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HUMANİTAR VƏ İCTİMAİ ELMLƏR

HUMANITIES AND SOCIAL SCIENCES

Child's Language Development

Mariam Koberidze[1*], and Tinatin Mshvidobadze[2]

Abstract. *This research paper examines the psycholinguistic aspects and cognitive foundations of child language development, the causes of language development delays, and potential solutions to this issue. Utilizing descriptive, historical-comparative, and critical analysis methods, the study analyzes contemporary theories regarding child language development based on the latest scientific literature. The research demonstrates that the stages of language development in children up to six years of age—specifically the pre-speech, one-word, two-word, and "telegraphic style" stages—correspond sequentially to phonemic, morphological, syntactic, and pragmatic aspects. The article concludes that all children, regardless of their linguistic background, acquire speech habits, phonemic units, and phonological values in the same sequence. Tools for assessing language development in preschool-aged children must vary across languages, as language development disorders manifest differently in different languages and their markers are not universal. In this regard, the Georgian language is distinguished by its specific phonetic system and grammar. The practical value of the study lies in the fact that the obtained results will facilitate the determination of characteristic age-related norms, the early diagnosis of language delays, and the refinement of preschool education methodology.*

Keywords: *language development, preschool age, Georgian language, language acquisition, psychological aspect, cognitive basis, speech disorders, morphosyntax*

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Uşağın dil inkişafı

Mariam Koberidze[1*], Tinatin Mşvidobadze[2]

Xülasə. *Bu tədqiqat işi uşaqlarda dil inkişafının psixolinqvistik aspektlərini və koqnitiv əsaslarını, dil inkişafındakı ləngimələrin səbəblərini və bu problemin həlli yollarını araşdırır. Təsviri, tarixi-müqayisəli və tənqidi təhlil metodlarından istifadə etməklə, işdə müasir elmi ədəbiyyata əsasən uşaqlarda dil inkişafı ilə bağlı mövcud nəzəriyyələr təhlil edilir. Tədqiqat göstərir ki, altı yaşa qədər uşaqlarda dil inkişafı mərhələləri — xüsusilə nitqöncəsi, birsözlü, ikisözlü və "teleqraf üslubu" mərhələləri — ardıcıllıqla fonemik, morfoloji, sintaktik və praqmatik aspektlərə uyğun gəlir. Məqalədə belə bir nəticəyə gəlinir ki, dil mühitindən asılı olmayaraq, bütün uşaqlar nitq vərdişlərini, fonemik vahidləri və fonoloji dəyərləri eyni ardıcıllıqla mənimsəyirlər. Məktəbəqədər yaşlı uşaqlarda dil inkişafının qiymətləndirilməsi vasitələri dillərə görə fərqlənməlidir; çünki dil inkişafı pozuntuları müxtəlif dillərdə fərqli şəkildə təzahür edir və onların əlamətləri universal deyil. Bu baxımdan, gürcü dili özünəməxsus fonetik sistemi və qrammatikası ilə fərqlənir. Tədqiqatın praktiki əhəmiyyəti ondan ibarətdir ki, əldə edilən nəticələr yaşa uyğun xarakterik normaların müəyyən edilməsinə, dil inkişafı ləngimələrinin erkən diaqnostikasına və məktəbəqədər təhsil metodologiyasının təkmilləşdirilməsinə kömək edəcəkdir.*

Açar sözlər: *dil inkişafı, məktəbəqədər yaş, gürcü dili, dilin mənimsənilməsi, psixoloji aspekt, koqnitiv əsas, nitq pozuntuları, morfosintaksis*

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1. Introduction

Language and speech acquisition in early childhood form the foundation of a child's cognitive, social, and emotional development. The period from birth to age six represents the most intensive and sensitive phase for the development of linguistic competencies. During this age span, the child not only builds a vocabulary but also intuitively masters complex grammatical and syntactic structures, which subsequently become the primary tools for their thinking and socialization.

The issue of child language development is one of the global problems. Therefore, every study that addresses this issue is relevant from a linguistic point of view. Psycholinguistics, a discipline close to psychology and linguistics, studies what mechanisms are involved in the process of speaking and understanding linguistic expressions, and what psychophysical and neurolinguistic factors influence the development of a child's speech: age, gender, genetic disorders, autism spectrum conditions, and other factors (Mindadze, 2019, pp. 5–10).

Some studies confirm that language development disorders manifest different symptoms in different languages. It depends on the difficulty of the particular language. For example, the comparison of the narratives of Georgian children aged 3–5 years with the narratives of Spanish, German, English, and Hebrew-speaking children (task: description of a scene in a picture) revealed that different regularities are characteristic of Georgian-speaking adults.

The Georgian speech system is characterized by distinctive pronunciation, intonation, a specific phonetic system, and lexical structure. Cognitive analysis proves that the typical error in the development of the Georgian language—phonetic difficulties—is caused by difficulties in the phonetic stage and articulatory control, and grammatical problems are caused by a deficit related to the positional ring (Gamkrelidze et al., 2008, pp. 472–486).

Although to some extent the speech defect is related to a genetic disorder, it has been proven that early intervention and rehabilitation yield very good results when comparing the language component and the verbal behavior component.

The purpose of this article is to explore and study the psycholinguistic aspects and cognitive foundations of language development in Georgian-speaking preschool children, to identify the causes of language development impediments, to find ways to solve the problem, and to develop recommendations to improve outcomes. Accordingly, we defined the goal of the study: to identify problems that hinder the language development of children under the age of six. How is the specificity of the Georgian language expressed in children's language development? What types of mistakes do they make and what causes them? Does the genetic factor or the physiological factor cause the speech disorder? How does a child produce these or those language constructions? What stages can we encounter in language development? By describing the characteristics of the child's language development and finding a specific problem, we can help specialists to develop strategies to improve the child's language development and use them in practice.

Several sciences can study the same field of reality. For example, language is studied by linguistics, psychology, philosophy, anthropology, neurology and others. Each of them selects a different theoretical or practical aspect of language as the object of their research and, accordingly, when studying the phenomenon of language, they rely on different theories, use different means of research and different tools.

Theoretical background

The oldest problem is to find out the mechanism that is the basis of a child's speech. Despite the fact that the child's cognitive resources seem to be somewhat limited, the child completely masters the most complex structure of his native language in just 3–4 years. Moreover, the child easily connects certain grammatical regularities to each specific case of using the native language and soon becomes a full-fledged member of the linguistic collective: the child can already generate and understand an infinite number of new sentences of the native language.

In connection with this issue, we review the scientific literature and related theories, including their characteristics and components. There are radically different theories that try to explain the process of language acquisition by a child. Each of them recognizes that a child enters a stimulating environment for language development with a certain type of readiness. The difference of opinion is related to the exact definition of the latter: is this readiness universal or does it depend on the peculiarities of a particular language? Is this readiness only a specific opportunity for language acquisition or is it a prerequisite for the acquisition of any skill? (Goldin-Meadow, 2019, pp. 1–8).

According to Noam Chomsky, a child acquires the linguistic system, which is a unity of subtle and abstract principles, without explicit teaching. Accordingly, he came to the view that if there are no appropriate environmental conditions that would have conditioned the process of language acquisition

by the child, then the explanation should be sought in the possibility of innate syntactic knowledge and the existence of specific procedures for language learning (Chomsky, 1959, pp. 26–58).

The problem with nativist theory is that there may be certain principles underlying a particular language that are unique to that language and not shared by other languages.

According to social-cognitive theory, the specific processes underlying a particular language may be carried out through the involvement of larger, more general learning mechanisms. Observing these theories shows that they are influenced by the cultural values and belief systems of a particular time. However, one important thing distinguishes theories from opinions and views: the "life expectancy" of a theory depends on scientific confirmation. In other words, all theories must be tested using an unbiased set of research procedures agreed upon by the scientific community.

