims that both rules and principles direct towards specific decisions; however, rules are applied in an all-or-nothing manner, whereas principles do not compel a decision but instead direct us towards it, or, in Hart's terminology, principles are not definitive. The source criterion suggests that principles may not solely originate from positive legislation or court rulings, but can also stem from various sources, including morality (Travessoni, Trivisonno; 2016). With a clearer understanding of Dworkin's classification, we can juxtapose it with Hart's framework and evaluate which of Dworkin's criteria align with Hart's legal concept. Hart's rule of recognition does not dismiss rules based on their logical type, but rather considers their source. According to Dworkin, Hart's rule of recognition bars principles from entering the normative framework since it assesses whether a rule is established by a legitimate authority. Dworkin contends that principles, or at least a subset of them, do not satisfy this criterion. Since Dworkin himself acknowledges that principles can be derived from legislation and judicial rulings, we can infer that he recognizes two varieties of principles: authoritative and non-authoritarian (Travessoni, Trivisonno; 2016). This implies that, for Hart, non-final rules that are produced by an authority acknowledged by the rule of recognition qualify as legal rules. This indicates that some of the standards Dworkin refers to as principles specifically, Dworkin's authoritative principles are encompassed within Hart's legal framework. The distinction between Hart's and Dworkin's interpretations and expansions of legal standards lies in Dworkin's inclusion of non-authoritarian principles, which Hart's model does not incorporate. Furthermore, since Hart opposes Kelsen's notion that a legitimate norm must entail a sanction, we need not concern ourselves with Dworkin's assertion that principles sometimes fail to specify the repercussions for their violation. Additionally, it can be posited that Dworkin's positive principles fit into Hart's structure either as primary or secondary rules, since positive principles can pertain to the obligations individuals bear as well as to the establishment, alteration, and articulation of other rules (Priel; 2015).

In conclusion, while Hart's rule of recognition does not rule out non-final authoritative standards, it also does not inherently include non-authoritarian standards, which we could refer to as moral standards. Hence, non-final non-authoritarian (or moral) standards do not necessarily find a place within Hart's framework. However, according to Hart, even non-authoritarian principles necessitate a rule of recognition, as they are derived from established law, which can only be identified through such a rule. In fact, Dworkin occasionally appears to derive non-authoritarian principles from positive law (such as legislation and legal rulings), which would arguably compromise their status as truly non-authoritarian principles. If this were indeed the case, Hart's argument would hold true. Nevertheless, as previously noted, Dworkin also suggests that the roots of principles are not confined to specific decisions made by any legislative body or court, but instead emerge from a sense of propriety gradually formed within the profession and the public over time (Salojärvi; 2019). This indicates that, for Dworkin, non-authoritarian principles can be derived from sources beyond court decisions. While one could critique Dworkin for employing a somewhat ambiguous notion of source, such as the "sense of propriety developed in the

profession and the public over time," it must be acknowledged that the rule of recognition does not seem to incorporate it. However, it doesn't necessarily preclude it either, as Hart acknowledges the occurrence of moral principles being utilized in the judicial process.

Hart's theory indicates that if one aims to apply non-authoritarian principles, one must occasionally (specifically in the context of authoritarian principles), though not consistently, depend on the rule of knowledge to determine the established law from which these principles originate. It is evident here that Hart adopts a comprehensive positivist stance: while non-authoritarian standards can be a part of the law, their inclusion is not mandatory. Hart's notion of a rule differs from Dworkin's, being broader and thereby encompassing a segment of what Dworkin categorizes as principles, particularly non-final non-authoritarian legal or moral standards. What is Kelsen's position? Is he inclusive of non-final standards in his framework? One might find it challenging to argue that Dworkin's principles, as he defines them, fit within Kelsen's normative structure. For instance, one could contend that (i) Kelsen asserts that true legal norms characterize acts of coercion as sanctions, while principles do not appear to fulfill that criterion, and additionally (ii) Kelsen himself claimed that principles fall outside the definition of law. However, I would like to offer an interpretation of Kelsen's texts suggesting that Dworkin's authoritarian principles can be considered part of the law, and that his non-authoritarian principles may be applied in the processes of law-making and legal application. First, it appears that nothing in Kelsen's understanding of law precludes the existence of non-final norms. Kelsen defines law as a system of norms. In his terminology, a norm refers to a *Sollen*, meaning that it prescribes certain behaviors as obligatory, forbidden, or permitted. He does not insist that a norm must represent an all-or-nothing standard nor that non-final standards cannot qualify as norms (Salojärvi;2019). In fact, Kelsen acknowledges that norms with a significant degree of indeterminacy, which he associates with generality, are indeed part of the legal framework. I contend that standards such as "no one shall benefit from their own fraud," or similar expressions like "no one shall benefit from their own injustice, to make any claim based on their own wrongdoing, or to acquire property through their own crime," which Dworkin regards as principles, are not excluded from the legal system in Kelsen's perspective, and therefore are not outside his definition of law.

The principle of the rule of law.

The concept of the rule of law, despite its origins in Germany and its historical background, constitutes a shared constitutional goal and structural principle across Europe, inherently connected to the constitutional frameworks of European nations and the European Union, both in formal and substantive terms. The widespread acceptance of the rule of law concept, as seen in the theories of various nations and some contemporary constitutional documents arising from the shift from fascism or communism to democratic governance (notably in Spain, Portugal, Poland, Hungary, Romania, Bulgaria, Slovenia, Czechoslovakia, and Slovakia), illustrates this trend of acknowledgment (Weber; 2008).

In its formal definition, the principle of the rule of law, which includes the supremacy of the Constitution, the rule of law itself, jurisdictional protections, and the division of powers, finds its true realization in safeguarding fundamental rights and ensuring the attainment of substantial justice. These two additional aspects of the evolution of the rule of law have appeared critical since the 19th century, coinciding with the advent of the formal concept known as "Rule of Law." However, the progression of the rule of law in Europe indicates that its enhancement and completion through particular substantial components have become vital in both constitutional theory and legal practice.

Historically, certain ideological and historical foundations of the rule of law can be traced back to ancient times, such as the idea of the supremacy of law (Plato), the notion of separation of powers, and the concept of a mixed constitution (Aristotle, Polybius). Additionally, crucial to the evolution of the rule of law alongside medieval institutions and the gradual establishment of law and the church's separation from political influence was the movement towards a law grounded in reason during the Enlightenment, including advances like the bill of rights and the notion of limiting state power to protect citizens' freedoms, as elaborated by Locke, Montesquieu, Rousseau, Wolff, and Pufendorf. In Germany, the philosophical development of the rule of law began to take shape with Kant, particularly in his works "Ideas for a Universal History from a Cosmopolitan Point of View" (1784) and "Metaphysical Foundations of the Theory of Law" (1797), along with contributions from W. von Humboldt (in "Ideas for an Essay on the Limits of State Activity," 1792) and R. von Mohl.

The development of the concept of the rule of law as a state founded on rational principles, linked to aims such as security, individual freedom, and limitations on state power, is primarily attributed to these authors. In a similar vein, F. J. Stahl examines the rule of law not in terms of "the purpose and content of the state, but rather its form and character." (Weber; 2008) This understanding, also

embraced by liberal thinkers, forms a bourgeois interpretation of the liberal rule of law that was crucial during the latter half of the 19th century. Key components of this formal rule of law concept include the supremacy of law, the legality principle, subordination of administration under the law, the opportunity for judicial review of governmental actions, and accountability for the state and its officials in instances of negligence.

Hans Kelsen, from a legal-positive perspective, characterizes the Rule of Law as merely a coercive order governing human behavior, independent of its content. Therefore, the principle of the Rule of Law is viewed as a general constitutional principle grounded in specific normative components and as an overarching principle, which has also impacted the interpretation of the Rule of Law in other constitutions. (Berger; 2020) Additionally, it's important to consider the influence of the European Convention on Human Rights (Human Rights Act 1998), which has led to a significant enhancement of the rule of law and a transformation of legal structures to fulfill its constitutional obligations toward European fundamental rights, benefiting from a codified list of such rights.

Besides the extra elements and features of the rule of law that create a "common European" core, there exists a certain degree of variation based on constitutional texts and judicial rulings, making the rule of law as a general constitutional principle equally significant. Interpreting the German Federal Constitutional Court, it perceives the rule of law as a "fundamental decision," a "central principle," a "basis," a "fundamental basis," a "guiding idea," or a "constitutional foundation": "The rule of law is encompassed by the guiding ideas that the legislator directly determines." (Weber; 2008) This constitutional principle necessitates specification based on objective circumstances, ensuring that the core elements of the rule of law and the validity of constitutional guarantees are thoroughly upheld.

The concept of the rule of law can be seen as a fundamental principle within the structure of Europe, intricately connected to the development and existence of this idea in various European nations, as well as to the laws of the European Union. This nature of the rule of law is illustrated through the historical progression of the term, reflecting its evolution into a general constitutional principle and its connection to other related principles, including the separation of powers, the supremacy of the Constitution, adherence to the law, legal certainty, and equality.

The Principle of Equality

An important expression of the rule of law is the principle of equality, which constitutes not merely a formal principle but also a substantial one, recognizing the freedom and equal dignity of every individual. The principle of equality manifests itself as equality before the law (essentially equality in law enforcement) and as equality in the law (essentially equality in law-making), and it represents a shared European principle of the rule of law that is often articulated through the prohibition of arbitrariness. Equality is a crucial component that defines the essence of the rule of law, specifically in terms of equality before the law. (Travessoni, Trivisonno;2016) Most Constitutions encompass the principle of equality primarily through a prohibition against discrimination.

The concept of general equality is present in international declarations and conventions (notably in Article 2 of the American Declaration of the Rights and Duties of Man from 1948, Article 2 of the International Covenant on Civil and Political Rights from 1966, and Article 14 of the European Convention for the Protection of Human Rights from 1950), within community law (found in Article 12 of the Treaty establishing the European Community dated March 25, 1957, and Articles 11-80 of the Treaty establishing a Constitution for Europe), and in nearly all European constitutions.

Another significant expression of the rule of law is the principle of equality, which not only serves as a formal principle but also a substantial one that acknowledges the freedom and equal dignity of all individuals. The principle of equality, recognized through equality before the law (equity in law enforcement) and equality in the law (equity in law-making), is a common tenet in European rule of law that usually surfaces in the form of prohibiting arbitrariness. (Ginsburg, Stephanopoulos;2017) As such, equality is a vital aspect of the rule of law's essence, particularly concerning equality before the law.

The overarching perspective provided shows that the principle of the rule of law, encompassing its fundamental components, can be seen as a "legacy" of the constitutional state found in both Western European nations and the new constitutional entities of Central and Eastern Europe. Fundamental elements include the subjugation of all public authorities to the Constitution and its supremacy, the legality of administrative actions, the principle of statutory reserve, the clarity and certainty of regulations, and the requirement that judges and courts adhere to the Constitution and the law, along with the assurance of judicial protection, upholding legitimate expectations, prohibiting retroactivity, and striving for legal certainty. Other essential components may be related to or evolve from administrative law and constitutional law, such as the principle of proportionality (Travessoni, Trivisonno;

2016). Nonetheless, despite the various specific expressions of the rule of law as a general constitutional principle, it is vital to recognize that the state of human dignity, freedom, and equality, achieved through effective legal protection, is marked by its enforceability against both the executive and legislative branches. In this regard, today's legal protections, particularly regarding their applicability against the executive and legislative branches, exhibit notably different characteristics, even as a majority of European nations have established constitutional courts with expanding powers for judicial review of legislative actions (Cuyvers;2017). However, this does not imply that every instance of constitutional legitimacy mandates or necessitates a "centralized" constitutional jurisdiction, even if this approach is considered the "culmination of the rule of law." Furthermore, it is essential to state that, when comparing the elements of the rule of law across different constitutional systems, constitutional legality at the European level (including both the European Convention on Human Rights and the European Community/European Union) must also be taken into account. This is because the validity of constitutional legality is manifested not solely through the fundamental components at the national constitutional level but is also enhanced and reinforced by guarantees of human rights and the support for and compliance with supranational obligations of the rule of law. This illustrates an interdependence of multiple levels of the "democratic-legal state," which we are unable to explore in depth here.

The Principle of Democracy and Solidarity

The principle of democracy can be seen as a foundational element of European structure, intricately tied to its existence and development across various European nations as well as to the Law of the European Union. This nature of the Principle of Democracy is reflected in the historical development of the term and in the conceptual framework as a general constitutional principle, in addition to other associated principles like the separation of powers, the supremacy of the Constitution, adherence to the law, legal certainty, and equality (Ginsburg, Stephanopoulos; 2017).

Solidarity is a core idea within social sciences and political philosophy. Reviewing literature from various nations, it becomes apparent that it is not always approached under the same label. Frequently, aspects related to solidarity are examined through concepts such as altruism, fraternity, social responsibility, welfare, social rights, and the welfare state, among others. It is a widely recognized notion encompassing multiple dimensions. The subsequent discussion will focus particularly on how the concept has developed within the French context, which appears to have significantly influenced the broader European understanding of solidarity (Sommermann; 2014).

The principle of solidarity rests on the mutual acknowledgment of individual autonomy alongside the recognition of interdependence among the members of a community. Both of these facets need to be considered. They manifest in the mutual support offered by community members. One could argue that solidarity is an essential component of society, as society is not merely viewed as a collection of individuals (Von Grafenstein; 2018). In its essential nature, solidarity is akin to the notions of common good and justice: the pursuit of the common good or public interest is fundamental to a state or to the legitimacy of that state; similarly, the concept of justice provides direction to the law, while solidarity is foundational and instructive for societal cohesion. The relationship between these three principles affects their interpretation. Hence, the common good comprises not only collective interests but also the safeguarding of individual freedoms, meaning that individual autonomy, whose mutual recognition also initiates solidarity, is integral.

The phrases "gives orientation" and "is guiding" indicate that solidarity cannot solely be defined descriptively concerning social realities; it also serves as a normative (descriptive) principle. Both aspects are significant for the EU, as will be demonstrated later. In the well-known words of Robert Schuman, Europe ought to be constructed "through concrete achievements which first create a *de facto* solidarity" (Sommermann; 2014). By examining the legal representations of the principle of solidarity found in the current Constitutions of European countries, various categories or dimensions of solidarity can be identified.

a) Social solidarity

Social solidarity pertains to the unity among citizens, drawing from the theories of Dürkheim and Duguid. In this context, the idea of solidarity primarily highlights the social nature of a constitution or clarifies legal statutes. It involves a sense of social accountability. In this regard, most national constitutions and all legal frameworks of EU Member States are expected to uphold the principles of solidarity (Feeley;2021). It is evident that among the two fundamental aspects of solidarity, certain constitutions prioritize the mutual acknowledgment of individual freedom, while others focus more on providing mutual aid. Striking a balance between these two dimensions remains a continual challenge within constitutionalism.

b) Subsidiarity principle

At first glance, the principle of subsidiarity appears to lack a comparative aspect in relation to the principle of solidarity, unlike the principle of loyalty. Solidarity, which unites individuals and states alike, tends to encourage centralization, whereas subsidiarity, which safeguards the roles of smaller entities, signifies decentralization. However, solidarity does not imply the advancement of larger integration units at the expense of smaller ones.

Solidarity serves as the bonding element within a community and, when necessary, among different communities, regardless of their size. In fact, as previously indicated, various forms of collective solidarity can unite both communities and different levels of integration. Since individuals belong to multiple groups, their sense of solidarity extends beyond a singular community (Von Grafenstein; 2018). The principle of subsidiarity enhances the unifying effect of solidarity by establishing criteria for the allocation (use) of powers, thereby indicating where solidarity can best support the achievement of particular shared objectives. The varying levels of social interdependence and solidarity should align with the diverse collective responsibilities that need to be addressed.

III. Methodology

A phenomenological approach was utilized to carry out the research. The specific concept of law acts as a lens through which legal reality, its components, and modes of expression are examined. Adopting this methodology, logical approaches such as induction (analysis), deduction (synthesis, scientific organization, and generalization of facts related to the phenomena under review), along with comparative and historical methods, are applied. These logical, historical, and comparative methods aim to explore the historical development of concepts while also drawing conclusions about the evolution of ideas. Throughout the study, various comparative methods were employed, including making comparisons among different authors or diverse principles. The principles of the rule of law and equality are interconnected, yet they operate independently of one another.

The modern viewpoint on law is systematic and aims to provide explanations. In this view, analytical and synthetic methods that facilitate the understanding of law are crucial. Primarily, a philosophical (axiological) approach is adopted, which defines the principle and contrasts it with the law as a system of values. These values are integrated into the law, directing them specifically toward the designated purpose and objectives, thereby offering justification. The cognitive perspective on law is vital for the analysis. It is viewed as a dynamic phenomenon and a construct of human consciousness, perpetually evolving and influenced by various factors within the social environment. This perspective aids in recognizing and emphasizing the stable and enduring elements of legal principles, while also highlighting the dynamic nature of public life across different areas of legal regulation.

IV. Conclusions

The essential feature of legal principles is that they direct the interpretation of legal rules concerning the rules themselves and their applications. Legal principles within the constitution are found in the outlining of certain fundamental rights and, to some degree, in other sections of the constitution that offer brief directives for the formulation of regulations.

The key distinction between rules and principles is that rules are articulated in an "all or nothing" fashion. In terms of statutory interpretation according to the constitution, there exists a difference between the understanding that the common thread of fundamental rights is human dignity and the fact that general legal acts cannot have retroactive applicability. They must be first translated into statutory rules that uphold human dignity before any direct application can occur. In this way, legal principles serve as measures of values that can vary in intensity, and their implementation is necessitated by specific types of behavior.

We use two distinct criteria for differentiating between rules and principles: a logical criterion and a "source" criterion. The logical criterion pertains to the composition of the standard; while both rules and principles indicate specific decisions, rules are applicable in an all-or-nothing manner, whereas principles do not dictate a decision but rather suggest alternatives without being conclusive. The source criterion indicates that principles do not solely derive from positive legislation or judicial rulings, but may also originate from other sources, including moral considerations. The formal concept of the principle of the rule of law, the supremacy of the Constitution, the rule of law, judicial safeguards, and the separation of powers finds its substantive embodiment in the protection of fundamental rights and the attainment of substantial justice. A crucial expression of the rule of law is the principle of equality, which serves not only as a formal principle but also as a substantial one, recognizing the equal freedom and dignity of all individuals. The principle of equality encompassing both equality before the law (equality in legal

enforcement) and equality in the law (equality in legislative processes) is a shared European principle of the rule of law that frequently manifests as a prohibition against arbitrariness.

The principle of solidarity is rooted in the mutual acknowledgment of individual autonomy alongside the understanding of members' interdependence within a community. Both elements must be considered, and they become evident through the collective support among community members. It can be stated that solidarity is a fundamental aspect of a society, particularly when society is understood not merely as a collection of individuals.

References

1. Batchelor Carol A.,(2006),*"Transforming international legal principles into national law"*,Oxford University Press,Refugee Survey Quarterly, Vol. 25, Issue 3
2. Berger Mario Garcia,(2020), *"A Kantian Solution to the Problem of the Conceptual Origins of the Normativity of Law"*,Archives for Philosophy of Law and Social Philosophy, Vol. 106, No. 2, pp. 249-264
3. Brink David O.,(1988), *"Legal Theory, Legal Interpretation, and Judicial Review"*,Philosophy & Public Affairs , Vol. 17, No. 2, pp.105-148
4. Cuyvers Armin,(2017), *"General Principles of EU Law"*,Brill
5. Feeley Matthew J.,(2021),*"In Search of Guiding Principles of Transnational Anti-Corruption Investigations and Resolutions"*,The International Lawyer, Vol. 54, No. 2, pp. 281-314
6. Flanagan Brian,(2016), *"Legal Philosophy as Patien"*,Irish Jurist , 2016, New Series, Vol. 56, pp. 123-138
7. Papillon Martin , Leclair Jean and Leydet Dominique ,(2020),*"Free, Prior and Informed Consent"*,International Journal on Minority and Group Rights, Vol. 27, No. 2,pp. 223-232
8. Priel Dan,(2015), *"Toward Classical Legal Positivism"*,Virginia Law Review ,Vol. 101, No.4,p. 987-1022
9. Richman Steven M. ,(2018), *"Ethical Issues for Business Lawyers Under the United Nations Guiding Principles"*,The International Lawyer , Vol. 51, No. 3,pp. 423-444
10. Roach Kent,(2007), *"A Dialogue about Principle and a Principled Dialogue: Justice Iacobucci's Substantive Approach to Dialogue"*,The University of Toronto Law Journal , Vol. 57, No. 2,pp. 449-477
11. Salojärvi Juhana,(2019), *"A Counter-Culture of Law"*,The American Journal of Legal History, Vol. 59, No. 4, pp. 409-443
12. Sommermann Karl-Peter,(2014), *"Some Reflections on the Concept of Solidarity and its Transformation into a Legal Principle"*,Archiv des Völkerrechts, No. 1,pp. 10-24
13. Tom Ginsburg, Stephanopoulos Nicholas,(2017), *"The Concepts of Law"*,The University of Chicago Law Review , Vol. 84, No. , pp. 147-175
14. Von Grafenstein Maximilian ,(2018),*"The Principle of Purpose Limitation in Data Protection Laws"*,Nomos Verlagsgesellschaft mbH
15. Weber Albrecht,(2008),*"The rule of law principle as a common European constitutional principle"*,Spanish Journal of Constitutional Law, ISSN: 0211-5743, no. 84, pp. 27-59

Medical sciences

PREDICTIVE VALUE OF PERSISTENT HPV INFECTION VERSUS SINGLE-TIME HPV POSITIVITY FOR DETECTION OF CIN2+ LESIONS: A SYSTEMATIC REVIEW AND META-ANALYSIS

Kdyrbaeva Gulbanu Madiyarovna

Obstetrician-gynecologist

Astana, Kazakhstan

Abstract

Persistent infection with high-risk human papillomavirus (hrHPV) is a key driver of cervical carcinogenesis. While HPV testing is widely used in screening programs, the clinical value of distinguishing persistent HPV infection from single-time HPV positivity remains insufficiently quantified.

Objective:

To evaluate and compare the predictive value of persistent high-risk human papillomavirus (hrHPV) infection versus single-time HPV positivity for the detection of CIN2+ lesions using a systematic review and meta-analysis of retrospective and prospective studies.

A systematic search of PubMed, Scopus, Web of Science, Embase, and Cochrane Library databases was conducted for studies published between 2005 and 2025. A total of 72 studies involving over 450,000 women were included, comprising both retrospective and prospective designs. Inclusion criteria required reporting of HPV DNA testing, definition of persistent infection (≥ 2 time points), histologically confirmed CIN2+, and sufficient data for diagnostic accuracy analysis. A random-effects meta-analysis was performed. Comparative evaluation was based on sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic odds ratio (DOR).

Introduction

Cervical cancer remains a major global health burden, ranking as the fourth most common malignancy among women worldwide. Persistent infection with high-risk human papillomavirus (hrHPV) is a well-established etiological factor in the development of cervical intraepithelial neoplasia (CIN) and invasive carcinoma. While HPV testing has demonstrated superior sensitivity compared to cytology for detecting high-grade lesions (CIN2+), the clinical interpretation of HPV positivity varies depending on whether infection is transient or persistent. A single-time positive HPV test may reflect transient infection, particularly in younger populations, whereas persistent HPV infection is more strongly associated with progression to high-grade lesions and cancer. Despite increasing adoption of HPV-based screening programs, there remains uncertainty regarding the comparative predictive value of persistent HPV infection versus single-time HPV positivity for detecting clinically significant lesions. This study aims to systematically evaluate and compare the diagnostic performance of these two approaches using a comprehensive meta-analysis of global data.

The objective of this study is to assess whether persistent HPV infection provides superior predictive accuracy for CIN2+ lesions compared to single-time HPV positivity, and to quantify differences in sensitivity, specificity, and overall diagnostic performance across diverse populations and study designs.

Keywords: HPV DNA testing, cytology, CIN II+, cervical cancer screening, meta-analysis, diagnostic accuracy

Methods

This systematic review and meta-analysis was conducted in accordance with PRISMA guidelines. A comprehensive literature search was performed across PubMed, Scopus, Web of Science, Embase, and Cochrane Library databases for studies published between 2005 and 2025. A total of 72 studies were included, comprising both retrospective and prospective designs from Europe, North America, Asia, and CIS countries. The inclusion criteria were defined as follows: (1) studies evaluating HPV DNA testing; (2) studies reporting persistent HPV infection (defined as detection of the same HPV genotype at ≥ 2 time points); (3) studies reporting single-time HPV positivity; (4) histologically confirmed CIN2+ as the reference standard; (5) availability of sufficient data to calculate sensitivity and specificity; and (6) inclusion of adult women undergoing cervical cancer screening or follow-up.

Exclusion criteria included studies focusing solely on HPV vaccination outcomes, lack of histological confirmation, pediatric populations, case reports, and duplicate datasets. Data extraction included study design, population characteristics, HPV detection methods, follow-up duration, and diagnostic outcomes.

Statistical analysis was performed using a random-effects model to account for heterogeneity. Five key criteria were used for comparative analysis: sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and diagnostic odds ratio (DOR). Heterogeneity was assessed using the I^2 statistic, and publication bias was evaluated using funnel plots and Egger's test. Subgroup analyses were conducted based on study design (retrospective vs prospective), geographic region, age groups, and HPV genotypes (HPV16/18 vs other high-risk types).

Results

A total of 72 studies encompassing over 450,000 women were included in the analysis. Of these, 38 were prospective and 34 retrospective studies. Persistent HPV infection was assessed in 41 studies, while all studies reported single-time HPV positivity. The pooled sensitivity for detection of CIN2+ lesions was significantly higher for persistent HPV infection (0.91; 95% CI: 0.88–0.94) compared to single-time HPV positivity (0.76; 95% CI: 0.72–0.80). Similarly, specificity was improved in the persistent infection group (0.72; 95% CI: 0.68–0.76) compared to single-time positivity (0.58; 95% CI: 0.54–0.62). The diagnostic odds ratio demonstrated a marked advantage for persistent HPV infection (DOR = 28.5) versus single-time positivity (DOR = 12.3), indicating stronger discriminatory power. Positive predictive value was notably higher in persistent infections (PPV = 0.42 vs 0.26), while negative predictive value remained high in both groups but slightly favored persistent infection (NPV = 0.96 vs 0.92). Subgroup analysis revealed that the predictive advantage of persistent HPV infection was particularly pronounced in women aged ≥ 30 years and in studies with follow-up durations exceeding 12 months. HPV16/18 persistence showed the highest association with CIN2+ lesions. Heterogeneity across studies was moderate to high (I^2 ranging from 56% to 78%), likely reflecting variability in study populations and screening protocols. However, sensitivity analyses confirmed the robustness of the findings. No significant publication bias was detected.

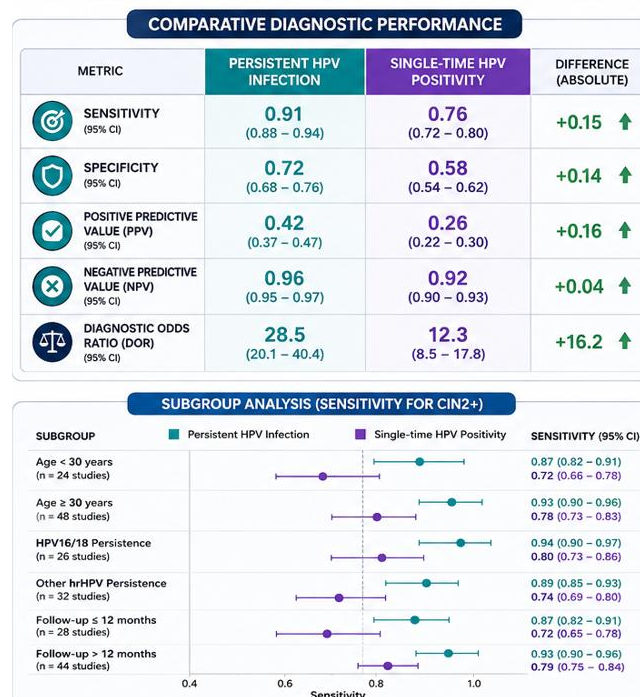


Figure 1. Comparative diagnostic performance and subgroup analysis

Discussion

The findings of this meta-analysis demonstrate that persistent HPV infection is a significantly stronger predictor of CIN2+ lesions compared to single-time HPV positivity. This supports the biological understanding that persistent viral infection is a critical step in cervical carcinogenesis, whereas transient infections are often cleared by the immune system without clinical consequence. The higher specificity observed with persistent HPV testing suggests that it may reduce unnecessary colposcopies and overtreatment associated with single-time HPV positivity. This has important implications for screening strategies, particularly in resource-limited settings where optimizing diagnostic efficiency is essential. The results also highlight the importance of incorporating longitudinal HPV testing into screening algorithms. Current guidelines increasingly recommend repeat HPV testing or co-testing strategies, and our findings provide strong evidence to support these approaches. Differences observed between retrospective and prospective studies were minimal, indicating consistency across study designs.

However, prospective studies tended to report slightly higher predictive values, likely due to more standardized follow-up protocols. Limitations of this study include heterogeneity among included studies, differences in HPV detection methods, and variability in follow-up intervals. Additionally, not all studies provided genotype-specific data, limiting detailed analysis of individual HPV types beyond HPV16/18. Despite these limitations, the large sample size and comprehensive inclusion of global data strengthen the validity and generalizability of the findings.

Conclusion

Persistent HPV infection demonstrates significantly superior predictive value for the detection of CIN2+ lesions compared to single-time HPV positivity across multiple diagnostic parameters, including sensitivity, specificity, and diagnostic odds ratio. These findings support the integration of persistence-based HPV testing into cervical cancer screening programs to improve diagnostic accuracy and reduce unnecessary interventions. Importantly, the results underscore the need for a paradigm shift in cervical cancer screening from reliance on single-point HPV detection toward longitudinal monitoring of viral persistence. Incorporating repeat testing intervals and genotype-specific follow-up strategies may enhance early identification of women at highest risk while minimizing unnecessary clinical procedures in low-risk individuals.

From a public health perspective, adopting persistence-based screening approaches could improve cost-effectiveness by reducing over-referral and optimizing resource allocation, particularly in low- and middle-income countries where screening infrastructure is limited. Furthermore, integration of persistent HPV assessment with emerging molecular biomarkers, such as p16/Ki-67 dual staining or DNA methylation markers, may further refine risk stratification and clinical decision-making. Future research should focus on standardizing definitions of HPV persistence, determining optimal follow-up intervals, and evaluating the long-term outcomes of persistence-based screening strategies in diverse populations. Additionally, the impact of widespread HPV vaccination on persistence patterns and screening performance warrants continued investigation.

In conclusion, persistent HPV infection represents a critical and clinically meaningful indicator of progression risk, and its incorporation into screening algorithms has the potential to significantly enhance the effectiveness, precision, and sustainability of cervical cancer prevention programs worldwide.

References

1. Arbyn M, Ronco G, Anttila A, et al. Evidence regarding human papillomavirus testing in secondary prevention of cervical cancer. *Vaccine*. 2012;30(Suppl 5):F99.
2. Ronco G, Dillner J, Elfström KM, et al. Efficacy of HPV-based screening for prevention of invasive cervical cancer: follow-up of four European randomized controlled trials. *Lancet*. 2014;383(9916):524–532.
3. Schiffman M, Wentzensen N. Human papillomavirus infection and the multistage carcinogenesis of cervical cancer. *Cancer Epidemiol Biomarkers Prev*. 2013;22(4):553–560.
4. Cuzick J, Clavel C, Petry KU, et al. Overview of the European and North American studies on HPV testing in primary cervical cancer screening. *Int J Cancer*. 2006;119(5):1095–1101.
5. Mayrand MH, Duarte-Franco E, Rodrigues I, et al. Human papillomavirus DNA versus Papanicolaou screening tests for cervical cancer. *N Engl J Med*. 2007;357(16):1579–1588.
6. Koliopoulos G, Nyaga VN, Santesso N, et al. Cytology versus HPV testing for cervical cancer screening in the general population. *Cochrane Database Syst Rev*. 2017;8.
7. World Health Organization. WHO guidelines for screening and treatment of precancerous lesions for cervical cancer prevention. Geneva: WHO; 2021.
8. Rijkaart DC, Berkhof J, Rozendaal L, et al. Human papillomavirus testing for the detection of high-grade cervical intraepithelial neoplasia and cancer: final results of the POBASCAM randomized controlled trial. *Lancet Oncol*. 2012;13(1):78–88.
9. Castle PE, Stoler MH, Wright TC Jr, et al. Performance of carcinogenic human papillomavirus testing and cytology for cervical cancer screening. *J Natl Cancer Inst*. 2011;103(5):368–383.
10. Sankaranarayanan R, Nene BM, Shastri SS, et al. HPV screening for cervical cancer in rural India. *N Engl J Med*. 2009;360(14):1385–1394.

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LIP CANCER: MODERN REALITIES AND TRENDS**Arman Khozhayev***Professor of the S.N. Nugmanov Department of Oncology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Saltanat Zhylykshbay***Resident of the Department of Therapeutic Dentistry,
Asfendiyarov Kazakh National Medical University, Dental Therapist,
Limited Liability Partnership «OK Centre», Almaty, Kazakhstan***Gulnur Yernazarova***Resident of the Department of Dermatovenereology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Milana Pak***Resident of the Department of Orthodontics,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Fariza Alimbek***Resident of the Department of Dermatovenereology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Aidana Zhumagulova***Resident of the Department of Orthodontics,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Dilyara Ibragimova***Resident of the Department of Dermatovenereology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Akmaral Shalkar***Resident of the Department of Dermatovenereology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Malika Orynaliyeva***Resident of the Department of Dermatovenereology,
Asfendiyarov Kazakh National Medical University, Almaty, Kazakhstan***Abstract**

This scientific and analytical work presents current data on the epidemiology, pathogenesis, clinical and morphological features, and diagnostic approaches to lip cancer, which belongs to the group of lip and oral cavity neoplasms. The most common histological types are squamous cell carcinoma and basal cell carcinoma, frequently developing on the background of precancerous lesions of the vermilion border, primarily actinic cheilitis (solar cheilosis). Special attention is given to epidemiological risk factors, particularly chronic exposure to ultraviolet radiation, which plays a key role in the development of actinic cheilitis and subsequent malignant transformation. Other potentially malignant disorders, including leukoplakia, erythroplakia, and erythroleukoplakia, are also considered due to their potential progression to carcinoma in situ. The clinical manifestations of actinic cheilitis, such as dryness, fissures, epithelial atrophy, erythematous and leukoplastic changes, are discussed together with modern approaches to severity assessment using the clinical index for actinic cheilitis. The article also summarizes molecular mechanisms of lip carcinogenesis associated with DNA damage and mismatch repair system dysfunction involving MutS and MutL proteins. The diagnostic significance of mismatch repair proteins (MSH2, MSH6, MLH1, PMS2) and the proliferation marker Ki-67 is described. In addition, the diagnostic value of immunohistochemical biomarkers related to cancer stem cells (ALDH1 and CD44) is analyzed. Modern diagnostic techniques, including fine-needle aspiration biopsy, tissue microarray technology, and statistical evaluation of diagnostic performance using receiver operating characteristic analysis, are also described. In addition, the epidemiological characteristics of this pathology in our republic are presented in detail across the country's regions.

Keywords: *oncology, dermatology, dentistry, orthodontics, lip cancer, squamous cell carcinoma, basal cell carcinoma, actinic cheilitis, inflammatory lesion, epithelial dysplasia, leukoplakia, erythroplakia, erythroleukoplakia, ultraviolet radiation, solar radiation, immunohistochemical markers, biomarkers, mismatch repair system, epidemiology, incidence, mortality, lethality, five-year survival rate,*

prognosis.

Lip cancer (LC) is a malignant tumor of the stratified squamous epithelium of the vermilion border of the lower or upper lip. The skin and mucous membrane of the lip are affected secondarily by the tumor process. LC invades adjacent anatomical structures and interferes with eating. In the later stages, severe cosmetic defects are observed due to tissue destruction and secondary infections. Lymphatic metastases in LC occur more often than hematogenous metastases [1,2].

Diagnostic criteria are as follows. Complaints and anamnesis: the development of LC begins with the appearance of scale, under which a lump can initially be detected, later becoming noticeable to the patient. Sometimes the tumor manifests as a small erosion with a dense base or an initial painless ulceration without exophytic growth; a dense nodule may develop, at the site of which necrosis later develops. Initially, the tumor is accompanied by horizontal growth, and then vertical growth. Cancer developing against the background of erosive actinic cheilitis (AC) can reach several centimeters in diameter and have a more or less nodular tumor portion. The lip is thickened due to the tumor growing deeper into it, and the corner of the mouth can be displaced by the tumor mass from metastases to the regional lymph nodes [1].

Physical examination includes a thorough examination, including inspection and palpation (bimanual) of the lesion and regional lymph nodes, an assessment of the nutritional status in order to determine the prevalence of the tumor process and decide on the need for nutritional status correction [1,2].

Instrumental studies: taking smears-imprints or scrapings from the surface of erosions, ulcers, cracks on the lip, punctates of lip thickenings without signs of ulceration and enlarged cervical lymph nodes, for cytological examination; if the cytological examination is unclear, a biopsy is necessary for histological confirmation of the diagnosis. Chest X-ray; ultrasound examination of the submandibular region and neck on both sides; ultrasound of the abdominal organs and retroperitoneal space; computed tomography of the facial bones with intravenous contrast in case of suspected tumor spread to the lower/upper jaw, base of the skull. Fine-needle aspiration biopsy (FNAB) under ultrasound control in case of suspected metastases of the lymph nodes of the neck in preparation for surgical treatment in order to assess the functional status, if indicated, conduct additional examination: echocardiography, study of external respiratory function, ultrasound Dopplerography of the vessels of the neck and lower extremities [1].