2. Materials and methods

While working on the scientific paper, we used historical-comparative, descriptive, and critical analysis methods based on the research objectives.

Using the descriptive analysis method, we identified problems related to the child's language development and the stages of language development; using the historical-comparative method, we chronologically studied theories and opinions related to language development. Using the critical analysis method, we formulated conclusions and recommendations based on a critical analysis of language development theories, the latest scientific literature and empirical materials.

3. Results

Language is an integral part of our daily lives. We use it as naturally and effortlessly as we breathe or walk. Through language, we express our wishes, thoughts, needs, and plans. Most children acquire language automatically. As a rule, moderate linguistic stimulation is enough for a child to become a competent user of the language by the age of four. Therefore, we easily forget what a difficult and complex phenomenon we are dealing with, and we remember it when we meet a person who, for example, speaks, but is not understood or, on the contrary, does not understand why his peers are laughing or what the teacher is asking him to do.

In psycholinguistic studies, the issue of language acquisition occupies an exceptionally prominent place. Psychologists and linguists alike are interested in what processes underlie mastering the native language, learning a foreign language, and acquiring linguistic knowledge. Indeed, how does a child learn such a complex system as language in such a short time? What phases or stages will a language learner go through? How does a child learn so easily what is so difficult for adults trying to master a foreign language? When does language learning end? When do we know we know a language? What is the connection between learning native and foreign languages? What is the relationship between language and culture?

In everyday conversation, we use "language" and "speech" as synonyms. For example, when we want to describe the language development of a child, we say: "Nino speaks perfectly, while David is late in speaking", or "Lela does not speak, but she is already two years old". In professional terminology, language competence and speech are two different concepts—closely related to each other but conceptually distinct; therefore, when discussing language development disorders, it is necessary to distinguish language from speech. For example, a person may have difficulty acquiring language or

speaking, or both. Language means possessing a vocabulary and knowing the rules of grammar; speech means the pronunciation of words, articulation (correct pronunciation of speech sounds using the mouth, lips and tongue), tone of voice, and rhythm of speech. However, it is also possible to convey the word in sign language. To explain simply, language is a mental phenomenon, and speech is one of its forms of expression.

Four stages can be distinguished in the process of language development, namely: the pre-speech stage, the one-word stage, the two-word stage, and the telegraphic stage.

Pre-speech stage

Before children utter their first word, they make individual sounds. It is interesting that children of different linguistic affiliations show great similarities in the process of mastering the phonological systems of their languages. It can sometimes take several years for a child to fully master the phonological system of their native language, but the initial stages of acquisition are universal and the same for all languages. The child acquires the phonological system in a certain sequence and shows an amazing systematicity during acquisition.

During the first three months, the child's articulatory behavior is mainly limited to screaming. From the fourth month, the child begins to produce the first sounds, rather, streams of sounds, including sounds that are foreign to the child's immediate language environment. After a certain period of time, children no longer make articulate sounds. This period can last for several weeks, and after that they begin to speak properly, that is, they utter their first words. A child's first words are usually vowel-consonant alternations and are most often presented in the order /baba/, /mama/, /papa/. Such a development is confirmed in practically all language groups and is considered a universal regularity.

According to Jakobson, the above-mentioned regularity stems from the nature of language. He called this phenomenon the principle of maximum contrast. The beginning of speech with /pa/, /ma/ sounds has an articulatory basis. The /a/ sound is a vowel that is pronounced with the mouth as wide open as possible, while the /p/ sound is a labial sound that is pronounced with the mouth as wide as possible. That is, when pronouncing /pa/, in accordance with the principle of maximum contrast, the maximum opening and closing of the mouth oppose each other; in addition, the vowel and consonant properties of the sounds also contrast with each other (Jakobson, 1969, pp. 253–254).

As we mentioned above, from the fourth month, children intensively start pronouncing different sounds. It is interesting that some sounds characteristic of this stage (for example, "l" and "r", which are pronounced quite clearly) are rarely found in the first words of the child.

This process appears to be biologically determined, as the same phenomenon is observed in children who are deaf from birth, who produce such sounds until about six months of age, and then gradually stop producing them (Arevadze et al., 2023, pp. 15–25).

It is assumed that at this stage the child learns to group sounds and transform them into melody (intonation). Children of this age not only "speak" spontaneously, but also react to their parents' voice. Parents often address infants with a language different from normal speech, characterized by overly soft, caressing intonations (infant-directed speech). Cooper and Aslin (1990, pp. 1584–1595) experimentally demonstrated that babies are more attracted to this kind of caressing speech. In the named experiment, two-day-old children were addressed with two types of speech registers: ordinary, "adult-directed" language (adult-directed speech) and caressing language directed at children. The same experiment was

also performed on one-month-old children. Caressing was found to hold the attention of both groups of children longer, as measured by gaze fixation duration. Another experiment also confirms that children distinguish such an address from ordinary speech and pay more attention to it. At the age of one year, children usually speak their first word.

One-word stage

A child begins to speak at the age of about one year, when they utter their first word. As a rule, this word is a specific noun. The first words of the child—mother, ball, car—refer to those people or objects that play a special role in the child's life and are connected with their immediate surroundings: they move, make a sound, or are played with by the child. The peculiarity of children's first words is that they usually use them with multiple meanings. When a child, for example, says the word "ball", they can mean not only a ball but all round objects: the moon, a clock, a plate... The child only gradually associates this word with a real ball. So, for example, one-and-a-half-year-old Nino first called a candle "fua" (the word "fua" came from imitating the sound of a candle being extinguished by blowing on it), and then this word referred to everything that shines: the sun, the moon, the lighting of a room chandelier, car headlights, etc. Before the age of three, it is common to expand the meaning of the word in this way. Such a phenomenon is called generalization. Generalization can take place in two directions: if the child calls all animals "dog", i.e. dog, cat, bird, then we are dealing with the phenomenon of overgeneralization. If the child calls "dog" only the neighbor's Caucasian shepherd, then we are dealing with a narrowing of the meaning; this phenomenon can be called undergeneralization.

It is not difficult for parents to guess the child's language behavior. Often, by naming a single word, children make their demands when they want to obtain an object or play with someone. Sometimes they make a kind of assumption about an object when they name it (most of the time, they point towards it) and they seem to ask the elders to confirm that this object is really called what they think. A child's one-word utterances are actually syntactic units because they stand for a sentence. One-word expressions are, in principle, complete sentences. These are not abbreviated sentences used by adults. Often the same word uttered by a child has a different intonation—affirmative, interrogative—and a word spoken by a child can have different meanings depending on the intonation. For example: Booth – this is a ball; Booth? - Is this a ball? Booth! - Give me the ball! Or let's play with a ball! and others.

As can be seen from the observation, at this stage of language development, intonation is of crucial importance. Often, when the mother or the person whom the child addresses does not respond to the child's utterances, the child tries to make that person understand what they have to say by repeating the word multiple times and with increased intonation.

Two-word stage

From about 18 months of age, children begin to combine words into two-word expressions, which, just as in the one-word stage, require context to be understood. "Mama car" can mean "Mom, bring me a car", "Mom, draw me a car", "Is this car mine?", etc. It is often said that the transition from the one-word stage to the two-word stage is caused, on the one hand, by the increase in the child's experience (knowledge), and on the other hand, by the need to formulate the intended thought more precisely, to avoid mistakes during interaction. The question is how valid the second argument is, since the one-word stage "car" is, given the situation and intonation, just as intelligible (or unintelligible) as the two-word "mother machine". The transition to the two-word stage should be conditioned by the psychophysical

development of children. It has been observed that children of a year and a half can often produce longer sequences of sounds than single or two-word utterances (Mindadze, 2019, pp. 5–10).

In our opinion, at this stage, the child's speech is not only a sequence of sounds, but also a cognitive action. In this case, mental development, in particular the development of memory ability, should play a major role. The length of sentences produced and perceived by an adult also depends on memory. It can be seen that some words are used much more often and are mostly found only in certain positions. The analysis of such two-word sentences shows that when connecting words, the child divides them into two classes: one consists of pivot words or operators, and the other consists of numerous words that are initially used in one-word sentences.

For a Georgian child, the supporting word can be "want", which connects other words in a two-word sentence: I want mother, I want father, I want milk, I want dad... The number of supporting words increases slowly. Only a few new keywords appear per month. In addition to supporting words, other words can also be found in a one-word sentence. The observation here shows that the child's two-class system of speech does not correspond to the word-class system of adults. The child creates simple relationships within the limited vocabulary they have already mastered. Research has shown that the number of two-word sentences by month increases approximately as follows: 14, 24, 54, 89, 350, 1400, 2500. Therefore, a very large number of new word combinations are created in a short period of time (Gamkrelidze et al., 2008, pp. 480–482).

Base-word constructions also perform a variety of semantic functions in a child's speech. These are the basic functions that characterize human speech in general. They appear in the speech of children of different cultural groups. During the creation of a two-word sentence by the child, the language already shows universal and unique characteristics, which are presented in the child's speech: 1. place, name (there, father, here, mother); 2. request, command (some porridge, some milk...); 3. Rejection (Lela no); 4. Description of the situation or event (father is sleeping); 5. Expression of belonging (Dato's car, my ball); 6. Definition of quality (the car is big); 7. Question (where is mother?). These are subordinate clauses.

Telegraphic stage

After the two-word stage, children move on to the telegraphic style. These kinds of sentences consist of many words (mainly nouns and verbs), but tense and person markers are not yet generally used. For example, "I forgot", "I believe", "I'm happy", "I'm sad" and others, that is, the use of concepts expressing the child's inner state and feelings, usually starts at the age of two to two and a half years. All these stages are accompanied by a constant deepening of knowledge of vocabulary and grammatical forms.

In the scientific literature, there is also a different differentiation of the stages of language development: 1. Holophrases (around 12 months of age). The description of this stage basically coincides with the description given in the "one-word stage". In this typology of describing the child's speech, it is also important that one word stands for the whole sentence and expresses one or another intention of the child according to the current situation: a question, a request, a demand (Cameron-Faulkner et al., 2003). 2. Word combinations (around 18 months of age). At this stage, pairs of words (including the base word) are formed; a kind of speech scheme is created, which contains "immovable" and "moving" elements, which is the basis for subsequent language constructions; 3. Constructions created around the verb (around 24 months of age). At this stage of language acquisition, children learn to group linguistic

elements around the verb. 4. Constructions similar to adult speech (previous position subordinate, then direct addition, then listener) (Szagun, 2008, pp. 4–32).

In our opinion, the child's language is structural from the very beginning. It strives for regularity and hierarchical relationships soon appear in it. The linguistic structures (phonemic, morphological, syntactic, pragmatic) that the child gradually acquires always correspond to the linguistic structures of an adult.

When observing a child's speech, we should take into account that in some children's speech, the period of using constructions with a base word may be very short and not clearly expressed. Alongside these constructions, other types of two-word expressions gradually appear.

A child's grammatical system is characterized from the very beginning by superficial and deep levels. Let's consider a few of the child's expressions: 1. A cup of coffee; 2. party hat; 3. Nino sock; 4. ball chair; 5. Nino ball.

From the examples given, it can be seen that these sentences convey five different semantic relations of different depths: 1. Connection (cup and coffee); 2. Belonging (Nino's sock); 3. Determining relation (ceremonial hat); 4. Location (the ball is on the chair); 5. Subject-object relation (Nino is playing ball).

In adult speech, we establish semantic relations between sentence members based on syntactic forms. In child speech, we cannot determine semantics between words without taking into account context.

4. Discussion

The first study was conducted in Georgia, which serves to raise awareness of language development disorders. The initiative belonged to Tamar Kalandadze - professor of human development science, neurodevelopmental disorders, and special education, Doctor of Educational Sciences, and Associate Professor at Østfold University College. According to this study, language development disorders occur in approximately 10–13% of 4–5-year-old children. Sometimes it accompanies other disorders; sometimes it exists independently, in isolation. The incidence of isolated disorders is 7–8% and is not associated with any known cause or condition (e.g., autism or Down syndrome). As a result of the research, the lack of tools for the assessment of language development disorders, the need to raise awareness and knowledge and conduct research in the Georgian context was highlighted. The lack of research is the most serious problem, because language development is expressed in different ways in different languages, and its markers are not universal (Kalandadze, as cited in Ashughashvili, 2024).

Preschool children with specific language impairment may encounter the following difficulties:
1. Language comprehension: They need more time to answer, and their answers are short. They may not answer us at all or we may need to repeat and simplify the instructions several times. They often rely on visual information to get things right, such as looking and observing others in the process to understand exactly what the instruction means.
2. Use of language: They may not use different words. They may have difficulty connecting words together to form a sentence. Their language can often be difficult to understand. They may point when they want something instead of naming it.
3. Social and learning skills: Although they may be quite social, it may be difficult to make friends or play with other children. It is difficult for them to engage in play with others, so they often prefer to play alone because it is easier (Grist et al., 2021, pp. 18–29).

How can we help such children? Give the child an opportunity to make a suggestion, express an opinion, and establish communication with other children and adults during the conversation.

5. Conclusion

Thus, the scientific article chronologically examines the stages and linguistic aspects of language development in a child under six years of age in relation to modernity. The numerous problems related to the development of children's language and the constant interest of linguists determined the relevance, purpose, and methodological foundations of our scientific work.

The process of a child's language development is of three types: 1. The process of perceiving spoken or written language; 2. The process of producing linguistic expressions; 3. The process of language acquisition.

Dividing a child's language development into stages (pre-speech stage, one-word stage, two-word stage, telegraphic stage) will reveal speech-related problems. The stages of a child's speech development correspond to the development of phonemic, morphological, syntactic, and pragmatic aspects of language.

Theories of child language development, as the main source of modern psycholinguistics, require a critical approach. Child language development is complex, so conclusions cannot be drawn based on any one theory.

Observing the dynamics of a child's language development requires knowledge of the child's individual, psychological, and age-related characteristics. A child's environment, society, parents, mental processes, genetic factors, age, gender, and cognitive skills (memory, thinking, perception, etc.) determine a child's language development.

Preschool language development disorders are a global problem that can significantly affect a child's academic development and the quality of life of a citizen. Therefore, evidence-based practice is necessary for children with language development disorders. It is important that planned studies be carried out in collaboration with experienced, competent Georgian and foreign neuropsychologists and speech and language therapists.

The instrument for studying the language development of preschool children should be different for different languages, because language development disorders manifest themselves differently in different languages, and their markers are not universal. Instruments used in one specific language will be of little help in diagnosing Georgian-speaking children, as the Georgian speech system is distinguished by its pronunciation, intonation, specific phonetic system, and lexical structure. The lack of studies based on the specifics of a particular language is a serious problem.

The generalization of the results of the work will lay the foundation for the emergence of innovative approaches and theories, which is important for the development of modern psycholinguistics, and will help individuals and specialists interested in studying the issue to develop strategies to improve children's language development and apply them in practice. We believe it is important to study the impact of modern digital technologies on the language development of preschool children.