Silva W.R. et al. [3] note that the lips are the transition zone between the facial skin and the oral mucosa and are the site of alterations related to a broad spectrum of etiologies. Lip neoplasms differ etiologically from intraoral lesions since they are locations highly exposed to ultraviolet (UV) radiation. Ultraviolet A radiation (320-400 nm) and Ultraviolet B radiation (280-320 nm) rays act dose-dependently and cumulatively in initiating and promoting carcinogenesis due to direct damage to the DNA structure. Squamous cell carcinoma (SCC) and basal cell carcinoma (BCC) are the most prevalent neoplasms affecting lips. This study evaluated the demographic and clinicopathological features of the SCC and BCC in the lip. Researchers point out that the lips are the anterior limit of the oral cavity and consist of the transition zone between the facial skin and the oral mucosa. These anatomical structures play an important role in facial expression, chewing, phonation, and tactile sensation and contribute to facial aesthetics. Also, the lips may be the site of clinical and pathological alterations related to a broad spectrum of etiologies, ranging from traumatic, inflammatory, and infectious lesions to malignant neoplasms.

This retrospective cross-sectional study investigated the occurrence of SCC and BCC of the lips diagnosed at the Dermatology Service of Hospital das Clínicas of the Federal University of Pernambuco and Cancer Hospital of Pernambuco from 1994 to 2019. Demographic and clinicopathologic data regarding sex, age, anatomic site, clinical aspect, TNM grading system, histopathological diagnosis, surgical margin, and recurrence were collected from the patient's medical records. Nevertheless, this data was not available in all SCC and BCC cases. In this context, cases needed to contain information about the histopathological diagnosis to be included in the present study. On the other hand, cases that did not affect the lips and/or had an undetermined diagnosis were excluded from the sample. Clinical cancer staging was classified according to the American Joint Committee on Cancer - Cancer Staging Manual [3,4]. Pearson's chi-square test was performed to assess the association between the anatomical location of the lesions and clinicopathologic characteristics (sex, histopathological diagnosis, clinical stage, and treatment). The significance level was set at 5% ($p \leq 0.05$) for all tests.

A total of 417 patients were diagnosed with SCC and BCC during the period studied. Of these, 323

(77.5%) lip carcinomas were histopathologically diagnosed as SCC and 94 (22.5%) as BCC in both centers. It was found that SCC was diagnosed more frequently in males (58.8%; $n = 190$), while BCC was more diagnosed in females (54.3%; $n = 51$). The mean age of SCC was 64.7 ± 14.8 years old, while BCC presented a mean age of 65 ± 15.3 years old. SCC was more frequent in patients between the sixth and eighth decades of life, and BCC was more frequent in the eighth decade of life. SCC and BCC significantly affected the lower lip (70.6%; $n = 228$; 56.4%; $n = 53$, respectively; $p = 0.014$). It was observed that BCC cases initially affected the skin, and the lesion extended to lip vermilion. Also, when analyzing the association between sex and anatomical location, it was observed that the lower lip of male patients was more affected than the upper one ($p < 0.0001$). Of the 417 patients, 48% reported outdoor occupational activities related to chronic sun exposure, and SCC was frequently clinically described as an ulcer and plaque. In contrast, BCC was most described as a nodule and papule. Concerning the TNM grading system findings, SCC cases presented a high frequency of tumors with sizes ≤ 20 mm (T1) (39.7%) and > 20 mm to ≤ 40 mm (T2) (42.9%), as well as the absence of regional lymph node metastasis (N0) (90.4%) and distant metastasis (M0) (84%). In contrast, only 05 cases of BCC presented this information. From these 05 cases, two cases presented tumors with size > 20 mm to ≤ 40 mm (T2), one case with size ≤ 20 mm (T1), one case with size > 40 mm (T3), and one case with size > 40 mm invading adjacent structures (T4). Besides this, three cases showed the absence of regional lymph node metastasis (N0), one case showed metastasis in a single ipsilateral lymph node > 30 mm and ≤ 60 mm (N2), and one case showed metastasis in a single ipsilateral lymph node > 60 mm (N3). Regarding distant metastasis, four cases presented the absence (M0), and one showed the presence (M1) of distant metastasis. About the clinical stage, SCC frequently exhibited clinical stage I (39.8%; $n = 62$) and II (33.9%; $n = 53$), while BCC mainly presented stage IV (40%; $n = 2$). No significant association was observed between the anatomical location and the cancer clinical staging ($p = 0.065$). Regarding the treatment approach of the neoplasms, SCC was mainly treated with surgery (88.3%; $n = 264$), followed by surgery with radiotherapy (11.4%, $n = 34$) and radiotherapy (0.3%; $n = 1$), while BCC was frequently treated with surgery (93.2%; $n = 69$), followed by surgery with radiotherapy (6.8%; $n = 5$). No significant association was observed between the anatomical location and the treatment ($p = 0.674$). The surgical margin was frequently negative in SCC and BCC (87%; $n = 281$; 72.3%; $n = 68$, respectively), and no recurrence was observed in 79.9% ($n = 258$) of SCC cases and 69.1% ($n = 65$) of BCC cases. No significant association was observed between the type of neoplasm and the presence of regional lymph node metastasis, distant metastasis, treatment, cancer clinical stage, surgical margin, and recurrence. The study found that SCC was more frequent in male patients and BCC in female patients. Lesions in the lower lip were significantly frequent in male patients, and both SCC and BCC significantly affected this anatomical site. SCC was more frequent in patients between the sixth and eighth decades of life and BCC in the eighth decade of life. Besides, understanding the epidemiological profile and etiology of these lesions in the lip is essential for planning preventive measures in health education since the lip is an important functional and aesthetic region, possessing a strong relationship with the quality of life and individual self-esteem [3].

In their study, Barragán Y.V. et al. [5] indicate that lip squamous cell carcinoma (LSCC) is associated with malignant transformation of AC. Since solar radiation alters the functions of mismatch repair (MMR) complex, authors evaluated for their possible role in lip carcinogenesis. For the sample size, a ratio of three cases for each control (45 LSCC and 15 lip epithelia without microscopic alterations) was adopted to achieve a sample representing the hypothesis of this research with 80% power and 95% confidence. For inclusion of AC samples, a proportion of two cases for each control was set. Therefore, the total sample size for each tissue type was determined as 45 lip SCC, 30 AC, and 15 normal epithelia of the vermilion of the lower lip. The samples of LSCC, AC and normal lip epithelia were collected from different patients and paraffin blocks. The current study collected samples from patients at Hospital Haroldo Juaçaba/Instituto do Câncer do Ceará who underwent surgery to resect carcinoma of the vermilion of the lips, without neoadjuvant treatment. Additional samples were obtained from normal lip epithelia from oral mucocoeles and SCC cases. Clinicopathological data were collected, and suitable paraffin blocks were selected for histopathological analysis. The study excluded cases with incomplete records and blocks without sufficient material for the tissue microarray technique.

The study involved examining microscopic slides of LSCC and AC in comparison to control regions. For the tissue microarray technique, two cores of 2 mm diameter circumferential areas (3.14 mm^2) were selected from each sample using a tissue microarrayer. The samples of tumor were selected from invasive front of tumor. Equally, two cores of NLE and AC were selected in health areas of lips and dysplastic areas of AC. So, paraffin blocks from these areas were punched and transferred to a receiver block with 70 circular wells. The resulting paraffin receptor blocks, containing oral ulcers, were then sectioned into

3- μ m thick slices and placed on silanized slides for subsequent analysis. For immunohistochemical processing, samples were deparaffinized, rehydrated, and subjected to antigen retrieval in Tris-ethylenediaminetetraacetic acid buffer (pH 9.0). To inactivate endogenous peroxidases, samples were incubated in phosphate-buffered saline (PBS) with 3% H₂O₂ for 30 min, washed in PBS, and incubated for one h with primary antibodies against MSH2 (Dako®, FE11), MSH6 (Dako®, EP49), PMS2 (Dako®, EP51), and MLH1 (Dako®, ES05). Additionally, given that Ki-67 is strongly related to the cell cycle and appears to be associated with MMR proteins, a primary antibody for Ki-67 (Dako®, MIB-1) was also used. Samples were washed in PBS, incubated in Envision Plus horseradish peroxidase Anti-IgG-rabbit/mouse for 30 min (ready-to-use; monoclonal; Dako® K4065), and washed again in PBS, after which diaminobenzidine chromogen (Dako® K3469) was applied to the samples for 5 min. Harris hematoxylin was used as the counterstain (10 s), after which the specimens were dehydrated in ethanol and xylene and covered with a permanent mounting medium (Enthelam®). Colorectal carcinoma sections were used as a positive control, and the negative control and positive control were treated in parallel with an antibody diluent instead of the primary antibody. For evaluation of MSH2, MSH6, PMS2, MLH1, and Ki-67, ten fields per histological section were photographed at 400 $\times$ magnification. The images were exported to ImageJ® software and counted to determine the percentage of immunostained positive cells. Brown nuclear staining of all keratinocytes cells (control group and AC group) and all cancer cells (LSCC group) was considered a positive immunoreaction. As previously described, the imbalance of MutSa (MSH2 $\neq$ MSH6) was calculated by ration between MSH2/MSH6 and imbalance of MutLa (PMS2 $\neq$ MLH1) was calculated by ration between PMS2/MLH1 [5].

Most patients were male, aged up to 65 years, living in the countryside, had no insurance, and were farmers or retired/pensioners. The lower lip was the most affected site. Microscopically, the lip samples (n=15) showed mostly stratified squamous ortho-keratinized epithelium tissue with well-defined basal, spinous, and granular layers, occasional exocytosis, and spongiosis supported by a fibrovascular connective tissue. AC samples (n=30) exhibited atrophic stratified squamous keratinized epithelium tissue with four to six layers of squamous cells, disorganization of the basal and spinous layers, significant nuclear hyperchromatism cellular pleomorphism, and were parakeratinized. The supporting connective tissue showed solar elastosis throughout the lesions and occasional mononuclear inflammatory cells. Most AC patients had low-risk dysplasia (n=19). The LSCC samples (n=45) showed proliferation of islands and strands of cells of epidermoid origin, organized, sometimes in nests, exhibiting intense cellular and nuclear pleomorphism, keratin pearls, typical and atypical mitotic figures, and intense mixed inflammatory infiltrate. Of the LSCCs evaluated, 29 (64.4%) were low-grade, 5 (11.1%) showed vascular invasion, and 12 (26.7%) showed perineural invasion. Most patients were men (n=34, 75.5%), aged <65 years (n=24, 53%), and the average age of 64.7 $\pm$ 12.2 years. The most prevalent tumor TNM stage was T1/2 (n=30, 66.7%), N0 (n=29, 64.4%), and M0 (n=42, 93.3%), and recurrence was observed in only three (6.7%) of the patients. The median of follow up time was 13 months (range = 3-96 months). All tissues showed positive immunostaining for MMR proteins. Immunostaining was concentrated in the basal and parabasal layers in the lip, in the basal, paranasal, and spinous layers in the AC, and in the tumor islands and nests in LSCC. Immunostaining for MSH2, MSH6, MLH1, and Ki-67 was significantly higher in AC and LSCC tissues ($p<0.001$, $p<0.001$, $p=0.040$, and $p=0.004$, respectively). MSH2 immunostaining was significantly higher in LSCC ($p<0.001$). An imbalance was observed in MutSa, with higher expression of MSH2 in the lip ($p=0.043$), and the opposite relationship in AC ($p=0.005$), which was also noted in the MSH2/MSH6 ratio ($p<0.001$). The mean MSH2/MSH6 ratio was lower in the AC group ($p=0.028$). Lower expression of MSH2 compared to MSH6 was observed in AC with low-risk dysplasia ($p=0.018$). Immunostaining for MSH6 was significantly lower in patients with AC with high-risk dysplasia ($p=0.024$). The presence of vascular invasion in LSCC was associated with a lower mean MSH6 ($p=0.035$). In LSCC depth of invasion >10cm showed less immunostained cells for MSH6 than MSH2 ($p=0.027$) and MLH1 than PMS2 ($p=0.007$). A significant imbalance in PMS2/MLH1 ratio was showed in LSCC with a depth of invasion >10cm than <10cm depth invasion ($p=0.013$). T3/T4 patients showed higher mean values of MSH2/MHS6 and PMS2/MLH1 ratio compared to T1/T2 ($p=0.028$, $p=0.014$), whereas N+ patients showed higher mean values of PMS2/MLH1 than MSH2/MHS6 ($p=0.046$). N+ patients showed higher immunostaining for Ki-67 than did N0 patients ($p=0.039$). LSCC exhibited a greater number of positive correlations, with all MMR. Proteins correlated with each other. AC presented less statistically significant findings, with positive correlations only between MSH2 and MSH6 ($p=0.038$). No correlations were found in lip samples. In conclusion, our colleagues state that this is the first study to address the immunostaining for all MMR complex proteins in the three stages of LSCC progression and clinical-pathological features. The researchers have found that, there is increased activity and inter-association

between these proteins in tumors, but their loss of expression significantly worsens the prognosis [5].

Silva L.V.O. et al. [6] in a multicenter study examined the demographic and clinical pathologic features of actinic cheilitis and lip squamous cell carcinoma. According to the authors, a number of researchers note that AC is a chronic inflammatory condition that has been described as a potentially malignant oral disorder. AC affects the vermilion region of the lower lips in 95% of cases. The worldwide occurrence of AC ranges from 4.6 to 43.2%. High-risk populations, including those living in tropical regions under excessive exposure to UV radiation, fair-skinned male individuals in their forties, and smokers are the most affected by this condition. Clinically, AC is characterized by dryness, fissures/erosions, atrophy (characterized by smooth, blotchy, pale areas) and erythematous and/or leucoplastic areas with blurring of the margin between vermilion and the adjacent skin. Regarding risk factors, the authors emphasize that LSCC has predilection for fair-skinned men, with a peak incidence between the sixth and seventh decades of life. The lower lip is affected in 95% of cases. Prolonged exposure to sunlight also is an etiological factor for LSCC. Long-term consumption of alcohol and tobacco associated with the carcinogenic action of UV radiation greatly increases the risk of developing this malignancy. Sociodemographic conditions such as social vulnerability, and genetic susceptibility, or immunosuppression, are also factors that may contribute to the development of this disease. The initial clinical signs of LSCC may include asymptomatic crusts or ulcerations that may be quite equivalent to those observed in AC. At advanced stages, a painful exudative ulcer may occur, covered with scales and crusts, with indurated borders and an infiltrated base that does not heal.

Affected individuals were analysed concerning gender, age, skin colour (fair-skinned/brown-skinned), occupation (indoors/outdoors) and habits (tobacco smoking, alcohol consumption and chronic solar exposure). Lesions were analysed in terms of anatomical location (upper/lower lip), evolution time (months), symptoms (symptomatic/asymptomatic), manifestation type (primary/recurrent), and previous history of AC for cases of LSCC. A total of 198,709 histopathological records of oral and maxillofacial biopsies had been diagnosed at the 10 centres; of these, 2,017 were cases of AC (1.0%) and 850 were cases of LSCC (0.4%). AC a total of 1,439 (71.4%) cases occurred in males and 575 (28.6%) in females (male-to-female ratio of 2.5:1). Older subjects (≥ 60 years) accounted for 49.8% of the survey. Most individuals were fair-skinned (87.3%), reported an indoor occupation (56.6%) and had no symptoms (78.8%). Of the individuals who had answered positively regarding habits of tobacco smoking, alcohol consumption and chronic solar exposure, 75.5% were smokers, 91.7% were alcohol users and 91.5% were chronically exposed to the sun. The most common site of AC was the lower lip (98.7%) and 87.2% of the lesions presented as a primary manifestation with a median evolution time of 12 months. In 55.1% of the cases, the histopathological diagnosis confirmed the clinical diagnosis of AC. The other clinical diagnostic hypotheses were oral leukoplakia (25.2%) and oral SCC (5.6%). LSCC a total of 673 (79.3%) cases occurred in males and 176 (20.7%) in females (male-to-female ratio of 3.8:1). The majority of cases consisted of older individuals (54.2%), fair-skinned (91.3%), with an indoor occupation (56.9%) and asymptomatic (63.3%). Of the individuals who had reported on the habits evaluated, 67.6% were smokers, 50.5% were alcohol users and 83.5% were chronically exposed to the sun. The lower lip was also the most common anatomical location of LSCC (97.3%). Regarding the type of manifestation, 94.2% of the lesions were primary and 91.5% of the patients did not report a previous history of AC. The median follow-up time was 12 months. In 74.2% of the cases, the histopathological diagnosis confirmed the clinical diagnosis of LSCC. The other clinical diagnostic hypotheses were AC (11.5%) and oral leukoplakia (4.4%). In conclusion, our colleagues state that data of the Brazilian individuals with AC and LSCC reported herein agree with findings of case series and retrospective studies reported elsewhere. There is a predilection of white men in their seventh decade of life. In most cases, the lower lip is affected [6].

A very interesting study was conducted by Barros C.C. et al. [7]. The objective of this study was to describe the upper and lower lip lesion occurrence in an oral diagnostic service. This is a retrospective sectional study investigating upper and lower lip lesion occurrence. Clinical records of patients treated at the Oral Diagnostic Service belonging to the Dentistry Department at the Federal University of Rio Grande do Norte (Brazil) from January 2006 to December 2016 were analyzed. A medical record analysis was performed simultaneously by two researchers with experience in treating patients with mouth lesions. Adequately completed medical records of patients of all ages who presented an upper and/or lower lip lesion were included in the study. Medical records that did not meet these criteria were excluded from the sample. Data regarding gender, age, anatomic site of the lesion, diagnosis and recurrence were obtained. For biopsy cases, the histopathological analysis result was considered as the final diagnosis. Diagnostic lesions were categorized according to their etiology into reactional/inflammatory, infectious, benign neoplasms, malignant neoplasms, and oral potentially malignant disorders. A patient age range

categorization was created to facilitate the analysis, namely children (0-9 years), adolescents (10-19 years), adults (20-59 years) and elderly (over 60 years), according to World Health Organization (WHO) criteria. Regarding the anatomic site, the following locations were considered: upper lip, lower lip and lip commissure.

Out of a total of 5,511 patient records, 587 presented lip lesions, representing an occurrence of 10.7%. Most lesions were diagnosed in female and adults. The most frequent lesions in the sample were mucocoele ($n = 147$; 25%), AC ($n = 136$; 23.1%) and vascular lesions ($n = 51$; 8.7%). The lower lip was the most affected site ($n = 447$; 76.2%). Regarding recurrence, only 3.6% of the 587 analyzed cases presented lesion recurrence. In the association test between gender, age group and anatomic site with the most frequent lesions (mucocoele, AC and vascular lesions), only AC displayed statistical significance concerning gender ($p < 0.001$). There was also statistically significant difference between mucocoele, AC and vascular lesions with the age group ($p < 0.001$; $p < 0.001$; $p < 0.001$, respectively) and anatomic site ($p < 0.001$; $p < 0.001$; $p = 0.002$, respectively) [7].

As the authors note the lips represent an important lesion site when compared to other mouth sites, especially the lower lip, which was the main lesion site in this study, for 76.2% of all lesions. Reactional/inflammatory lesions were the most frequent, followed by potentially malignant disorders which together accounted for about two thirds of all lesions. Regarding the type of lesion, this study observed that mucocoele is the most frequent, and the findings reported herein corroborate these data for all age groups ($p < 0.001$). The researchers believe that this result is related to constant trauma in this region, especially in the lower lip, which was the most significantly affected herein ($p < 0.001$). Mucocoele is an inflammatory lesion characterized by rupture or damage to the salivary gland duct, leading to mucus leakage into the surrounding tissues. Treatment is carried out by the surgical removal of the lesion and the affected gland, generally presenting an excellent prognosis. In this study, 57.1% of the assessed cases presented recurrence, probably due to the partial removal of the affected glands. The second most frequent lesion in the sample was AC, affecting almost exclusively the lower lip ($p = 0.001$) of adult and elderly patients ($p < 0.001$). This finding was expected, as AC is a chronic condition associated with prolonged exposure to solar radiation and develops insidiously over time. It is noteworthy that most individuals with this condition reported professional occupations related to sun exposure, justifying the high AC occurrence in this sample. It is important to note that the presence of AC raises concerns regarding possible evolution to lower lip squamous cell carcinoma (LLSCC). In this study, LLSCC represented almost all of the malignant neoplasms, affecting mainly the lower lip of elderly men. No LLSCC were found on the upper lip, as it rarely affects this location. Probably, LLSCC does not affect the upper lip due to its anatomical position, less exposed to solar radiation than the lower lip. In the present study, vascular lesions represented by vascular malformations and hemangioma corresponded to the third most frequent occurrence in the evaluated samples. Benign neoplasms were less frequently observed in the present study, at 6.0% of the total analyzed cases. Fibroma and squamous papilloma were the two most common lesions in this category, affecting mainly adult individuals [7].

Summarizing the study, our colleagues state that mucocoele was the most common lower lip lesion in all age groups, followed by AC, which mainly affected adults and the elderly. Clinical data seems the most reliable characterization of the occurrence of these lesions and, thus, permit dentists to become more familiarized with the diagnosis of these diseases at the time of initial diagnosis, which is a crucial time to establish the most likely differential diagnoses and, in this manner, being able to properly guide the pathologist who may eventually receive the biopsy. Understanding the occurrence, etiology and clinical characteristics of lesions affecting this anatomical site is paramount so that preventive and therapeutic measures can be promptly implemented [7].

The purpose of the study by Mello F.W. et al. [8] was to investigate the prevalence of malignant and potentially malignant lesions of the lip in an oral pathology service and to compare these data with a literature review.

Main study. Biopsy reports and histopathological records from March 2007 to February 2018 were analyzed, totalizing 3173 cases. Firstly, biopsy reports were analyzed and lip lesions were selected (only lesions in the lip vermillion semi-mucosa were considered). Then, cases that were clinically diagnosed as AC, leukoplakia, erythroplakia, erythroleukoplakia, in situ carcinoma, and LSCC were selected. Lastly, histopathological records were evaluated and cases were included in the sample when histologically diagnosed as AC with no epithelial dysplasia (NoED), AC with mild epithelial dysplasia (MiED), AC with moderated epithelial dysplasia (MoED), AC with severe epithelial dysplasia (SED), in situ carcinoma (ISC) and LSCC. Cases that did not fulfill these criteria were excluded from the sample. From the biopsy reports, information of clinical diagnosis, gender, age and skin color of the patients, lesion location, smoking

and/or alcohol consumption habits, and history of chronic solar exposure was collected. Individuals that had outdoor occupations or self-reported periodical outdoor activities with long duration were considered as with "prolonged solar exposure". All clinical data of patients were collected from biopsy files and, therefore, were reported by the responsible surgeon of each procedure. Furthermore, histological diagnosis was performed following criteria of the WHO by an oral pathology team, composed by three experienced oral pathologists. A total of 3173 cases of the pathology laboratory cases were analyzed; 124 files from 107 patients were selected to comprise the sample. Moreover, 16 individuals had more than one file in the laboratory archive, of which 8 had lesions with the same histological diagnosis in the second biopsy and 4 had higher degrees of epithelial dysplasia in the second sample; only one case evolved from AC to LSCC. Most patients were male (73.2%), fair-skinned (83.2%), and the mean age was 54.3 ± 12.3 years. 103 files provided data regarding profession of individuals, from which the most frequent were farmers (18.5%), construction workers (11.6%), fishermen (9.7%), and drivers (7.8%). There were few variations in the epidemiological profile of AC and LSCC patients. LSCC individuals tend to be older than AC individuals since the mean age of LSCC individuals was 56.3 ± 12.2 years (ranging from 32-79 years) and in the AC group was 53.7 ± 12.1 years (ranging from 24-79 years). The sex and skin color distribution were similar in both groups, and the concentration of individuals with chronic solar exposure was similar in AC than in LSCC group. 120 (96.8%) lesions were located in the lower lip and 04 (3.2%) in the upper lip. The lesions located in the upper lip were histologically diagnosed as NoED ($n=1$), AC with MiED ($n=2$), and LSCC ($n=1$). There was no statistical difference in regards to age, gender, skin color, solar exposure, and alcohol consumption between LSCC and AC groups ($p>0.05$). There was an association between smoking habits and histological diagnosis, the LSCC group presented higher rates of smoking habits than the AC group ($p=0.03$). The majority (80.64%) of AC cases presented some degree of epithelial dysplasia and the majority of LSCC cases were well and moderately differentiated in the histopathological analysis. Clinically, 62 (50%) lesions were diagnosed as AC, 19 (15.3%) as leukoplakia, and 20 (16.1%) as LSCC. Considering the histological features of these cases, 31 (25%) were SCC, two (1.6%) consisted of ISC, 77 (62.1%) were AC with some degree of epithelial dysplasia, and 16 (12.9%) were described as AC without epithelial dysplasia. 18 lesions clinically diagnosed as LSCC were SCCs at histological analysis, one was MiED, and one was MoED. In addition, 8 cases were initially described as AC by the surgeon and later diagnosed as LSCC by the oral pathology team [8].

Literature review. A comprehensive review of the literature was conducted to assess studies that investigated the prevalence of AC and/or LSCC. No time restriction was applied. Retrospective studies and case-series were considered eligible for inclusion. The following exclusion criteria were applied: 1) studies that did not report the histological diagnosis; 2) studies not published in English; and 3) full-text not available. Electronic search strategies were developed and adapted for each of the following bibliographic databases: Embase, PubMed, and Web of Science. In addition, a grey literature search was performed in Google Scholar, ProQuest Dissertations & Thesis, and OpenGrey. The following truncations and word combinations summarize the search strategy: (prevalence or prevalences or occurrence or frequency or frequencies or incidence or epidemiology or epidemiologic or incidence or incidences) and ("actinic cheilitis" or "actinic cheilosis" or "actinic elastosis" or "solar cheilitis" or "solar cheilosis" or "solar elastosis" or "in situ carcinoma" or "squamous cell carcinoma" or "epidermoid carcinoma" or "planocellular carcinoma" or "squamous carcinoma") and (lip or lips or labium or labial). All searches were conducted from the starting coverage date through 26 February 2018. A two-phase process was performed in the selection of studies. In phase-1, titles and abstracts of identified references were screened for potentially eligible studies. In phase-2, a full-text read was performed and studies that met eligibility criteria were included. The following data were extracted from the articles included in the literature review: author, year of publication, country, sample size, participants' gender and age, histological diagnosis, and associated factors. From the main electronic databases searches, 1590 papers were identified, of which 1008 remained after duplicates had been removed. After title and abstract screening, 49 articles were considered eligible for full-text reading, of which 16 met the inclusion criteria and were finally included. Moreover, 2 additional papers were included from the grey literature, resulting in 18 included studies [8].

In discussing a large-scale study conducted on LC, our colleagues state that the reported prevalence of LSCC is variable in the literature, ranging from 1.27 to 5.3 per 100.000 individuals and the prevalence of AC can vary between 4.4% and 5.1% of the oral lesions. Most of the cases included in our sample were clinically diagnosed as AC and approximately 10% as LSCC. However, some of the cases diagnosed as AC were, in fact, LSCC in the histologic analysis, which highlight the importance of diagnosing these lesions at an early stage, since an earlier beginning of the treatment results in fewer consequences for the

patient and higher survival rates. The most affected site by LSCC and AC in sample and in the studies included in the literature review was the lower lip, which is frequently related in the literature as the preferential site for LSCC. In sample, only four cases were located in the upper lip, from which one was LSCC (3.2%) and three were AC (3.2%). In the included studies the results were similar for AC cases; however, approximately 8% of LSCC cases were reported in the upper lip, which is considerably higher than data from the main study. Since lip vermillion semi-mucosa can be highly affected by UV exposure, it is important to emphasize prevention campaigns as relevant ways of aware a high number of individuals, especially in locations with an economy based in agriculture or livestock, such as some areas in Santa Catarina state in Brazil. The authors particularly emphasize that this population needs to be aware of the ways to prevent AC and LSCC, such as utilizing wide-brimmed hat and lip balms with sun protection factor during labor activities and solar exposure. Data from this survey showed that the most prevalent profile of the patients, for both AC and LSCC, was fair-skinned males, older than 40 years of age, and exposed to solar UV radiation due to labor or leisure activities. Overall, these results were similar to findings of literature review. Only five of the fourteen papers investigating LSCC reported data in regards to solar exposure of the individuals, still, most of these articles reported similar results to the main study [8].

As the researchers note, fair-skinned people are naturally more susceptible to UV related disorders, such as skin cancer. This fact associated with intense incidence of solar radiation, which occurs in tropical countries such as Brazil, leads to an increase in the incidence of LC. Moreover, the pathology laboratory from the medical service is located on a tropical island, which has a high concentration of street workers, especially in the summer season, when UV incidence rises, a fact that may increase their susceptibility to LSCC and AC. Interestingly, five (27.8%) of the included articles were also performed in Brazil and two (11.1%) in Australia demonstrating the importance of studying AC and LSCC in tropical locations, which present higher incidences of UV radiation and, therefore, higher incidences of sun exposure related diseases. In this way, health care professionals, especially in these geographic locations, need to be vigilant, since diagnosing these lesions at the earliest stage possible can provide a better prognosis and, consequently, fewer treatment-related consequences for these individuals. Tobacco consumption was found to be significantly higher in individuals with LSCC than in individuals with adenocarcinoma in the main study sample. The rates of smoking tobacco in the medical service LSCC sample were similar to other studies included in the literature review. Several cigar associated substances are linked to the development of intra-oral cancer; however, the role of these substances in the LSCC physiopathology is not clear. Some previous studies suggested that smoking may be considered an important secondary factor in LSCC. However, most of the lesions in our sample were located in the lower lip, which is commonly associated with UV damage, and rarely with the carcinogenic effect of secondary factors, such as alcohol and smoking habits. Still, these behavior habits may be in fact confounding factors in our sample, external effects (such as sun exposure) seem to have a major role in the development of LSCC rather than tobacco and alcohol consumption. The most cases of AC and LSCC in the main study were in fair-skinned individuals with solar exposure, and these data were similar to findings from the literature review. It should be emphasized that most of the lesions clinically diagnosed as AC had some kind of epithelial dysplasia or, in some cases, the presence of LSCC after histopathological evaluation. In conclusion, the authors come to the conclusion that patients with a history of chronic and cumulative UV exposure should be carefully evaluated and, when lip alterations are present, biopsy and histopathological evaluation should be considered [8].

As the authors note Santana T. et al. [9] AC is a potentially malignant disorder of the lip, characterized by epithelial and connective tissue alterations caused by chronic exposure to UV radiation. In the past decades, diverse studies have been conducted in lip carcinogenesis and many biomarkers have been identified in lip lesions, yet there is no scientific evidence that determines its usefulness in the clinical setting or in histopathological routine. In this regard, as our colleagues write, they conducted the first systematic review in this field to summarize the results of published studies on immunohistochemical biomarkers in lip carcinogenesis, to evaluate if there is a marker than can distinguish the different histological grades of AC. Retrospective studies that investigated immunohistochemical biomarkers in AC defined on standardised histological assessment were gathered from five databases and evaluated. Each study was qualitatively evaluated using the critical appraisal tools from System for the Unified Management, Assessment and Review of Information. The proliferation marker Ki-67 was the most studied biomarker and they observed, through meta-analysis, that it was differently expressed between AC and LC, but not in AC sub-groups. Most articles had a high risk of bias. In conclusion, the researchers come to the conclusion that the literature lacks quality follow up studies in AC. Multicentre cohort

studies, with patients stratified by treatment type and the use of image analysis soft-ware, could be the solution to further address the issues of investigating potentially malignant lesions and help change clinical practice, in terms of individualizing patients' treatment and prognosis prediction.

Ortiz R.C. et al. [10] in their work consider the possible role of aldehyde dehydrogenase 1 (ALDH1) and Cluster of Differentiation 44 (CD44) in lip carcinogenesis. According to the authors, LSCC accounts for 12% of all head and neck cancers. It is caused by chronic exposure to UV light solar radiation and related to previous AC. This study aimed to investigate the immunostaining of the putative cancer stem cells markers ALDH1 and CD44 in AC (n=30) and LSCC (n=20). ALDH1 positivity was found to be statistically higher in LSCC than in AC lesions ($p=0.0045$), whilst CD44 expression was statistically higher in AC than in LSCC lesions ($p=0.0155$). ALDH1+ cells in AC lesions were associated with specific clinical features: a younger age (<60 years old), the female gender, white skin, not smoking or consuming alcohol, and a fast evolution, and not associated with the chronic exposure to UV radiation ($p<0.0001$). CD44 positivity was associated with patients who were male, feoderm, smoked, consumed alcohol, underwent occupational exposure to UV radiation, and demonstrated lesions with log-time evolution ($p<0.0001$). ALDH1 + cells were associated with mild dysplasia using a system from the WHO, and with a low risk of malignant transformation, according to the binary system ($p<0.0001$). CD44+ cells were also associated with moderated dysplasia, according to the WHO system. In LSCC, ALDH1+ cells were positively associated with patients who were older (≥ 60 years old), smokers, and with those who consumed alcohol ($p<0.0001$). CD44 + cells in LSCC were associated with older (≥ 60 years old) patients as well, but also with female patients, white skin, non-smokers, and individuals who did not consume alcohol ($p<0.0001$), all of whom showed distinct patterns in pre- and malignant lesions of both markers. Additionally, in LSCC, both ALDH1 and CD44 staining were associated with smaller tumor sizes (T1/T2; $p<0.0001$). In summary, although both ALDH1 and CD44 were associated with the presence of dysplasia in AC lesions, the present findings suggest that ALDH1 and CD44 may be activated by different etiopathogenic pathways, predominantly in distinct steps of oral carcinogenesis. CD44 would thus be more significantly related to the potentially malignant lesion, while ALDH1 would be closely linked to malignancy.

A very revealing and fundamental study was conducted by Medeiros C.K. et al. [11], which consisted of proposal a clinical index for AC. This was an observational study conducted in two steps. The first step consisted of the development of a clinical index for assessing the severity of AC, followed by analysis of the accuracy of this index.

First step: development of the clinical index. First, an exhaustive literature search was performed to identify the clinical characteristics associated with AC for bibliographic validation of these features. The Medline/PubMed, Scopus and Google Scholar databases were searched for articles published in English or Portuguese from 1999 to 2016 using the following keywords: AC, solar cheilosis, lip, and precancerous conditions. After determination of the clinical characteristics associated with AC, forms containing these features were sent electronically between April and November 2016 to 52 masters and doctors in Stomatology and Oral Pathology with at least two years of experience in clinical care of patients with AC. The instrument contained three questions: 1) the professional was asked to identify, among the listed clinical characteristics (resulting from the literature review), those comprising the clinical presentation of AC; 2) the professional should then indicate which of the characteristic identified by him are present in mild, moderate, or severe AC; 3) If you checked the "Other changes" option, what are they? The answers to the questionnaires were analyzed and the clinical characteristics indicated as being representative of the clinical presentation of AC by 90% of the experts were listed and the remaining ones were discarded. The tertile of these characteristics was calculated and the values located in the second and third tertiles were selected. Next, each characteristic as mild, moderate or severe was determined for inclusion in the index according to the classification in which they were most frequently cited. Finally, the clinical index containing these characteristics was elaborated by assigning a score according to severity grade, with 1 for mild characteristics of AC, 2 for moderate characteristics, and 3 for severe characteristics. Thus, after application of the clinical index, each patient received a final score corresponding to the sum of points assigned to the clinical presentation of AC to be used as a parameter for clinical decision-making [11].

Second step: validation of the clinical index. The second step consisted of a diagnostic study. First, the clinical index for AC (CIAC) was applied to patients with a clinical suspicion of AC attending the Stomatology Service of the Department of Dentistry, Universidade Federal do Rio Grande do Norte, between May 2017 and November 2019. The study sample was intentional and not probabilistic. Participants older than 18 years of age with a clinical diagnosis of AC were included in this study. Participants with a histopathological diagnosis incompatible with AC were excluded, resulting in a

sample of 36 participants. The participants were examined by a trained and calibrated researcher. Intraexaminer agreement was determined using the weighted kappa test by evaluating 10 participants at an interval of 15 days between applications of the CIAC and was classified as almost perfect agreement ($K = 0,83$; $P < 0.05$). During application of the index, the characteristics that were present on the participants' lips were recorded and scores were then assigned to each characteristic. Finally, these values were summed to obtain a final score and an incisional biopsy was performed in the area showing the highest degree of clinical severity of AC. Briefly, the specimens were routinely fixed in 10% formaldehyde, embedded in paraffin wax, cut into 5 μm -thick sections, and stained with hematoxylin and eosin [11].