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World Literature: Concept, Evolution, Criteria, and Critical Perspectives

Nadjat Mous

Abstract. *This study examines the term "world literature," a contested concept in comparative literary studies. It traces the concept's development, identifies the criteria used to classify literary works as world literature, and distinguishes world literature from related terms such as national literature, comparative literature, and the universality of literature. The study also compares Western and Arab critical perspectives, including those of René Étiemble, Paul Van Tieghem, Mohammed Ghenimi Hellal, and Fouad Merai. The findings show that world literature is generally understood as literature that transcends national and linguistic boundaries, is translated and widely received, and retains humanistic, intellectual, and artistic value. However, definitions remain multiple and are shaped by the critic's school of thought, cultural context, and ideological orientation.*

Keywords: *world literature, universality of literature, comparative literature, national boundaries, transcendence*

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Dünya ədəbiyyatı: anlayış, təkamül, meyarlar və tənqidi yanaşmalar

Nadjat Mous

Xülasə. *Bu tədqiqat müqayisəli ədəbiyyatşünaslıqda mübahisəli bir anlayış olan "dünya ədəbiyyatı" terminini araşdırır. Bu konsepsiyanın inkişafını izləyir, ədəbi əsərləri dünya ədəbiyyatı kimi təsnif etmək üçün istifadə olunan meyarları müəyyən edir və dünya ədəbiyyatını milli ədəbiyyat, müqayisəli ədəbiyyat və ədəbiyyatın universallığı kimi əlaqəli terminlərdən fərqləndirir. Tədqiqat həmçinin René Étiemble, Paul Van Tieghem, Mohammed Ghenimi Hellal və Fouad Merai də daxil olmaqla Qərb və ərəb tənqidi baxışlarını müqayisə edir. Nəticələr göstərir ki, dünya ədəbiyyatı ümumiyyətlə milli və dil sərhədlərini aşan, tərcümə olunan və geniş şəkildə qəbul edilən, humanist, intellektual və bədii dəyəri qoruyan ədəbiyyat kimi başa düşülür. Lakin tərifl ər çoxsaylı olaraq qalır və tənqidçinin düşüncə məktəbi, mədəni kontekst və ideoloji istiqaməti ilə formalaşır.*

Açar sözlər: *dünya ədəbiyyatı, ədəbiyyatın universallığı, müqayisəli ədəbiyyat, milli sərhədlər, transsendensiya*

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1. Introduction

Comparative literature, like other fields, relies on a set of tools, methodologies, and terms used by critics and researchers to study literary works. Among the most prominent terms in comparative studies is "world literature," which sparked intense debates worldwide in the 1920s. Critics differed over the criteria and standards for defining a literary work as "universal," thereby granting it the quality of universality and distinguishing it from other works. Universality is used as a measure of a work's success, elevating it beyond national confines to a broader, more comprehensive scope. This distinction aims to select the finest works produced by human creativity throughout history.

This study clarifies the nature of world literature by presenting diverse perspectives on the concept and tracing its evolution from its inception to the present day. It also examines the criteria for classifying creative works within world literature and addresses terminology associated with comparative studies, including comparative literature, national literature, and the universality of literature. Since every researcher has their own perspective on this term, the study presents the viewpoints of selected Western and Arab researchers.

Accordingly, the study addresses the following questions:
1. How has the concept of world literature evolved?
2. What criteria determine whether a literary work belongs to world literature?
3. How does world literature differ from comparative literature, national literature, and the universality of literature?
4. How do Western and Arab critics define and evaluate world literature?

2. Methods

This study is a qualitative, conceptual, and comparative textual analysis. It does not employ experimental or statistical methods. Instead, it examines definitions, historical accounts, critical essays, and theoretical discussions related to world literature and comparative literature.

The corpus includes dictionaries of literary terms, histories of comparative literature, theoretical monographs, journal articles, translated works, and conference papers. Key sources include Allouche's (1987) Dictionary of Literary Terms, Makki's (1987) Comparative Literature: Its Origins, Development, and Methods, Hellal's (2008) Comparative Literature, Van Tieghem's (n.d.) Comparative Literature, and articles by Boukhalfa (2019) and others.

The analytical procedure involved five steps:
1. Identifying definitions and conceptual dimensions of world literature (Allouche, 1987, p. 33).
2. Tracing the historical emergence of the term from eighteenth-century Germany to twentieth-century global criticism (Makki, 1987, pp. 634–636).
3. Comparing criteria used to classify works as world literature (Boukhalfa, 2019, p. 78).
4. Distinguishing world literature from related terms in comparative studies (Hellal, 2008, p. 93).
5. Contrasting Western and Arab critical perspectives (Boukhalfa, 2019, p. 86; Hellal, 2008, p. 93; Merai, 1982, p. 64).

The study is interpretive and relies on secondary sources. Its limitation is that it does not measure the reception or influence of specific literary works empirically; rather, it synthesizes existing critical discourse.

3. Results

3.1. Definitions and Conceptual Scope

The term "world literature" encompasses several definitions. According to Allouche's (1987) Dictionary of Literary Terms, world literature is "any literature that has managed to transcend its geographical and national boundaries to embrace universal human visions" (p. 33). In this sense, world literature is literature that has moved beyond its national borders to reach other nations.

The study identifies multiple meanings of the term:
- The quantitative sum of national literatures of all peoples throughout human history, regardless of artistic or aesthetic level.
- The collection of selected creative models produced by humanity.
- The process of mutual influence and enrichment among national literatures, emerging at an advanced stage of human civilization.
- The general characteristics that define the development of literatures of different peoples and regions throughout history.

Maxim Gorky referred to world literature in this last sense. He stated that there is no world literature because no common language exists among all peoples. Still, the literary works of all writers are imbued with a unity of general human feelings, thoughts, and opinions (as cited in Pageaux, n.d., p. 29).

Hellal (2008) affirms that world literature is that which has transcended linguistic and national boundaries and been translated into other world languages because of its high literary quality (p. 93). Therefore, it is read extensively, its works spread widely, and it is received with enthusiasm. The criteria for universality are widespread dissemination, high readership, and positive reception (Boukhalfa, 2019, p. 78).

3.2. Historical Beginnings

The first attempts in this field began in Germany, particularly from the eighteenth century onward (Makki, 1987, p. 634). These attempts involved summarizing the history of literature in general or at least the history of European literature from the Middle Ages onward. This early effort bore no relation to what is now known as world literature (Makki, 1987, p. 634).

Examples include:

- The Italian priest Denina's Revolutions of Ancient and Modern Literature, published in Turin in 1760 (Makki, 1987, p. 634).
- Madame de Staël's Literature in its Relations with Social Systems, published in 1800, which connected literature with social phenomena and drew examples from various European literatures (Makki, 1987, p. 634).
- Friedrich Bouterwek's History of Poetry and Eloquence from the End of the Thirteenth Century, published in 12 volumes between 1801 and 1819 (Makki, 1987, p. 635).
- Sismondi's The Literature of Southern Europe, published in 4 volumes in 1813, which studied medieval literature, beginning with the Arabs, then Provençal and Old French works, Italian, Spanish, and Portuguese literature (Makki, 1987, p. 635).
- Friedrich Schlegel's History of Ancient and Modern Literature, published in 1815 (Makki, 1987, p. 635).

These works are considered summaries of the histories of literature for particular nationalities.
Later, works bearing the term "world literature" appeared, such as De Gubernatis's History of World Literature, published in Italian in 1883, and August Wilhelm Schlegel's Lectures on Dramatic Art and Literature, which appeared in 1811 (Makki, 1987, p. 636).

3.3. Goethe and Post-Goethean Development

The German poet Goethe first used the term "world literature" in 1827, in his commentary on the French translation of his play Tasso (Makki, 1987, p. 636). Goethe proposed a historical study of the development of national literatures, suggesting that differences between them would disappear, leading to a unified whole in which each nation plays its part within the human community (Makki, 1987, p. 636). However, he realized the impossibility of this idea and tempered his enthusiasm. He stated:

I repeat, the point is not that nations should think in the same way, but that they should learn to understand one another. If mutual love is not their goal, then at least they should learn to tolerate one another. (as cited in Makki, 1987, p. 637).

Goethe aimed for tolerance among different peoples to produce a refined, humane literature.
Many writers and critics embraced the concept of world literature after Goethe. Friedrich Schlegel drew inspiration from Herder and called for transcending personal favoritism and blind prejudice (Makki, 1987, p. 637). Madame de Staël believed each nation should guide innovation and that all nations should welcome foreign ideas (Makki, 1987, p. 637).

While scholars of the nineteenth and pre-mid-twentieth centuries aspired to literary unity for Europe alone, the end of the colonial era forced thinkers to reconsider many literary, scientific, and social assumptions (Makki, 1987, p. 638). The trend that made Europe the sole possessor of all human values began to decline. Consequently, literary works translated into other languages became those that could reach a horizon transcending the boundaries of the language in which they were written. Thus they were considered part of world literature (Makki, 1987, p. 638).

3.4. Contemporary World Literature: Writers, Themes, and Criteria

The concept of world literature has changed since Goethe. Some understand world literature as a call to preserve timeless literary works as the product and heritage of all humanity by translating, explaining, and facilitating their circulation (Makki, 1987, pp. 639–640). Examples include the works of Dante, the

Mu'allaqat, Abu al-Ala al-Ma'arri, al-Mutanabbi, Shakespeare, Goethe, and others whose fame has transcended all boundaries. The term has come to be associated with timeless works published under titles such as Masterpieces of World Literature, Immortals, Nobel Prize Winners, and Heritage of Humanity (Makki, 1987, pp. 639–640).

Contemporary world literature also encompasses the period between the two world wars. Criticism, particularly by Arab scholars, has focused on works by James Joyce, Lawrence, Hemingway, Bernard Shaw, Eliot, Victor Hugo, and other international writers who left a clear mark on literature in the late nineteenth and early twentieth centuries, up until the outbreak of World War II (Raghib, 1990, p. 56).

The themes of contemporary world literature include:

- Crystallizing modern man's perspective on the universe and its concerns.
- The alienation of man in this world and the choice of his moral responsibility, as exemplified by Albert Camus and Jean-Paul Sartre.
- The mystery of the universe: modern man has lost all possible explanations for the mystery of the universe. He has not found a moral law to deliver him from absurdity and ambiguity. This is reflected in the works of Samuel Beckett and Eugène Ionesco.

The criteria of world literature include:

- The literary work embodies timeless values.
- Addressing ideas and values that provoke reflection and debate across time.
- The relevance of themes to different eras.
- Possessing high literary quality.
- Widespread dissemination, high readership, and positive reception (Boukhalfa, 2019, p. 78).

3.5. Related Terms: Comparative, National, and Universal Literature

Comparative literature differs from world literature in its functions. Comparative literature is the discipline that studies literature beyond the borders of a single country and compares it with the literature of another country, or with a group of literatures from other countries, by examining the history of exchange and influence to reveal similarities and differences (Makki, 1987, p. 642). World literature, on the other hand, is the sum of all literatures created by humanity that have spread to most countries of the world. Comparative literature studies and compares these literatures (Makki, 1987, p. 642).

World literature differs from national literature in two ways:

- Its connection to the elements it focuses on.
- The way these elements are organized (Makki, 1987, p. 642).

In comparative literature, "national literature" refers to literature concerned with the national struggles of a particular people, while "world literature" refers to humanistic literature that addresses universal human issues (Makki, 1987, p. 643). In terms of dissemination, "national literature" refers to a people's literature based on its influence and spread within its national context, whereas "world literature" refers to its influence and spread beyond that context (Makki, 1987, p. 643).

The term "universality of literature" is used in several senses: sometimes it refers to writers who have transcended the boundaries of their national cultures and achieved international recognition, and sometimes to themes or movements that constitute a common element across world literatures (Al-Andalusi, 2012).

Hellal (2008) defines universality as the departure of literature from the realm of the language in which it was written to the literature of other languages or literatures. This universality is a common phenomenon among literatures in certain eras, and it is required by literature influenced by other cultures in some periods due to specific factors that drive it to transcend its national boundaries, either to influence other literatures or to keep pace with the global literary movement. (p. 93)

The universality of literature is based on several principles:

- Selecting literature influenced by other literatures to enrich and elevate national literature (Hellal, 2008, p. 94).
- Originality: beneficial influence and fruitful, rational imitation, avoiding mere mimicry (Hellal, 2008, p. 94).
- The elite of talented individuals: preserving talent while following global intellectual and artistic movements (Hellal, 2008, p. 95).
- Considering literary influence as a movement of revival and guidance (Hellal, 2008, p. 95).
- The availability of a suitable environment for reception (Hellal, 2008, pp. 96–97).

Factors contributing to the universality of literature include:

- A feeling of inadequacy in national literature.
- Migrations and wars.
- Exposure to books and translations across different literatures.
- Newspapers and magazines (Hellal, 2008, pp. 96–97).

3.6. Western and Arab Critical Perspectives

Western Critics

René Étiemble called for a reconsideration of what scholars do who monitor and enumerate major literary works (Boukhalfa, 2019, p. 86). He called for including forgotten literatures from other continents that were omitted because scholars disregarded their literary and artistic value (Boukhalfa, 2019, p. 86). He questioned the neglect of immortal literary works that have gained widespread popularity beyond their national borders, such as Tales of One Thousand and One Nights, Maqamat al-Hariri, and the novels of Taha Hussein and Naguib Mahfouz (Boukhalfa, 2019, p. 86). The contemporary Russian critic Bakhtin presented the role of the Arab mind in the development of world literature (Boukhalfa, 2019, p. 86). Étiemble stressed the need to pay attention to literatures forgotten because of ignorance or disregard, especially those from Africa, Asia, and Latin America (Todorov, 2007, p. 144). Ignoring any national literature within the realm of world literature for reasons unrelated to literature itself will leave a distorted picture of human thought.

Étiemble also emphasized the need to move beyond Eurocentrism, calling for openness to other human literatures (Madani, 2003, p. 48). He attacked French centrism and Eurocentrism in comparative literature studies. He urged comparatists to rid themselves of chauvinism and break free from the narrow confines of European literature, emphasizing engagement with other global centers of civilization, such as Arabic and Far Eastern cultures like Chinese and Japanese (Madani, 2003, p. 48). In his view, world literature is broader than European literature (Marino, n.d., p. 6).

Paul Van Tieghem, in his book History of World Literatures, advocated for literary models that achieved popularity and fame and then influenced other literatures, such as the works of Homer, Dante, Shakespeare, and others (Van Tieghem, n.d., p. 111). Van Tieghem emphasized the need for researchers

to be meticulous and trace intellectual and artistic values to ascertain originality and identify aspects of influence and interaction between literatures (Van Tieghem, n.d., p. 111). Artistic quality is among the most important criteria for world literature, but this does not negate the fact that some literary works achieve temporary success, and that this success is increasingly global. He states, "We see that success—temporary—is growing, often accompanied by a global influence" (Van Tieghem, n.d., p. 111). This global influence may result from factors such as winning prestigious international awards like the Nobel Prize in Literature.

Arab Critics

Mohammed Ghenimi Hellal discussed the universality of literature and explained its factors. He dedicated a chapter of his book Comparative Literature to the universality of literature and its factors, rejecting the concept of "world literature" as impossible (Hellal, 2008, p. 93).

He states:
The idea of world literature, in our view, is impossible to realize, because literature is, first and foremost, a response to the intellectual and social needs of the homeland and the nation, and its subject is to nourish these needs; it is primarily local and objective (Hellal, 2008, p. 93).

These local themes also carry universal aims, expressed through national issues, hopes, and pains. He distinguishes between world literature and the universality of literature. In his view, world literature is an impossible concept, as every literature has its own nationality and local identity. The universality of literature, however, "is the transcendence of literatures within their national boundaries, in pursuit of all that is new," with the aim of intellectual and artistic collaboration (Hellal, 2008, p. 94).