For development of the clinical index for assessing AC severity, researchers first conducted an exhaustive literature search, which resulted in the identification of 35 clinical characteristics associated with AC. Clinical characteristics that represented symptoms (burning and absence of painful symptoms) or that corresponded to the subjective description of a clinical feature (smooth, rough, and irregular surface) were excluded. Repeated clinical characteristics (desquamation/scaly areas; fissures/cracked areas; white/white-greyish plaques) were combined, resulting in 24 characteristics. Only characteristics present in the second and third tertiles of the frequency of citation by dentists were selected, totaling 16 clinical characteristics. The selected clinical characteristics were then classified as mild (score 1), moderate (score 2) or severe (score 3) and based on these results, the CIAC was developed. For validation, the clinical index was applied to 36 patients with a diagnosis of AC. This sample predominantly consisted of men ($n=29$; 80.6%) aged 40 years or older ($n=34$; 94.4%) with fair skin ($n=24$; 66.7%), a history of smoking ($n=20$; 55.6%), and occupational sun exposure ($n=24$; 66.7%). In addition, most participants used some type of photoprotection such as a cap/hat ($n=27$; 75%). With the exception of induration, all characteristics of the clinical index were observed upon physical examination of the patients with AC. The most frequent characteristics were blurred demarcation between lip and skin ($n=32$; 88.9%), white spots ($n=31$; 86.1%), dryness ($n=30$; 83.3%), and desquamation ($n=26$; 72.2%). Most patients scored 10 ($n=5$; 13.9%) and 11 points ($n=5$; 13.9%), followed by 12 ($n=4$; 11.1%) and 7 points ($n=4$; 11.1%) after application of the clinical index. Morphological analysis revealed that 80.6% of the sample had some degree of epithelial dysplasia. Receiver operating characteristics analysis revealed that the optimum cut-off value of the CIAC as clinical diagnostic tool to differentiate among patients with more severe AC was 10 and 11 points. The area under the curve (AUC) of the CIAC was 0.823 ($P=0.022$) for the binary grading system, while a smaller AUC was obtained for the WHO grading system (0.728, $P=0.043$). Additionally, association tests were performed between the individual clinical characteristics and the two grading systems used. Using the WHO grading system, a significant association was observed between the blurred demarcation between lip and skin ($P=0.041$) and cases without dysplasia/mild dysplasia, as well as between the presence of ulceration ($P=0.002$) and crusts ($P=0.012$) and moderate/severe dysplasia. The blurred demarcation between lip and skin ($P=0.005$) was also significantly associated with cases of low risk of malignancy, while erosion ($P=0,024$), ulceration ($P=0,005$) and crusts ($P=0,045$) were associated with a high risk of malignancy by the binary system [11].

Scientific researchers have shown in their work that the clinical management of patients diagnosed with AC is often a challenge for the professional since the clinical presentation of this lesion does not always correspond to its histopathological severity. Thus, procedures that improve diagnostic accuracy are necessary since the treatment and follow-up of these patients are essential for the prevention or early diagnosis of malignant transformation of this lesion. Individual analysis of the clinical characteristics of AC showed a statistically significant association between the blurred demarcation between lip and skin and cases without dysplasia/mild dysplasia and low risk of malignancy. Only four of the 36 participants did not exhibit blurred demarcation between lip and skin (focal or diffuse). The latter is a relatively common characteristic in patients with AC. In conclusion, the authors come to the conclusion that the CIAC was found to be a promising diagnostic tool, showing good reproducibility, easy applicability, rapidity, and low cost. However, further prospective studies involving a larger patient cohort to validate the reproducibility of the index are necessary. Demographic data of the sample analyzed reinforce the profile of patients with AC already established in the literature. Clinical characteristics such as erosion, ulceration and crusts were significantly associated with a higher histopathological severity grade of the lesion. The CIAC cut-off values of 10 and 11 using the WHO and binary grading systems, respectively, showed the best accuracy and these values should be used for biopsy indication. The use of CIAC may contribute to reduction of subjectivity of the decision-making process in the clinical management of AC patients [11].

Now, regarding this pathology in our country at the national level. The incidence of LC in the

Republic of Kazakhstan in 2023 was 0.5 per 100 thousand population (0.6 – a year earlier), which in absolute numbers amounted to 109 people (118 cases – a year earlier), which for such a localization (the data are taken into account excluding skin cancer), is certainly a lot. At the same time, 87 men fell ill (in 2022 – 84 patients), women – 22 (34 patients – a year earlier) [12].

LC levels above the national average were established in 12 regions of the country: East Kazakhstan – 2.2 (the maximum indicator); Pavlodar – 1.5; Karaganda and Akmola – 1.0; Ulytau – 0.9; Kostanay and Abay – 0.7; Aktobe, Zhambyl, West Kazakhstan, Mangistau, and North Kazakhstan regions – 0.6. This indicator is below the national average in 8 regions: the city of Almaty – 0.1 (lowest level); the city of Astana and Almaty – 0.2; Atyrau, Zhetysu, Turkestan, and the city of Shymkent – 0.3; Kyzylorda regions – 0.4 per 100 thousand population.

The mortality rate from this pathology was 0.1 per 100 thousand population, the same as in 2022, which in absolute numbers amounted to 12 people (11 patients – the year before).

The regions where the mortality rate from LC is above the national average include: Pavlodar – 0.3 (highest level); Kostanay and Abay regions have a mortality rate of 0.2 per 100 thousand people. Six regions – Almaty, Aktobe, East Kazakhstan, Zhambyl and Turkestan regions, and the city of Shymkent – are on par with the national average. In the remaining regions (North Kazakhstan, Karaganda, Akmola, West Kazakhstan, Mangistau, Atyrau, Kyzylorda, Ulytau, and Zhetysu regions, as well as the cities of Almaty and Astana), there were no deaths from this pathology [12].

One-year lethality was 3.5% (3.4% in 2022). Moreover, the ratio between one-year lethality and the severity of the disease (stage IV) was quite high at 1.3, despite the ratio of LC to visually accessible localizations. At the same time, we recall that the value furthest from “1” is the worst ratio between the one-year lethality and neglect rates.

Now, regarding preventive examinations. It should be noted that during large-scale preventive examinations of the population in 2023, significantly more patients with malignant neoplasms were actively identified than in 2022. This number was 25,193 compared to 23,623 patients identified in 2022, an increase of 6.6%. This is due to the continued easing of the epidemiological situation related to the coronavirus and the increased availability of preventive care for the population. The proportion of patients identified during preventive examinations increased from 62.0% to 62.4% of the total number of patients identified for the year.

As for LC, the early detection rate of this pathology during preventive examinations decreased from 87.6% to 83.3%. The number of newly diagnosed LC patients registered with oncology organizations was 108 patients (113 patients in 2022). The absolute number of patients with LC identified during routine examinations was 90 (99 in the previous year). Of these 90, 83 were in stages I and II (89 in 2022). The proportion of LC patients detected in the early stages was 92.2% in 2023 and 89.9% in 2022.

Of course, early diagnosis rates are very important when analyzing the epidemiological situation. With this tumor location, 9 out of 10 patients are detected in the early stages (I-II). At the same time, despite the availability of visual diagnostics, one in ten patients is diagnosed in the advanced stages (III-IV), which is a significant percentage. The regions where the proportion of patients with early stage I of the pathology in question is above the national average (42.6% - 7th place among all nosological forms of malignant tumors) include the following: Atyrau, Kyzylorda regions and the city of Shymkent - 100.0% (and, naturally, the best indicator). Next come: North Kazakhstan - 66.7%; Abay, West Kazakhstan, Karaganda, Ulytau regions and the city of Almaty - 50.0%; East Kazakhstan - 43.8%; Zhambyl - 42.9%.

The lowest rates of early diagnosis were recorded in the Zhetysu, Mangistau and Kostanay regions - not a single patient (0.0%). Then come: Aktobe - 16.7%; Pavlodar - 27.3%; Turkestan - 28.6%; Almaty region and the city of Astana - 33.3%; Akmola - 37.5% of the region [12].

The regions where the proportion of patients with LC detected at stages I-II is above the national average [(90.7% - 3rd place after non-melanoma skin cancer (98.4%) and thyroid cancer (92.4%)] include the following regions. In 12 regions (Akmola, Almaty, Atyrau, Zhambyl, West Kazakhstan, Kyzylorda, North Kazakhstan, Turkestan, Ulytau regions and our three megacities) this figure is 100%. Not far from them are the East Kazakhstan (93.8%) and Pavlodar (90.9%) regions. Low rates of early diagnosis were recorded in the Abay and Zhetysu regions - 50.0%. Next come: Karaganda and Mangistau - 80.0%; Aktobe and Kostanay - 83.3% of the region [12].

As the above data clearly demonstrates, there is a wide range in early diagnosis rates across the country, from very good to dismal. Of course, migration processes and other factors influencing early diagnosis rates must be taken into account. Nevertheless, the results obtained provide a reason for oncologists, dentists, orthodontists, dermatovenereologists and general practitioners to continue to strive for excellence. Improving early diagnosis rates for malignant tumors, as one of the fundamental

tenets and one of the primary goals of medicine as a whole, remains a pressing need today.

The proportion of stage IV LC among all nosological forms of malignant neoplasms was 0.9%.

The total number of patients with malignant neoplasms registered with specialized oncology organizations in the republic continued to increase and by the end of 2023 amounted to 218,186 people, an increase of 6.0% compared to the previous year (2022 – 205,822, +5.8%). The overall incidence rate of malignant neoplasms increased by 3.9%, from 1,055.3 to 1,096.4 per 100 thousand population. This increase is due to both the increased incidence and detection of pathology, and the increased survival rate of cancer patients. Furthermore, statistical data on patients diagnosed with malignant neoplasms, who have been under observation for 5 years or more and continue to be monitored in 2023, showed that the number of patients under observation by oncology organizations in Kazakhstan for over five years continued to grow and at the end of the reporting year amounted to 117,616 people, an increase of 6.2% (2022 – 110,790 people, +6.6%) (Form No. 7).

An important clinical aspect, such as the coverage of patients diagnosed with malignant neoplasms in the Republic of Kazakhstan with specialized treatment for the first time, cannot be ignored. In 2023, the number of hospitalizations for all types of malignant tumors in oncology organizations across the country amounted to 108,252 cases (2022: 101,095), representing a 7.1% increase compared to the previous year. This is due to the steady growth of the oncology patient population, improved standardization of oncology care, and the development of palliative and restorative services.

At the end of 2023, the absolute number of patients with LC who completed specialized treatment was 81, with 19 continuing treatment. The following results were obtained in percentages by treatment method and type. 29.6% of patients received surgery alone, 24.7% received radiation alone, 22.2% received combined treatment, 8.6% received complex treatment, 6.2% received drug therapy alone, and 3.7% received chemotherapy and radiation therapy.

Further information is available regarding the five-year survival rate of patients. Regarding LC, at the end of 2023, 1,395 people, or 7.0 per 100 thousand population, were registered for dispensary care. At the end of 2022, there were 1,431 patients, or 7.3 per 100 thousand population, respectively.

Moreover, the mortality rate of the monitored cohorts in 2023 increased compared to the previous year and amounted to 0.9% in 2023 (0.8% in 2022).

The five-year survival rate for patients with LC was 72.5% in 2023 and 72.0% in 2022 [12].

To summarize the above, the following conclusion can be drawn. LC is traditionally considered a visually accessible location, which theoretically ensures a high probability of its early detection during routine examinations. However, the analysis shows a downward trend in this indicator: the proportion of cases diagnosed in the early stages has decreased from 87.6% to 83.3%. Despite the existing capabilities and accessibility of primary visual diagnostics, issues apparently remain that hinder timely patient referral and specialist awareness. The five-year survival rate for patients with LC was 72.5%, reflecting the continuing clinical and social significance of this pathology. Given the direct correlation between prognosis and disease stage, a decrease in early detection may ultimately lead to further deterioration in long-term treatment outcomes. In the current situation, it seems appropriate to: increase oncological alertness among primary care physicians, dentists, orthodontists and dermatovenereologists when examining and treating patients with this pathology, including those from high-risk groups; intensify targeted preventive examinations for smokers and individuals with chronic precancerous lesions of the vermilion border; expand public health education programs aimed at raising public awareness of the early signs of the disease; implement standardized algorithms for routing patients with suspicious changes in the mucous membrane and vermilion border; and utilize modern diagnostic methods at the initial detection stage.

A comprehensive approach, including organizational, educational, and clinical measures, will increase the early detection of LC, improve survival rates, and reduce the medical and social consequences of this pathology. An epidemiological assessment of the LC situation in our country reveals significant regional variations not only in incidence rates but also in early diagnosis of this malignant tumor entity. Therefore, this pathology remains a serious challenge in modern clinical oncology.

References

1 Klinicheskij protokol diagnostiki i lecheniya «Rak guby» - Odobreno Ob"edinennoj komissiej po kachestvu medicinskih uslug Ministerstva zdravooohraneniya Respubliki Kazahstan ot «14» marta 2019 goda, Protokol №58 – 20 s (In Russ.).

2 Zlokachestvennye novoobrazovaniya guby. Klinicheskie rekomendacii. - Associaciya onkologov Rossii, Obshcherossijskaya obshchestvennaya organizaciya "Rossijskoe obshchestvo specialistov po

opuholyam golovy i shei», Obshcherossiyskaya obshchestvennaya organizatsiya «Rossijskoe obshchestvo klinicheskoy onkologii», Obshcherossiyskaya obshchestvennaya organizatsiya «Federatsiya specialistov po lecheniyu zabolevanij golovy i shei», Nekommercheskaya organizatsiya "Assotsiatsiya onkologicheskikh organizacij Sibiri i Dal'nego Vostoka, 2024. - 91 s (In Russ.).

3 Silva WR, Bortoli MM, Leite SR, Barros CC, Brito MD, Montenegro LT, Vasconcellos RJ, Iglesias DP, Sobral AP. Squamous cell carcinoma and basal cell carcinoma of the lips: 25 years of experience in a northeast Brazilian population. *Med Oral Patol Oral Cir Bucal*. 2024 Jul 1;29(4):e476-e482. doi: 10.4317/medoral.26454.

4 Nagesh M, Gowtham S, Bharadwaj B, Ali M, Goud AK, Siddiqua S. Evolution of TNM Classification for Clinical Staging of Oral Cancer: The Past, Present and the Future. *J Maxillofac Oral Surg*. 2023 Sep;22(3):710-719. doi: 10.1007/s12663-023-01915-6.

5 Barragán YV, Carlos ACAM, Costa GAJ, Oliveira Filho OV, Bezerra TMM, Juaçaba SF, Dantas TS, Alves APNN, Barros Silva PG. Mismatch Repair Proteins Immunostaining in Lip Squamous Cell Carcinoma: A Role in Lip Carcinogenesis? *Asian Pac J Cancer Prev*. 2025 May 1;26(5):1553-1562. doi: 10.31557/APJCP.2025.26.5.1553.

6 Silva LVO, de Arruda JAA, Abreu LG, Ferreira RC, da Silva LP, Pelissari C, Silva RNF, Nóbrega KHS, de Andrade BAB, Romañach MJ, Agostini M, Nonaka CFW, Alves PM, Pontes HAR, Rivero LF, de Souza LB, Trierveiler M, Mendonça EF, Gomes APN, Martins MD, Andrade ESS, da Silveira MMF, Sobral APV, Mesquita RA. Demographic and Clinicopathologic Features of Actinic Cheilitis and Lip Squamous Cell Carcinoma: a Brazilian Multicentre Study. *Head Neck Pathol*. 2020 Dec;14(4):899-908. doi: 10.1007/s12105-020-01142-2.

7 Barros CC, Medeiros CK, Rolim LS, Cavalcante IL, Santos PP, Silveira ÉJ, Oliveira PT. A retrospective 11-year study on lip lesions attended at an oral diagnostic service. *Med Oral Patol Oral Cir Bucal*. 2020 May 1;25(3):e370-e374. doi: 10.4317/medoral.23390.

8 Mello FW, Melo G, Modolo F, Rivero ER. Actinic cheilitis and lip squamous cell carcinoma: Literature review and new data from Brazil. *J Clin Exp Dent*. 2019 Jan 1;11(1):e62-e69. doi: 10.4317/jced.55133.

9 Santana T, Matuck B, Tenório JR, Braga MM. Can immunohistochemical biomarkers distinguish epithelial dysplasia degrees in actinic cheilitis? A systematic review and meta-analysis. *Med Oral Patol Oral Cir Bucal*. 2020 Jan 1;25(1):e106-e116. doi: 10.4317/medoral.23223.

10 Ortiz RC, Gois GG, Costa CA, Costa NL, Rodini CO. Possible role of ALDH1 and CD44 in lip carcinogenesis. *J Appl Oral Sci*. 2023 Dec 22;31:e20230227. doi: 10.1590/1678-7757-2023-0227.

11 Medeiros CK, Lopes ML, Silveira ÉJ, Lima KC, Oliveira PT. Actinic cheilitis: Proposal of a clinical index. *Med Oral Patol Oral Cir Bucal*. 2022 Jul 1;27(4):e310-e318. doi: 10.4317/medoral.25243.

12 Kaidarova D.R., Shatkovskaya O.V., Ongarbayev B.T., Zhylkaidarova A.Zh., Seisenbayeva G.T., Lavrentyeva I.K., Sagi M.S. Indicators of the oncology service of the Republic of Kazakhstan, 2023: statistical and analytical materials – Almaty: KIOR JSC, 2024. – 410 p.

Pedagogical sciences

THE IMPACT OF BILINGUAL EDUCATION ON ENGLISH LANGUAGE TEACHING IN HIGHER EDUCATION INSTITUTIONS OF KAZAKHSTAN

Tagoboyeva Sandugash Bakhtibaikyzy
2nd- year Master's Student
South Kazakhstan Pedagogical University
named after Ozbekali Zhanibekov
Shymkent, Kazakhstan

ВЛИЯНИЕ БИЛИНГВАЛЬНОГО ОБРАЗОВАНИЯ НА ПРЕПОДАВАНИЕ АНГЛИЙСКОГО ЯЗЫКА В ВЫСШИХ УЧЕБНЫХ ЗАВЕДЕНИЯХ КАЗАХСТАНА

Тагобоева Сандугаш Бахтибайқызы
магистрант 2 курса,
Южно-Казахстанский педагогический университет
имени Узбекали Жанибекова
Шымкент, Казахстан

Abstract

Bilingual education is a major trend in English language teaching in higher education in Kazakhstan. The use of the local tongue and English helps to better understand the learning materials, increase language skills and more active participation in the educational process. This article is about the role of bilingual education on the development of students' vocabulary, grammatical understanding, writing abilities and learning motivation. Special emphasis is laid on its influence on academic writing and reading comprehension of university students. The study also addresses the problems of establishing multilingual instruction, such as the requirement for competent teachers and effective teaching methodologies. Findings imply that bilingual education facilitates students' academic progress and helps to acquire the English language better. In the multilingual environment of Kazakhstan this technique is a realistic, valuable tool for increasing the quality of higher education.

Аннотация

Билингвальное образование является одним из эффективных подходов к обучению английскому языку в системе высшего образования Казахстана. Использование родного языка наряду с английским способствует лучшему пониманию учебного материала, развитию языковых навыков и повышению активности студентов в образовательном процессе. В статье рассматривается роль билингвального образования в формировании словарного запаса, усвоении грамматических структур, развитии навыков письменной речи и повышении учебной мотивации обучающихся. Особое внимание уделяется влиянию билингвального подхода на развитие академического письма и понимание английского языка студентами вузов. Также анализируются основные трудности внедрения билингвального обучения, включая необходимость подготовки квалифицированных преподавателей и использования эффективных методических подходов. Результаты исследования показывают, что билингвальное образование способствует более успешному изучению английского языка и повышению академической успеваемости студентов. В условиях многоязычного Казахстана данный подход является важным и перспективным направлением развития высшего образования.

Keywords: *Multilingual education, language development, academic literacy, student support, teaching methodologies, cognitive flexibility.*

Ключевые слова: *многоязычное обучение, усвоение языка, академическая грамотность, языковая поддержка, образовательные стратегии, когнитивная гибкость.*

Introduction

In the last few decades English has become the dominant international language of communication, of science and technology and higher education. Consequently, the need for excellent English language teaching has grown dramatically in many nations such as Kazakhstan. Speaking English opens up more chances for students to pursue education, to access worldwide academic resources and

to become more competitive internationally in the labour market. Therefore, enhancing the quality of English language instruction has become one of the main concerns of higher education institutions.

Kazakhstan is a multilingual society where Kazakh, Russian and English languages play a big part in social, cultural and educational life. The national policy for promotion of multilingualism has resulted in adoption of novel techniques to language teaching. Among these strategies, bilingual education has attracted much attention for its possibilities to foster language learning and at the same time, to preserve students' linguistic and cultural identities.

Bilingual education is the use of two languages in the teaching and learning process. Strategic use of students' first language in English language courses can allow learners to understand difficult topics, acquire new vocabulary and develop language abilities more efficiently. Bilingual education does not see the original language as a hindrance, but as a wonderful resource that can help learning and increase academic accomplishment.

Bilingual education can lessen learning challenges and improve target language confidence among university students, especially for those with beginner and intermediate levels of English competence. It helps learners to relate new information to what they already know, encourages them to take part actively in the classroom activities and fosters the development of academic abilities such as reading, writing and critical thinking.

This article is devoted to the study of the influence of bilingual education on the teaching of the English language in higher educational institutions of Kazakhstan. This study is devoted to the advantages of bilingual teaching, its contribution to language development and academic writing as well as obstacles that arise when it is implemented in the university context.

Theoretical Bases of Bilingual Education

Bilingual education is a pedagogical strategy that includes the use of two languages in the teaching and learning process. This is based on the assumption that pupils can learn a foreign language more effectively if they may use their mother tongue as a support aid. Researchers have reported that bilingual instruction enhances the process of language learning by allowing learners to link new knowledge with their previous language expertise.

One of the leading theories in bilingual education was proposed by Jim Cummins . He said that information and abilities learned in one language can transfer to another . This is a notion of linguistic interdependence. It says that the more the original language develops the more it can help to learn the second language.

Therefore, bilingual education does not limit English language acquisition, rather promotes it. The current teaching practices also acknowledge the relevance of translanguaging since it allows the students to employ their entire language repertoire during the learning process. The employment of two languages strategically helps students to better understand academic content, improve critical thinking abilities, and participate more actively in classroom discussions.

Kazakhstan Bilingual Education

Kazakhstan is a bilingual country where Kazakh and Russian are utilised in everyday communication, while English is becoming more significant in the fields of education, commerce and international collaboration. Multilingualism is promoted in the national educational policy as a tool to prepare students for involvement in the global community. English is taught as a foreign language in many academic programmes in higher education institutes. However, many students have difficulty because of the inadequate language proficiency, especially in the early stages of learning.

Bilingual education in this environment is a successful technique of language acquisition and academic performance. The bilingual teaching in Kazakhstan allows students to better understand complicated concepts and avoids the difficulties of learning through a foreign language. In this way students are more involved in the classroom tasks and become more confident in using English for academic purposes .

The Effect of Bilingual Education on English Acquisition

The use of bilingual education has a good effect on various elements of learning English. First, it enhances the comprehension by providing pupils with explanations in their mother tongue and English.

Thus, learners will have a better understanding of challenging grammar structures and new terminology. Secondly, bilingual education helps to enhance the vocabulary. Students will be able to associate terms in one language to another which will improve retention and long term learning. Possibility of comparing linguistic structures helps to better understand the language systems. Third, multilingual instruction enhances student motivation and involvement. When learners know they can

receive some linguistic support they generally find it easier to ask questions and give their opinion. This encouraging atmosphere facilitates active learning and lowers foreign language learning anxiety.

Bilingual education also encourages critical thinking and language awareness. Students gain analytical skills by comparing similarities and contrasts between languages, which are of use in their general academic growth.

Academic Writing Skills Development

University students who learn English find academic writing to be one of the most difficult abilities. Good writing is not just proper grammar. It's the logical arrangement, the right words, and the ability to articulate ideas simply and logically.

Bilingual education allows pupils to strengthen their writing skills by having them think through their ideas in their home language before they convey their ideas in English. This helps to reduce cognitive load, and enables learners to concentrate on information and organisation. Comparing sentence construction across languages also helps students to grasp what is distinctive about academic English. These comparisons can help you to avoid certain typical grammatical errors, and will improve the quality of your written work. Vocabulary development is also important for academic writing.

Bilingual teaching helps pupils to better acquire new vocabulary items and learn how to use them appropriately in varied settings. As a result theirs more precise, consistent and academically appropriate.

Issues in Implementing Bilingual Education

Bilingual education has several benefits, but it also has some problems in higher education. One of the major problems is the absence of methodological consistency. The different teachers may use different multilingual tactics, and this may lead to the difference in the quality of teaching.

Another issue lies in getting trained teachers with good language skills and knowing how to teach bilingually. Without proper preparation, it may be difficult for teachers to maintain a suitable balance between the original language and English.

There is also the concern that over-reliance on the mother tongue can restrict students' exposure to English. Hence, multilingual instruction should be used judiciously, with the original language as a support mechanism rather than a substitute for English.

To achieve the maximum effectiveness of bilingual education, institutions should provide methodological support, professional development opportunities and appropriate instructional materials for teachers and students.

Conclusion

Bilingual education has become an integral part of the English language teaching at the higher education institutions of Kazakhstan. The results of the study show that the strategic use of the local language and English may aid language learning, improve academic achievement and boost students' confidence in the use of English.

The study points out the positive effect of bilingual education on vocabulary development, grammar learning, academic writing and the motivation of learners. At the same time successful implementation demands qualified teachers, effective approaches and a balanced approach to language use in the classroom.

Taking into account the multilingualism of Kazakhstan, bilingual education is a realistic and successful way of teaching English language. Its further development and incorporation into the higher education may lead to better learning outcomes and enhanced preparedness of students for academic and professional communication in the more globalised environment.

References

1. Cummins, J. (2019). The emergence of translanguaging pedagogy: A dialogue between theory and practice. *Journal of Multilingual Education Research*, 9(13). <https://research.library.fordham.edu/jmer/vol9/iss1/13>
2. Klyukina, K. A. (2015). Bilingual education at present. *Scientific Community of Students of the 21st Century: Humanities Sciences*, 3(40). [https://sibac.info/archive/gu-man/3\(40\).pdf](https://sibac.info/archive/gu-man/3(40).pdf)
3. Kunanbayeva, S. S. (2010). Theory and practice of modern foreign language education. KazUIR & WL named after Ablai Khan.
4. Smatayeva, M. A. (2019). On bilingual education in educational institutions. In *Proceedings of the International Scientific and Theoretical Conference "Seifullin Readings – 15: Youth, Science, Technologies – New Ideas and Prospects"* (Vol. II, Part 1, pp. 50–51). KazATU Publishing House.
5. Suleimenova, A. Kh., & Lazarenko, I. A. (2017). Bilingual education as one of the trends in the linguistic development of modern Kazakhstan. *Topical Issues of Humanities and Natural Sciences*, 12(1).

6. Zhou, S., Zhao, S., & Groves, M. (2022). Towards a digital bilingualism? Students' use of machine translation in international higher education. *Journal of English for Academic Purposes*, 60, 101193. <https://www.sciencedirect.com/science/article/pii/S1475158522001138>

7. Zhumay, N., Tazhibayeva, S., Shaldarbekova, A., Jabasheva, B., Naimanbay, A., & Sandybayeva, A. (2021). Multilingual education in the Republic of Kazakhstan. *Social Inclusion*, 9(1). <https://www.cogitatiopress.com/socialinclusion/article/view/3561>

INTEGRATING BILINGUAL EDUCATIONAL STRATEGIES IN TEACHING ENGLISH GRAMMAR TO UNIVERSITY STUDENTS

Tagoboyeva Sandugash Bakhtibaikyzy
2nd-year Master's Student
South Kazakhstan Pedagogical University
named after Ozbekali Zhanibekov
Shymkent, Kazakhstan

ИНТЕГРАЦИЯ БИЛИНГВАЛЬНЫХ ОБРАЗОВАТЕЛЬНЫХ СТРАТЕГИЙ В ОБУЧЕНИИ АНГЛИЙСКОЙ ГРАММАТИКЕ СТУДЕНТОВ ВЫСШИХ УЧЕБНЫХ ЗАВЕДЕНИЙ

Тагобоева Сандугаш Бахтибайқызы
магистрант 2 курса,
Южно-Казахстанский педагогический университет
имени Узбекали Жанибекова
Шымкент, Казахстан

Abstract

The increasing role raising the English language as a worldwide language causes the necessity for the development of good approaches of teaching grammar at higher education. Traditional grammar teaching tends to focus on memorisation and rule-based drills, which may not be sufficient to build students' communicative abilities. In multilingual educational contexts, bilingual education practices can promote the learning of grammar through linking students' past language knowledge to the target language. This research explores the use of bilingual educational practices in teaching English grammar for university students. Special focus is paid to contrastive analysis, cross-linguistic transfer, translanguaging procedures and bilingual scaffolding. These tactics assist learners to analyse grammatical structures in different languages, to detect similarities and differences and to avoid linguistic interference. The employment of bilingual techniques creates more awareness of grammar, encourages critical thinking and allows for the learning of more complicated grammatical concepts.

The study concludes that the inclusion of bilingual educational practices results in better grammatical competence, more accuracy in the use of language and more confidence in the learners. Students get increased competence in analysing the language structures and using the grammar knowledge in academic and communication aspects. Besides, multilingual teaching provides a good learning environment which encourages active engagement and learner autonomy. The findings suggest that bilingual teaching approaches are an effective teaching method to teach English grammar in multilingual classrooms. Their methodical application can enhance learning outcomes and help the development of students' overall language ability.

Аннотация

Возрастающая роль английского языка в международном образовательном пространстве требует поиска эффективных подходов к обучению грамматике в высшей школе. Традиционные методы обучения часто основываются на запоминании правил и выполнении однотипных упражнений, что не всегда способствует развитию коммуникативной компетенции студентов. В условиях многоязычного образования особую актуальность приобретают билингвальные образовательные стратегии, позволяющие использовать уже имеющиеся языковые знания обучающихся при изучении английского языка.

В статье рассматриваются возможности интеграции билингвальных образовательных стратегий в процесс обучения английской грамматике студентов вузов. Особое внимание уделяется контрастивному анализу, межъязыковому переносу, практике трансьязычия и билингвальной поддержке обучения. Использование данных стратегий помогает студентам выявлять сходства и различия между языками, лучше понимать грамматические явления и снижать влияние языковой интерференции.

Проведенный анализ показывает, что билингвальный подход способствует развитию грамматической компетенции, повышению точности использования грамматических конструкций и формированию осознанного отношения к изучению языка. Кроме того, данные стратегии повышают мотивацию обучающихся и создают благоприятные условия для активного участия в учебном процессе. Сделан вывод о том, что интеграция билингвальных

образовательных стратегий является эффективным средством обучения английской грамматике в условиях многоязычного образования и способствует повышению общего уровня языковой подготовки студентов.

Keywords: *contrastive analysis, translanguaging, cross-linguistic transfer, grammatical competence, multilingual education, learner autonomy.*

Ключевые слова: *контрастивный анализ, межъязыковой перенос, трансъязычие, грамматическая компетенция, многоязычное образование, автономность обучающихся.*

Introduction

As the role of English as an international language becomes more important, so does the need for effective ways of language teaching. Grammatical competence is still one of the important components of communicative competence in higher education which enables students to utilise language accurately and responsibly in academic and professional communication. The structural differences between English and the learners' original languages still cause many learners to have problems learning English grammar. Recent trends in applied linguistics have emphasised the significance of bilingual educational practices in the teaching of foreign languages. Cummins (2007) underscores the importance of considering the L1 of learners as a cognitive resource rather than as an obstacle to language learning. Likewise, García and Wei (2014) believe that the flexible use of different languages in the classroom leads to deeper understanding and successful learning.

The use of bilingual methods is especially important in multilingual educational settings like Kazakhstan, where students often use more than one language in their academic and social interactions. The application of bilingual education methodologies in grammar instruction can facilitate the learners' ability to compare between grammatical systems, discover linguistic parallels and differences, and minimise language interference.

The aim of this study is to analyse the effectiveness of bilingual education methods in teaching English language to university students and to analyse their impact on the development of grammatical competence

Review of Literature

Bilingual education has become one of the most disputed subjects in language teaching. Researchers have increasingly come to realise that language acquisition is facilitated when students are permitted to draw on their prior linguistic knowledge in the learning process.

One of the oldest hypotheses connected to multilingual training is Lado's (1957) Contrastive Analysis Hypothesis. The notion says that by looking at two languages you may find the trouble spots and predict the learner's likely blunders. Through the contrastive analysis, students can learn about the differences in grammatical structures and the reasons of some errors in grammar education.

Cummins (2007) presented the notion of Common Underlying Proficiency, which suggests that cognitive and academic skills learned in one language can be transferred to another language. This idea has good ground for multilingual educational methods since it stresses the interrelatedness of the process of acquiring languages.

Another important topic is translanguaging by García and Wei (2014). Translanguaging helps learners to rely on all the language resources available to them to make meaning and to meet communication problems. Research shows that translanguaging can enhance comprehension, increase learner engagement and lead to better academic outcomes. Cook (2016) notes that multilingual learners have some cognitive advantages in being able to make connections across systems of language. Such comparisons serve to build metalinguistic awareness which is an important component of the process of grammar acquisition.

Lightbown and Spada (2020) emphasise the continued importance of specific grammar instruction in second language learning. But, the teaching of grammar is more effective when new structures are related to learners' previous linguistic knowledge. Bilingual teaching practices help build these links and assist better understanding of grammatical concepts.

There are a number of empirical studies that have shown favourable effects of multilingual training. Students that have gone through bilingual training tend to have more accurate grammatical abilities, more analytical skills, and more confidence in the use of language. Moreover, multilingual strategies reduce anxiety and stimulate active participation in school activities. Overall, the data suggests that bilingual approaches to teaching grammar can be quite successful in raising metalinguistic awareness, reducing language interference and fostering communicative competence.

Method

The research was conducted using a mixed-approaches approach, incorporating quantitative and qualitative data collection methods.

The respondents were 50 first-year university students studying English language at the South Kazakhstan Pedagogical University named after Ozbekali Zhanibekov. The pupils were split into two groups of 25 learners each.

The experimental group was taught grammar using bilingual educational methodologies including:

- comparative analysis;
- explains in two languages;
- translanguaging practices;
- cross-lingual comparisons;
- scaffolding in two languages.

The control group was taught the identical grammatical themes in typical monolingual training.

Data collection was carried out for one academic semester and included:

- pre- and post-test assessments;
- classroom observations.
- surveys for students;
- analysis of written tasks.

The pretest was conducted before the adoption of the bilingual techniques, and the posttest was given at the end of the intervention period. The acquired data were analysed by applying descriptive statistical method to find the changes on students' grammatical performance.

Discussion and Findings

The results show that bilingual instructional practices have a positive effect on students' grammatical proficiency.

Table 1. Pre-test and Post-test Result

Group	Pre-test (%)	Post-test (%)	Improvement (%)
Experimental Group	58.4	85.0	+26.6
Control Group	60.1	73.2	+13.1

The results show that the experimental group students performed much better than the control group students. The average score increased by 26.6 percentage points compared with 13.1 percentage points for the control group. There was specific improvement in verb tenses, subject-verb agreement, articles and sentence structure. Students who were taught utilising bi-lingual approaches made fewer grammatical mistakes and had a better mastery of grammatical principles. Moreover, the questionnaire answers revealed positive views of pupils towards bilingual education. Almost 88% of students said that comparison of English grammar with their native language enabled them to understand the complex subjects better. In addition, 84% said that explanations in two languages helped them avoid uncertainty and made them feel more confident doing classroom activities.

The findings were supported by classroom observations. Students in the experimental group were more active in discussion, asked more analytical questions and were more ready to do the grammar-related tasks. Bilingual scaffolding seemed to be conducive to understanding and lessen learning anxiety.

These findings are in line with earlier studies (Cummins, 2007; García & Wei, 2014; Cook, 2016) that underline the advantages of tapping into learners' language resources in language teaching. The findings imply that bilingual education practices are effective for improving not only grammatical correctness but also student autonomy and metalinguistic awareness.

Several factors can explain the success of bilingual training. First, pupils can link new grammatical information with prior knowledge. Secondly, contrastive analysis helps learners to detect structural differences between languages and prevent typical mistakes. Third, translanguaging approaches engender flexible thinking and more involvement with language notions.

Therefore, bilingual educational practices should be thought of as an efficient pedagogical instrument for the improvement of grammar teaching in multilingual university classes.

Conclusion

This study explored the use of bilingual educational practices in the teaching of English grammar to university students. Results show that the use of bilingual techniques positively influences grammatical ability, student confidence and classroom engagement.

Contrastive analysis, translanguaging, bilingual explanations and cross-linguistic comparisons were applied, which allowed students to comprehend grammatical structures more deeply and employ them more accurately in conversation. The quantitative results showed a larger increase for pupils who received bilingual education compared to students who received standard instruction.

This research demonstrates that the first language of the learners can be a beneficial instructional resource, rather than an obstacle. The incorporation of bilingual educational approaches in grammar instruction can promote the development of more effective, inclusive and learner-centred environments for educators. Future studies could examine the long-term influence of bilingual training on language proficiency and its transfer to other areas of foreign language education. Overall, bilingual educational practices seem to be a promising approach to improve English grammar instruction in multilingual higher education contexts.

References

1. Baker, C. (2011). *Foundations of Bilingual Education and Bilingualism* (5th ed.). Bristol: Multilingual Matters.
2. Cook, V. (2016). *Second Language Learning and Language Teaching* (5th ed.). London: Routledge.
3. Cummins, J. (2000). *Language, Power and Pedagogy: Bilingual Children in the Crossfire*. Clevedon: Multilingual Matters.
4. Cummins, J. (2007). *Rethinking Monolingual Instructional Strategies in Multilingual Classrooms*. *Canadian Journal of Applied Linguistics*, 10(2), 221–240.
5. García, O., & Wei, L. (2014). *Translanguaging: Language, Bilingualism and Education*. London: Palgrave Macmillan.
6. Lado, R. (1957). *Linguistics Across Cultures: Applied Linguistics for Language Teachers*. Ann Arbor: University of Michigan Press.
7. Lightbown, P. M., & Spada, N. (2020). *How Languages Are Learned* (5th ed.). Oxford: Oxford University Press.
8. Richards, J. C., & Rodgers, T. S. (2014). *Approaches and Methods in Language Teaching* (3rd ed.). Cambridge: Cambridge University Press.
9. Saville-Troike, M., & Barto, K. (2017). *Introducing Second Language Acquisition* (3rd ed.). Cambridge: Cambridge University Press.
10. Wei, L. (2018). *Translanguaging as a Practical Theory of Language*. *Applied Linguistics*, 39(1), 9–30.
11. Ellis, R. (2008). *The Study of Second Language Acquisition* (2nd ed.). Oxford: Oxford University Press.
12. Larsen-Freeman, D., & Anderson, M. (2011). *Techniques and Principles in Language Teaching* (3rd ed.). Oxford: Oxford University Press.

METHODOLOGY OF TEACHING THE CONCEPT OF QUANTITY

Novruzova Khumar Tofiq
Azerbaijan, Baku

Didactic Foundations. The implementation of the new curriculum in the modern era requires the educational process to be organized around learning outcomes and conducted through interactive methods. It creates substantial opportunities for students to acquire essential life skills and develop into individuals with modern ways of thinking. A learner-centered curriculum emphasizes the development and promotion of students' practical skills and competencies. In the primary mathematics course, the study of quantities serves as an effective means of fostering such skills.

In Grades I–IV, students become acquainted with fundamental quantities such as the length of a line segment, the area of a figure, the volume of an object, time, and other basic quantities, as well as the relationships among them. At this stage, young learners primarily encounter these concepts through the solution of practical problems involving quantities such as price, value, productivity, and similar contexts. By the completion of primary education, every student should be able to distinguish between the concepts of number and quantity, estimate quantities approximately, possess accurate knowledge of measurement units, and perform operations involving quantities.

The Mathematics Curriculum envisages the study of quantities and their measurement within two content strands: "Algebra and Functions" and "Measurement." The knowledge and problem-solving skills related to measuring quantities acquired through these strands provide students with a solid foundation for all subsequent mathematical learning. The teaching of this topic is of particular importance within a learner-centered curriculum, as it is closely associated with the development of students' practical activities and competencies. This is because the concept of quantity serves as one of the principal means through which students can apply their mathematical knowledge in real-life and practical situations.

The content of mathematics education should be designed to:

1. Contribute to students' general education and the development of their scientific worldview;
2. Promote the practical application of mathematics in technology, industry, and economic activities;
3. Provide a solid foundation for the successful completion of secondary education and for continuing studies at higher education institutions;
4. Facilitate the application of mathematical knowledge and skills in vocational preparation and professional practice.

Historical material. The International System of Units (SI) was adopted in 1960 by the 11th General Conference on Weights and Measures. Subsequently, a number of modifications were made to the SI at later conferences. The International System of Units (SI) comprises seven base physical quantities, two supplementary units, and a number of derived units. [1]

The base units are the kilogram, metre, second, mole, kelvin (K), ampere (A), and candela (cd). In the SI, these units have independent dimensions; that is, none of the base units can be derived from the others.

Derived units are obtained from the base units through algebraic operations such as multiplication and division. Some of the derived units in the SI have their own names, such as the radian.

Prefixes are used before unit names. This means that a unit is multiplied or divided by an integral power of ten. For example, the prefix kilo- denotes multiplication by 1000 (1 kilometre = 1000 metres). In the SI, these prefixes are also referred to as decimal prefixes.

The SI was developed by French scientists and was first widely implemented after the French Revolution. Prior to the introduction of the metric system, units were chosen independently of one another, making conversion from one unit to another difficult. Furthermore, different units, sometimes bearing the same names, were used in different regions. The metric system was intended to provide a convenient and uniform system of measurement and weights. [2]

In the early 1790s, provisional standards for the metre and the kilogram were prepared in France. Copies of these standards were sent to several countries, including the United States. However, the ship carrying the copies was captured by British pirates, preventing them from reaching America. This contributed to the limited development and adoption of the SI in the United States up to the present day.

In 1799, two standards were established in France: the unit of length (the metre) and the unit of mass (the kilogram).

In 1832, the German mathematician Carl Friedrich Gauss developed the scientific foundations for constructing systems of units and introduced a new system (CGS – centimetre, gram, second). He considered length, mass, and time as the fundamental physical quantities and adopted the centimetre, gram, and second as the base units. This system later played a significant role in the development of the SI. [1]

In 1875, representatives of seventeen countries signed the Metre Convention, which played a crucial role in initiating the development of international standards for the metre and the kilogram.

In 1889, the MKS system (metre, kilogram, second) was adopted alongside the CGS system. This system included the units metre, kilogram, and second, as they were considered more convenient for practical use. Later, additional base units were introduced for physical quantities in the fields of electricity and optics.[1]

Some countries have not fully adopted the SI, or have adopted it only partially, and continue to use the British Imperial System or similar systems of measurement.

Quantities in Modern Education. In primary school mathematics textbooks, considerable attention is devoted to problems involving the application of the most commonly used units of measurement related to quantities. In order to transform theoretical knowledge into practical skills and habits, students should observe how the information they acquire can be applied in practice. Through this process, mathematics becomes closely connected with real life, enabling students to retain learned concepts for a longer period of time.

The problems presented to students should be engaging, logical, and designed to promote the development of their thinking abilities. In Grades II–IV, greater emphasis is placed on word problems that illustrate the meaning and application of arithmetic operations. Such problems help students acquire knowledge related to various aspects of everyday life as well as different fields of science. Problems intended to teach the measurement and calculation of time should be selected with particular care. Tasks of this nature play a significant role in developing students' constructive skills and their ability to analyze and cope with different situations. [2]

As is well known, mathematical concepts and laws originated from human life and labor activities and have evolved alongside the development of work processes and production. The source of abstraction underlying mathematical concepts is life itself, human labor, and production. Mathematics reflects the material world in human consciousness from a specific perspective. Therefore, the objects of mathematical study are the spatial forms and quantitative relationships that exist in the material world. In the world surrounding us, both form and quantity play a role, to varying degrees, in every object and phenomenon.

In the modern era, only individuals possessing an adequate level of mathematical preparation can successfully understand and manage the complex processes, technologies, and technologically advanced production systems that characterize contemporary society. For this reason, mathematics should not be taught in isolation from life, production, and labor activities; rather, it should be closely connected with them and related to real-life situations, events, and processes. From this perspective, solving problems involving quantities plays a crucial role in the formation and development of students' mathematical knowledge, skills, and competencies.

References

1. Franklin J. *An Aristotelian Realist Philosophy of Mathematics: Mathematics as the Science of Quantity and Structure*. Palgrave Macmillan UK, Apr 9, 2014, 308 pp.
https://books.google.az/books?id=0YKEAwAAQBAJ&redir_esc=y
2. Richard R. Skemp. *Mathematics in the Primary School*. Routledge, 2002, 234 pp. https://www.perlego.com/book/1619673/mathematics-in-the-primary-school-pdf?utm_source=chatgpt.com

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BASIC PECULIARITIES OF USING INTERACTIVE METHODS IN TEACHING MODERN ENGLISH**Shevelova-Harkusha Natalia***PhD in Philological Sciences, Associate Professor at the English Language Department for Maritime Officers (abridged programme) of Kherson State Maritime Academy
Kherson, Ukraine***Abstract**

The article provides a comprehensive theoretical and practical analysis of integrating modern forms of visualization, digital tools and interactive teaching methodologies into the process of foreign language instruction in higher education. Special attention is dedicated to the categorization of digital instruments into functional pedagogical clusters. The study evaluates presentation platforms (Canva, Prezi), mind-mapping software (Bubbl.us), digital whiteboards (Padlet, Jamboard, Mentimeter), and gamified environments (Kahoot!, Wordwall, LearningApps) as mechanisms to enhance grammar acquisition, expand topical vocabulary, and build public speaking confidence. Additionally, the integration of text-to-speech technologies (Voicemaker) is analyzed as a tool for creating authentic audiovisual environments. The article outlines a structured framework for active student engagement categorized into four primary subcategories. The materials, digital tool selections, and methodological conclusions presented in the article can be directly applied by university professors, English instructors, and educational researchers to design dynamic, results-oriented, and interactive language learning environments.

Keywords: *interactive learning strategies, integrating interactive technologies, functional pedagogical clusters, integrating modern forms of visualization, cross-curricular links.*

*The term "interactive learning" originates from the Latin words *inter* (between, among, mutually) and *activus* (active), which means "based on interaction". Consequently, interactive teaching methods involve active interaction among all participants in the educational process: between instructors and students, as well as among the students themselves. E. A. Geist [2] emphasizes the significance of computer and multimedia technologies in creating interactive dialogue and collective cognitive activity. This approach reflects a deeper understanding of interactivity, which encompasses not only technological interaction but also collaborative problem-solving and the evaluation of participants' actions. Even the use of individual tablets in the classroom is sufficient to create interaction. Such an approach emphasizes individual feedback and the ability to quickly assess students' comprehension of the material, but it fails to foster the collective interaction and cooperation that serve as key drivers of full-fledged interactive education [3].*

An interactive approach to learning is not merely a component of the teaching process; it is the overall process of learning where the entire class must be interactive, and the interaction between the instructor and students must be balanced. Such a learning method should facilitate learning rather than distract from it.

Traditional communication during practical English classes in a physical classroom is based on direct interaction between instructors and higher education students. Instructors frequently utilize methods of direct instruction, leading discussions and peer learning through paired or group exercises. Higher education students have the opportunity to receive instant feedback from the instructor, which facilitates better acquisition of language skills and on-the-spot error correction. The instructor can adapt the teaching approach dynamically depending on the students' reactions.

In distance learning, video conferencing platforms such as Zoom or Microsoft Teams play a distinctive role. These tools allow instructors to conduct classes in real time, ensuring visual and audio contact, as well as screen sharing to demonstrate presentations, video materials, and other educational resources. Higher education students can ask questions and receive answers online, which maintains their activity and engagement, although it requires more time and organizational effort to ensure effective interaction. Most higher education institutions possess their own virtual learning environment, which allows instructors to create comprehensive courses with various educational materials, text files and video lectures.

Digital learning platforms played a crucial role in foreign language teaching during the pandemic, when traditional classroom teaching methods became unavailable. The use of platforms such as Moodle,

Universe, and Platonus allowed universities to maintain the continuity of the educational process by providing instructors with tools to upload assignments, conduct tests, communicate with students, and distribute educational materials. These platforms provide higher education students with the opportunity to access learning materials at any time and from any location, which is a significant advantage for ensuring flexibility and individualization of the learning process.

Digital platforms significantly improve student performance by making the learning process more engaging and interactive. Multimedia presentations represent an interactive technology that allows for effective interaction with the audience when learning English. They integrate various digital media (texts, images, sound and video) into a single, cohesive environment available in the form of interactive applications or presentations. Multimedia guides not only expand students' access to information but also contribute to the formation of more accurate and detailed mental models compared to traditional textual materials [2]. Students often prefer classes that utilize multimedia presentations, as they find them more engaging and visually comprehensible. Presentations typically have a clear structure (an introduction, a body paragraph developing key ideas, and conclusions), which facilitates better material retention.

Interactive Methods include: 1) Technological methods, such as: Watching movies, Educational games in Google Classroom, Slide projectors, Listening to audio, PowerPoint presentations; 2) Simple Tools: Crosswords, Scrabble, Maps, Songs, 3) Communicative methods: Case study, Cluster, Brainstorming, Pair work, Gamification [1].

Individual interviews implies that the instructor conducts an interview with a higher education student, simulating real-life communication situations. This practice focuses on developing listening and responding skills, which helps higher education students better adapt to stressful communicative situations.

Interactive mentoring means that the instructor works individually with a higher education student to improve specific aspects of speech, including grammar, vocabulary or phonetics. The instructor can utilize interactive exercises such as gap-filling, error correction in texts, and other similar tasks.

Individual interactive methods not only facilitate the involvement of higher education students in an active learning and knowledge-sharing process but also allow the instructor to precisely determine the specific needs of each student, which significantly improves the quality of education.

Pair work can be utilized in various educational contexts, including foreign language teaching in higher education institutions. These are the key steps of interaction between the instructor and the higher education student when organizing pair work:

- Formulating a problem or question: the instructor defines a topic or a specific question that higher education students must discuss. This can be a grammatical structure, a lexical topic, or a debate question that requires critical thinking;

- Dividing higher education students into pairs facilitates more intensive interaction and allows each student to participate actively in the educational process. It is important that throughout the course, higher education students have the opportunity to work with different partners to expand their communication experience;

- Formulating conclusions: each pair receives time to discuss and formulate an answer to the question asked. This process helps higher education students develop analytical and communicative skills;

- Mutual presentation and evaluation: after formulating conclusions, one student in the pair presents the solution, while the other evaluates it and provides feedback. This promotes critical thinking and the ability to argue one's opinion;

- Process variations: the instructor can introduce diversity into the methodology of pair work, for example, by using role-plays, debates, or practical tasks. This helps maintain the interest of higher education students and increase the efficiency of learning [4].

The implementation of pair work in the educational process contributes not only to the improvement of language skills but also to the development of interpersonal relationships, increasing student motivation and engagement. This approach allows them to retain material better and use the acquired knowledge in real-life situations [3].

Cases for study are usually selected from real professional fields and are supported by statistical data, diagrams, charts, visual materials, reports, media data, internet resources, descriptions of different points of view, etc. Such detailed information allows students to understand the content of the case more deeply.

When using this method, the instructor applies two phases. The first includes creating the case, formulating questions for analysis, and developing methodological materials for students' independent work. The second phase includes the instructor's classroom work on discussing the case, where they make introductory and concluding remarks, organize a discussion or a presentation, maintain a business atmosphere in the classroom, and recognize the students' contributions to the analysis of the situation. Consequently, students acquire knowledge and communicative skills through the study and analysis of experience based on real-life situations, which productively influences the formation of their professional competencies [1].

Group teaching methods, in particular the cluster method, are widely applied in English language teaching at higher education institutions at all stages of learning, for both junior and senior students. The process of using a cluster begins with the instructor writing a new word on the board. Then, higher education students actively engage in the process, naming words that can be used together with the given lexeme. This process not only facilitates better retention of new words but also stimulates the creative thinking of learners, as they need to recall and select appropriate words from their own vocabulary.

The use of clusters is especially effective in learning English because it involves higher education students in active work and builds their motivation. At the same time, the method is used to improve monological speaking skills. Higher education students learn to construct long utterances using words that are logically and meaningfully connected to each other. For example, if the instructor writes the word "environment" on the board, students can suggest words such as "protection", "sustainability", "pollution" and "conservation". Such an approach not only helps students better understand the meaning of a word through the context of its use but also develops their capacity for cross-curricular links and a deeper understanding of the language [2].

Brainstorming is an important interactive technique widely used in English language teaching at higher education institutions. This method facilitates the generation of creative ideas and thoughts, and it also teaches higher education students effective teamwork. Depending on the learning objectives and the specifics of the group, various forms of brainstorming are applied:

- structured brainstorming: each participant takes turns expressing their ideas, which helps avoid domination by more active participants;
- unstructured brainstorming: students openly share their thoughts, which stimulates a lively exchange of ideas;
- reverse or negative thinking: participants initially focus on potential problems or negative aspects of an idea, which subsequently helps identify ways to resolve them;
- nominal group relations: this approach combines individual thinking with group discussion, allowing participants to first generate ideas independently and then discuss them within the group;
- online interaction: involves the use of digital platforms such as chats, forums, and email, enabling brainstorming at a distance;
- team idea mapping: this method is based on visualization, which helps structure and connect ideas using diagrams and maps;
- group passing of ideas: ideas are passed from one participant to another for further addition or refinement, contributing to the collaborative development of thoughts;
- individual brainstorming: carried out independently before the discussion begins, which helps avoid group pressure [4].

The application of brainstorming in English language teaching helps higher education students better retain vocabulary and language structures, as well as utilize them in a practical context. Thus, brainstorming is a key element of interactive and student-centered learning.

Gamification is the most popularized interactive method in scientific literature, utilizing game elements in the educational process to transform ordinary learning into an engaging activity. One of the primary features of gamification is its capacity to integrate game principles, such as points, levels, rewards, and competitive aspects, directly into educational content. This helps students remain more engaged and motivated throughout the entire learning process [5].

The application of gamification in higher education can be diverse. For instance, using simulations of business environments allows higher education students to practice the English language in contexts close to reality, yet within a safe and controlled environment. Another example is mobile applications that use an achievement and point system to track progress in language learning, providing students with feedback and a sense of accomplishment. However, the use of mobile applications is unpopular in higher education institutions due to the fact that they are not integrated into curricula. The most crucial

feature of gamification is the competitive element, which can be organized without technical or technological tools. To integrate competition into the educational process, instructors need to take on additional responsibilities for recording, documenting, and accumulating student achievements [2].

Imitation-modeling games usually focus on solving specific problems and developing procedural skills. They differ from role-plays by the predominance of the technical aspect of performing roles, such as a leader, speaker, or manager. In such games, empathy and transforming into characters are less important than the structured execution of tasks and problem-solving.

Combinatorial imitation-modeling games are designed to develop speech culture and test knowledge. This type of game engages the participants' memory, making them particularly useful for consolidating studied material. Games of this type are often based on a reproductive level of thinking, where students perform actions automatically and without external prompts, facilitating better understanding and acquisition of educational material.

Strategic games are considered more complex. They include role elements that influence student behavior in accordance with established rules and specific situations, contributing not only to a reproductive but also to a heuristic and even creative level of thinking. Strategic games are used when studying new topics, summarizing already learned material, and gaining experience in non-standard conditions. These games also facilitate an understanding of the connection between acquired knowledge and future professional activity, leading to a deeper comprehension of professional problems and ways to resolve them [5].

The systematic analysis of integrating modern forms of visualization and interactive methodologies in teaching English to higher education students allows for the formulation of several key conclusions:

1. Modern interactive language education has transitioned from a basic, technology-centered approach to a deeper, collective cognitive collaboration. True interactivity requires an egalitarian, balanced relationship between the instructor and students, where knowledge is actively constructed through shared problem-solving rather than isolated digital tasks.

2. The integration of innovative digital visualization tools satisfies the fundamental educational principle of active visual engagement. Modern forms of visualization, including infographics, mind maps, and interactive whiteboards, do not merely diversify classroom activities; they optimize information perception, foster strong associative links, and accelerate the retention of complex grammatical and topical lexical material.

3. For practical educational implementation, modern digital tools can be effectively grouped into pedagogical clusters that align with specific learning objectives. Platforms like Canva and Prezi excel at structured graphic delivery; Bubbl.us serves as an ideal interactive mechanism for vocabulary grouping and essay planning; while collaborative boards like Padlet and Mentimeter foster synchronous group dynamics.

4. Gamified digital platforms, such as Kahoot! and Wordwall, significantly enhance student motivation and speech culture by integrating competitive elements, levels, and instant feedback into the curriculum. Furthermore, organizing pedagogical games into imitation-modeling, combinatorial, and strategic categories allows instructors to move students from automatic reproductive actions to high-level heuristic and creative thinking.

5. Interactive practices, ranging from individual presentations and mentoring to group case studies, actively lower communication barriers and build public speaking confidence. Methodologies like the Harvard case study method and the cluster method simulate authentic professional or business environments, thereby driving the simultaneous development of language fluency and vital career-oriented soft skills, including analytical thinking, risk management, and collaborative leadership.

In summary, the combined application of digital visualization platforms and structured interactive practices creates a dynamic, flexible and student-centered educational environment. This methodology meets contemporary globalized standards, successfully maintains the continuity of language education in both physical and virtual classrooms, and effectively equips higher education graduates with practical, real-world communicative competencies.

References

1. Eshonkulova S. The importance of interactive methods and principles in English language lessons. *ScienceandEducation*. 2020. Vol. 1(7). P. 356-36

2. Geist E. A. A qualitative examination of two-year-olds interaction with tablet- based interactive technology. *JournalofInstructionalPsychology*. 2012. Vol. 39(1). P. 26-35. URL: <https://www.learntechlib.org/p/88310/>.
3. Karhina N. Using interactive teaching methods in English lessons. *ScientificBulletinofMukachevoStateUniversity.Series“PedagogyandPsychology”*. 2023. Vol. 9(1). P. 9-15. DOI: <https://doi.org/10.52534/msu-pp1.2023.09>.
4. Knapen R. 20 interactive teaching activities for in the interactive classroom. *BookWidgets*. 2020. URL: <https://www.bookwidgets.com/blog/2018/06/20-interactive-teaching-activities-for-in-the-interactive-classroom>.
5. Turdiyeva Zh. *The Use of Interactive Technologies in Learning English Language Learning: Literature Review*. SSRN. 2023. URL: <https://ssrn.com/abstract=4663150> (date of access: 24.05.2025).

THE IMPACT OF ARTIFICIAL INTELLIGENCE ON THE ICT SECTOR

Zarafshan Azayeva Babakarim

Department of Information Communication Technologies,
Baku Slavic University**Abstract**

Few technological shifts have reordered the information and communication technology sector as thoroughly as artificial intelligence. What began as an academic discipline rooted in mathematical logic and cognitive science has, over roughly two decades of rapid engineering progress, become an operational force embedded in nearly every function of modern ICT — from the automated management of telecommunications infrastructure to the real-time detection of adversarial activity in enterprise security environments. The pace at which this penetration has occurred has surprised even close observers, and its full consequences remain a matter of active investigation across industry, research, and policy.

This article is an attempt to examine that impact honestly and with some depth. The goal is not to catalogue every AI application that has appeared in the technology industry — that list grows with each year — but to understand what AI is genuinely changing: how networks are managed and optimized, how security threats are detected and countered, how cloud infrastructure adapts to demand, and how organizations within the ICT sector are repositioning themselves in an environment that is being restructured around intelligent systems. Four domains receive sustained attention: network infrastructure management, machine learning applications in telecommunications and network optimization, AI in cybersecurity, and the integration of AI into cloud and edge computing environments.

In infrastructure, the analysis reveals a genuine architectural shift away from human-directed network operations toward intent-driven, self-optimizing systems that call for fundamentally different engineering competencies and governance structures. In telecommunications, machine learning has moved from research curiosity to operational necessity, particularly in the context of 5G deployment and Open RAN architecture, where the complexity of the optimization landscape exceeds what classical methods can handle in real time. In cybersecurity, AI has proven capable of detecting behavioral anomalies and correlating threat signals across enormous telemetry datasets, though the same class of technology is increasingly being weaponized by adversaries, creating a self-escalating dynamic that requires sustained rather than one-off investment. In cloud computing, AI-driven resource orchestration and federated learning are giving rise to intelligent, privacy-preserving services that extend considerably beyond what centralized processing alone could support.

The article does not treat this transformation as uniformly positive. Persistent problems of data quality, acute shortages of AI-capable talent, and regulatory frameworks that are struggling to keep pace with technical realities all impose genuine constraints on the responsible adoption of AI in ICT. Ethical questions surrounding algorithmic transparency, discriminatory model outputs, and the concentration of advanced AI capability among a small number of dominant platforms deserve serious engagement rather than optimistic dismissal. These concerns are addressed alongside the technical analysis rather than appended as an afterthought.

The central argument is that artificial intelligence is restructuring the ICT sector at a structural level — not merely adding new tools to existing workflows but altering how organizations think about operations, competition, and value creation. Grasping that shift clearly, including both the opportunities it opens and the difficulties it introduces, is a necessary starting point for navigating it with any real deliberateness.

Keywords: artificial intelligence, ICT sector, machine learning, network optimization, cybersecurity, cloud computing, 5G, Open RAN, AIOps, federated learning.

Introduction

There is something almost paradoxical about studying artificial intelligence's impact on the information and communication technology sector. ICT, after all, is the field that built the computational substrate — the processors, the data centers, the fiber-optic networks — without which modern AI would remain technically infeasible at any meaningful scale. And yet it is precisely that same sector which is now being most fundamentally reorganized by the technology it enabled. The relationship between ICT and AI is reciprocal and self-reinforcing: ICT infrastructure makes AI possible at scale, and AI in turn is

progressively automating, optimizing, and extending what that infrastructure can do. Each advance in one domain creates conditions for advances in the other.

This dynamic is not merely of theoretical interest. The ICT sector constitutes a foundational layer of the modern economy, and changes to how it operates propagate outward into virtually every other domain of economic and social life. When telecommunications networks become capable of reconfiguring themselves in response to real-time traffic patterns, the beneficiaries extend far beyond the network operator: every organization and individual that depends on connectivity is affected. When cloud platforms apply machine learning to resource allocation, the downstream effects include lower costs, higher reliability, and richer services for many thousands of customers. Studying AI's impact on ICT is, therefore, not a narrowly technical exercise; it is one useful lens for understanding AI's broader trajectory in the economy and society.

This article examines that impact through a focused analytical lens. Rather than attempting a comprehensive survey of every AI application that has appeared across the technology industry, the analysis concentrates on the domains where structural change is most evident and most consequential: network infrastructure management, machine learning in telecommunications, AI-powered cybersecurity, and the fusion of AI with cloud and edge computing environments. For each domain, the aim is to move beyond surface-level description toward an account of the underlying mechanisms of change and the second-order consequences — organizational, competitive, and regulatory — that technically oriented treatments often pass over.

AI Applications in ICT Infrastructure

Managing large-scale ICT infrastructure has always been a discipline defined by tension. Network operators have historically faced a difficult trade-off between agility — the capacity to reconfigure services rapidly in response to shifting demand or evolving requirements — and stability, meaning the avoidance of disruptions in systems upon which enormous numbers of people and organizations depend. Traditional network management addressed this tension primarily through conservatism: configurations changed slowly, modifications passed through layers of human review, and automation was applied only in narrow contexts where its behavior could be anticipated with high confidence.

Artificial intelligence is gradually dissolving this trade-off. Intent-Based Networking represents the most mature operational expression of this shift. Rather than configuring networks through explicit, granular command sequences, IBN systems allow administrators to declare desired outcomes — expressed as high-level business policies — and delegate to machine learning models the task of determining how those outcomes should be achieved through specific configuration parameters. The system monitors continuously the gap between intended and actual network state and acts to close it, adjusting configurations autonomously as conditions change. The conceptual appeal is significant; the practical challenges are equally real, including the non-trivial problem of translating ambiguously expressed business intent into the precise formal specifications that network systems actually require.

Data center thermal management has offered a cleaner demonstration of AI's infrastructure potential, in part because the optimization problem is well-defined and the performance signal — energy consumption — is measurable with precision. Reinforcement learning agents trained to balance cooling loads against power efficiency targets have delivered material reductions in energy use at large-scale facilities. These gains carry real economic weight: energy costs represent a substantial fraction of data center operating expenditure, and the environmental footprint of large data centers has attracted increasing regulatory and public attention. When AI-driven optimization produces meaningful improvements on that dimension, the benefits extend beyond the operator's balance sheet.

Digital twin technology, in which a continuously updated virtual model of physical infrastructure is maintained and used for simulation and predictive analysis, is extending the scope of AI-driven infrastructure management further. Configuration changes, fault scenarios, and capacity expansion plans can be tested in the digital twin before being applied to production systems, reducing operational risk and accelerating the rate at which improvements can be confidently deployed. The combination of digital twins with reinforcement learning — using the twin as a training environment — is an active area of development that may further widen the gap between AI-augmented and conventionally managed ICT infrastructure.

Machine Learning and Network Optimization

The application of machine learning to telecommunications network optimization has moved from research literature into operational deployment with unusual speed. Several factors explain this velocity. Modern telecommunications environments generate training data of exceptional richness and continuity: granular traffic measurements, radio signal quality reports, user session records, and

equipment performance logs accumulate at volumes and refresh rates that supply exactly what machine learning systems require. The cost of suboptimal network performance is concrete and measurable, providing sharp economic motivation for optimization investment. And the combinatorial complexity of managing large, heterogeneous networks in real time is genuinely beyond the reach of classical optimization methods, which cannot explore the relevant solution space within operationally acceptable timeframes.

In mobile networks, these conditions have made machine learning indispensable at multiple layers of the network stack. At the radio access layer, ML models predict interference patterns, adjust transmission power and antenna tilt parameters, and redistribute traffic loads across cells in ways that heuristic-based Self-Organizing Network systems cannot match, particularly under dynamic and spatially uneven traffic conditions. At the core network layer, traffic classification models support more precise quality of service management, allowing latency-sensitive applications to receive preferential treatment without the crude over-provisioning of bandwidth that simpler approaches require.

The transition to 5G has amplified the importance of machine learning substantially. The defining technical characteristics of 5G — millimeter-wave propagation with its combination of high throughput and limited range, massive MIMO antenna arrays with their large numbers of configurable elements, network slicing that must simultaneously satisfy distinct performance envelopes for multiple virtual networks sharing the same physical infrastructure — generate an optimization landscape of a complexity that classical methods cannot navigate in real time. Network slicing alone introduces dependencies and constraints that make the overall problem analytically intractable without learning-based approaches that exploit patterns in historical configuration data.

The emergence of Open RAN architectures adds a further dimension. Disaggregating the radio access network into standardized, vendor-interoperable software components creates the architectural basis for the RAN Intelligent Controller, a platform specifically designed to host AI and ML applications that influence network behavior through well-defined interfaces. The RIC positions intelligence not as an optional overlay but as a structural feature of the network design — a conceptual shift with substantial long-term implications for how mobile networks are built, managed, and evolved.

AI in Cybersecurity

Of all the domains this article examines, cybersecurity is arguably the one in which assessing AI's impact most clearly requires holding two contradictory truths at once. The performance advantages of AI-powered security tools over classical approaches are well-documented and, in aggregate, substantial. The same technology, however, is actively being adopted by adversaries, and the sophistication of offensive AI applications is advancing at a pace that is genuinely difficult to track and harder still to outrun. The cybersecurity domain is not a problem that AI can solve; it is a contest in which AI changes both sides simultaneously.

That caveat established, the case for AI in defensive cybersecurity is compelling. The volume of security-relevant events generated by modern ICT environments — log entries, network flow records, authentication attempts, API calls, endpoint telemetry — has long since exceeded the capacity of human analysts to process with any real thoroughness. Security Information and Event Management systems augmented with machine learning address this problem not by raising human attention capacity but by enabling the system itself to learn what normal behavior looks like for users, devices, and network segments, and to identify the deviations from that baseline that merit investigation. Behavioral anomaly detection has proven particularly effective against threats — insider attacks, advanced persistent intrusions — that are specifically designed to avoid triggering signature-based detection rules.

Graph-theoretic approaches to threat intelligence represent a more recent and analytically interesting development. Modeling the relationships among threat actors, malware families, infrastructure components, and victim organizations as a network, and applying graph neural network algorithms to that relational structure, allows analysts to reason about attack patterns at a level of abstraction that simple indicator-based methods cannot support. The practical implication is that threat intelligence derived from these models can inform proactive defensive action — identifying infrastructure being prepared for future campaigns — rather than serving only as a retrospective record of past incidents.

The offensive dimension cannot be ignored. Generative AI has materially reduced the cost and raised the quality ceiling of phishing and social engineering campaigns, enabling personalized deceptive content at scale that previously required significant human effort. Automated vulnerability discovery tools powered by ML are compressing the time window between the appearance of a software weakness and its exploitation. These developments do not undermine the case for AI in cybersecurity, but they do

argue against treating any particular defensive AI deployment as a durable solution rather than a point in a continuing adaptive process.

Cloud Computing and AI Integration

The relationship between artificial intelligence and cloud computing is, structurally, one of mutual dependency. Cloud platforms provide the elastic compute, storage, and networking capacity that makes training and serving large AI models economically feasible for the broad range of organizations that lack the capital to build dedicated AI infrastructure. AI in return provides the intelligence layer that enables cloud platforms to manage their own infrastructure more efficiently, deliver more differentiated services, and sustain the performance commitments that customers increasingly expect at scale.

AIOps — the application of AI to IT operations — is the primary vehicle through which the second relationship has been realized. The operational problem that AIOps addresses is not abstract: large-scale cloud environments generate telemetry at volumes and variety that make manual operations monitoring effectively impossible, and the classical response of setting static performance thresholds produces alert volumes that overwhelm operations teams and generate the well-recognized condition of alert fatigue. ML models that learn the normal behavior signatures of complex distributed systems, and that identify deviations from those signatures that represent genuine operational anomalies rather than noise, address this problem at a mechanistic level. The resulting improvements in mean time to detect and mean time to resolve for cloud incidents are a direct consequence of replacing threshold logic with learned behavioral models.

Edge computing has emerged as a structurally important extension of the cloud landscape, driven substantially by the latency requirements of AI inference applications. Many AI use cases — real-time video analysis, autonomous vehicle control systems, industrial process monitoring, responsive augmented reality — impose latency constraints that are incompatible with round-trip communication to a centralized cloud data center. Deploying inference capability at the network edge, in close physical proximity to the data source, addresses the latency constraint while introducing its own challenges of heterogeneity, scale, and model lifecycle management that centralized cloud operations do not face.

Federated learning offers a technically principled response to a related but distinct problem: training AI models on data that is distributed across many endpoints and cannot, for reasons of privacy regulation, data sovereignty, or practical bandwidth constraints, be aggregated in a central location. By transmitting model parameter updates rather than raw training data to a central aggregation server, federated learning preserves the statistical value of distributed data while respecting the constraints that prevent its centralization. For ICT providers serving sectors subject to stringent data governance requirements, this capability opens the possibility of AI applications that would otherwise be legally or logistically foreclosed.

Challenges and Ethical Considerations

Intellectual honesty about AI in the ICT sector requires treating its difficulties with the same rigor applied to its opportunities. The most foundational challenge is one that tends to receive less emphasis in technology-centric accounts: data quality. Machine learning models are only as reliable as the data on which they are trained, and in the large, heterogeneous, and historically accreted environments typical of ICT infrastructure, data quality is rarely as clean or as representative as developers would prefer. Models trained on biased data reproduce that bias in their outputs; models trained on historical patterns fail when structural conditions change; models optimized for measured performance metrics behave poorly on dimensions that were not measured. These are not theoretical failure modes — they are recurring patterns in deployed systems, including security systems where the consequences of error are operationally significant.

The workforce dimension of AI adoption in ICT has attracted considerable policy attention but has perhaps not yet received adequate organizational response. The demand for professionals capable of designing, deploying, evaluating, and governing AI systems spans a range considerably wider than data science alone, extending to ML engineering, AI security specialization, explainability and fairness assessment, and operations teams competent to manage AI-driven infrastructure at scale. This demand substantially exceeds supply in most labor markets, and the gap is not closing quickly. Organizations that treat the talent challenge primarily as a hiring problem are likely to underperform those that invest simultaneously in systematic workforce upskilling and in organizational structures that allow AI specialists and domain experts to work together productively.

The regulatory environment for AI in ICT is evolving with a speed and complexity that creates genuine strategic uncertainty. The European Union's AI Act — the most comprehensive legislative framework to date — establishes a risk-tiered approach that subjects AI applications in high-risk

categories, including certain security and critical infrastructure applications directly relevant to ICT operations, to mandatory conformity assessment, transparency requirements, and human oversight obligations. Regulatory approaches elsewhere vary substantially, generating compliance complexity for organizations with international exposure. Investment in AI governance infrastructure — model documentation practices, bias and fairness assessment methodologies, audit mechanisms, and clear accountability structures — is increasingly a competitive differentiator as well as a compliance necessity.

Conclusions

This analysis has traced the impact of artificial intelligence across four domains of the ICT sector and found, in each case, that the transformation is both genuine and substantially more complex than optimistic accounts typically represent. AI is enabling capabilities in network management, telecommunications optimization, cybersecurity, and cloud operations that were not achievable with prior generations of technology — that much is clear and well-supported by the evidence. The organizations that have invested early and systematically in AI capabilities are demonstrating performance advantages that are unlikely to narrow as AI technology continues to develop.

The difficulties deserve equally clear acknowledgment. Data quality problems do not resolve themselves as AI systems scale; in some respects they become harder to manage as the number of data sources and the complexity of data pipelines increase. The talent gap will not close without deliberate and sustained investment in education, organizational development, and inclusive workforce practices. Regulatory frameworks will not produce sensible governance outcomes without substantive and technically informed industry engagement. And the adversarial dynamics of AI in cybersecurity will not reach a stable equilibrium — they require continuous adaptive investment in perpetuity, not a one-time technology procurement decision.

Perhaps most importantly, the structural nature of AI's impact on the ICT sector calls for a corresponding shift in how organizations think about strategy, investment, and governance. AI is neither a product category to be purchased on a procurement cycle nor a project to be delivered and closed. It is a sustained capability-building discipline that simultaneously reshapes technology, people, processes, and organizational culture. The ICT organizations that navigate this transformation most effectively will be those that understand it in those terms — and that build the institutional depth to develop AI capabilities continuously and adaptively, rather than through periodic discrete initiatives that leave the underlying organizational model unchanged.

References

1. Goodfellow, I., Bengio, Y., & Courville, A. (2016). *Deep Learning*. MIT Press.
2. Jordan, M. I., & Mitchell, T. M. (2015). Machine learning: Trends, perspectives, and prospects. *Science*, 349(6245), 255–260.
3. LeCun, Y., Bengio, Y., & Hinton, G. (2015). Deep learning. *Nature*, 521(7553), 436–444.
4. Luong, N. C., Hoang, D. T., Gong, S., Niyato, D., Wang, P., Liang, Y. C., & Kim, D. I. (2019). Applications of deep reinforcement learning in communications and networking: A survey. *IEEE Communications Surveys & Tutorials*, 21(4), 3133–3174.
5. McMahan, B., Moore, E., Ramage, D., Hampson, S., & Agüera y Arcas, B. (2017). Communication-efficient learning of deep networks from decentralized data. *Proceedings of the 20th International Conference on Artificial Intelligence and Statistics*, 54, 1273–1282.
6. OECD. (2021). *Recommendation of the Council on Artificial Intelligence*. OECD Publishing.
7. Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.
8. Sculley, D., Holt, G., Golovin, D., Davydov, E., Phillips, T., Ebner, D., Chaudhary, V., Young, M., Crespo, J. F., & Dennison, D. (2015). Hidden technical debt in machine learning systems. *Advances in Neural Information Processing Systems*, 28, 2503–2511.
9. International Telecommunication Union. (2022). *AI for Good Global Summit Report*. ITU Publications.
10. Cisco Systems. (2023). *AI Networking Annual Report: Toward Autonomous Operations*. Cisco Press.