Fouad Merai, in a paper presented in 1986 at the Second Conference on Comparative Literature, began with Marxist literary theory, which links the development of literature to that of society (Merai, 1982, p. 64). Merai criticized the Eurocentric bias that dominated the concept of world literature. He believed that adopting such a concept hinders the study of Arabic literature beyond its national boundaries, whereas the Marxist concept facilitates it (Merai, 1982, p. 64). In his view, world literature is not the sum of great works, but rather "the sum of all literatures in the world." Therefore, the comparatist's role is not to discover aspects of influence and being influenced, but to build a history of world literature on a scientific basis grounded in the unity of humanity's developmental history (Merai, 1982, p. 64).

4. Discussion

The findings show that "world literature" is not a fixed or universally agreed-upon concept. Instead, it is a contested term whose meaning shifts according to historical period, critical school, and cultural perspective. The study identifies two broad orientations. The first emphasizes transcendence, translation, dissemination, and reception: a work becomes world literature when it moves beyond its national and linguistic boundaries and is read widely in other languages. The second emphasizes national and local roots: literature begins as a response to national needs and social realities, and its universality emerges from the sincerity and depth of that national consciousness.

Goethe's use of the term in 1827 marks a key moment, but his vision was not simply to erase national differences. Rather, he called for mutual understanding and tolerance among nations. Later critics expanded, revised, or rejected this vision. Étiemble and Van Tieghem represent moderate Western positions: Étiemble calls for including neglected literatures and ending Eurocentrism, while Van

Tieghem focuses on literary models that achieve popularity and influence. Both reject the narrow, hard-line Eurocentrism of some earlier historical schools.

Arab critics contribute a distinct perspective. Hellal (2008) rejects the idea of world literature as impossible, arguing that literature is primarily local and national (p. 93). For him, universality is not the same as world literature; it is the transcendence of national boundaries in pursuit of novelty and intellectual-artistic collaboration (p. 94). Merai (1982), influenced by Marxist theory, treats world literature as the sum of all literatures and links it to societal development (p. 64). He criticizes Eurocentrism for hindering the study of Arabic literature beyond its national boundaries (p. 64).

The study also clarifies important terminological distinctions. Comparative literature is a discipline that studies literature across national borders. National literature reflects a people's local and national context. World literature consists of works that have transcended their national boundaries, been translated, and achieved widespread fame while retaining humanistic, intellectual, and artistic value. The universality of literature refers to literature's movement beyond its national boundaries in pursuit of novelty and intellectual-artistic collaboration.

The criteria for world literature combine aesthetic quality, timeless values, cross-temporal relevance, and broad reception. However, these criteria are not purely objective. Power relations, translation flows, publishing industries, international awards, and critical gatekeeping shape them. This is why Étiemble's call to include forgotten and neglected literatures remains important: excluding literatures for reasons unrelated to their artistic value distorts our picture of human thought.

This study has significant implications for comparative literature. Comparatists should avoid chauvinism and Eurocentrism, remain open to diverse literary traditions, and recognize that universality does not require erasing national identity. Translation is central to world literature because it enables works to reach readers beyond their original language. At the same time, the study acknowledges its limitations: it is a conceptual and interpretive synthesis rather than an empirical analysis of reception, translation rates, or canon formation.

5. Conclusion

This research concludes the following points:

- Goethe was the first to use the term "world literature" in the sense of openness to the literatures of other nations.
- Eurocentrism dominated the selection of world literary works, especially in the French school, at the beginning of the term's establishment.
- Some critics, such as René Étiemble, called for the inclusion and study of literatures of forgotten nations, as they may become part of world literature due to their intellectual and artistic value.
- The term "world literature" has acquired several meanings depending on the currents and schools of thought adopted by each researcher.
- It is necessary to distinguish between comparative literature, national literature, and the universality of literature.
- Despite multiple definitions, the prevailing concept remains: certain works transcend their national boundaries, are disseminated among other peoples, achieve widespread fame after translation, and retain their humanistic, intellectual, and artistic values.
- The universality of literature has foundations that determine its course and direction.

- Expressing human issues in a creative, original, and aesthetically pleasing style ensures their enduring presence throughout the ages, thus classifying them as world literature.
- The concept of world literature has taken on multiple meanings among Western and Arab critics, depending on each critic's thought and orientation.

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Dynamic effects of tourism CO_2 emission intensity and economic growth under the framework of SDG 13

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Abstract. *The relationship between carbon emission intensity and economic growth in the tourism sector is of significant importance for formulating sustainable development policies. This study examines the impact of CO_2 emission intensity in the tourism sector on economic growth within the framework of the UN Sustainable Development Goal (SDG) 13: Climate Action. Tourism CO_2 emission intensity represents the ratio of carbon emissions generated by tourism activities to economic output and serves as a key indicator of the sector's environmental efficiency. A systematic analysis of existing empirical and comparative studies reveals that, while tourism development supports economic growth, the structure of energy consumption and the effectiveness of environmental policies directly influence emission intensity. The use of renewable energy, the development of green transportation, the promotion of eco-innovations, and the implementation of low-carbon tourism strategies contribute to reducing emissions and strengthening long-term economic sustainability. The study emphasizes that integrating climate policy, green investments, and sustainable tourism management is essential for achieving the targets of SDG 13.*

Keywords: *tourism, CO_2 emission intensity, economic growth, SDG 13, sustainable tourism, climate change*

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DİM 13 çərçivəsində turizmin CO_2 emissiya intensivliyi və iqtisadi artımın dinamik təsirləri

Flora Kərimova[1*], Asif Abdullayev[1], Günel Quliyeva[1], Aftandil Məmmədli[1]

Xülasə. *Turizm sektorunda karbon emissiyalarının intensivliyi ilə iqtisadi artım arasındakı əlaqə dayanıqlı inkişaf siyasətinin formalaşdırılması baxımından mühüm əhəmiyyət daşıyır. Bu tədqiqat BMT-nin 13-cü Dayanıqlı İnkişaf Məqsədi — "İqlim dəyişikliyinə qarşı mübarizə" çərçivəsində turizm sektorunda CO_2 emissiyalarının intensivliyinin iqtisadi artıma təsirini araşdırır.*

Turizmdə CO_2 emissiyalarının intensivliyi turizm fəaliyyətləri nəticəsində yaranan karbon emissiyalarının iqtisadi məhsulun həcminə nisbətini ifadə edir və sektorun ekoloji səmərəliliyinin əsas göstəricilərindən biri hesab olunur. Mövcud empirik və müqayisəli tədqiqatların sistemli təhlili göstərir ki, turizmin inkişafı iqtisadi artımı dəstəkləsə də, enerji istehlakının strukturu və ekoloji siyasətin səmərəliliyi emissiyaların intensivliyinə birbaşa təsir göstərir. Bərpa olunan enerjidən istifadə, yaşıl nəqliyyatın inkişafı, ekoloji innovasiyaların təşviqi və aşağı karbonlu turizm strategiyalarının tətbiqi emissiyaların azaldılmasına və uzunmüddətli iqtisadi dayanıqlılığın möhkəmləndirilməsinə töhfə verir. Tədqiqatda vurğulanır ki, iqlim siyasətinin, yaşıl investisiyaların və dayanıqlı turizm idarəçiliyinin inteqrasiyası 13-cü Dayanıqlı İnkişaf Məqsədinin hədəflərinə nail olmaq üçün zəruridir.

Açar sözlər: *turizm, CO_2 emissiyalarının intensivliyi, iqtisadi artım, DİM 13, dayanıqlı turizm, iqlim dəyişikliyi*

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1. Introduction

Tourism is a key driver of economic growth, employment, and regional development, yet it also contributes significantly to carbon emissions. This study examines the dynamic impact of CO_2 emission intensity in tourism on economic growth within the context of sustainable development. Emission intensity is assessed as a strategic indicator that determines the efficiency and competitiveness of the tourism sector. The study also analyzes the role of green energy, eco-innovation, and sustainable tourism management in achieving the goals of SDG 13.

2. Literature review

The relationship between the tourism sector's contribution to economic growth and the rise in carbon emissions is a significant topic of research within the context of sustainable development. Under SDG 13, the primary objective is to strike a balance between the economic benefits of tourism and the reduction of emissions. Existing studies indicate that tourism drives up CO_2 emissions through transportation, accommodation, energy consumption, and service infrastructure (Lee & Brahmasrene, 2013; Paramati et al., 2017). Khan et al. (2020), Nosheen et al. (2021), and Lenzen et al. (2018) have highlighted the importance of energy efficiency, renewable energy, and the carbon footprint of tourism. Recent research focuses on green energy, emission intensity, and carbon transfer. Nevertheless, studies examining the complex relationship between the CO_2 emission intensity of tourism, economic growth, and SDG 13 remain limited.

3. Data and Methodology

The methodological framework of the study is based on examining the relationship between CO_2 emission intensity in the tourism sector and economic growth within the context of SDG 13. An econometric analysis using panel data was conducted based on international statistical information. Tourism revenues, energy consumption, renewable energy usage, and economic openness were

considered as control variables. Fixed and random effects models, panel cointegration, and dynamic panel approaches were employed. Furthermore, international documents regarding climate policy, green tourism, and carbon emission reduction were evaluated through comparative and qualitative analysis. The use of country case studies and the comparison of various data sources enhanced the reliability of the findings.

4. Results and Discussion

Research shows that tourism development boosts GDP, employment, foreign currency earnings, and regional development; however, increased energy consumption in transport, accommodation, and infrastructure drives up CO_2 emissions. Renewable energy, energy-efficient buildings, smart systems, electric transport, and digital technologies can reduce both emissions and costs. Carbon taxes, green investments, and environmental standards promote low-carbon tourism, strengthening the sector's competitiveness by balancing economic growth with sustainability.

Table 1
Dynamic effects of tourism CO_2 emission intensity, economic growth, and SDG 13 indicators

Factor Group	Impact	Economy	Ecology	SDG 13
Revenue & Infrastructure	±	GDP / Growth ↑	Energy / Build ↑	Risk
CO_2 Intensity	-	Efficiency ↓	Carbon footprint ↑	Direct (-)
Green Transition (Energy, Investment, Transport)	+	Costs ↓ / Competitiveness ↑	Emissions ↓ / Eco-efficiency ↑	+++
Policy & Certification	- / +	Resource efficiency	Standards ↑ / Emissions ↓	+++
Sustainable Management	+	Stability	Eco-balance	Strategic

Source. Prepared by the author based on a summary of the literature (Conefrey & Hanrahan, 2025; Gazeloğlu & Erkılıç, 2025; Khan et al., 2020; Nosheen et al., 2021; Paramati et al., 2017; Shereni, 2024; Shi et al., 2024; Zhao et al., 2024; Lenzen et al., 2018 and other sources).

Tourism development boosts GDP, employment, and growth, but it can also increase energy consumption and carbon emissions. Green competitiveness supports sustainable development through renewable energy, efficiency, low-carbon transport, and innovation. Artificial intelligence enhances resource efficiency, reduces emissions, and strengthens climate adaptation.

In a simple way, we can express green competitiveness as follows:

$$G = k1\ P / (E + R + C)$$

Where k1 is a constant coefficient and indicates the overall efficiency of the system. This formula shows that as productivity increases and energy, resource, and carbon emissions decrease, green competitiveness increases.

To include the impact of AI, let us assume that AI application increases productivity and simultaneously reduces resource, energy, and emissions use. We can model this as follows:

$$P = P0\ (1 + a\ A)$$

$$E = E0\ (1 - b\ A)$$

$$R = R0\ (1 - c\ A)$$

$$C = C0\ (1 - d\ A)$$

Here P0, E0, R0, C0 are the initial levels, and a, b, c, d are positive coefficients indicating the effect of AI.

Substituting these expressions into the formula for G:

$$G = k1\ [P0\ (1 + aA)] / [E0(1 - bA) + R0(1 - cA) + C0(1 - dA)]$$

This model shows that as A increases (i.e., as AI is applied more), productivity increases, while the denominator decreases, and as a result, G increases.

We can write the sustainable development indicator in a broader form. Let D consist of environmental, economic, and social components:

$$D = k2\ (G + S + Q)$$

Where S is the social benefit (e.g., quality of jobs for local people) and Q is the quality of service. We can model the impact of AI on these indicators in the same way:

$$S = S0\ (1 + m\ A)$$

$$Q = Q0\ (1 + n\ A)\ \text{Thus:}$$

$$D = k2\ [G + S0(1 + mA) + Q0(1 + nA)]$$

The implication of this model is that AI increases the overall level of sustainable development by improving not only technical efficiency, but also social and qualitative aspects.

For a simpler interpretation, we can also write the total effect in a combined form:

$$D = k3\ (1 + t\ A)$$

Here, t represents the overall positive impact of artificial intelligence. When $t > 0$, the application of artificial intelligence enhances sustainable development. In tourism, AI boosts productivity, reduces resource and energy consumption, minimizes carbon emissions, and strengthens green competitiveness. The 3D model illustrates the relationship between green competitiveness and sustainable development as the intensity of AI application increases. In the model, the X-axis represents AI intensity, the Y-axis represents resource efficiency, and the Z-axis represents the overall sustainable development indicator.

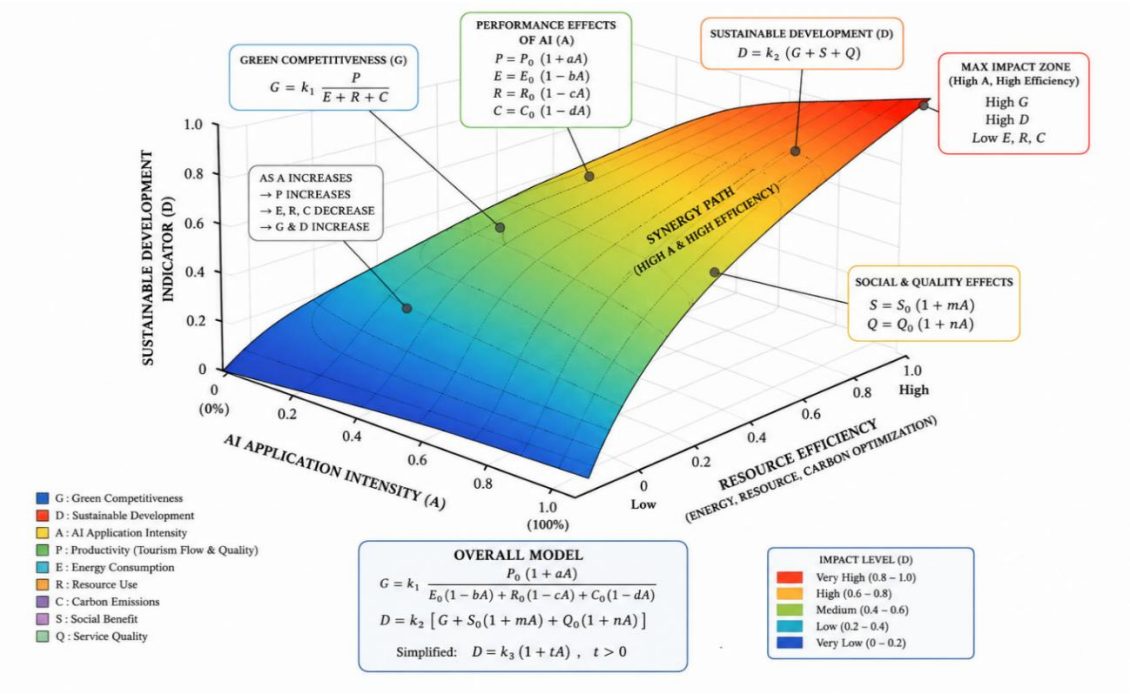


Chart 1

Three-dimensional conceptual model of the dynamic effects of AI-supported tourism mechanisms on green competitiveness and sustainable development

Source. Compiled by the author.