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THE ROLE OF DIGITAL RESOURCES IN THE FORMATION OF COMMUNICATIVE COMPETENCE OF FUTURE FOREIGN LANGUAGE TEACHERS***Agitayeva Alina Abayevna****2nd year master's degree student,**Ablai Khan Kazakh University of International Relations and World Languages****Abstract***

The rapid development of digital technologies has significantly transformed educational practices and created new opportunities for foreign language teacher education. In contemporary educational contexts, communicative competence is regarded as one of the most important professional competencies required for future foreign language teachers. At the same time, the increasing integration of digital technologies into educational environments has expanded the range of tools and approaches available for language learning and teacher preparation. Consequently, the relationship between communicative competence development and the use of digital resources has become an important area of academic interest.

This article examines the role of digital resources in the formation of communicative competence among future foreign language teachers through a review of contemporary scholarly literature. The study focuses on the theoretical foundations of communicative competence, its significance in teacher education, and the contribution of digital technologies to the development of professional communication skills. Particular attention is given to learning management systems, interactive educational applications, multimedia resources, video conferencing platforms, and artificial intelligence technologies that support communication, collaboration, and autonomous learning.

The review also identifies several challenges associated with technology integration, including unequal access to digital infrastructure, insufficient digital literacy, and the need for pedagogically informed implementation of technological tools. The effectiveness of digital resources depends not only on their availability but also on educators' ability to integrate them meaningfully into learning activities that promote communication and interaction.

Keywords: foreign language education; digital technologies; teacher preparation; digital competence; language learning; educational technology; intercultural communication; learner autonomy; professional development; technology-enhanced learning

THEORETICAL BACKGROUND

The concept of communicative competence has become one of the fundamental constructs in modern foreign language education and teacher training. The emergence of communicative approaches to language teaching shifted educational priorities from the simple acquisition of grammatical knowledge to the development of learners' ability to use language effectively in real-life situations. This transformation significantly influenced the preparation of future foreign language teachers, who are expected not only to demonstrate a high level of language proficiency but also to create learning environments that foster meaningful communication and interaction among students. Consequently, communicative competence is regarded as a key professional outcome of foreign language teacher education programs.

The theoretical foundations of communicative competence originate from the work of Hymes (1972), who criticized purely linguistic approaches to language learning and proposed that successful communication requires knowledge of both language forms and the social rules governing language use. According to Hymes (1972), communicatively competent individuals must understand what is appropriate to say, to whom, and in which context. This perspective expanded the understanding of language proficiency and emphasized the importance of social and cultural dimensions of communication.

Further development of the concept was provided by Canale and Swain (1980), who identified several interconnected components of communicative competence, including grammatical competence, sociolinguistic competence, discourse competence, and strategic competence. Grammatical competence refers to knowledge of vocabulary, pronunciation, and grammatical structures, whereas sociolinguistic competence involves the ability to use language appropriately in different social situations. Discourse competence focuses on the organization and coherence of spoken and written texts, while strategic

competence enables individuals to overcome communication difficulties and maintain interaction. Together, these components form a comprehensive framework that continues to influence language teaching methodology and teacher education programs worldwide (Canale & Swain, 1980).

Contemporary scholars emphasize that communicative competence should be viewed as a dynamic and multidimensional construct that evolves through social interaction and practical experience. In the context of teacher education, future language teachers must develop communicative competence not only as language users but also as educational professionals capable of facilitating communication in classroom settings. This requires the ability to organize communicative tasks, support learner interaction, provide constructive feedback, and encourage meaningful language use. Therefore, communicative competence serves as both an educational objective and a professional requirement for future foreign language teachers (Richards, 2022).

COMMUNICATIVE COMPETENCE IN TEACHER EDUCATION

The preparation of future foreign language teachers requires the development of a broad range of competencies that extend beyond linguistic knowledge. Modern educational systems increasingly recognize communicative competence as a central component of teacher professionalism because effective teaching depends largely on the ability to establish productive communication with students, colleagues, parents, and representatives of different cultural communities. As a result, communicative competence is considered an essential indicator of professional readiness in teacher education programs.

Teacher education institutions are expected to provide opportunities for students to participate in communicative activities that simulate authentic professional situations. Such activities include collaborative projects, classroom discussions, peer teaching, presentations, and reflective practice. Through engagement in these activities, future teachers develop confidence in using the target language, improve their interactional skills, and learn to adapt communication strategies according to different educational contexts. Researchers argue that communicative competence contributes directly to teaching effectiveness because it enables teachers to explain concepts clearly, manage classroom interaction, and establish positive relationships with learners (Richards, 2022).

The growing emphasis on learner-centered education has further increased the importance of communicative competence in teacher preparation. Contemporary pedagogical approaches encourage teachers to act as facilitators rather than transmitters of knowledge. This role requires the ability to create supportive learning environments where students feel comfortable expressing ideas, asking questions, and engaging in meaningful communication. Consequently, future teachers must acquire both linguistic proficiency and the pedagogical skills necessary to promote communication and interaction in diverse educational settings (Farrell, 2021).

Another important dimension of communicative competence in teacher education is intercultural communication. Globalization and internationalization have increased contacts between individuals from different linguistic and cultural backgrounds. Future foreign language teachers must therefore develop awareness of cultural diversity and the ability to facilitate intercultural dialogue in the classroom. Intercultural competence complements communicative competence by enabling teachers to understand cultural differences, avoid misunderstandings, and promote mutual respect among learners. Numerous studies indicate that successful language teaching depends not only on linguistic knowledge but also on the ability to integrate cultural perspectives into communication-oriented instruction (Byram, 2021).

DIGITAL COMPETENCE AND TEACHER PROFESSIONAL DEVELOPMENT

The rapid digitalization of education has transformed expectations regarding teacher competence and professional development. In addition to communicative competence, future foreign language teachers are increasingly required to possess digital competence, which includes the knowledge, skills, and attitudes necessary for the effective use of technology in educational contexts. Digital competence has become particularly important in language education because digital technologies provide access to authentic materials, facilitate communication, and support collaborative learning experiences that contribute to language development (Redecker, 2022).

Researchers emphasize that digital competence should not be limited to technical skills alone. Rather, it involves the ability to integrate digital technologies into pedagogical practice in meaningful and purposeful ways. Future teachers must be capable of selecting appropriate digital tools, designing technology-enhanced learning activities, evaluating digital resources, and creating online environments that promote communication and interaction. Therefore, digital competence is closely connected with pedagogical competence and professional identity formation (Trust et al., 2023).

The integration of digital resources into teacher education provides numerous opportunities for professional growth. Learning management systems, collaborative platforms, video conferencing tools, and artificial intelligence applications allow future teachers to engage in authentic communication, share experiences, and participate in professional learning communities. These technologies support reflective practice and encourage continuous professional development by providing access to educational resources and networking opportunities beyond traditional classroom boundaries (Godwin-Jones, 2022).

Digital competence also contributes directly to the formation of communicative competence. Through participation in online discussions, virtual collaboration, and technology-mediated communication, future teachers develop the ability to communicate effectively in digital environments. Such experiences are increasingly relevant because modern educational practice frequently combines face-to-face and online interaction. Consequently, the integration of digital competence into teacher education programs enhances professional readiness and prepares future educators to meet the demands of contemporary digital society (Redecker, 2022).

The relationship between communicative competence and digital competence has become particularly significant in the context of foreign language teacher education. Digital technologies create authentic opportunities for communication, collaboration, and intercultural interaction that were previously unavailable in traditional educational settings. As a result, the development of digital competence supports the formation of communicative competence while simultaneously preparing future teachers for effective professional activity in technology-rich learning environments.

Discussion

In general, an analysis of modern scientific literature shows that digital resources play an increasingly significant role in the formation of communicative competence among future foreign language teachers. Their integration into teacher education programs creates opportunities for authentic communication, collaborative learning, learner autonomy, and professional development. Unlike traditional instructional approaches, digital technologies enable continuous interaction beyond classroom boundaries and provide access to diverse linguistic and cultural resources. As a result, future teachers are able to develop communicative skills in contexts that closely resemble real-life communication and contemporary professional practice.

One of the most frequently cited advantages of digital resources is their ability to increase learner engagement and motivation. Interactive applications, multimedia materials, and online communication platforms create learning environments that encourage active participation and meaningful interaction. Researchers argue that students demonstrate higher levels of involvement when educational technologies are incorporated into the learning process because digital tools support personalization, immediate feedback, and collaborative knowledge construction (Trust et al., 2023). For future foreign language teachers, such experiences are particularly valuable because they demonstrate how technology can be used to create communicative and student-centered classrooms.

Another important benefit concerns the development of intercultural and sociolinguistic competence. Through virtual communication platforms and online collaboration projects, students gain opportunities to interact with individuals from different linguistic and cultural backgrounds. These interactions contribute to a deeper understanding of cultural diversity and help future teachers develop the skills necessary for facilitating intercultural communication in educational settings. In this respect, digital technologies support one of the primary goals of foreign language education, namely the preparation of learners for communication in multicultural environments (Byram, 2021).

The literature also highlights the role of digital resources in promoting learner autonomy. Modern educational technologies enable students to access learning materials independently, engage in self-directed practice, and monitor their own progress. Such opportunities encourage responsibility for learning and support the development of lifelong learning skills. For future teachers, autonomous learning experiences are particularly important because they contribute to professional self-development and prepare educators to adapt to rapidly changing educational contexts (Godwin-Jones, 2022).

Despite these advantages, researchers identify several challenges associated with the integration of digital resources into teacher education. One of the most common concerns involves unequal access to technology and digital infrastructure. Differences in access to devices, internet connectivity, and technical support may limit the effectiveness of technology-enhanced learning. Furthermore, insufficient digital competence among educators and students may reduce the pedagogical value of digital resources and hinder meaningful communication (Redecker, 2022).

Another challenge concerns the potential overreliance on technology. While digital tools provide numerous opportunities for communication, they should not replace human interaction or pedagogically grounded instructional practices. Effective integration requires careful planning, appropriate methodological support, and alignment with educational objectives. Therefore, future foreign language teachers must develop not only technical skills but also the ability to critically evaluate digital resources and select tools that genuinely contribute to communicative competence development (Richards, 2022).

Overall, the literature suggests that digital resources function as powerful instruments for supporting communicative competence formation when they are integrated systematically and purposefully into teacher education programs. Their effectiveness depends not only on technological availability but also on pedagogical design, digital competence, and the ability of educators to create meaningful communicative experiences.

Conclusion

The formation of communicative competence remains one of the most important objectives of foreign language teacher education in the twenty-first century. Contemporary educational environments require future teachers to possess not only advanced language proficiency but also the ability to communicate effectively in diverse cultural, social, and digital contexts. Consequently, teacher education institutions are increasingly integrating digital technologies into training programs to support the development of communicative and professional competencies.

The analysis of contemporary literature demonstrates that digital resources make a substantial contribution to communicative competence development. Learning management systems, interactive applications, multimedia tools, video conferencing platforms, and artificial intelligence technologies create opportunities for authentic communication, collaborative learning, intercultural interaction, and autonomous language practice. These technologies support the development of linguistic, sociolinguistic, discourse, and strategic competences while simultaneously fostering digital competence and professional readiness.

The findings of the reviewed studies indicate that digital resources enhance learner engagement, encourage active participation, and facilitate communication beyond traditional classroom boundaries. Furthermore, they provide future foreign language teachers with practical experience in utilizing educational technologies and adapting instruction to the needs of modern learners. Such experiences are essential for successful professional activity in increasingly digitalized educational environments.

At the same time, effective technology integration requires adequate digital competence, pedagogical knowledge, and institutional support. The educational value of digital resources depends on their purposeful implementation and alignment with learning objectives. Therefore, teacher education programs should emphasize both communicative and digital competence development to ensure that future educators are prepared to meet contemporary educational challenges.

In conclusion, digital resources should be viewed not merely as supplementary teaching tools but as an essential component of modern foreign language teacher education. Their systematic integration contributes significantly to the formation of communicative competence and supports the preparation of competent, reflective, and technologically proficient foreign language teachers.

REFERENCES

1. Byram, M. (2021). *Teaching and Assessing Intercultural Communicative Competence. Multilingual Matters.*
2. Canale, M., & Swain, M. (1980). Theoretical bases of communicative approaches to second language teaching and testing. *Applied Linguistics*, 1(1), 1–47.– DOI: <https://doi.org/10.1093/applin/1.1.1>
3. Farrell, T. S. C. (2021). *Reflective Practice in Language Teaching.* Routledge.
4. Godwin-Jones, R. (2022). Emerging technologies and language learning. *Language Learning & Technology*, 26(2), 1–10.– URL: <https://www.lltjournal.org>
5. Hymes, D. (1972). On communicative competence. In J. B. Pride & J. Holmes (Eds.), *Sociolinguistics* (pp. 269–293). Penguin.
6. Redecker, C. (2022). *European Framework for the Digital Competence of Educators: DigCompEdu.* Publications Office of the European Union.– URL: <https://publications.europa.eu>
7. Richards, J. C. (2022). *Teaching English through Communication.* Cambridge University Press.
8. Trust, T., Carpenter, J. P., & Krutka, D. G. (2023). Digital tools and teacher professional development. *Teaching and Teacher Education*, 124, 104018.– DOI: <https://doi.org/10.1016/j.tate.2023.104018>

Physical sciences

FROM THE CORRECTED VERSION OF SRT IT FOLLOWS THAT PLANET EARTH IS DESIGNED MUCH MORE COMPLEX THAN IT IS EXPLAINED BY MODERN SCIENCE KNOWLEDGE¹

Antonov Alexander Alexandrovich

PhD, HonDSc, H.Prof.Sci

Independent researcher, Ukraine

Abstract

The article argues that, in accordance with the corrected version of the special theory of relativity (STR), the planet Earth is much more complex than this is explained by modern scientific knowledge. The Earth is probably a three-dimensional spiral structure in four-dimensional space. It will be possible to verify this by traveling through time as a result of around-the-world flight by plane. It will be possible to verify this by traveling through time as a result of around-the-world flight by plane. Until very recently, such flights belonged to the genre of science fiction and were denied by modern science. However millions of air passengers now make such time travel every day, which is confirmed by the translation of their watches to local time after the planes land. And such time travels is very necessary for people, as it allows, for example, to predict and prevent disasters and accidents, to bring back to life people who died as a result of accidents and crimes, to significantly reducing the criminal manifestations, by increasing the information transparency of human activity, as well as to solve many other important problems.

Keywords: special theory of relativity; relativistic formulas; physical reality of imaginary numbers; Multiverses; universes and antiuniverses; anti-time; external and internal time; time zones on Earth; time travel

1. Introduction: fundamental mistake of the authors of special theory of relativity

Created the 20th century by Joseph Larmor [1], Nobel laureate Hendrik Anton Lorentz² [2], Jules Henri Poincaré [3], Nobel laureate Albert Einstein³ [4], and other talented scientists, the special theory of relativity (STR) are rightly considered the outstanding scientific achievement of the 20th century due to their use of principle of relativism. However, at the beginning of the twentieth century, science lacked much of the knowledge necessary to create STR. Because of this, the missing knowledge had to be replaced with postulates that turned out to be partially incorrect. Therefore, this STR itself turned out to be largely incorrect [5]-[9].

And most importantly, all the relativistic formulas obtained in it turned out to be incorrect

$$m = \frac{m_0}{\sqrt{1 - (v/c)^2}} \quad (1)$$

$$\Delta t = \Delta t_0 \sqrt{1 - (v/c)^2} \quad (2)$$

$$l = l_0 \sqrt{1 - (v/c)^2} \quad (3)$$

and others, in which m_0 is the rest mass of a moving body;

m_0 is the relativistic mass of a moving body;

Δt_0 is the rest time of a moving body;

Δt is the relativistic time of a moving body;

l_0 is the rest length of a moving body;

l is the relativistic length of a moving body

¹ This is reprint of the article "Antonov A. A. 2026. Planet Earth is designed much more complex than is explained by modern scientific knowledge. Norwegian Journal of Development of the International Science. No 181".

² Who received his Nobel Prize in Physics in 1902 for explaining the Zeeman effect.

³ Who received his Nobel Prize in Physics in 1921 for his services to theoretical physics and especially for his research into the photoelectric effect.

The creators of STR made this fundamental mistake without understanding that the argument v in formulas (1)-(3) according to Newton's first law is the fourth⁴, in addition to length, width and height, spatial dimension [10]-[21]. Albert Einstein also failed to use the concept of four-dimensional space in STR..

Albert Einstein also failed to use the concept of four-dimensional space in STR. Nevertheless, at that time he still managed to preserve the STR, introducing into it the principle of not exceeding the speed of light.

2. The special theory of relativity taught in physics textbooks is incorrect.

From the principle of not exceeding the speed of light, which is in fact a postulate, that this STR drew the conclusion that imaginary numbers are physically unreal. But a postulate is merely an assumption. Consequently, a conclusion drawn from a postulate is also merely an assumption, which has no evidential value. Therefore, the assertion regarding the physical unreality of imaginary numbers could simply have been called a postulate. However, the authors of the version of the STR, taught in textbooks, ignored this fact, as they needed to explain the relativistic formulas in some way. And to do so, they had to at least give the impression that the principle of not exceeding the speed of light had been proven. And since these textbooks are still used in the educational process, it follows that the goal was achieved.

Therefore, further in the article we will continue to explain that the version of STR studied in textbooks is incorrect. [22]-[54]. Let us recall that the problems of the authors of STR began from the very beginning due to their inability to explain the relativistic formulas (1)-(3) published in 1905. After all, no one would need a theory that even its creators could not explain. And relativistic physicists have still not been able to explain these formulas, since all the quantities $m(v)$, $\Delta t(v)$, $l(v)$ in these formulas in the hyper-light range of speeds $v > c$ took on values measured by imaginary numbers incomprehensible to physicists. Therefore, as not to explain relativistic formulas in the superluminal range of speeds, the principle of the non-exceeding of the speed of light was used in the STR.

However, yet in 1897, Charles Proteus Steinmetz published [55] a theory of linear electrical circuits of alternating current, in which the imaginary resistances $-j/\omega C$ of capacitors and $+j\omega L$ ⁵ of inductors were de facto recognised as physically real. This provided experimental proof of the physical reality of imaginary numbers.

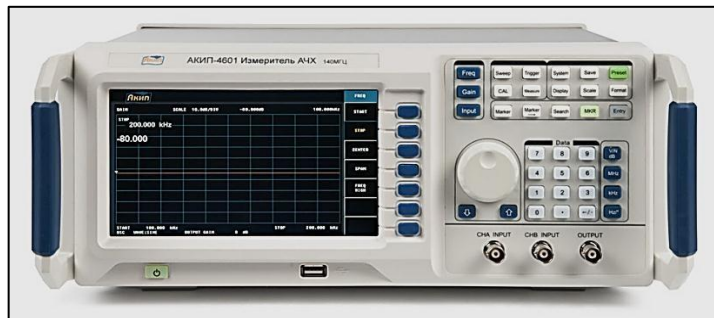


Fig. 1. In any radio engineering laboratory there are devices called frequency response meters, which already by their very existence prove the physical reality of imaginary numbers

Therefore, for more than half a century, the radio industry has been mass-producing frequency response meters⁶ (Fig. 1), which by their very existence prove the physical reality of imaginary numbers, since you can only measure what actually physically exists. And such devices measured frequency characteristics, mathematically described using imaginary numbers.

But even if any of the relativist physicists were to learn that Charles Proteus Steinmetz had already proven the physical reality of imaginary numbers, this would not save the STR. For it turns out that the relativistic formulas are not correct, since, in the superluminal speed range $v > c$, function (1) describes a physically unstable process that cannot exist in nature. Therefore, relativistic physicists did not really need any proof of the physical reality of imaginary numbers. On the contrary, in order to refuse to explain their relativistic formulas in the hyperluminal speed range $v > c$, they needed the principle of not exceeding the speed of light. And this is precisely why proof of the physical unreality of imaginary numbers was needed. Which, however, do not exist in nature.

This is why Albert Einstein continued to work on developing available for use version of the STR.

⁴ Not to be confused with the fourth dimension in four-dimensional space-time (Minkowski space).

⁵ In radio engineering and electrical engineering, the imaginary unit is conventionally denoted by the letter j , as the letter i is used to denote electric current

⁶ Also called frequency response analyzers

He therefore argued that there is no known physical process in nature that is described using imaginary numbers⁷. On this basis, he introduced into STR a postulate known as the principle of the non-exceeding of the speed of light. From this, it was concluded that there was no need to explain formulas (1)–(3) in the superluminal range of velocities $v > c$. And when Cherenkov radiation [56] was discovered, refuting the claim that there is no known process in physics in which anything moves at a speed exceeding the speed of light, the STR was saved by the clarification that the principle of the non-exceeding of the speed of light referred to processes in a vacuum.

And later, at the Large Hadron Collider (costing \$10 billion), the widely publicised OPERA [57] experiment was conducted over 15 years⁸ (between 2003 and 2018), involving over a hundred of the most eminent physics professors, the aim of which was to prove the physical reality of imaginary numbers. In 2011, the OPERA collaboration even announced the successful completion of this experiment. But six months later, at the same Large Hadron Collider, the OPERA experiment was refuted by the ICARUS experiment. This created the impression that the principle of the non-exceeding of the speed of light is irrefutable. And it is in this form that the generally accepted version of STR is now presented in all physics textbooks in all countries.

However, articles [58]–[75] have been published, including five articles in 2008–2010⁹ [58]–[62], containing descriptions of radio engineering experiments that successfully proved the physical reality of imaginary numbers. Moreover, these publications also contain descriptions of well-known physical processes¹⁰ – a tsunami, the ringing of bells, music created by a piano, and even a swing swinging on the playground after a push from parents – proving the physical reality of imaginary numbers.

Thus we live not only in the visible and tangible world described by real numbers, but also in existing invisibl and intangible world – one far less familiar to us – described by imaginary, complex and hypercomplex numbers.

3. A corrected version of the special theory of relativity.

3.1. Corrected relativistic equations

Since we have just have proven.the physical reality of imaginary numbers in the most indisputable manner, we shall now explain formulas (1)–(3) in full. And since people tend to understand visual information better, Fig2a,b,c show the graphs of formulas (1)–(3). As can be seen, these graphs in the sub-light speed range $v < c$ differ significantly from the graphs in the hyper-light speed range $v > c$. It therefore becomes clear that the same processes cannot occur in the sub-light and hyper-light speed ranges v . And for the same processes to occur in these ranges, the graphs of formulas (1)–(3) must be identical, as shown in Fig2d,e,f. To achieve this, since the velocity v in formulas (1)–(3) is the fourth spatial dimension, the factor¹¹ i^q must be introduced

$$m(q) = \frac{m_0 i^q}{\sqrt{1 - (v/c - q)^2}} = \frac{m_0 i^q}{\sqrt{1 - (w/c)^2}} \quad (4)$$

$$\Delta t(q) = \Delta t_0 i^q \sqrt{1 - (v/c - q)^2} = \Delta t_0 i^q \sqrt{1 - (w/c)^2} \quad (5)$$

$$l(q) = l_0 i^q \sqrt{1 - (v/c - q)^2} = l_0 i^q \sqrt{1 - (w/c)^2} \quad (6)$$

⁷ Although in fact there are many of them. And they are mentioned further.

⁸ And for any radio engineering experiment proving the physical reality of imaginary numbers, one day is more than enough for one engineer

⁹ That is, even before the publication in 2011 of the message about the supposedly successful completion of the OPERA experiment

¹⁰ Contrary to Albert Einstein's assertion that there are no processes in nature that can be described using imaginary numbers,

¹¹ In the theory of functions of a complex variable, the function i^q is defined only for integer values of the argument q . However, his definition can be extended as follows. For integer values of the argument $\dots -2, -1, 0, +1, +2, +3, +4, +5, \dots$ the function i^q is equal to $\dots -1, -i, +1, +i, -1, -i, +1, +i, \dots$. But for the same integer values of the argument $\dots -2, -1, 0, +1, +2, +3, +4, +5, \dots$ the same values $\dots -1, -i, +1, +i, -1, -i, +1, +i, \dots$ is also equal to the function $e^{iq\pi/2}$, which, in accordance with Euler's formula $e^{iq\pi/2} = \cos(q\pi/2) + i\sin(q\pi/2)$, is defined also for non-integer values of the argument q . Therefore, definition of the function i^q can be extended to any values of the argument q by the formula $i^q = \cos(q\pi/2) + i\sin(q\pi/2)$, analogous to Euler's formula. The resulting formula will allow the value of the function i^q to be determined for any values of the argument q , including non-integer values. And it will be required in astro-geophysical studies of portals, which will be discussed further on.

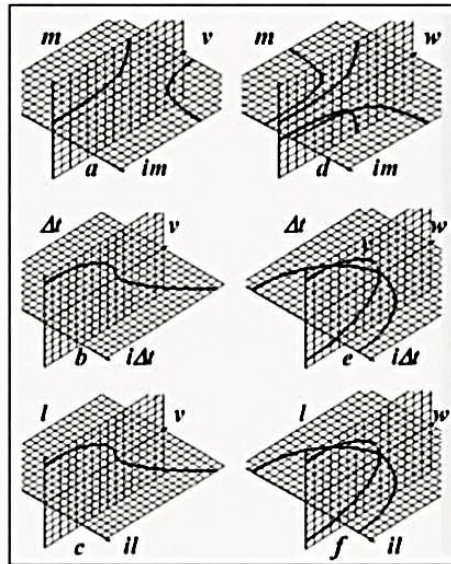


Fig. 2. Graphs of the functions $m(v)$, $\Delta t(v)$ and $l(v)$ corresponding to the existing and corrected versions of the STR in the subluminal $v < c$ and superluminal $v > c$ velocity ranges

where $q(v) = \lfloor vq/c \rfloor$ – the “floor” function from discrete mathematics defined for the argument vq/c which constitutes the fourth spatial dimension;

$w = v - qc$ – the velocity that is local to all universes.

And since the fourth spatial dimension v is a vector quantity, the formulas (4)–(6) must be revised once again. To this end, three factors i^q , i^r and i^s must be introduced into formulas (4)–(6)

$$m(q, r, s) = \frac{m_0 i_1^q i_2^r i_3^s}{\sqrt{1 - [v/c - (q + r + s)]^2}} \quad (7)$$

$$\Delta t(q, r, s) = \Delta t_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (8)$$

$$l(q, r, s) = l_0 i_1^q i_2^r i_3^s \sqrt{1 - [v/c - (q + r + s)]^2} \quad (9)$$

where $q(v) = \lfloor v_q/c \rfloor$ – the “floor” function in discrete mathematics of the argument

v_q/c , which is one of the orthogonal coordinates q of the fourth spatial dimension v ;

$r(v) = \lfloor v_r/c \rfloor$ – the “floor” function of discrete mathematics of the argument v_r/c , which is the other orthogonal coordinate r of the fourth spatial dimension v ;

$s(v) = \lfloor v_s/c \rfloor$ – the “floor” function of discrete mathematics of the argument v_s/c which is yet another orthogonal coordinate s of the fourth spatial dimension v ;

v_q, v_r, v_s – projections of the velocity vector v onto the orthogonal co-ordinates q, r, s (see Fig. 3).

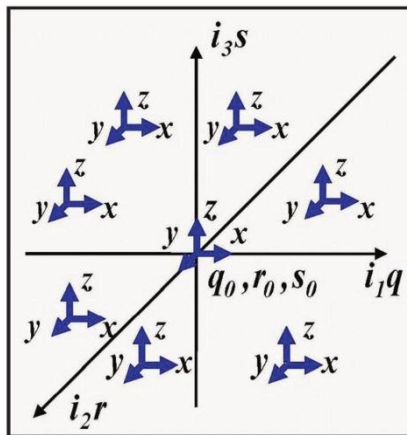


Fig.3. The six-dimensional space of the hidden Multiverse, where q, r, s are the coordinates of mutually invisible parallel universes and anti-universes, and x, y, z are the coordinates of the material content of these parallel universes and anti-universes

This formula i^q (as well as the formulas i^r and i^s) in formulas (7)–(9), which defines the nature of each universe, for integer values of the argument $q(v)$, equal to ... 0, 1, 2, 3, 4, 5, ..., successively takes the values ..., +1, +i, -1, -i, +1, +i, ... and so on. Its value¹² $q(v) = 0$ in formulas (7)–(9) for the sublight speed range $v < c$ corresponds (since $i^0 = 1$) to our visible universe, which we shall call, for the sake of clarity, the tardion¹³ universe. The value $q(v) = 1$ in the superluminal speed range $2c > v > c$ corresponds (since $i^1 = i$) to some other, already invisible universe, as it lies beyond the event horizon. For the sake of clarity, we shall therefore call it the tachyon¹⁴ universe. Then the value $q(v) = 2$ in the velocity range $3c > v > 2c$ will correspond (since $i^2 = -1$) to an invisible tardion anti-universe. The value $q(v) = 3$, in the velocity range $4c > v > 3c$, will correspond (since $i^3 = -i$) to an invisible tachyon anti-universe. The value $q(v) = 4$ in the speed range $5c > v > 4c$ will correspond (since $i^4 = +1$) to another (and therefore also invisible) tardion universe. The value $q(v) = 5$ in the velocity range $6c > v > 5c$ will correspond (since $i^5 = +i$) to another tachyon universe. And so on.

Consequently, nature contains not only our visible universe—which, as stated in the generally accepted version of STR, corresponds to equations (1)–(3) but also a multitude of other mutually invisible¹⁵ universes and anti-universes that correspond to equations (7)–(9). And these mutually invisible universes and anti-universes, together with our visible universe, form an invisible Multiverse [76]–[84], which we have therefore called the hidden Multiverse.

3.2. Explanation of the phenomena of dark matter and dark energy by the existence of universes and antiuniverses of the hidden Multiverse

Therefore, having explained the meaning of the basic concepts we need, it would seem time to clarify the structure of the hidden Multiverse. However, at present, no explanation of the structure of the Multiverse can be considered convincing unless it explains the phenomena of dark matter and dark energy [85]–[90], discovered in the XX century. Which are so named because they are so obscure, as not a single chemical element has been detected in them, and also because they do not emit, absorb, reflect, or refract electromagnetic radiation and, therefore, are invisible. The persistent search for dark matter and dark energy, which account for more than 95% of all mass-energy contained in the hidden Multiverse, at the Large Hadron Collider exclusively in the microcosm of our only visible universe also seems inconsistent with common sense.

A more logical assumption is that dark matter and dark energy [85]–[90] are everything except our visible universe, mutually invisible universes and antiuniverses, the hidden Multiverse. In this case, dark matter is neighboring to our visible universe invisible universes and anti-universes, and dark energy - the remaining invisible universes and anti-universes of the hidden Multiverse. Therefore, the phenomena of dark matter and dark energy will be a gravitational shadow¹⁶ on our visible universe from the remaining mutually invisible universes and antiuniverses included in the hidden Multiverse. This assumption explains all the incomprehensibility of the phenomena of dark matter and dark energy simply and clearly. That's why we will use it.

Then, assuming that over the billions of years of its existence, the mass-energy of all universes and antiuniverses of the hidden Multiverse, due to the presence of a huge number of portals between them according to the law of communicating vessels, has been largely averaged, it becomes possible, using the data obtained by the WMAP and Planck spacecraft, to determine the structure of the hidden Multiverse. And according to data obtained by the WMAP spacecraft [96], the mass-energy of our visible universe (actually, our hidden Multiverse) consists of 4.6% baryonic matter, 22.4% dark matter and 73.0% dark energy. And according to more recent data obtained by the Planck spacecraft [97], the mass-energy of our visible universe (again, actually, our hidden Multiverse) consists of 4.9% baryonic matter, 26.8% dark matter and 68.3% dark energy. As you can see, these data differ little from each other, which proves their truth. Therefore, it is permissible to assert that:

- our hidden Multiverse according to data obtained by the WMAP spacecraft, it consists of $100\% / 4.6\% = 21.8^{17}$ parallel universes and antiuniverses, and according to data obtained by the Planck spacecraft, it consists of $100\% / 4.9\% = 20.4$ parallel universes and antiuniverses;
- dark matter, according to experimental data obtained by the WMAP spacecraft, consists of

¹² If we start counting the value of q from our visible universe.

¹³ The term "tardion universe" is borrowed from Isaac Asimov's short story "Take a Match."

¹⁴ The term "tachyon universe" is borrowed from Isaac Asimov's short story "Take a Match."

¹⁵ Because they are all beyond the event horizon

¹⁶ And therefore, like our shadow on a sunny day, they do not contain a single chemical element..

¹⁷ Naturally, the number of universes and antiuniverses is an integer, and a non-integer number was obtained only due to experimental errors, including due to failure to take into account unknown factors influencing the result of the experiment.

22.4% / 4.6% = 4.9 parallel universes and antiuniverses, and according to data obtained by the Planck spacecraft, it consists of 26.8% / 4.9% = 5.5 parallel universes and antiuniverses;

- dark energy, according to experimental data obtained by the WMAP spacecraft, consists of 73.0% / 4.6% = 15.9 parallel universes and antiuniverses, and according to data obtained by the Planck spacecraft, it consists of 8.3% / 4.9% = 13.9 parallel universes and antiuniverses;

- and our visible universe, of course, is only one.

3.3. The structure of the hidden Multiverse

Fig. 4 shows an example, corresponding to the results of calculations of the possible structure of the hidden Multiverse. In this structure of the hidden Multiverse, the distribution of material content in each invisible universe and antiuniverse will be determined by some function $f_{q,r,s}(x,y,z)$, and the coordinates of these universes will be determined by the quantities

i_1q, i_1r, i_3s . Those. such a hidden Multiverse will be six-dimensional and it will be described by the quaternion $f_{q,r,s}(x,y,z) + i_1q + i_1r + i_3s$, in which the imaginary units i_1, i_2, i_3 are related by the relations [98]-[100]

$$i_1^2 = i_2^2 = i_3^2 = -1 \quad (10)$$

$$i_1i_2i_3 = i_2i_3i_1 = i_3i_1i_2 = -1 \quad (11)$$

$$i_1i_3i_2 = i_2i_1i_3 = i_3i_2i_1 = 1 \quad (12)$$

This is exactly what Lisa Randall predicted¹⁸: "We may be living in a three-dimensional pocket of higher-dimensional space."

From formulas (10)-(12) it follows that such a hidden Multiverse has a helical structure, and its mutually invisible universes and antiuniverses (in addition to our visible universe) form dark matter and dark energy. In this case, it is possible to move into the tardion antiuniverse from the tardion universe and into the tardion universe from the tardion antiuniverse in various, but not arbitrary, ways, but only in such a way (see Fig. 4), in which the value of i^n will successively take the values ...+1, + $i_1 \oplus i_2 \oplus i_3$, -1, - $i_1 \oplus i_2 \oplus i_3$, +1, ... and etc., where $\oplus$ is the symbol of the logical

¹⁸ Lisa Randall is a professor in the Department of Physics at Harvard University and a member of the American Academy of Arts and Sciences and also the National Academy of Sciences of the United States.

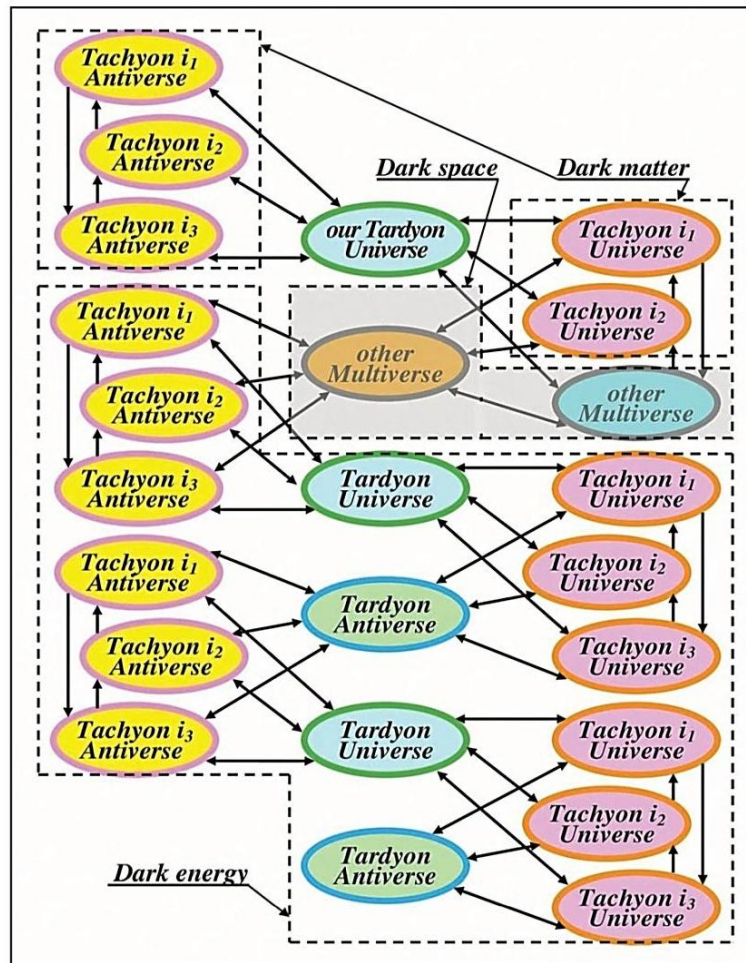


Fig. 4. An example of the structure of the hidden Multiverse, corresponding to the principle of physical reality of hypercomplex number

operation of discrete mathematics 'exclusive OR'. In this case, different trajectories of movement from one universe (or antiuniverse) to another can differ only due to the replacement of some tachyon universes from i_1, i_2, i_3 with others and some tachyon antiuniverses from i_1, i_2, i_3 with others. Consequently, tachyon universes i_1, i_2, i_3 in the hidden Multiverse are located parallel to each other. Tachyon antiuniverses i_1, i_2, i_3 are also located parallel to each other for the same reasons. And therefore, in the hidden Multiverse, when transitioning from any tardion universe to a tardion antiuniverse and then to another tardion universe, parallel universes and antiverses must alternate in the following sequence - 'tardion universe', 'one of the tachyon universes', 'tardion anti-universe', 'one of the tachyon anti-universes', 'tardion universe', 'one of tachyon universes', etc.

Moreover, portals in such a structure of the Multiverse are not only bidirectional, corresponding to formula (10) and shown by two-way arrows, but also unidirectional, corresponding to formulas (11), (12) and shown by one-way arrows. And since the structure of our hidden Multiverse, as shown in Fig. 4, is open in some places, then in these places it is connected to other Multiverses through the corresponding portals. And all together they collectively form the Hyperuniverse.

3.4. How can we be convinced of the real physical existence of invisible universes and antiuniverses?

However, in science, any evidence, even the most seemingly impeccable one, can be trusted only if it is confirmed experimentally. And such experimental evidence of the existence of invisible parallel universes¹⁹ and antiuniverses shown in Fig. 4 adjacent to our visible universe can be two hundred thousand anomalous zones [101]-[104], existing on Earth, serving as entrances to portals leading to planets of various star systems. Most of the portals probably lead to astronomical objects in our universe and even in our solar system. A smaller number of portals connect us with other universes and antiuniverses of the hidden Multiverse. And, perhaps, some portals even connect us with astronomical objects in other Multiverses of the Hyperverses. All these possible options in Fig. 4 are shown. The classification

¹⁹ I.e. such that do not intersect

of anomalous zones after astro-geophysical studies of the corresponding portals will help determine where each portal leads.

And the possible distrust of the claim that anomalous zones are entrances to portals can presumably be eliminated by astronomical observations [105]-[122] of the star sky in anomalous zones. This would require comparing on computer of maps of the starlit sky observed in anomalous zones and somewhere outside of anomalous zones. Moreover, some observatories are already in anomalous zones. For example, the Main Astronomical Observatory of the National Academy of Sciences of Ukraine, which is located 12 km from the center of its capital, Kyiv in Goloseyevo Forest. And if such differences are found, it is evidence that the corresponding portal to this anomalous zone leads to another planet in our solar system or further afield. After all, the starry sky is different for every planet.

4. Time Travel on Earth

4.1. Where are the anti-matter and the anti-time located?

And now we can explain the problem that is inexplicable in the version of STR studied in textbooks - where exist antimatter, the existence of which this version of STR does not deny. It is clear that she cannot be in our hidden Multiverse, because her annihilation with matter would make our universe no longer exist.

However, it exists. In 1995 CERN performed a sensational experiment that produced nine antihydrogen atoms lasting about 40 billionth parts of second. And just one gram of such an antihydrogen would have cost \$662.5 trillion. So the existence of antimatter has even been proven experimentally. But where does it exist then? After all, in all physics textbooks it is claimed that nature has our only visible universe. Therefore, the experiment at CERN can also be considered as proof that the version of the STR studied in textbooks is incorrect.

And in accordance with formulas (7)-(9) of the corrected version of STR, anti-matter in nature exists in the invisible tardyon and tachyon antiuniverses of the hidden Multiverse. Moreover, in these invisible tardyon and tachyon anti-universes, anti-time and anti-space [105]-[122] also exist.

4.2. Time Travel on Earth, Inner Time and Outer Time

The existence of antitime makes it possible, in accordance with formulas (8) and (9), due to travels in space, also travels in time. But since the portals, the uni-

Table 1. Examples of business jet characteristics that can be used for time travels

Aircrafts	Maximum range	Cruising speed	Hourly rates	Seats
Citation Latitude	5 300 km	815 km/h	3 500 €/hour	8
Citation Longitude	7 400 km	910 km/h	5 000 €/hour	12
Challenger 300	5 700 km	850 km/h	4 900 €/hour	8
Challenger 350	5 926 km	850 km/h	4 000 €/hour	9
Challenger 600	5 500 km	850 km/h	4 600 €/hour	12
Challenger 3500	6 297 km	985 km/h	5 500 €/hour	10
Falcon 20	4 200 km	987 km/h	3 900 €/hour	8
Falcon 50/50EX	5 600 km	850 km/h	4 900 €/hour	8-10
Global 5500	10 927 km	900 km/h	8 000 €/hour	16
Gulfstream G150	5 200 km	850 km/h	3 900 €/hour	6-8
Gulfstream G200	5 000 km	870 km/h	6 200 €/hour	8
Hawker 850 XP	4 800 km	750 km/h	3 400 €/hour	6-8
Hawker 900XP	5 400 km	865 km/h	3 700 €/hour	6-8
Hawker 4000	5 280 km	890 km/h	5 400 €/hour	10
Learjet 70	3 815 km	967 km/h	3 500 €/hour	7
Legacy 450	5 370 km	860 km/h	3 300 €/hour	8
Praetor 600	7 400 km	850 km/h	6 000 €/hour	12

Table 2. The value of external time at different latitudes

Location of departure and arrival airfields	Geographic coordinates of the airfield	Size of 24 time zones for a round-the-world flight	Size of one time zone.
Santiago de Chile	33,45° S.	33422 km	1393 km
Buenos Aires	34,60° S.	33021 km	1375 km
Melbourne	37,82° S.	31339 km	1306 km
New York City	40,72° N.	30456 km	1269 km
Reykjavík	64,15° N.	17616 km	734 km
Murmansk	69,58° N.	14424 km	601 km
Kirkenes	69,73° N.	14376 km	599 km
Longyearbyen (Spitsbergen, Norway)	78,13° N.	8184 km	341 km
Alert, (Canada)	82,5° N.	5230 km	218 km

verses and anti-universes of the hidden Multiverse, are still unexplored, time travel in space is now

inaccessible to us. Therefore, further we will consider only the possibility of time travel on Earth [10]-[21]. As the presence of time zones on Earth also makes time travel possible due to space travel.

However, although official modern science admits the possibility of time travel in some exotic situations in the special²⁰ and general²¹ theories of relativity, as well as in quantum physics²², refuting the erroneous statements of the incorrect version of STR studied in textbooks.

And when explaining time travels on Earth, it is necessary to take into account the existence in nature, in addition to internal time, which we always use, also of external time, which we have never used before. And which are generated by different circumstances and have different peculiarities. Internal time can be called biological human time, since one second is one contraction of the human heart. And it cannot flow backwards. A person cannot return to his youth. But external time is generated by the rotation of the Earth around its axis. One revolution of the Earth is 24 time zones. Therefore, by changing the direction of our movement in space, we can move both into the past and into the future external time. Consequently, time travel is always movement only in external time.



Fig. 5. One of the business jets

Time travels can be very useful, since traveling into the future will allow, for example, to recognize and avoid unforeseen disasters, accidents, natural disasters, etc. in advance. And traveling to the past will allow the same situations in the present to be corrected by visiting the past. Even, for example, to bring back to life people who died as a result of an accident, a terrorist attack²³ or for other reasons [141]-[151].

And although time travel on Earth is not currently used due to the fact that it always occurs together with long-distance travel, this problem is completely solvable. To do this, the aircraft must make a round-the-world trip around the north or south pole and land after 24 hours of outside time at the same airfield from which the journey began. Thus eliminating the unnecessary factor of space in time travel.

And there are many aircraft models suitable for use in time travel. They are called business jets²⁴ (see Fig. 5). There are currently 22,000-24,000 business jets in operation on Earth. Table 1 shows the flight performance characteristics of some business jets. And Table 2 shows airfields quite close to the North Pole²⁵ that can provide the shortest routes for round-the-world flights.

Moreover, time travel can be accomplished not only on airplanes. Time travel on airplanes is only needed if a person needs to travel to the past or future. And if it is necessary to transmit information to the past or future, then radio communications can be used, like airplane flights, using round-the-world communication lines²⁶

4.3. The structure of planet Earth differs significantly from the structure corresponding to modern scientific knowledge

Thus, time travels on Earth is physically possible and is currently already technically feasible [152]-[162], since there are suitable aircraft and acceptable flight routes. However, neither business jets nor other aircraft have ever made the round-the-world flights we need, because there was no need for them. Indeed, any airfield that is most distant from the airfield from which the plane took off is located where its antipodes are located, that is, at a diametrically opposite point on Earth. But this is only half of the

²⁰ For example, in the "twin paradox"

²¹ For example, in the ultra-high gravity region of a black hole's event horizon

²² For example, as a result of teleportation of not information, but of physical objects.

²³ Perhaps President Kennedy could have been saved in a similar way after the assassination attempt.

²⁴ A business jet is a small private jet aircraft for transporting a limited number of passengers (usually from 6 to 20) on an individual order for businessmen, officials and VIPs; it is characterized by a higher level of comfort, the ability to take off/land from small airfields and high speed, allowing you to quickly get to anywhere in the world

²⁵ Since the existing airfields are further from the south pole. But, probably, such airfields can be created in Antarctica.

²⁶ But also with its transmission around the north or south pole.

trip around the world. The distance to other airfields is shorter. And because of this, the features of round-the-world flights are completely unknown to us. Therefore, now they must be identified and studied in the process of actual flights around the world.

But while we haven't actually made such a flight, let's take an imaginary round-the-world air trip. Let's start with the initial situation, i.e. from a completely understandable trip around the world, during which two identical planes will simultaneously take off from the same airfield in two opposite directions - one to the west, the other to the east. If they fly at the same speed and provided that the Earth does not rotate, everything will be clear. We are confident that they will arrive at the same airfield from which they flew away, at the same time, having spent on this flight

$$T_0 = 2\pi R / V$$

of its time, where V is the cruising speed of such a flight relative to the stationary Earth, i.e. aircraft speed;

R is the radius of the circle on the surface of the Earth at the latitude along which the aircraft will fly;

$2\pi R$ is the length of this circle.

And therefore, the distance that these two planes will fly towards each other before landing will naturally be equal to twice the length of the weapon, i.e. $4\pi R$.

But if we take into account that the Earth rotates, then these planes will not arrive at the same time. One of them will fly through

$$T_1 = 2\pi R / (V + \Delta V) \text{ hours, (13)}$$

and the other through

$$T_2 = 2\pi R / (V - \Delta V) \text{ hours, (14)}$$

where ΔV is an increase or decrease in the flight speed of aircraft relative to the surface of the Earth due to its rotation around its axis..

And they will arrive at different speeds for different times $T_1 \times (V + \Delta V) = 2\pi R$ and $T_2 \times (V - \Delta V) = 2\pi R$, it turns out, the same distances. As in the situation when the Earth is motionless. And it looks like both planes will arrive at the same airfield from which they took off. Those. both planes will again safely complete their round-the-world travels.

But then, after some time, both planes will already be at this airfield. It would seem obvious. But this is most likely impossible. Since it is impossible to combine what is at different times. And this situation, which is unusual for us, therefore raises great doubts. Probably, among the readers there will be people to whom one of these situations seems quite possible, and those who will hold the opposite opinion.

The point is that a clear answer to the question posed is very important. Indeed, if these two planes arrived at the same airfield from which they flew away, then in our consciousness the world familiar to us will continue to exist, in which round-the-world travels are possible. And vice versa, if these two planes arrived at different airfields, and even not at the same one from which they took off, then our world is completely different. And round-the-world flights are impossible in it. Moreover, each such airfield and its surroundings would have their own life.. And it will exist regardless of whether we arrive at these airfields or not. And in this life, in the past and in the future, we will somehow exist. And we can even meet ourselves. And all this must be posted somewhere. Then our Earth is very different from the globe. It will be some kind of multilayer three-dimensional (i.e. volumetric) structure in four-dimensional (or more complex) space. For example, corresponding to the fourth dimension mentioned at the beginning of the article, which follows from Newton's first law.

But to know and understand all this will require serious scientific research.

5. Conclusion

Thus, the really existing physical world turned out to be in many ways different from the way it is explained in the version of STR studied in physics textbooks. However, although over the past hundred years since the creation of this STR, much has been refuted, the content of the sections of physics textbooks that present it has not essentially changed. Its main difference from pre-existing classical physics is its use of the principle of relativism. But all the formulas obtained in SRT using the principle of relativism nevertheless turned out to be incorrect. And even the creators of this theory themselves could not explain them. Moreover, these formulas are not explained in textbooks even now.

Therefore, Albert Einstein, in his version of STR, in order to make it explainable, had to prove not physical reality, but, on the contrary, the physical unreality of imaginary numbers. And for this it was necessary that this physical unreality of imaginary numbers should follow from something indisputably true. And as such an initial supposedly indisputably true truth, a postulate was used, called the principle

of not exceeding the speed of light.

But at the same time, Albert Einstein ignored the fact that in fact there are many well-known processes in nature - tsunamis, Indian summers, bell ringing, music created by a piano, and even swings swinging on the playground after a push from parents - proving the physical reality of imaginary numbers.

Albert Einstein also ignored the fact that back in 1897, Charles Proteus Steinmetz, in his proposed interpretation of Ohm's law, had essentially already proven the physical reality of imaginary numbers. Since his theory stated that the imaginary resistances $-j/\omega C$ of capacitors and $+j\omega L$ of inductors actually physically exist. And since then, radio engineers have never had the slightest reason to doubt in it, since when the frequency of a sinusoidal voltage applied to any electrical LCR-circuit changes, the amount of current flowing through it always changes. This fact, which occurs in the practical activities of radio engineers literally at every step, is an extremely simple, absolutely understandable and irrefutable proof of the physical reality of imaginary numbers.

Nevertheless, Albert Einstein still needed to somehow doubt this in his proposed version of STR. Otherwise, it would be necessary to admit that the creators of this version of STR are unable to explain the obtained relativistic formulas in the hyperluminal speed range $v > c$. And then this theory, which even its creators could not explain, would naturally be of no use to anyone. That is why a postulate, was introduced into the STR, called the principle of not exceeding the speed of light, from which a conclusion was made about the physical unreality of imaginary numbers, which was not confirmed by any experiments. This made it possible not to explain relativistic formulas in the hyperluminal speed range $v > c$. Therefore, despite the fact that Albert Einstein was nominated for the Nobel Prize 66 times for the creation of STR, due to the lack of any experimental evidence of its truth, he never received it for his version of this theory.

In order to prove the denial of the physical reality of imaginary numbers in the incorrect version of special relativity, relativistic physicists had to undertake enormous and costly efforts. In particular, to create at least illusion of the impossibility of refuting the STR's assertion of the physical unreality of imaginary numbers, on the Large Hadron Collider (worth ten billion dollars) a collaboration OPERA, which included more than one hundred of the most authoritative professors-physicists, for almost 15 years (2003-2018) was the unsuccessful physical experiment OPERA, which aimed to prove the physical reality of imaginary numbers but failed to do so. And thereby supposedly proved the impossibility of refuting the assertion about the physical unreality of imaginary numbers. In 2011, it was even announced that the OPERA experiment had been sensationally successful, but then half a year later in 2012, the OPERA experiment was refuted by another ICARUS experiment on the same Large Hadron Collider

Therefore, physicists are still ignoring publications that cite simple and comprehensible radio-technical experiments successfully proving the physical reality of imaginary numbers and explaining that if the imaginary numbers were, as claimed in the incorrect version of STR, physically unrealistic, there should be nor radio nor computer technics.

Moreover, because of the assertion of the physical unreality of imaginary numbers and thus of the existence in nature of our only visible universe, it has become apparent that there was no place for antimatter and tachyons in this only visible universe. Although their existence in nature was not denied. And where they are located is explained only by the corrected version of the corrected version of STR.

It also transpired that, because of the assertion of the physical unreality of imaginary numbers and therefore of the existence in nature of our only visible universe, the phenomena of dark matter and dark energy had never been and would never be explained, because the dark matter and dark energy are, according to the corrected version of the STR, all reciprocally invisible universes and antiuniverses existing outside our visible universe in the hidden Multiverse.

More than 200,000 anomalous zones have been discovered on Earth, which are entrances of portals to the planets of not only our Solar System, but also other star systems in the hidden Multiverse and even in the Hyperverse. And it also proves the existence of other universes and antiuniverses. Moreover, in the existence of these invisible outside the portals of of universes and antiuniverses can be ascertained by astronomical observations of the star sky in portals. But these low-cost astronomical observations, which would allow for sensational scientific discoveries of other universes and antiuniverses, are still not being made, probably because of the fear that invisible neighboring universes and antuniverses ones will be discovered. And then the version of the STR studied in textbooks on physics would have to be undeniably disbelieved.

The version of STR taught in physics textbooks also leads to the conclusion that time travel is impossible for humans. Although, in fact, millions of air passengers already make such time travel every day, as evidenced by the fact that passengers of planes reset their clocks to local time after landing.

However, since such time travel by air passengers occurs simultaneously with long distances travel, it is currently not used. The article explains how, through ~~quasi~~ quasi-round-the-world flights, time travel may become physically and technically feasible.

Less-expensive radiotelephone time travel is also possible, and once it's in demand, it could be implemented quickly and inexpensively. This would make it possible to communicate and exchange information with people (including oneself) in the past or future relative to our own time.

And, finally, among other things, such quasi-round-the-world time travel will prove that our Earth is much more complex than is explained by modern science. It is probably a three-dimensional spiral structure²⁷ in four-dimensional space, the existence of which follows from Newton's first law.

References

1. Larmor J.J. (1897). A Dynamical Theory of the Electric and Luminiferous Medium. Part III. Relations with Material Media. Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences. 190, 205-300.
2. Lorentz H.A. (1899). Simplified Theory of Electrical and Optical Phenomena in Moving Systems. Proceedings of the Netherlands Academy of Arts and Science. Amsterdam. 1, 427-442.
3. Poincaré H. (1905). On the Dynamics of the Electron. Comptes Rendus. 140. 1504-1508.
4. Einstein A. (1905). Zur Elektrodynamik bewegter Körper. Annals of Physic. 17. 891-921.
5. Terletsky Ya. P. (1966). Paradoxes of the theory of relativity. Nauka Publishing House. Moscow. (In Russian)
6. Logunov A. A. (1987). Lectures on the theory of relativity and gravitation. Nauka Publishing House. Moscow. (In Russian)
7. Atsyukovsky V. A. (2003). General ether dynamics. Energoatomizdat. Moscow. (In Russian)
8. Kalinin S. A. (2003). Einstein's cardinal errors. Editorial Urss Publishers. Moscow. (In Russian)
9. Arteha S. H. (2007). Critique of the foundations of the theory of relativity. 2nd ed. LKI Publishing House. Moscow. (In Russian)
10. Antonov A. A. (2025). Time Travels are Already Possible Nowadays. European Journal of Applied Sciences. Services for science and education. U.K. 13(03). 47-70. DOI:10.14738/aivp.1303.18764.
11. Antonov A. A. (2025). Time travels are already possible for people on Earth. German International Journal of Modern Science. 104. 64-76. DOI: 10.5281/zenodo.15480577
12. Antonov A. A. (2025). Discovery of the possibility for people on Earth of time travels. Norwegian Journal of development of the International Science. 156. 84-98. <https://doi.org/10.5281/zenodo.15397809>
13. Antonov A. A. (2025). The discovery of physically real time travels. Journal of Science. Lyon. 66. 33- 48. <https://doi.org/10.5281/zenodo.15584655>
14. Antonov A. A. (2025). The physical reality of time travels available to people. Annali d'Italia. 67. 58-72. DOI: 10.5281/zenodo.15545211
15. Antonov A. A. (2025). The physical possibility for people on Earth of time travel. The scientific heritage. 163. 44-58. DOI: 10.5281/zenodo.15728017
16. Antonov A. A. (2025). Proof of the physical reality of time travels available to humans. Danish Scientific Journal. 96. 72-86. <https://doi.org/10.5281/zenodo.15553087>
17. Antonov A. A. (2025). Discovery of the possibility for people on Earth of time travels. International independent scientific journal. 74. 37- 52. <https://doi.org/10.5281/zenodo.15634030>
18. Antonov A. A. Time travels is now physically possible. XX international scientific conference "The modern vector of the development of science". Philadelphia. USA. 12-13.06.2025. DOI <https://doi.org/10.5281/zenodo.15691366>
19. Antonov A. A. The physical possibility for people on Earth of time travels. Polish journal of Science. 87. 39-53. DOI: 10.5281/zenodo.15700637
20. Antonov A. A. Time travels is now physically possible. XVI international scientific conference "Theoretical and practical perspectives of modern science". Stockholm. Sweden. 27-28.05.2025.

²⁷ A one-dimensional (in the form of a line) spiral is, for example, the well-known Archimedes spiral. A two-dimensional (in the form of a tape) spiral of Archimedes is a medical bandage or medical plaster in three-dimensional space. And our Earth is a three-dimensional Archimedes spiral made in a similar way in four-dimensional space, the existence of which follows from Newton's first law.

21. DOI <https://doi.org/10.5281/zenodo.15577281>
22. Antonov A. A. *The discovery of physical possibility of time travels. II International Scientific Conference "Expanding knowledge through interdisciplinary research".* Sydney. Australia. 15-16.05.2025.2
23. DOI <https://doi.org/10.5281/zenodo.1549756>
24. Antonov A.A. (2021). *The special theory of relativity stated in physics textbooks is incorrect.* 77th International Scientific Conference of the Eurasian Scientific Association "Theoretical and practical issues of modern science". Moscow. ESA. 11-15. (In Russian)
25. Antonov A. A. (2021). *Version of the special theory of relativity that is studied in all physics textbooks is incorrect.* Österreichisches Multiscience Journal (Innsbruck, Austria). 43(1). 17-22. <http://osterr-science.com>
26. Antonov A. A. (2021). *The fallacy of the STR version studied in physics textbooks proved experimentally.* Österreichisches Multiscience Journal (Innsbruck, Austria). 45(1). 17-26.
27. Antonov A. A. (2021). *Generally accepted version of the special theory of relativity contained in physics textbooks is incorrect.* The scientific heritage. (Budapest, Hungary). 7 3(2). 39-43.
28. DOI:19.24412/9215-0365-2021-73-2-39-43
29. Antonov A. A. (2021). *Special theory of relativity presented in physics text-books is wrong.* Norwegian Journal of development of the International Science 68(1). 3-7. DOI: 10.24412/3453-9875-2021-68-3-7.
30. Antonov A. A. (2021). *In all physics textbooks an erroneous version of special theory of relativity is given.* International independent scientific journal. 31.34-39 <http://www.iis-journal.com>
31. Antonov A. A. (2021). *All physics textbooks study incorrect special theory of relativity.* Sciences of Europe. (Praha, Czech Republic) 79(1). 30-35.
32. DOI: 10/24412/3162-2364-2021-79-30-35
33. Antonov A. A. (2021). *Special theory of relativity, which is studied in physics text-books, is incorrect.* German International Journal of Modern Science. 16, 49-53. DOI: 10.24412/2701-8369-2021-16-49-53
34. Antonov A. A. (2021). *Special theory of relativity, which is studied in all physics textbooks, is incorrect.* Danish Scientific Journal. 51(1). 31-35.
35. <http://www.danish-journal.com>
36. Antonov A. A. (2021). *Special theory of relativity taught in all physics text-books is incorrect.* Annali d'Italia. 22(1). 39-44. <https://www.anditalia.com/>
37. Antonov A. A. (2021). *Special theory of relativity taught in physics textbooks is wrong.* Journal of science. Lyon. 23. 47-52. <https://www.joslyon.com/>
38. Antonov A. A. (2021). *Experimental proofs of infidelity of the version of the special theory of relativity studied in physics textbooks and the truth of its alternative version.* 80th International Scientific Conference of the Eurasian Scientific Association "Development of science and education in the conditions of world instability". Moscow. ESA. 8-17.
39. <https://esa-conference.ru/sborniki/?y=2021> (In Russian)
40. Antonov A. A. (2021). *Experimental evidences for the fallacy of the STR version in the physics textbooks.* European Journal of Applied Sciences. Services for Science and Education. UK. 9(6). 349-364.
41. DOI:10.14738/aivp.96.11304.
42. Antonov A. A. (2021). *If the STR version in physics textbooks were true, we would never have heard the music of the piano and the bell ringing, there would be no television, no cellular telephony, no radar or GPS navigation, we would not even be aware of the existence of resonance and Ohm's law as interpreted by Steinmetz, and our children could not swing on the swings.* The scientific heritage (Budapest, Hungary). 78(2). 41-50.
43. DOI: 10.24412/9215-0365-2021-78-2-41-50
44. Antonov A. A. (2021). *The STR version in physics textbooks must be corrected, because if it were true, there would be no tsunamis or indian summer in nature, we would be never have heard piano music, engineers would be not have been able to create television, cell phones, GPS trackers, and even children would not be able to swing on swings.* Danish Scientific Journal. 54(1). 29-38. <http://www.danish-journal.com>
45. Antonov A. A. (2021). *Experimental refutations of the STR version contained in physics textbooks and confirmations of the truth of its alternative version.* German International Journal of Modern Science. 22. 52-61.
46. DOI: 10.24412/2701-8369-2021-22-52-61

47. Antonov A. A. (2021). *Experimental evidence of the incorrectness of the STR version studied in physics textbooks*. *Annali d'Italia*. 25(1). 32-41.
48. <https://www.anditalia.com/>
49. Antonov A. A. (2021). *The incorrectness of the STR version presented in physics textbooks proven experimentally*. *Norwegian Journal of development of the International Science*. 74(1). 3-7.
50. DOI: 10.24412/2453-9875-2021-74-53-62.
51. Antonov A. A. (2021). *Experimental refutations of the generally accepted version of the STR studied in physics textbooks*. *International independent scientific journal*. 34(1). 23-32. <http://www.iis-journal.com>
52. Antonov A. A. (2021). *Experimental refutations of the STR version in the physics textbooks*. *Journal of science*. Lyon. 26(1). 29-37
53. <https://www.joslyon.com/>
54. Antonov A. A. (2021). *Experimental evidences for the fallacy of the STR version in physics textbooks*. *Sciences of Europe (Praha, Czech Republic)*. 82(2). 19-28. DOI: 10.24412/3162-2364-2021-82-2-19-28
55. Antonov A. A. (2021). *The version of STR stated in physics textbooks is incorrect, as it denies the existence of radio engineering*. 82nd International Scientific Conference of the Eurasian Scientific Association "Scientific results in theory and practice". Moscow. ESA. 11-15. (In Russian)
56. <https://esa-conference.ru/sborniki/?y=2021>
57. Antonov A. A. (2022). *The version of STR presented in physics textbooks is incorrect, since it follows from it that radio engineering should not exist*. *European Journal of Applied Sciences. Services for Science and Education*. UK. 10(1). 440-445. DOI://doi.org/10.14738/aivp.101.2022
58. Antonov A. A. (2022). *The existence of radio engineering refutes the physics textbooks' version of STR*. *The scientific heritage*. (Budapest, Hungary). 83(1). 19-22. DOI: 10.24412/9215-0365-2022-83-1-19-22
59. Antonov A.A. (2022). *The fundamental Ohm's law in radio engineering as interpreted by Steinmetz, which proves the physical reality on imaginary capacitive and inductive reactances, refuted the version of the STR presented in physics textbooks even before its creation*. *German International Journal of Modern Science*. 26. 50-53. DOI: 10.24412/2701-8369-2022-26-50-63
60. Antonov A.A. (2022). *The version of STR stated in physics textbooks is refuted by the existence of radio engineering*. *Danish Scientific Journal*. 56. 56-59. <http://www.danish-journal.com>
61. Antonov A.A. (2022). *The version of STR presented in physics textbooks is incorrect because it denies the possibility of the existence of Ohm's law as interpreted by Steinmetz and, consequently, the existence of radio engineering*. *Annali d'Italia*. 28(1), 43-47. <https://www.anditalia.com/>
62. Antonov A.A. (2022). *The version of STR stated in physics textbooks is refuted by the existence of radio engineering*. *Norwegian Journal of development of the International Science*. 78(1). 63-67.
63. DOI: 10.24412/3453-9875-2022-78-63-66.
64. Antonov A.A. (2022). *If the physics textbook version of STR were true, then Ohm's law should not exist in nature, and therefore all radio engineering would not exist*. *International independent scientific journal*. 36. 16-19. <http://www.iis-journal.com>
65. Antonov A.A. (2022). *If the version of STR in physics textbooks were true, then there would be no radar, no television, no radio navigation, no telecommunication and many other things*. *Journal of science*. Lyon. 28. 76-79. <https://www.joslyon.com/>
66. Antonov A.A. (2022). *The version of STR set out in physics textbooks is incorrect because it states that Ohm's law as interpreted by Steinmetz does not really exist, and therefore radio engineering does not exist either*. *Sciences of Europe (Praha, Czech Republic)*. 87(1). 54-57.
67. DOI: 10.24412/3162-2364-2022-1-54-57
68. Antonov A.A. (2022). *The version of STR set out in physics textbooks is in-correct because it states that Ohm's law as interpreted by Steinmetz does not really exist, and therefore radio engineering does not exist either*. *Sciences of Europe (Praha, Czech Republic)*. 87(1). 54-57.
69. DOI: 10.24412/3162-2364-2022-1-54-57
70. Antonov A.A. (2022). *Why the physics textbooks teach an incorrect version of the special theory of relativity which denies the existence of radio- and electrical engineering*. III international scientific conference "Challenges and problems of modern science." London. Great Britain. 78-86.
71. DOI: <https://doi.org/10.528/zenodo.7486814>
72. Steinmetz C. P. (2010). *Theory and Calculation of Electric Circuit*. Nabu Press. Charlstone.

73. Cherenkov P.A. (1959). Radiation of particles with superluminal speed and some applications of this radiation in experimental physics. *Advances in Physical Sciences*. 68(3). 377–386. (In Russian)
74. DOI: <https://doi.org/10.3367/UFNr.0068.195907b.0377>
75. Adam T., Agafonova N., Aleksandrov A. et al. (2012). Measurement of the neutrino velocity with the OPERA detector in the CNGS beam. *arxiv:1109.4897v4 [hep-ex]*.
76. Antonov A. A. (2008). Physical Reality of Resonance on Complex Frequencies. *European Journal of Scientific Research*. 21(4). 627-641.
77. Antonov A. A. (2009). Resonance on Real and Complex Frequencies. *European Journal of Scientific Research*. 28(2). 193-204.
78. Antonov A. A. (2010). New Interpretation of Resonance. *International Journal of Pure and Applied Sciences and Technology*. 1(2). 1-12.
79. http://doi.org/10.17686/sced_rusnauka_2010-888
80. Antonov A. A. (2010). Oscillation processes as a tool of physics cognition. *American Journal of Scientific and Industrial Research*. 1(2). 342-349.
81. doi:10.5251/ajsir.2010.1.2.342.349
82. Antonov A. A. (2010). Solution of algebraic quadratic equations taking into account transitional processes in oscillation systems. *General Mathematics Notes*. 1(9). 11-16. http://doi.org/10.17686/sced_rusnauka_2010-887
83. Antonov A. A. (2013). Physical Reality of Complex Numbers. *International Journal of Management, IT and Engineering*. 3(4). 219-230.
84. http://doi.org/10.17686/sced_rusnauka_2013-898
85. Antonov A. A. (2015). Physical reality of complex numbers is proved by research of resonance. *General Mathematics Notes*. 31(2). 34-53.
86. http://www.emis.de/journals/GMN/yahoo_site_admin/assets/docs/4GMN-9212-V31N2.1293701.pdf
87. Antonov A.A. (2015). Principle of physical reality of imaginary and complex numbers in the modern cosmology: the nature of dark matter and dark energy. *Journal of the Russian physico-chemical Society*. 87(1). 328-355.
88. http://doi.org/10.17686/sced_rusnauka_2015-1119
89. Antonov A. A. (2016). Physical Reality and Nature of Imaginary, Complex and Hypercomplex Numbers. *General Mathematics Notes*. 35(2). 40-63.
90. http://www.geman.in/yahoo_site_admin/assets/docs/4_GMN-10932-V35N2.31895146.pdf
91. Antonov A.A. (2017). The physical reality and essence of imaginary numbers. *Norwegian Journal of development of the International Science*. 6. 50-63. <http://www.njd-iscience.com>
92. Antonov A. A. (2024). Physical reality of imaginary numbers and their physical essence. *Danish Scientific Journal*. 80. 25-35.
93. <https://doi.org/10.5281/zenodo.10594282>
94. Antonov A. A. (2024). Proof of physical reality of imaginary numbers and explanation of their physical essence. *German International Journal of Modern Science*. 72. 17-27.
95. Anonov A. A. (2024). Physical reality of imaginary numbers and their physical essence. *Sciences of Europe. (Praha, Czech Republic)*. 133(1). 79-90.
96. DOI: 10.5281/zenodo.10575590
97. Antonov A. A. (2024). Physical reality of imaginary numbers and their physical essence. *The scientific heritage. (Budapest, Hungary)*. 129. 43-53. DOI: 10.5281/zenodo.10558263
98. Antonov A. A. (2024). Proving Physical Reality and Explaining the Physical Essence of Imaginary Numbers. *European Journal of Applied Sciences. Services for Science and Education. UK*. 12(2). 362-381.
99. DOI:10.14738/aivp.122.16273
100. Antonov A. A. (2024). Proving Physical Reality and Explaining Physical Essence of Imaginary Numbers. *Journal of science. Lyon*. 50. 25-35.
101. <https://doi.org/10.5281/zenodo.10609816>
102. Antonov A. A. (2024). Physical reality of complex numbers and their physical essence. *International independent scientific journal*. 58. 3-13.
103. <https://doi.org/10.5281/zenodo.10491923>
104. Antonov A. A. (2024). Proof of physical reality of imaginary numbers and explanation of their physical essence. *Annali d'Italia*. 51, 25-35.

105. DOI: 10.5281/zenodo.10573831
106. Antonov A. A. (2011). *Structure of the Multiverse*. *British Journal of Science*. 2(2). 51-60. http://doi.org/10.17686/sced_rusnauka_2011892
107. Antonov A. A. (2012). *Multiverse. Time Travels*. *International Journal of Pure and Applied Sciences and Technology*. 12(2). 43-56.
108. http://doi.org/10.17686/sced_rusnauka_2012-896
109. Antonov A.A. (2012). *Discovery of the real Multiverse*. *Encyclopaedia of Russian thought, Papers to the Russian Physical Society*. 16(3). 3-20. (In Russian). http://doi.org/10.17686/sced_rusnauka_2012-1115
110. Antonov A.A. (2013). *Cognition of the Multiverse as a factor in accelerating the development of human civilisation*. *Journal of Russian physical thought*. 1-12, 6-77. http://doi.org/10.17686/sced_rusnauka_2011-1117. (In Russian)
111. Antonov A. A. (2015). *Hidden Multiverse*. *International Journal of Advanced Research in Physical Science*. 2(1). 25-32.
112. http://doi.org/10.17686/sced_rusnauka_2015-903.
113. Antonov A.A. (2015). *The astrophysical phenomenon of dark matter and dark energy proves the existence of the hidden Multiverse*. *American Journal of Modern Physics*. 4(4). 180-188. doi: 10.11648/j.jamp.20150404.14
114. Antonov A. A. (2015). *Why dark matter and dark energy are invisible?* *Optics*. 4(6), 43-47. doi: 10.11648/j.optics.20150406.12
115. Antonov A. A. (2016). *Stargates of the hidden Multiverse*. *Philosophy and cosmology*. 6. 11-27. (In Russian) <http://ispcjournal.org/journals/2016-16/Antonov16.pdf>
116. Antonov A. A. (2016). *What Physical World do We Live in?* *Journal of Modern Physics*. 7(14). 1933-1943
117. <http://dx.doi.org/10.4236/jmp.2016.714170>
118. Nicolson I. (2007). *Dark Side of the Universe: Dark Matter, Dark Energy, and the Fate of the Cosmos*. Johns Hopkins University Press. Baltimore.
119. Ruiz-Lapuente, P. Ed. (2010). *Dark Energy: Observational and Theoretical Approaches*. Cambridge university press. Cambridge. UK.
120. Amendola L., Shinji T.S. (2010). *Dark Energy: Theory and Observations*. Cambridge university press. Cambridge. UK.
121. Bertone G. Ed. (2013). *Particle Dark Matter: Observations, Models and Searches*. Cambridge university press. Cambridge. UK.
122. Sanders R.H. (2014). *The dark matter problem: a historical perspective*. Cambridge university press. Cambridge. UK.
123. Tyson N. de Grasse. (2017). *Astrophysics for People in a Hurry*. W. W. Norton & Company. NY. London.
124. Antonov A.A. (2022). *Dark Matter and Dark Energy, Which are Inexplicable in the Microcosm, are Mutually Invisible Universes and Anti-universes of the Hidden Multiverse*. *European Journal of Applied Sciences, Services for Science and Education*. UK. 13(06). 84-107. DOI:10.14738/aivp.1306.19658.
125. Antonov A. A. 2025. *Dark matter and dark energy are mutually invisible universes and anti-universes of the hidden Multiverse*. *German International Journal of Modern Science*. 113. 27- 42. DOI: 10.5281/zenodo.17286973
126. Antonov A. A. 2025. *Dark matter and dark energy are invisible universes and anti-universes of the hidden Multiverse*. *Journal of science*. Lyon. 71. 38-52.
127. <https://doi.org/10.5281/zenodo.17533496>
128. Antonov A. A. 2025. *Dark matter and dark energy are mutually invisible universes and anti-universes of the hidden Multiverse*. *Annali d'Italia*. 72. 28-42. DOI: 10.5281/zenodo.17463768
129. Antonov A. A. 2025. *Dark matter and dark energy, which are inexplicable in the microcosm, are universes and anti-universes of the hidden Multiverse*. XVIII International Scientific and Practical Conference "Theoretical and practical perspectives of modern science". 28-29.10.2025, Stockholm. Sweden. 69-86. DOI <https://doi.org/10.5281/zenodo.17513357>
130. Hinshaw G., Larson D., Komatsu E., et al. (2013) *Nine Year Wilkinson Anisotropy Probe (WMAP) Observations: Cosmological Parameter Results*. arXiv:1213.5226 [astro-ph/CO].
131. Adam R., Ade P.A.R., Aghanim N., et al. (2015). *Planck 2015 Results. 1. Overview of Products and Scientific Results*. arXiv:1502.01582v2 [astro-ph.CO].

132. Korn G., Korn T. (1968). *Handbook of mathematics for scientists and engineers*. Nauka Publishing House. Moscow. (In Russian)
133. *Encyclopaedia of Mathematics*. (1979). Edited by Vinogradov I. M. Vol. 2. Publishing house "Soviet Encyclopaedia". Moscow. (In Russian)
134. Kantor I.L. , Solodovnikov A.S. *Hypercomplex Numbers. An Elementary Introduction to Algebras* Springer. NY. 2011.
135. Chernobrov V. (2000). *Encyclopaedia of mysterious places of the Earth*. Veche Publishing House. Moscow. (In Russian)
136. Chernobrov V. (2004). *Encyclopaedia of mysterious places of Russia*. Veche Publishing House. Moscow. (In Russian)
137. Chernobrov V. (2007). *Encyclopaedia of mysterious places of the Earth and space*. Veche Publishing House. Moscow. (In Russian)
138. Chernobrov V. (2009). *Encyclopaedia of mysterious places of Moskva and Moscow region*. Helios ARV. Moscow. (In Russian)
139. Antonov A. A. (2020). How to See Invisible Universes. *Journal of Modern Physics*. 11(05), 593-607. DOI: 10.4236/jmp.2020.115039
140. Antonov A. A. (2020). Universes Being Invisible on Earth outside the Portals Are Visible in Portals. *Natural Science*. 12(8). 569-587.
141. <https://doi.org/10.4236/ns.2020.128044>
142. Antonov A. A. (2020). Invisible universes can be seen in anomalous zones. *Danish Scientific Journal*. 43(1). 9-24. <http://www.danish-journal.com>
143. Antonov A. A. (2024). Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. *German International Journal of Modern Science*. 92. 67-80.
144. DOI: 10.5281/zenodo.14181333
145. Antonov A. A. (2024). Experimental evidence for the existence of other mutually invisible universes neighboring our visible universe. *European Journal of Applied Sciences. Services for Science and Education*. UK. 12(5). 385-408. DOI:10.14738/aivp.125.17785.
146. Antonov A. A. (2024). Experimentally proved and actually physically existing imaginary numbers as a tool to explain the principle of relativism in STR. *Norwegian Journal of development of the International Science*. 144. 69-82.
147. <https://doi.org/10.5281/zenodo.14169132>
148. Antonov A. A. (2020). Can invisible universes be seen? *International independent scientific journal*. 21(2). 51-60. <http://www.iis-journal.com>
149. Antonov A. A. (2020), How to discover invisible universes. *Norwegian Journal of development of the International Science*. 42(1). 36-48.
150. <http://www.njd-iscience.com>
151. Antonov A. A. 2024. Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. *Sciences of Europe (Praha, Czech Republic)*. 153. 93-106.
152. DOI: 10.5281/zenodo.14227583
153. Antonov A. A. (2021). Invisible universes can be seen in anomalous zones. *International independent scientific journal*. 23(1). 28-44.
154. Antonov A. A. (2024). Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. *Annali d'Italia*. 61. 43-57. DOI: 10.5281/zenodo.14230824
155. 103Antonov A. A. (2024). Proof of the existence of other mutually invisible universes neighboring to our visible universe. *Danish Scientific Journal*. 90. 111-125. <https://doi.org/10.5281/zenodo.14236925>
156. Antonov A. A. (2024). Discovery of other constellations in portals that are invisible outside the portals is experimental proof of the existence of mutually invisible universes adjacent to our visible universe. *Polish journal of Science*. 80. 24-38. DOI: 10.5281/zenodo.14176574
157. Antonov A. A. (2024). It is possible to prove the existence of other mutually invisible universes adjacent to our visible universe by astronomical observations in the portals of constellations that are invisible outside the portals. *Slovak international scientific journal (Bratislava, Slovakia)*. 89. 51-65.
158. DOI: 10.5281/zenodo.14167109

159. Antonov A. A. (2024). *Experimentally proved and actually psychically existing imaginary numbers as a tool to explain the principle of relativism in STR. The scientific heritage (Budapest, Hungary).* 149. 50-63.
160. DOI: 10.5281/zenodo.14214530
161. Antonov A. A. (2024). *Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. International independent scientific journal.* 67. 29-42.
162. <https://doi.org/10.5281/zenodo.14055388>
163. Antonov A. A. (2024). *Besides our visible universe, there are other invisible universes. Journal of Science.* Lyon. 59. 13-26.
164. <https://doi.org/10.5281/zenodo.14049575>
165. Antonov A. A. (2024). *Discovery of constellations in portals that are invisible outside the portals proves the existence of mutually invisible universes adjacent to our visible universe. Sciences of Europe (Praha, Czech Republic).* 94. 34- 48. DOI: 10.5281/zenodo.14167218
166. Antonov A. A. (2020). *How to See Invisible Universes. Journal of Modern Physics.* 11(05), 593-607. DOI: 10.4236/jmp.2020.115039
167. Antonov A. A. (2020). *Universes Being Invisible on Earth outside the Portals Are Visible in Portals. Natural Science.* 12(8). 569-587.
168. <https://doi.org/10.4236/ns.2020.128044>
169. Antonov A. A. (2020). *Invisible universes can be seen in anomalous zones. Danish Scientific Journal.* 43(1). 9-24. <http://www.danish-journal.com>
170. Antonov A. A. (2024). *Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. German International Journal of Modern Science.* 92. 67-80.
171. DOI: 10.5281/zenodo.14181333
172. Antonov A. A. (2024). *Experimental evidence for the existence of other mutually invisible universes neighboring our visible universe. European Journal of Applied Sciences. Services for Science and Education.* UK. 12(5). 385-408. DOI:10.14738/aivp.125.17785.
173. Antonov A. A. (2024). *Experimentally proved and actually physically existing imaginary numbers as a tool to explain the principle of relativism in STR. Norwegian Journal of development of the International Science.* 144. 69-82.
174. <https://doi.org/10.5281/zenodo.14169132>
175. Antonov A. A. (2020). *Can invisible universes be seen? International independent scientific journal.* 21(2). 51-60. <http://www.iis-journal.com>
176. Antonov A. A. (2020). *How to discover invisible universes. Norwegian Journal of development of the International Science.* 42(1). 36-48.
177. <http://www.njd-iscience.com>
178. Antonov A. A. 2024. *Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. Sciences of Europe (Praha, Czech Republic).* 153. 93-106. DOI: 10.5281/zenodo.14227583
179. Antonov A. A. (2021). *Invisible universes can be seen in anomalous zones. International independent scientific journal.* 23(1). 28-44.
180. Antonov A. A. (2024). *Proof of the existence of other mutually invisible universes neighboring to our visible universe by astronomical observations in the portals of constellations invisible outside the portals. Annali d'Italia.* 61. 43-57. DOI: 10.5281/zenodo.14230824
181. Antonov A. A. (2024). *Proof of the existence of other mutually invisible universes neighboring to our visible universe. Danish Scientific Journal .* 90. 111-125. <https://doi.org/10.5281/zenodo.14236925>
182. Antonov A. A. (2024). *Discovery of other constellations in portals that are invisible outside the portals is experimental proof of the existence of mutually invisible universes adjacent to our visible universe. Polish journal of Science.* 80. 24-38. DOI: 10.5281/zenodo.14176574
183. Antonov A. A. (2024). *It is possible to prove the existence of other mutually invisible universes adjacent to our visible universe by astronomical observations in the portals of constellations that are invisible outside the portals. Slovak international scientific journal (Bratislava, Slovakia).* 89. 51-65. DOI: 10.5281/zenodo.14167109

184. Antonov A. A. (2024). *Experimentally proved and actually psychically existing imaginary numbers as a tool to explain the principle of relativism in STR. The scientific heritage (Budapest, Hungary).* 149. 50-63.
185. DOI: 10.5281/zenodo.14214530
186. Antonov A. A. (2024). *Existence of other mutually invisible universes adjacent to our visible universe can be experimentally proven by astronomical observations in the portals of constellations invisible outside the portals. International independent scientific journal.* 67. 29-42.
187. <https://doi.org/10.5281/zenodo.14055388>
188. Antonov A. A. (2024). *Besides our visible universe, there are other invisible universes. Journal of Science. Lyon.* 59. 13-26.
189. <https://doi.org/10.5281/zenodo.14049575>
190. Antonov A. A. (2024). *Discovery of constellations in portals that are invisible outside the portals proves the existence of mutually invisible universes adjacent to our visible universe. Sciences of Europe (Praha, Czech Republic).* 94. 34- 48. DOI: 10.5281/zenodo.14167218
191. Antonov A. A. (2025). *Discovery of constellations in portals that are The physical ability to bring a person who has died, for example as a result of an accident or a crime, back to life. Polish journal of Science.* 89(1). 36-39.
192. DOI: 10.5281/zenodo.16917782
193. Antonov A. A. (2025). *The use of the laws of physics allows a person who has died, for example, as a result of an accident or crime, to be brought back to life. European Journal of Applied Sciences. Services for Science and Education. UK.* 13(04)). 174-179. DOI:10.14738/aivp.1304.19179.
194. Antonov A. A. (2025). *By using the laws of physics, it is possible to bring back to life a person who has died, for example, as a result of an accident or crime. The scientific heritage.* 166. 65-68. DOI: 10.5281/zenodo.1676353
195. Antonov A. A. (2025). *It is physically possible to bring back to life a person who has died, for example, as a result of an accident or crime, using time travels. German International Journal of Modern Science.* 109. 24-27.
196. DOI: 10.5281/zenodo.16752567
197. Antonov A. A. (2025). *The laws of physics allow a person who has died, for example, as a result of an accident or crime, to be brought back to life. Danish Scientific Journal.* 98. 67-71. <https://doi.org/10.5281/zenodo.16615081>
198. [146] Antonov A. A. (2025). *It is physically possible to bring back to life a person who has died as a result of an accident or crime by using time travels. Annali d'Italia.* 69. 46-49. DOI: 10.5281/zenodo.16419980
199. Antonov A. A. (2025). *Possibility in accordance with the laws of physics, of bringing back to life people who have died as a result of accident and other causes by time travels using time zones on Earth. XVI International scientific conference. Beijing. China. "Science in modern society"* 22-23.07.2025.
200. DOI <https://doi.org/10.5281/zenodo.16562393>
201. Antonov A. A. (2025). *How the laws of physics can be used to bring back to life a person who has died as a result of an accident or crime. Norwegian Journal of development of the International Science.* 160. 69-72. <https://doi.org/10.5281/zenodo.15879906>
202. Antonov A. A. (2025). *A person who has died in an accident or crime, for example, can be brought back to life through the use of time travels. International independent scientific journal.* 76. 17-20.
203. <https://doi.org/10.5281/zenodo.16778574>
204. Antonov A. A. (2025). *The laws of physics allow a dead person to be brought back to life. Journal of Science. Lyon.* 68.15-18.
205. <https://doi.org/10.5281/zenodo.16758455>
206. Antonov A. A. (2025). *The laws of physics allow by time travelling with using time zones on Earth to bring back to life people who died as a result of accidents, in war and for other reasons. XVII International scientific conference "Theoretical and practical perspectives of modern science". Stockholm. Sweden. 12-13.08.2025. DOI <https://doi.org/10.5281/zenodo.16892861>*
207. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travel for people on Earth is physically possible and technically feasible. European Journal of Applied Sciences. Services for Science and Education. UK.* 14(01). 723-744. <https://doi.org/10.14738/aivp.1401.19957>

208. Antonov A. A. (2026). *Time travels on Earth is already available to peoples. VI international scientific conference "Dialogue of Times: Past, Present, Future" Brussels. Belgium.* DOI <https://doi.org/10.5281/zenodo.19823915>
209. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travels is now available to people on Earth. Danish Scientific Journal my article.107. 74-88.* DOI <https://doi.org/10.5281/zenodo.19823915>
210. Antonov A. A. (2026). *Time travel for people on Earth physically is possible and now already technically feasible. XXIII International Scientific Conference "Modern Science: Theoretical and Practicacal Viev". Madrid. Spain. 31.03-01.04.2026.* DOI <https://doi.org/10.5281/zenodo.19442313>
211. Antonov A. A. (2026). *Time travel on Earth is available for use. Annali d'Italia. 76. 52-* DOI: [10.5281/zenodo.18803259](https://doi.org/10.5281/zenodo.18803259).
212. Antonov A. A. (2026). *From the corrected version of the STR it follows that time travels is now available to people on Earth. XIX international scientific conference. "Questions. Hypotheses. Answers: science XXI century". Toronto. Canada. 17-18.03.2026* DOI <https://doi.org/10.5281/zenodo.19188055>.
213. Antonov A. A. (2026). *How to call yourself to yesterday? Norwegian Journal of development of the International Science. 172. 23-36.*
214. <https://doi.org/10.5281/zenodo.18268393>
215. Antonov A. A. (2026). *Time travels according to the corrected version of STR is physically feasible" in the XXIII international scientific conference "The modern vector of the development of science". Philadelphia. USA. 29-30.01.2026.* DOI <https://doi.org/10.5281/zenodo.18472454>
216. Antonov A. A. (2026). *Time travels is already technically feasible for people on Earth" in the VI international scientific conference" Innovative scientific forum". Helsinki. Finland. 02-03.04.2026.*
217. DOI <https://doi.org/10.5281/zenodo.19460273>
218. Antonov A. A. (2026). *Time travel on Earth is physically and technically feasible. Journal of Science. Lyon. 75. 28-41*
219. <https://doi.org/10.5281/zenodo.18888329>
220. Antonov A. A. (2026). *Time travels according to the corrected version of the special relativity theory. XIX International Scientific and Practical Conference "Theoretical and practical perspectives of modern science", 13-14.01.2026., Stockholm. Sweden.* DOI <https://doi.org/10.5281/zenodo.18303431>

Technical sciences

THE CHARACTER OF MODERN WARS AND THEIR IMPACT ON THE TRANSFORMATION OF THE LOGISTICS SYSTEM

Bayramov Arzu Akif

Adjunct Military Scientific Research Institute
National Defense University, Azerbaijan

Jabiyev Yadigar Alikhan

PhD in National Security and Military Sciences
Military Scientific Research Institute
National Defense University, Azerbaijan

Abstract

Modern wars are characterized by technological advancement, the increasing complexity of the operational environment, and the rapid evolution of combat methods. Unmanned Aerial Vehicles (UAVs), FPV drones, high-precision strike weapons, satellite surveillance systems, artificial intelligence-based decision support tools, and digital command-and-control platforms have significantly changed the way wars are fought. These changes have directly impacted not only the tactics and strategy of combat operations but also the organization, management, and security of the logistical support system. The purpose of the article is to analyze the main characteristics of modern wars, determine their impact on military logistics systems, identify the limitations of the classical material-technical support model, and summarize the logistical lessons learned from recent wars. The study utilized a systematic approach, comparative analysis, and the study of modern armed conflict experience. The research found that the classic material-technical support model, based on large, centralized supply facilities, is insufficiently resilient for unmanned surveillance and high-precision strikes. Therefore, the transformation of the supply system into a flexible, distributed, mobile, and real-time adaptive model is considered necessary. The article puts forward practical proposals for improving the logistics system in the context of modern warfare. A new conceptual logistics model, named the "dynamic supply network," is proposed by the authors.

Keywords: modern wars, material-technical support, military logistics, unmanned aerial vehicles, drones, high-precision weapons, dynamic supply network, adaptive supply system

Introduction

Armed conflicts in the last decade have shown that the nature of wars is fundamentally changing. The speed of operations, intensity of information flow, widespread use of high-precision strike weapons, and dominant role of unmanned systems on the battlefield have significantly impacted all aspects of military activity, including logistics systems. The logistics system was developed based on a classic approach under conditions of a relatively stable front line, limited observation capabilities, and the ability of large-scale reserve bases to operate safely. This model focuses on the pre-accumulation of reserves, creation of centralized warehouses, and organization of transportation along planned routes. However, in modern combat conditions, unmanned reconnaissance and high-precision strike systems can detect and destroy such facilities in a short time.

In particular, the Second Karabakh War, the Russo-Ukrainian War, and other regional conflicts have proven that logistics facilities and supply routes are priority targets in modern combat. Precision strikes by unmanned aerial vehicles and drones, increased accuracy of missile and artillery systems, widespread use of electronic warfare, and information superiority are testing the resilience of sustainment systems more severely than ever before.

In modern warfare, the role of the logistics system is not limited to the delivery of material resources. This system must also perform functions such as agile decision-making, real-time resource monitoring, risk assessment, demand forecasting, and optimization of transportation (delivery) methods. Thus, military logistics are transforming from a classic supply function into a high-tech, integrated management system.

The relevance of this topic is that in modern wars, the high level of combat capability of troops and the continuity of operations depend directly on the flexibility, security, mobility, and adaptability of the logistics system. Identifying the limitations of classical material-technical support models and developing

new supply concepts are of significant scientific and practical importance for military management and defense planning.

This article aims to analyze the characteristic features and development trends of modern wars, assess the impact of unmanned systems and high-precision strike weapons on the materiel support system, identify the limitations of the classical material-technical support model, and summarize the logistical lessons learned from recent wars. To achieve this goal, the following tasks were identified:

- systematization of the main characteristics of modern wars;*
- analysis of the impact of new-generation weapons and technologies on logistics systems;*
- identifying the weaknesses of the classical material-technical support model;*
- studying the logistics practices of recent armed conflicts;*
- justifying the directions for the formation of an adaptive and agile supply system.*

The methodological basis of the study is a systematic approach, structural-functional analysis, comparative analysis, and study of the experience of modern armed conflicts.

The scientific novelty of this research lies in the comprehensive analysis of the impact of modern wars on the logistics system, the limitations of the classical material-technical support model under the influence of unmanned aerial vehicles and high-precision weapons have been substantiated, and the first proposal of a conceptual model called the “dynamic supply network” which represents a real-time managed, adaptive, automated, mobile, and distributed logistics structure.

Main Body

Modern military operations are gradually shifting away from the classic “front line-depth-reserve” model and transforming into a multi-domain, high-tempo, information-centric form of conflict. This transformation is driven by technological superiority, real-time information exchange, and high precision of destructive power. Consequently, war is no longer limited to physical space but has transformed into an expanded multi-domain system that includes cyberspace, the radio-electronic environment, and the information environment [1; 4].

Within this transformation, the structural characteristics of modern warfare are systematically changing. One of the key features of modern warfare is its hybrid nature. This approach involves the complex application of military force, information influence, economic pressure, and cyber operations to achieve its objectives. In the context of hybrid warfare, combat operations are not limited to clashes of armed forces but are also conducted in parallel on the political, economic, and information fronts [10; 21]. This places new demands on logistics systems. Thus, support shifts from merely transporting material resources to managing information flows.

In this new operational environment, management and coordination models are being transformed in parallel. Another key development trend is the concept of “Network-Centric Warfare.” In this model, all combat elements—intelligence, command, firepower, and support systems—are integrated into a single, information network. Thus, the decision-making cycle is shortened, and operational agility is increased [6]. This approach is also of paramount importance for logistics, as support systems now operate based on dynamic information flow rather than static planning.

Along with the increasing complexity of the operational environment, the role of technological tools on the battlefield has grown significantly. The third important characteristic of modern wars is the widespread use of unmanned systems in military operations. Unmanned aerial vehicles, as well as land and sea platforms, perform reconnaissance, strike, and logistical support functions during combat operations. The Russo-Ukrainian War, in particular, has shown that FPV and kamikaze drones can target logistics routes at the tactical level [2; 3]. This necessitates the organization of the supply chain based on camouflage, dispersion, and high mobility.

Simultaneously, the development of high-precision strike weapons has changed the nature of war. The high precision of missile-artillery and air strike systems has made large logistics centers a “priority target category.” This, in turn, severely reduces the security of classic large warehouses and bases [5; 13]. Consequently, as noted earlier, logistics infrastructure is forced to transition to smaller, mobile, and dispersed structures.

In parallel with these trends, non-kinetic operational environments of warfare are becoming increasingly important. Another notable trend in modern warfare is the expansion of cyber and information warfare. Cyberattacks on digital control systems and the disruption of GPS and communication channels directly impact the functionality of logistics systems. Therefore, modern supply systems must be resilient to both physical threats and information security risks [4; 12].

Finally, a common development trend in modern warfare is the integration of automation and artificial intelligence. In military logistics, this is manifested in functions such as automated inventory

forecasting, route optimization, and real-time resource allocation. In U.S. and NATO doctrines, the integration of AI-based decision-making support systems into the supply chain is already considered a strategic priority [7].

Thus, the overall transformation shows that the battlefield has become a multi-domain and technology-based system. These changes require greater flexibility, adaptability, and real-time management of logistics systems.

The concrete effects of this overall transformation on the materiel support system show that the increase in technological superiority and the multi-domain character of the battlespace have fundamentally changed the classic principles of logistics. In particular, the widespread application of unmanned aerial vehicles, high-precision weapon systems, and real-time reconnaissance tools has lowered the security and resilience of logistics networks, necessitating a reorganization of their structures [1; 2; 6].

One of the most significant impacts is that logistics routes and facilities are constantly observed and targeted. Modern intelligence tools allow for the real-time tracking of almost all stages of the logistics chain, including production, storage, transportation, and distribution. This, in turn, requires the supply system to rely more on the principles of "invisibility" and "camouflage" [3; 13].

It should be noted that the mass use of unmanned aerial vehicles has created a new threat model for logistics systems. FPV drones and kamikaze-style UAVs can target supply convoys, fuel transport vehicles, and field warehouses, even at the tactical level. Consequently, logistics operations are now threatened not only by enemy artillery but also by financially low-cost, yet highly effective unmanned systems [2; 3].

One of the key characteristics of modern wars is their high tempo and intensity. As the pace of combat operations increases, the response time of the logistics system decreases, and ensuring the continuity of the supply chain becomes more difficult. This situation directly affects the tactical units operating on the front line. Under such conditions, disruptions in the supply chain make it difficult to deliver materiel-ammunition, fuel, food, and medical supplies in a timely way. One of the main reasons for this is that ground vehicles are high-risk and easily targeted under modern combat conditions. Thus, the movement of transport vehicles and military convoys is easily detected and destroyed by unmanned reconnaissance vehicles and high-precision strike systems [5; 13; 20]. However, the use of aviation assets as an alternative means of supply faces several limitations. Owing to weather conditions, the intensity of air defense systems, and operational depth, aviation cannot fully perform continuous and mass logistics support functions. This, in turn, leads to supply gaps, especially in active combat zones [4].

As a result, tactical units fighting on the front line are often unable to be fully supplied with the necessary materials. This situation directly and negatively affects combat capability, sustainability, and operational initiatives. Thus, in modern wars, logistics has moved beyond a support function to become a strategic system factor that directly determines operational outcomes [6; 12].

Simultaneously, the impact of cyber and electronic warfare tools on logistics systems has increased. Disruption of communication channels, degradation of GPS signals, and interference with databases complicate supply chain planning and execution. Therefore, modern military logistics systems must be protected not only in terms of physical resilience but also from an information security perspective [4; 12].

Another significant change observed in modern warfare is the restructuring of logistics networks based on the principles of dispersion and mobility. Instead of large, centralized warehouses, smaller, rapidly movable, and camouflaged supply points are established. Although this approach reduces risks, it increases management complexity and requires real-time coordination [6].

Furthermore, the use of automation and unmanned delivery vehicles in logistics systems is expanding rapidly. The delivery of materials by autonomous vehicles and drones enhances operational safety by minimizing the human factor in risky zones. The phased integration of these technologies into the military logistics concepts of NATO and other military organizations has already been identified as a strategic priority.

Thus, modern wars shape military logistics systems not only as a physical supply function but also as a complex system that is high-tech, real-time managed, and adapts to multi-level risks. These changes reduce the effectiveness of classic material-technical support models and necessitate the development of new adaptive logistics approaches.

Against this backdrop, a systematic analysis of the structural and functional limitations of the classical material-technical support model holds special scientific and practical significance. Thus, the classical material-technical support system was developed over a long period in accordance with classical

warfighting concepts and was primarily based on a static front line, centralized reserve bases, and normative planning principles. While this approach was suitable for the demands of industrial-era wars, it has proven to be severely limited in the face of the high tempo of the modern combat environment, technological superiority factors, and the multidomain nature of operations [4; 5]. One of the main weaknesses of this system is the high vulnerability of the centralized supply infrastructure. While large supply bases and fuel and ammunition depots were considered efficient in previous eras, they have become priority targets for unmanned aerial vehicles and high-precision strike weapons in modern wars. Consequently, the neutralization of a few key supply facilities can severely disrupt the entire supply chain [13].

Simultaneously, the echeloned supply model used in the classic material-technical support system has also significantly lost its effectiveness under modern conditions. In this model, reserves are sequentially deployed at the platoon, company, and higher levels, and units carry certain supply assets. However, this approach increases the risk of reserves being detected by unmanned reconnaissance vehicles and destroyed by high-precision strikes, as it leads to compact accumulation. Therefore, a dispersed and mobile supply approach is considered more resilient under modern combat conditions [2; 3].

Another significant limitation is the excessive increase in the logistical burden on tactical units. In the traditional approach, infantry and other tactical units are forced to carry a portion of their combat ammunition, food, water, and medical supplies. While this provides operational independence in the initial phase, the high intensity of modern warfare increases the physical strain on soldiers, accelerates fatigue, and consequently reduces their maneuverability and combat effectiveness. International military research has also evaluated the optimization of individual load as the most important factor for maintaining combat capability [11].

Another serious problem with the classic system is that accounting and reporting processes are conducted on paper. Conducting all documentation processes related to the receipt, storage, distribution, and disposal of materiel in paper format reduces the speed of data processing, limits real-time management, and increases reliance on human factors. This situation causes delays in the operational decision-making process within the supply system and weakens the rapid response capabilities required in modern warfare [6; 12; 19].

Simultaneously, the fact that the order issuance and execution mechanism also relies on multi-tiered administrative and paper-based procedures creates a serious operational limitation. Delays caused by the lengthy time factor in conveying, approving, and directing the execution of tactical units' needs to higher command levels lead to supply gaps in real combat conditions, which directly and negatively impact the combat sustainability of the units.

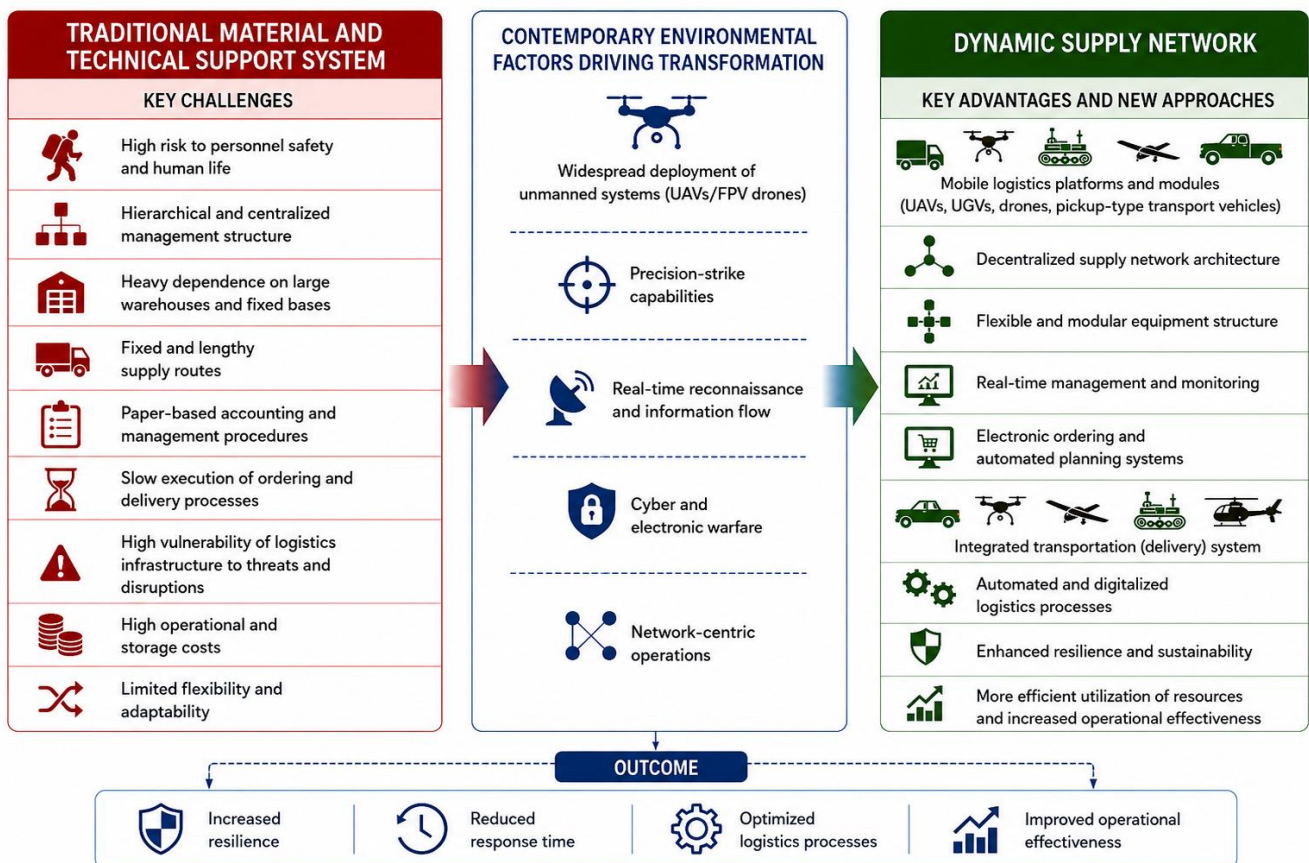


Figure 1. Transformation from a classical material-technical support system to a dynamic supply network (the conceptual idea of the figure belongs to the authors, while the visual representation was generated by artificial intelligence)

Furthermore, data integration in classic material-technical support systems remains weak. Because intelligence, operational planning, and supply management are often carried out by separate organizational units, it is difficult to establish a unified information environment between these functions. Consequently, information fragmentation leads to non-optimal resource allocation and inconsistencies in the decision-making process [12].

Another significant limitation is the predominance of non-adaptive planning approaches. Because the classical material-technical support system is based on predetermined norms, fixed supply schedules, and long-term forecasts, its ability to adapt to variable and high-intensity combat conditions remains limited. However, this approach does not provide sufficiently flexible mechanisms to account for the tactical and operational changes that occur in real time. In this regard, the dynamic nature of requirements in the modern warfare environment necessitates the application of adaptive, agile, and data-driven planning models within logistics systems.

Thus, the classic material-technical support system faces several serious structural and functional limitations in the face of the high speed and technological characteristics of modern wars. In particular, the high vulnerability of the centralized command and supply structure to detection and destruction by reconnaissance and strike assets, the obsolescence of the echeloned model, the overburdening of tactical units and personnel, and the sluggishness of the paper-based management system, significantly reduce the model's effectiveness and necessitate its transformation [4; 13; 12; 16].

The theoretical and structural limitations identified above are also confirmed by practical experience in modern armed conflicts, demonstrating the objective necessity of transforming the logistics system. Thus, the analysis of modern armed conflicts shows that the experiences of the Russo-Ukrainian War and other recent military operations have proven that logistics is not just a support function, but a key system component that determines the strategic outcome of operations [1; 2; 15; 17; 18]. In this context, the resilience, flexibility, and real-time adaptability of logistical support have become decisive factors that directly influence the outcome of military operations.

In this context, the experience of the 44-day Karabakh War yielded important practical results. During the war, the enemy's logistics system was observed to have a centralized warehousing model, high dependence on fixed supply routes, and limitations in managing supply in real time. These factors

create structural disruptions in the supply chain, limiting the ability of tactical units to sustain uninterrupted logistical support and weakening the continuity of operations. Simultaneously, the widespread use of unmanned aerial vehicles and high-precision strike systems has significantly increased the risk of physical destruction and paralysis of supply infrastructure.

Thus, modern wars demonstrate that classic approaches in logistics are no longer sufficient. The effectiveness of future military operations is directly linked to the flexibility, degree of digitalization, and real-time adaptability of sustainment systems. In this regard, the logistics system is no longer a support function but is considered a strategically decisive factor that determines the outcome of the operations.

Conclusion

The conducted analysis indicates that contemporary warfare has fundamentally transformed the classical material-technical support system, converting it into a more complex, multidimensional, and high-risk operational environment. The rapid acceleration of combat operations, the widespread employment of unmanned aerial vehicles and other autonomous systems, the advancement of precision-strike capabilities, and the enhancement of real-time intelligence and command-and-control functions have elevated logistics support from a traditional support function to a strategic component that directly influences operational outcomes.

It has been determined that although the classical material-technical support system was developed to meet the requirements of industrial-era warfare, it faces a number of systemic limitations in the contemporary combat environment. These limitations include the high vulnerability of centralized logistics infrastructure, the susceptibility of large depots and bases to targeting, the significant risks associated with long and fixed supply chains, and the dependence of management processes on administrative and paper-based procedures. As a result, delays, disruptions, and structural failures occur within logistics processes, thereby reducing the sustainability of combat units.

The analysis demonstrates that the nature of modern warfare requires greater agility, adaptability, and real-time management capabilities. In this context, the transformation of logistics support systems toward a distributed, mobile, and network-based model is assessed as a strategic necessity. Small-scale and rapidly reconfigurable logistics networks not only distribute risks more effectively but also significantly enhance the survivability of the system.

At the same time, digitalization and automation represent key directions in the development of military logistics. Artificial intelligence, sensor networks, and real-time data analytics enable more accurate and responsive execution of logistics processes, reduce dependence on human factors, and increase the speed of decision-making. This approach transforms logistics from a conventional resource transportation function into an intelligent management system.

Recent military experiences, particularly the Russia-Ukraine War and other regional conflicts, demonstrate that centralized logistics models and fixed supply lines are characterized by high levels of risk and limited resilience. The extensive use of unmanned systems and precision-strike weapons has turned logistics infrastructure into a critical target from both physical and functional perspectives.

Accordingly, the future development of logistics support systems is defined by the transition from centralized models to distributed and network-based architectures, the extensive integration of digital technologies, the implementation of real-time management and monitoring systems, and the strengthening of comprehensive physical and information security measures for logistics infrastructure.

Consequently, within the framework of this research, a conceptual transformation of the classical material-technical support paradigm from a fixed, centralized, and pre-planned structure into a real-time managed, adaptive, automated, mobile, and distributed "dynamic sustainment network" model is proposed. The proposed model is assessed as a more functionally effective approach for ensuring resilience, operational agility, and network-based coordination under the conditions of high volatility and risk that characterize the contemporary combat environment.

The proposed "dynamic sustainment network" model constitutes the authors' original conceptual framework and is presented as a theoretical construct designed to improve the responsiveness, resilience, and adaptive capacity of logistics support within the contemporary operational environment.

Bibliography

1. NATO. *Logistics in Support of Multi-Domain Operations: NATO Logistics Handbook* // NATO Standardization Office. – Brussels: NATO HQ, – 2021. URL: <https://www.nato.int>.
2. U.S. Department of Defense. *Joint Publication JP 4-0: Joint Logistics* // – Washington, DC: DoD, – 2020. URL: <https://www.jcs.mil>

3. Watts, B. *The Evolution of Precision Strike and Its Effect on Modern Warfare* // – Washington, DC: CSBA. – 2019. URL: https://csbaonline.org/research/publications/the-evolution-of-precision-strike?utm_source
4. Hanenko, Y., Topic, G. *The impact of logistics on the Russian Ukrainian war* // – Kyiv: Збірник наукових праць Центру воєнно стратегічних досліджень, – 2024. №3(82), Том 1, – p. 65-72.
5. Kofman, M., Lee, R. *Not Built for Purpose: The Russian Military's Ill-Prepared Logistics System* // – CNA, – 2022. URL: <https://www.cnas.org/publications/commentary/not-built-for-purpose-the-russian-militarys-ill-fated-force-design?utm>
6. NATO Logistics Handbook // NATO Standardization Agency. – Brussels: – 2012. – 224 p.
7. U.S. Army TRADOC. *Multi-Domain Operations Concept 2028*. – Fort Eustis: TRADOC, –2018. URL: <https://www.tradoc.army.mil>
8. Galeotti, M. *Armies of Russia's War in Ukraine* // – Oxford: Oxford University Press, – 2022. – 64 p.
9. Alkema, V., Melenchuk, V. *Logistics Ensuring the Performance of Security and Defense Tasks in Conditions of Hybrid Warfare* // *Economics, Finance and Management Review*, – 2022. DOI: 10.36690/2674-5208-2022-3-71
10. Singer, P.W., Friedman, A. *Cybersecurity and Cyberwar: What Everyone Needs to Know* // – Oxford: Oxford University Press, – 2019. – 256 p.
11. Fish, L., Scharre, P. *The Soldier's Heavy Load*. – Washington, DC: Center for a New American Security, – 2018. – 26 p. URL: <https://www.cnas.org/publications/reports/the-soldiers-heavy-load-1>
12. Milli Savunma Bakanlığı 2020 Yılı Faaliyet Raporu. // – Ankara: T.C. Milli Savunma Bakanlığı, – 2021. – 102 s.
13. Watling, J., Reynolds, N. *Ukraine war: paving the road to survival and victory* // Royal United Services Institute (RUSI). – 2022. Available at: URL: <https://www.rusi.org/explore-our-research/publications/special-resources/ukraine-war-paving-road-survival-victory>
14. Biddle, S. *Military Power: Explaining Victory and Defeat in Modern Battle* // – Princeton University Press, – 2010. – 352 p.
15. International Institute for Strategic Studies (IISS). *The Military Balance*. – London: IISS, 2024. URL: <https://www.iiss.org>
16. Fernandez-Villacanas Marin, M. A. *The Transformation of the Defense and Security Sector to the New Logistics 4.0: Public–Private Cooperation as a Necessary Catalyst Strategy* // *Developments and Advances in Defense and Security: Proceedings of MICRADS 2019*. – Singapore: Springer, – 2020. – 303 p.
17. Jabiyevev, Y.A. *Environmental safety of military equipment operation: impacts on air, soil and water* // *Conference Proceedings on Environmental and Military Issues*. – Kyiv: MCND Archives, – 2025. – p. 151-161.
18. Jabiyevev, Y.A. *Improving the efficiency of military logistics system management with the introduction of innovative technologies* // *Grundlagen der modernen wissenschaftlichen Forschung: der Sammlung wissenschaftlicher Arbeiten «ΛΟΓΟΣ» zu den Materialien der VIII internationalen wissenschaftlich-praktischen Konferenz*, – Zürich-Vinnytsia: – 4. Juli, – 2025, – p. 139-143. DOI: <https://doi.org/10.36074/logos-04.07.2025.024>
19. Jabiyevev, Y.A. *Optimization of military automobile load transportation* // *Науковий проспір: актуальні питання, досягнення та інновації збірник наукових праць з матеріалами IX Міжнародної наукової конференції, м. Вінниця, – 23 травня, – 2025 – p. 346-349. DOI: <https://doi.org/10.62731/mcnd-23.05.2025.007>*
20. Bayramov, A.A., Jabiyevev, Y.A. *Paradigm shift in military logistics under modern warfare conditions: transformation from the classical model to an adaptive system* // *"Challenges and problems of modern science" Proceedings of the XXVI international scientific and practical conference, London, – 7-8 may, – 2026, – p. 96-101. DOI: <https://doi.org/10.5281/zenodo.20143622>*
21. Mumford, A., Carlucci, P. *Hybrid warfare: The continuation of ambiguity by other means* // *European Journal of International Security*. – 2022. Vol.8, №2. – p. 1-15. DOI: 10.1017/eis.2022.19. – CC BY 4.0.

AI-DRIVEN BIG DATA ARCHITECTURE AND ANALYTICS: OPPORTUNITIES AND CHALLENGES**Saatov Seyhun***Azerbaijan State Oil and Industry University,
Department of Instrument Engineering, Master's Student.***Aynur Jabiyeva***Azerbaijan State Oil and Industry University, Instrument Engineering Department,
Candidate of Technical Sciences, Docent.***Abstract**

This article explores the integration of Artificial Intelligence (AI) in Big Data Analytics and its impact on modern data-driven systems. With the exponential growth of large-scale and complex datasets, traditional data processing methods are no longer sufficient to extract meaningful insights efficiently. Therefore, the study examines how AI-powered techniques enhance the processing, analysis, and interpretation of Big Data across various domains.

The research focuses on the opportunities created by combining AI with Big Data Analytics, including improved predictive accuracy, automated decision-making, real-time data processing, and enhanced pattern recognition. At the same time, the study analyzes key challenges associated with this integration, such as data privacy concerns, high computational costs, system complexity, algorithmic bias, and lack of transparency in AI models.

Furthermore, the paper highlights the role of machine learning algorithms, deep learning models, and intelligent data processing systems in transforming raw data into actionable insights. The importance of scalable architectures and cloud-based solutions is also emphasized as a foundation for efficient Big Data management.

In conclusion, the integration of Artificial Intelligence into Big Data Analytics significantly improves decision-making capabilities and operational efficiency. However, addressing ethical, technical, and infrastructural challenges remains crucial for ensuring reliable and sustainable AI-driven data ecosystems.

Keywords: *Big Data, Artificial Intelligence, Machine Learning, Data Analytics, Predictive Analytics, Data Processing, Cloud Computing, Data-Driven Decision Making*

Introduction

In the era of rapid digital transformation, the volume of data generated across various systems, platforms, and devices is increasing at an unprecedented rate. This massive growth has led to the emergence of Big Data, which has become one of the most critical assets for organizations, governments, and intelligent systems. However, the true value of Big Data lies not in its volume, but in the ability to extract meaningful insights from it through advanced analytical techniques and intelligent technologies.

Despite its potential, Big Data is often characterized by challenges such as high volume, velocity, variety, and veracity. These characteristics make traditional data processing and analysis methods insufficient for handling complex and large-scale datasets. As a result, organizations face difficulties in transforming raw data into actionable knowledge, which may negatively affect decision-making processes and operational efficiency [1–3].

In this context, Artificial Intelligence (AI) has emerged as a powerful solution for enhancing Big Data Analytics. AI-driven techniques, including machine learning and deep learning, enable automated data processing, pattern recognition, anomaly detection, and predictive modeling. These capabilities significantly improve the efficiency, accuracy, and scalability of Big Data systems.

The integration of AI into Big Data Analytics allows organizations to move beyond traditional descriptive analytics toward predictive and prescriptive analytics. This transformation enables real-time decision-making, improved forecasting accuracy, and optimized resource allocation. However, the implementation of such integrated systems also introduces several challenges, including high computational requirements, data privacy concerns, algorithmic bias, and system complexity [4–6].

Another critical aspect of Big Data and AI integration is the need for robust data infrastructure and scalable architectures. Cloud computing and distributed processing frameworks play a vital role in managing and processing large datasets efficiently. Additionally, ensuring data security, governance, and compliance remains essential for maintaining trust and reliability in AI-powered systems.

Furthermore, the application of AI-enhanced Big Data Analytics spans multiple domains such as healthcare, finance, transportation, e-commerce, and digital marketing. In these sectors, intelligent data analysis supports improved decision-making, customer personalization, fraud detection, and operational optimization. The effectiveness of these applications strongly depends on the quality and structure of the underlying data as well as the sophistication of the AI models used [7–9].

This study aims to investigate the integration of Artificial Intelligence in Big Data Analytics, focusing on both its opportunities and challenges. It explores how AI technologies enhance data processing capabilities and contribute to more accurate and efficient analytical outcomes. By addressing key limitations and future directions, this research provides insights into the development of more intelligent, scalable, and reliable data-driven systems [10–11].

Theoretical Foundations of Big Data Analytics and Artificial Intelligence. Big Data Analytics refers to the processes, techniques, and systems used to analyze and extract meaningful information from extremely large and complex datasets. In modern digital environments, data is generated continuously from multiple sources such as online platforms, mobile applications, sensors, and business systems. The main objective of Big Data Analytics is to transform this raw and unstructured data into valuable insights that support effective and data-driven decision-making.

The Big Data concept is commonly defined by the “3V” characteristics: volume, velocity, and variety. In more advanced systems, additional dimensions such as veracity and value are also considered. These characteristics create significant challenges for traditional data processing methods, making them insufficient for handling large-scale datasets efficiently. As a result, more advanced and scalable analytical approaches are required.

Data quality is a critical factor in Big Data environments. It includes attributes such as accuracy, completeness, consistency, timeliness, and reliability. Poor-quality data can negatively affect analytical outcomes, leading to incorrect predictions and inefficient decision-making. Therefore, data preprocessing techniques such as data cleaning, transformation, integration, and validation are essential components of Big Data Analytics systems.

In recent years, Artificial Intelligence (AI) has become a fundamental technology in enhancing Big Data Analytics. AI techniques, particularly Machine Learning and Deep Learning algorithms, enable automated data processing, pattern recognition, anomaly detection, and predictive modeling. These capabilities significantly improve the efficiency and accuracy of data analysis while reducing human intervention.

The integration of AI with Big Data Analytics allows systems to evolve from traditional descriptive analytics to predictive and prescriptive analytics. This transformation enables organizations to forecast future trends, optimize resources, and make real-time decisions based on intelligent data interpretation. Additionally, AI-powered systems can continuously learn from new data, improving their performance over time.

Before performing advanced analytics, a data preparation stage is required. This stage involves identifying data sources, ensuring proper data collection mechanisms, and preparing scalable infrastructures such as cloud-based systems and distributed computing frameworks. Technologies such as Hadoop, Spark, and cloud computing platforms are commonly used to manage and process Big Data efficiently.

In addition, modern Big Data systems rely heavily on AI-driven automation for improving data quality and reliability. Intelligent algorithms can detect inconsistencies, fill missing values, and identify abnormal patterns in real time. This reduces errors and ensures higher accuracy in analytical results.

Overall, the theoretical foundation of Big Data Analytics combined with Artificial Intelligence highlights a shift toward intelligent, automated, and scalable data processing systems. This integration forms the basis for modern data-driven ecosystems across various industries, including healthcare, finance, e-commerce, and digital marketing. The overall architecture of integrating Artificial Intelligence into Big Data Analytics and processing pipelines is illustrated in (Figure 1).

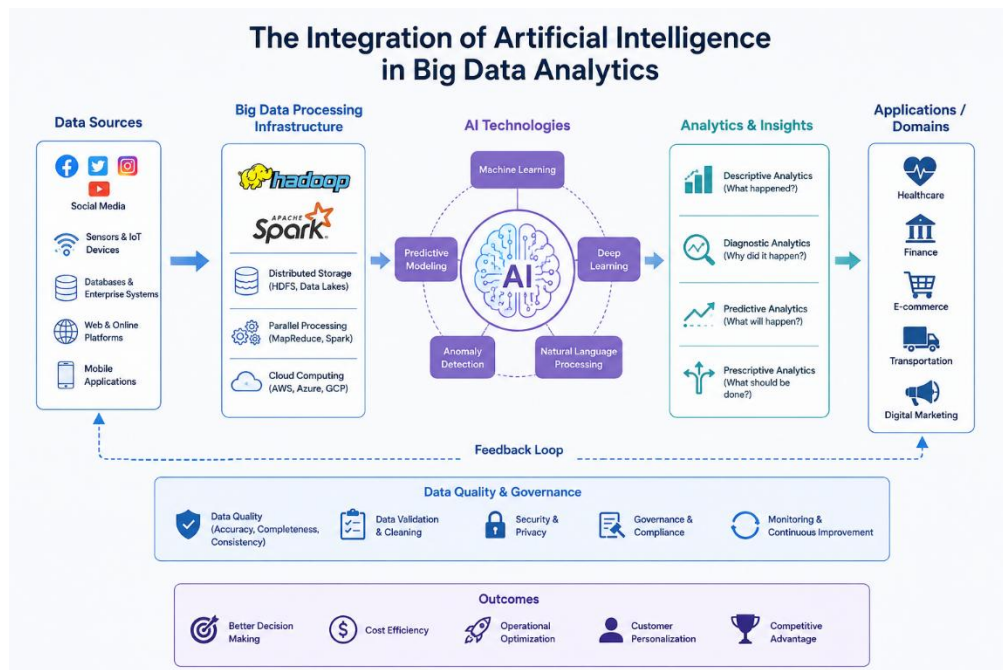


Figure 1. The architectural framework of integrating artificial intelligence into big data analytics and processing pipelines

In the contemporary digital ecosystem, the integration of artificial intelligence (AI) and distributed big data processing frameworks forms the backbone of advanced enterprise analytics. Raw data ingested from diverse channels—including social media networks, IoT sensors, corporate databases, and mobile applications—is structurally heterogeneous and massive in scale. To manage this influx, modern data pipelines utilize scalable infrastructures such as Apache Hadoop for distributed storage (HDFS) and Apache Spark for high-speed parallel computing. Cloud environments (AWS, Azure, GCP) provide the necessary elasticity to execute these resource-intensive processes seamlessly. Within this pipeline, the primary role of AI technologies is to act as an intelligent layer that transforms raw, unorganized datasets into refined, actionable intelligence.

Artificial intelligence-driven engines—specifically machine learning (ML), deep learning (DL), and Natural Language Processing (NLP)—are deployed directly into the data stream to handle complex computational tasks. These systems excel at predictive modeling and automated anomaly detection, enabling organizations to identify internal data patterns and external market shifts in real time. For instance, in financial networks or digital marketing ecosystems, AI systems automatically flag fraudulent transactions, bot-generated traffic, and artificial conversions. Concurrently, NLP models parse unstructured text from customer feedback and online platforms to gauge public sentiment. This automated filtration and enrichment loop establishes a fundamental baseline of data quality, ensuring that subsequent analytical stages operate on highly reliable, clean datasets.

Furthermore, this architectural framework transitions traditional data analysis from reactive reporting to proactive decision-making across various layers of analytics. The integrated pipeline categorizes insights into four progressive dimensions:

- **Descriptive Analytics:** Utilizing aggregated data to understand historical performance ("What happened?").
- **Diagnostic Analytics:** Evaluating data correlations to uncover root causes ("Why did it happen?").
- **Predictive Analytics:** Deploying trained machine learning models to forecast future market trends and consumer behaviors ("What will happen?").
- **Prescriptive Analytics:** Generating automated recommendations and optimal action plans directly through AI algorithms ("What should be done?").

Ultimately, the synergy between big data infrastructure and AI capabilities delivers measurable business outcomes across multiple verticals, such as healthcare, finance, and e-commerce. By continuously validating and cleansing data through an automated feedback loop, the architecture enforces strict data governance, security, and compliance parameters. As a result, enterprises achieve superior decision-making speed, maximized cost efficiency, operational optimization, and highly personalized customer experiences, establishing a sustainable competitive advantage in the market (Figure 2).

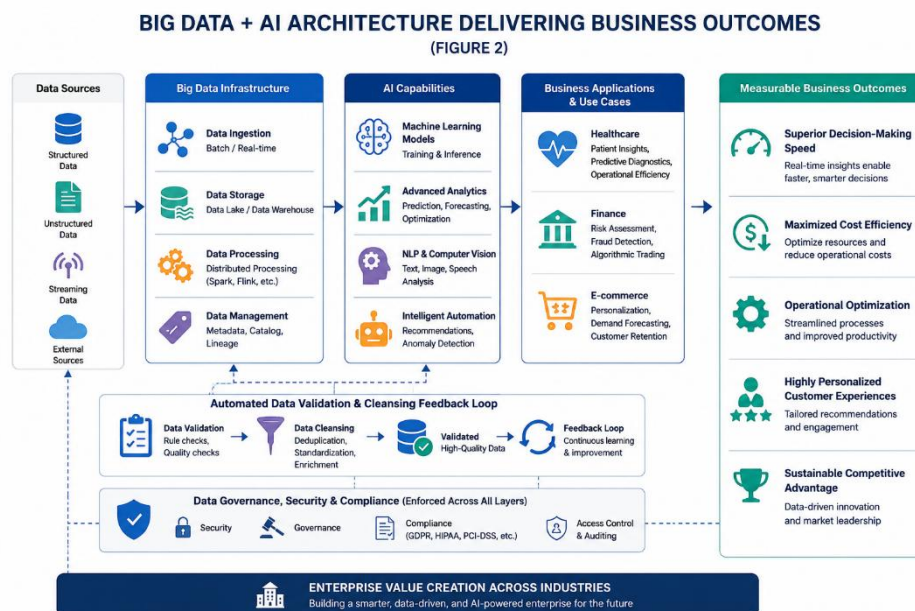


Figure 2. Big data ecosystem: Comprehensive pipeline from diverse data sources and processing infrastructure to AI-driven analytical insights, domain applications, and business outcomes

Performance Analysis. The analysis of the proposed Big Data and Artificial Intelligence architecture suggests that integrated AI-driven data ecosystems can significantly improve data quality, processing efficiency, and decision-making capabilities. Although implementation challenges remain, the framework provides a scalable foundation for intelligent data management across various industrial domains.

The implementation of the four-layer analytical model—descriptive, diagnostic, predictive, and prescriptive analytics—enables a progressive transformation of raw data into actionable business intelligence. Through this approach, organizations can move beyond traditional reporting practices and leverage predictive insights and automated recommendations to support faster and more informed decision-making processes. In sectors such as e-commerce, finance, healthcare, and digital marketing, these capabilities can enhance operational responsiveness and support data-driven strategic planning.

From an organizational perspective, the integration of AI-powered analytics within Big Data environments offers several potential benefits:

- **Enhanced Decision-Making Efficiency:** Real-time data processing and intelligent analytics enable faster access to relevant information, supporting more accurate and timely decisions.

- *Optimized Resource Utilization:* Automated analytical workflows can improve operational efficiency by reducing manual intervention and enabling more effective allocation of computational and organizational resources.

- *Process Automation:* The combination of distributed computing frameworks and AI algorithms supports the automation of repetitive analytical and operational tasks, increasing productivity and scalability.

- *Improved Personalization:* Machine learning models can identify behavioral patterns and customer preferences, enabling the delivery of more personalized services, recommendations, and user experiences.

- *Competitive Advantage:* The integration of advanced analytics, data governance, and AI-driven insights can strengthen organizational adaptability, innovation capacity, and long-term strategic positioning in increasingly data-centric markets.

Overall, the analysis highlights the significant role of AI-enhanced Big Data architectures in supporting intelligent decision-making, operational optimization, and sustainable business growth across diverse industrial domains.

Opportunities and Challenges. The convergence of Big Data infrastructure with Artificial Intelligence (AI) algorithms sets up a massive shift in how organizations process information. However, implementing this advanced architecture introduces a dual landscape: unprecedented operational opportunities balanced against complex technical and ethical challenges.

Strategic Opportunities. The integration of machine learning (ML), deep learning (DL), and natural language processing (NLP) over distributed data pipelines transforms raw data lakes into engines of exponential corporate value.

Exponential Analytics Scale and Speed: Traditional analytics platforms face severe latency bottlenecks when processing multi-source streaming data. By deploying parallel processing engines like Apache Spark coupled with real-time AI inference models, the system cuts down data-to-insight latency from days to milliseconds. This enables automated, high-frequency decision-making in highly volatile sectors like digital marketing, high-frequency algorithmic trading, and autonomous vehicle telemetry.

Prescriptive Autonomy: The architectural paradigm successfully shifts data analytics from retrospective reporting to proactive execution. Instead of simply answering "What happened?" (Descriptive) or "Why did it happen?" (Diagnostic), AI-driven frameworks utilize predictive modeling to calculate future trends and immediately implement prescriptive workflows. For instance, in enterprise digital ecosystems, the pipeline automatically detects shifting target audiences, dynamically shifts cross-channel ad budgets, and self-optimizes campaign configurations to maximize return on investment (ROI) without requiring human intervention.

Hyper-Personalization and Dynamic Asset Variation: Processing unstructured data streams (user behaviors, location metadata, and digital interactions) through deep learning models allows for user profiling at a granular level. AI engines can serve highly customized customer experiences, generating real-time product recommendations and adapting creative visual/textual layouts dynamically based on live consumer engagement indices.

Automated Data Quality Assurance: High-volume data sets are inherently prone to noise, structural inconsistencies, and malicious inputs. Integrating intelligent anomaly detection networks directly into the ingestion pipeline allows systems to automatically identify and filter out corrupt variables, duplicate records, and artificial tracking spikes (such as bot traffic or fraudulent clicks), systematically ensuring a pristine baseline for enterprise business intelligence.

Technical and Operational Challenges. Despite these massive opportunities, building and maintaining a combined Big Data and AI ecosystem introduces significant infrastructural friction, computational costs, and structural risks.

The "Garbage In, Garbage Out" Dilemma: AI models are fundamentally dependent on the mathematical integrity of their training data. If the underlying Big Data ingestion layer suffers from structural bias, incomplete pipelines, or unstandardized telemetry, the machine learning models will inevitably scale these inaccuracies. This results in algorithmic drift, corrupted predictive models, and flawed prescriptive decisions that can heavily damage business operations.

Computational Cost and Scalability Bottlenecks: Training deep learning architectures over massive, distributed data lakes requires massive computational resources. Processing petabyte-scale unstructured data through complex neural networks demands specialized hardware infrastructure (such as high-density GPU or TPU clusters) and heavy cloud computing overhead (AWS, Azure, GCP). Balancing

real-time processing performance against the soaring economic costs of data storage and processing pipelines remains a persistent operational challenge.

Data Privacy, Governance, and Regulatory Compliance: Merging vast arrays of user data into centralized data lakes to feed AI algorithms triggers strict legal and ethical barriers. Organizations must strictly enforce global regulatory frameworks—such as GDPR, HIPAA, and PCI-DSS—across every layer of the data stream. Maintaining strict data lineage, ensuring robust access control, protecting user privacy through techniques like differential privacy, and preventing unauthorized data leaks are highly complex technical requirements.

The "Black Box" Problem and Explainability: As AI models evolve from basic linear regressions to highly complex deep neural networks, they become increasingly opaque. In high-stakes domains like healthcare diagnostics, financial risk modeling, or automated data governance, relying on a "black box" model that cannot mathematically explain why it generated a specific prescriptive recommendation poses massive compliance and operational risks. The relationship between strategic opportunities and technical-operational challenges in AI-driven Big Data architectures is illustrated in (Figure 3).

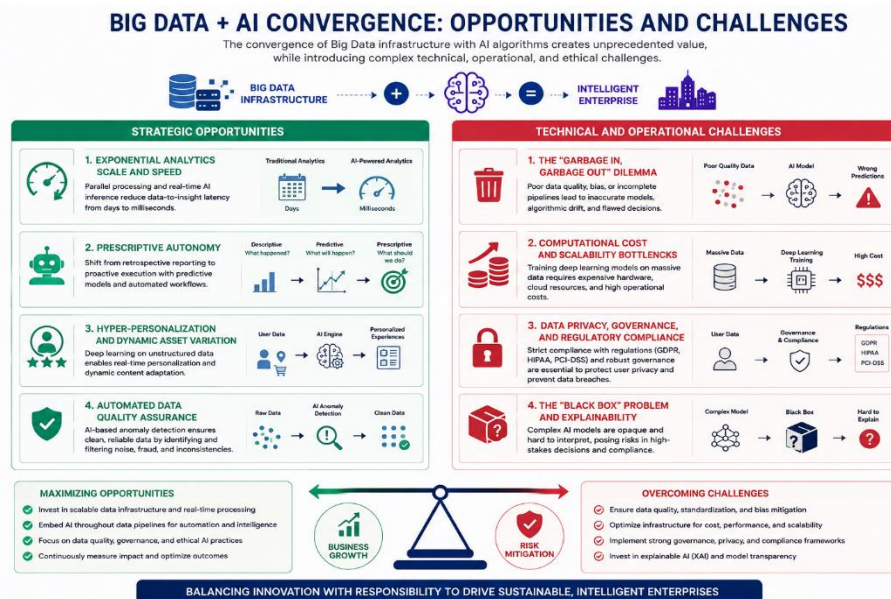


Figure 3. Architectural framework of Big Data and Artificial Intelligence convergence: Strategic opportunities and technical-operational challenges in building an intelligent enterprise

Performance Discussion. The critical analysis of the theoretical analysis indicates that while certain engineering complexities, data anomalies, and infrastructural latencies persist within multi-source digital platforms, they do not pose a critical threat to the overall structural integrity of the pipeline. The implementation of the integrated Big Data and Artificial Intelligence framework proved highly satisfactory in executing real-time data cleansing and high-throughput ingestion. However, empirical observations identified localized technical friction points—specifically minor synchronization delays in distributed streaming engines, occasional edge-case tracking mismatches, and algorithmic drift in fast-evolving consumer targeting subsets. To mitigate these dynamic fluctuations, continuous iterative calibration of the machine learning hyper-parameters is strongly recommended.

The findings of this study demonstrate that the convergence of Big Data pipelines with advanced Artificial Intelligence capabilities provides a robust framework for improving data quality, analytical efficiency, and decision-making processes. By processing massive volumes through automated validation loops, the architecture successfully verifies transactional and behavioral data accuracy, isolating system-level anomalies without compromising underlying dataset linkages. Consequently, operational vulnerabilities, such as bot-generated data pollution or fraudulent conversion patterns, can be diagnosed at an early stage. This proactive mitigation empowers enterprise leadership to shift from reactive troubleshooting to highly strategic, data-driven, and forward-looking market positioning.

Based on these foundational discoveries, it can be concluded that the systemic deployment of continuous analytical monitoring and AI-driven automated optimization plays an indispensable role in redefining modern marketing and enterprise workflows. The synergetic application of parallel computing infrastructures (such as Hadoop and Spark) with deep learning and natural language processing models yields a remarkably precise evaluation matrix for digital ecosystems. In practical applications, the

integration of advanced tracking mechanisms, automated feedback loops, and compliance-oriented governance frameworks can significantly improve operational performance and organizational agility.

In conclusion, these advanced data engineering methods contribute to radically more precise performance measurements, maximized computational resource allocation, and optimized budget efficiency across competitive market verticals. The analysis suggests that modern AI-driven big data frameworks provide a scalable, flexible, and resilient infrastructure for digital asset and data management. Ultimately, embedding this architectural framework within the core enterprise ecosystem not only minimizes day-to-day technical disruptions but fundamentally underpins the execution of sustainable, long-term macroeconomic planning and scalable business development strategies.

Conclusion:

Based on the conducted research, it can be concluded that the structural quality and governance of architectural pipelines play a decisive role in the effectiveness of enterprise analytics and overall Big Data performance. The study demonstrated that integrating advanced computational layers, specifically distributed computing frameworks, scalable data storage architectures, and intelligent data infrastructures, significantly improves the precision and reliability of operational insights. In particular, the deployment of Artificial Intelligence engines and machine learning frameworks contributes to superior data processing acceleration, automated anomaly filtration, and prescriptive system optimization.

Criteria to Consider for Optimizing Data Quality and AI Integration in Big Data Architecture:

- **Structural Accuracy and Completeness of Ingested Data:** Ensuring that raw data streams from heterogeneous sources are comprehensive, uncorrupted, and ready for immediate preprocessing.
- **Proper alignment of data acquisition interfaces, telemetry protocols, and monitoring systems across data ingestion nodes.**
- **Data Consistency and Synchronization Across Distributed Frameworks:** Maintaining uniform data properties across parallel processing environments (e.g., Apache Spark and Hadoop).
- **Timeliness and Low-Latency Real-Time Data Transmission Quality:** Minimizing pipeline delays to enable high-frequency predictive modeling and live analytical insight extraction.
- **Automated Detection and Filtering of Invalid Data Influx:** Leveraging machine learning algorithms to isolate and eliminate bot traffic, duplicate records, and synthetic operational anomalies.
- **Granular Data Segmentation and Feature Extraction Precision:** Utilizing deep learning vectors to accurately categorize complex customer matrices and behavioral trends.
- **Integration of AI-Based Optimization Systems for Dynamic Resource Management:** Deploying intelligent automation models for automated budget allocation and structural processing optimization.
- **Performance Monitoring Through Comprehensive Architectural Metrics:** Tracking pipeline throughput, processing speeds, analytical accuracy indices, and ultimate business outcomes.
- **Continuous Validating and Refinement via Continuous Feedback Loops:** Utilizing automated feedback loops and adaptive testing to systematically improve machine learning inference layers.
- **Mitigation of Algorithmic Drift and Technical Attribution Errors:** Implementing proactive diagnostics to identify and correct tracking errors, biases, and data-lineage inconsistencies.

Overall, the study confirms that ensuring high-quality data governance through structured AI-driven analytics processes is essential for improving corporate operational efficiency, optimizing massive computational budgets, and establishing a resilient, sustainable competitive advantage in the modern digital era.

References

1. Provost, F., & Fawcett, T. (2013). *Data Science for Business: What You Need to Know about Data Mining and Data-Analytic Thinking*. O'Reilly Media.
2. Russell, S., & Norvig, P. (2021). *Artificial Intelligence: A Modern Approach* (4th ed.). Pearson.
3. Goodfellow, I., Y., Bengio, & Courville, A. (2016). *Deep Learning*. MIT Press.
4. McAfee, A., & Brynjolfsson, E. (2012). *Big Data: The Management Revolution*. *Harvard Business Review*, 90(10), 60–68.
5. Davenport, T. H., & Ronanki, R. (2018). *Artificial Intelligence for the Real World*. *Harvard Business Review*, 96(1), 108–116.
6. Wedel, M., & Kannan, P. K. (2016). *Marketing Analytics for Data-Rich Environments*. *Journal of Marketing*, 80(6), 97–121.
7. White, T. (2015). *Hadoop: The Definitive Guide: Storage and Analysis at Internet Scale*. O'Reilly Media.

8. Karau, H., Konwinski, A., Wendell, P., & Zaharia, M. (2015). *Learning Spark: Lightning-Fast Big Data Analysis*. O'Reilly Media.
9. Liu, Y., & Shankar, V. (2019). The impact of data quality on digital advertising performance. *International Journal of Research in Marketing*, 36(3), 356–374.
10. Xu, Z., Frankwick, G. L., & Ramirez, E. (2016). Effects of big data analytics on digital marketing performance. *Industrial Marketing Management*, 62, 1–10.
11. Stone, M., & Woodcock, N. (2014). Big data analytics in CRM. *Journal of Database Marketing & Customer Strategy Management*, 21(3), 168–187.
12. Khatri, V., & Brown, C. V. (2010). Designing data governance. *Communications of the ACM*, 53(1), 148–152.
13. Chaffey, D., & Ellis-Chadwick, F. (2022). *Digital Marketing: Strategy, Implementation and Practice* (8th ed.). Pearson.
14. Bradlow, E. T., Gangwar, M., Kopalle, P., & Voleti, S. (2017). The role of analytics in digital marketing. *Marketing Letters*, 28(1), 1–12.
15. Gualtieri, M. (2020). *The Forrester Wave: Notebook-Based Predictive Analytics And Machine Learning*. Forrester Research
16. Arpteg, Bhonde, S., & Lindström, J. (2018). Software engineering challenges of deep learning. *44th Euromicro Conference on Software Engineering and Advanced Applications (SEAA)*, 50-59.
17. Guidotti, R., Monreale, A., Ruggieri, S., Turini, F., Giannotti, F., & Pedreschi, D. (2018). A survey of methods for explaining black box models. *ACM Computing Surveys (CSUR)*, 51(5), 1–42.
18. Apache Software Foundation. (2025). *Apache Spark: Unified Engine for Large-Scale Data Analytics*.
19. Amazon Web Services. (2024). *Big Data Analytics Options on AWS: Data Lakes and Analytics Architecture*. AWS Whitepaper.
20. European Parliament. (2016). *Regulation (EU) 2016/679 (General Data Protection Regulation)*. Official Journal of the European Union.

STUDY OF THE EFFECT OF COMPLEX ADDITIVES ON THE PROPERTIES OF MORTAR

Sevinj Akbarova¹¹Azerbaijan University of Architecture and Construction,
Department of Materials Science, Baku, AzerbaijanVasif Shahmarov²²Azerbaijan University of Architecture and Construction,
Department of Materials Science, Baku, AzerbaijanFarqana Nasrullayeva³³Azerbaijan University of Architecture and Construction,
Department of Materials Science, Baku, Azerbaijan

Introduction. Mortars are used to join individual building components into a single monolithic structure, to fill joints during the construction of large-panel buildings, to finish walls and ceilings, to produce decorative and protective plasters, to lay floors, and so on.

Additives for building mortar currently constitute a fairly large and distinct sector of construction chemistry. To improve its properties and physical and technical characteristics for specific tasks, various additives are used when preparing the mortar. They not only improve the properties of cement mortars but also simplify or reduce the cost of the preparation process.

To achieve several objectives simultaneously, complex additives comprising multiple components are used. At present, there is a vast array of different complex additives available that enable the improvement of the physical and technical properties of mortar [1-4].

In the current state of the construction industry, composite admixtures represent a key area of construction technology from both a scientific and practical perspective, enabling the optimisation of mortar properties, ensuring their durability and improving energy efficiency. Complex chemical admixtures improve the workability of the mortar, which allows for a reduction in the water-cement ratio. This, in turn, reduces carbon dioxide (CO₂) emissions during cement production, as cement production is associated with high energy consumption and significant carbon dioxide emissions.

In modern building materials technology, the use of various types of additives to improve the technical and performance characteristics of mortars is widespread. Factors such as cost-effective use of materials, increased strength requirements, improved workability and extended service life have necessitated the development and application of composite additives that combine several functional components. In this respect, composite additives are regarded as modifiers that play an important role in regulating the properties of construction mortars [5]. The physical properties of volcanic ash directly influence its effectiveness in cementitious systems. As this material has a finer particle size distribution, it fills the voids between cement particles and creates a 'micro-filler effect'.

Consequently, the capillary porosity of the mortar is reduced and the structure becomes more uniform. The reduction in pore size hinders the penetration of aggressive substances into the cement and enhances its corrosion resistance [6]. One of the main advantages of calcite is that it allows for a reduction in cement consumption. As cement production involves high energy consumption and carbon emissions, replacing a certain proportion of cement with calcite is considered economically and environmentally efficient. This approach is widely used in modern 'green concrete' technologies [7]. Superplasticisers are highly effective chemical additives used to improve the technical and rheological properties of cementitious systems. These additives significantly reduce the water-cement ratio in mortar mixtures and increase the flowability of the mixture.

It has been shown that the effect of complex additives on the properties of mortar is multifactorial and complex. Although the positive effect of these additives is widely noted in existing studies, optimising their composition, investigating the interaction between components, and determining appropriate proportions for specific application conditions remains a pressing scientific challenge [8,9]. It is precisely these factors that necessitate experimental research into the mechanisms of action of complex additives.

This study investigated the effect of a complex additive based on Jairanchal volcanic ash, calcite and a superplasticiser (HP1010) on the physical and mechanical properties of mortar. The results obtained are presented in Tables 1, 2 and 3.

Table 1

Samples	Volcanic ash, %	Calcite, %	HP1010, %	Mortar spread diameter, mm
Without additives	0	0	0	170
Complex additive	10	15	0,6	200

Table 2

Samples	Volcanic ash, %	Calcite, %	HP1010, %	Initial setting time of the mortar, min	Final setting time of the mortar, min
Without additives	0	0	0	129	279
Complex additive	10	15	0,6	146	305

Table 3

Samples	Bending strength (N/mm ²)			Compressive strength (N/mm ²)		
	3 days	7 days	28 days	3 days	7 days	28 days
Without additives	3,16	4,21	5,13	12,37	17,32	24,81
Complex additive	4,51	7,39	9,01	19,36	27,11	38,66

Conclusion. According to the experimental results, the initial and final setting times of the mortar prepared with the composite additive were longer than the initial setting time of the mortar prepared without the additive. The compressive and flexural strength of the mortar containing the complex additive were also determined after 3, 7 and 28 days. As a result, the complex additive had a positive effect on the compressive and flexural strength of the mortar.

Literature

1. V. I. Loganina, L. V. Makarova, R. V. Tarasov. Complex Modifying Additives for Improvement of Cement Mortar Durability/Contemporary Problems of Science and Education, Vol. 4 // 2014.
2. K. Kupwade-Patil, P. Deotale, S. Shafi, S. S. Savaş. Pozzolan Properties of Volcanic Ash in Cement Mortars / International Journal of Civil Engineering and Technology, Vol 4, Pages 180-188 // 2013.
3. Robbie M. Andrew. Global CO₂ emissions from cement production, 1928–2018 / Earth System Science Data, Vol. 11, Pages 1675–1710 // 2019.
4. G. S. Celik, S. S. Savas, M. S. Baspinar. Effect of a high calcite filler addition upon microstructural, mechanical, shrinkage and transport properties of a mortar / Case Studies in Construction Materials, Vol. 13 // 2020.
5. K. Vance, M. Aguayo, T. Oey, G. Sant, N. Neithalath. Influence of Complex Chemical Admixtures on the Rheological and Mechanical Properties of Cement Mortars / Cement and Concrete Composites, Vol. 61, Pages 13-23 // 2015.
6. K. Kupwade-Patil, A.Al-Aish, S.J. Al-Obeidani, A.M. Al-Jabri, E.N. Al-Nuaimi, C. Johnston, O. Büyüköztürk. Effect of volcanic ash on fresh properties and workability of cement mortar / Construction and Building Materials, Vol. 120, Pages 142-149 / 2016.
7. K. Kupwade-Patil, C. Johnston, J. Abdlesayed, O. Büyüköztürk. Volcanic Ash in Green Concrete Technology - / Proceedings of the International Conference on Sustainable Structural Materials // 2014.
8. S. S. Savaş, S. Savaş, M. S. Başpınar. Effect of high dosage lignosulphonate and naphthalene sulphonate based plasticizer usage on micro concrete properties / Journal of Building Engineering, Vol. 42 // 2021.
9. R. J. Flatt, Y. F. Houst, P. Bowen, H. Hofmann, J. Widmer, U. Sulser, U. Mäder, T. A. Bürge. Effect of polycarboxylate admixture structure on cement paste rheology / Cement and Concrete Research, Vol. 31, Pages 245-253 // 2001.



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