Chart 1 illustrates the impact of artificial intelligence on green competitiveness and sustainable development in the tourism sector. The X-axis represents the intensity of AI application; the Y-axis represents resource efficiency—encompassing energy use, resource utilization, and carbon emissions; and the Z-axis represents sustainable development. Increased AI adoption enhances efficiency, reduces emissions, and strengthens green competitiveness within the framework of SDG 13.

5. Conclusion

The relationship between CO_2 emission intensity in the tourism sector and economic growth highlights the importance of SDG 13. While tourism supports economic growth, it also drives up energy consumption and carbon emissions. Reducing carbon intensity can foster development through green energy, low-carbon transport, and eco-innovations. Artificial intelligence enhances resource efficiency, productivity, and emission reductions. A 3D model illustrates how AI balances economic efficiency with environmental responsibility. Green digitalization, financing, and carbon monitoring promote sustainable tourism.

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Informatization as a Driver of Social Acceleration: A Conceptual Analysis with Reference to Uzbekistan

Azizkhon Rasulov

Abstract. *This article examines informatization as a mechanism of social acceleration and evaluates its implications for contemporary social development, with particular reference to Uzbekistan. The study asks how digital infrastructures alter the speed of communication, knowledge production, institutional decision making, and everyday activity, and why time-saving technologies may simultaneously intensify time pressure. A qualitative conceptual design combines comparative analysis of theories of the network society, social acceleration, the infosphere, and digital inequality with document analysis of Uzbekistan's Digital Uzbekistan 2030 Strategy and recent international policy reports. The analysis identifies four linked mechanisms: compression of communication time, reconfiguration of social space, shortening of knowledge and innovation cycles, and acceleration of institutional services. These mechanisms expand access to information and reduce transaction time, but their benefits remain conditional on digital skills, reliable infrastructure, critical media literacy, and equal opportunities to use digital services. The Uzbek case shows that faster public services and wider digital access should be evaluated through social outcomes rather than technical speed alone. The article concludes that sustainable digital transformation requires a balance between efficiency and human capacity. Policy should therefore combine infrastructure investment with inclusive access, lifelong learning, information integrity, and transparent evaluation of whether digital systems reduce burdens for citizens.*

Keywords: *social acceleration, informatization, information society, digital transformation, temporal change, digital inequality, Uzbekistan*

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Sosial sürətlənmənin hərəkətverici qüvvəsi kimi informasiyalaşdırma: Özbəkistan timsalında konseptual təhlil

Azizkhon Rasulov

Xülasə. *Məqalədə informasiyalaşdırma sosial sürətlənmənin mexanizmi kimi araşdırılır və bu prosesin müasir cəmiyyətin inkişafına təsiri Özbəkistan nümunəsinə istinadla qiymətləndirilir. Tədqiqat rəqəmsal infrastrukturların kommunikasiya, bilik istehsalı, institusional qərarvermə və gündəlik fəaliyyətin sürətini necə dəyişdirdiyini, həmçinin vaxta qənaət edən texnologiyaların niyə eyni zamanda zaman təzyiqini artıra bildiyini izah edir. Keyfiyyət yönümlü konseptual yanaşma şəbəkə cəmiyyəti, sosial*

sürətlənmə, infosfer və rəqəmsal bərabərsizlik nəzəriyyələrinin müqayisəli təhlilini "Rəqəmsal Özbəkistan 2030" Strategiyası və beynəlxalq siyasət sənədlərinin təhlili ilə birləşdirir. Təhlil qarşılıqlı əlaqəli dörd mexanizmi müəyyən edir: kommunikasiya vaxtının sıxılması, sosial məkanın yenidən qurulması, bilik və innovasiya dövrlərinin qısalması, institusional xidmətlərin sürətlənməsi. Bu mexanizmlər məlumat əldə etmək imkanlarını genişləndirir və əməliyyat vaxtını azaldır. Lakin nəticələr rəqəmsal bacarıqlardan, etibarlı infrastrukturdan, media və informasiya savadlılığından, eləcə də xidmətlərdən bərabər istifadə imkanlarından asılıdır. Özbəkistan nümunəsi sürətli xidmətlərin bütün sosial qruplar üçün əlçatan və etibarlı olmasının zəruriliyini göstərir. Məqalə texniki sürətin sosial nəticələrlə birlikdə qiymətləndirilməsini və rəqəmsal transformasiyanın inklüziv giriş, ömürboyu təhsil, informasiya etibarlılığı və şəffaf monitorinqlə dəstəklənməsini təklif edir.

Açar sözlər: *sosial sürətlənmə, informasiyalaşdırma, informasiya cəmiyyəti, rəqəmsal transformasiya, zaman dəyişməsi, rəqəmsal bərabərsizlik, Özbəkistan*

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1. Introduction

Digital technologies have reduced the time needed to produce, transmit, and process information. Messages that once depended on physical movement can now circulate almost instantly; administrative transactions can be completed through online portals; and scientific collaboration increasingly takes place through connected databases and platforms. These changes affect more than communication technology. They alter the temporal organization of work, education, public administration, and daily life. Informatization can therefore be studied as a social process that changes how institutions and individuals allocate time, coordinate action, and respond to new information.

Social acceleration provides a useful framework for examining these changes. Rosa (2013) distinguishes technical acceleration, the acceleration of social change, and the acceleration of the pace of life. Technical systems increase the speed of transport, communication, and production. Faster innovation then shortens the expected life of knowledge, routines, and institutions. Individuals respond by trying to perform more actions within the same period. This sequence helps explain why devices designed to save time do not necessarily create more free time. Wajcman (2015) argues that time pressure emerges through the social organization of technology, work, and expectations rather than from devices alone.

The network society perspective adds an institutional dimension. Castells (2010) describes networks and information flows as central structures of contemporary economies and societies. In this setting, actors with the ability to access, interpret, and circulate information can coordinate across distance, while those without reliable access or adequate skills face new forms of exclusion. Floridi (2014) similarly treats digital transformation as the expansion of an infosphere in which online and offline activities increasingly overlap. These approaches show that acceleration is uneven: a service can become faster at the system level while remaining difficult to use for people with limited connectivity, literacy, disability support, or trust.

Uzbekistan offers a relevant national context for this analysis. The Digital Uzbekistan 2030 Strategy defines digital infrastructure, electronic government, digital skills, and sectoral transformation as long-term priorities (President of the Republic of Uzbekistan, 2020). The policy direction connects digitalization with public-service delivery, economic modernization, education, and regional development. The Organisation for Economic Co-operation and Development (OECD, 2024) notes that Uzbekistan has created institutional arrangements for coordinating digital transformation, including monitoring mechanisms and designated digital leadership within public bodies, while also identifying continuing needs in skills, coordination, and implementation capacity.

The research problem is that faster information processing is often treated as evidence of social progress without examining who benefits, what burdens are transferred to users, or how speed affects decision quality. Technical performance indicators such as transaction time, portal availability, or data-processing capacity are necessary but incomplete. Social evaluation must also consider accessibility, reliability, cognitive demands, information integrity, and the capacity of people and institutions to adapt.

This article asks two questions. First, through which mechanisms does informatization contribute to social acceleration? Second, what conditions allow faster digital systems to support inclusive development rather than reproduce inequality and time pressure? The article develops a conceptual model and applies it to the policy setting of Uzbekistan. Its contribution is a distinction between operational speed and socially beneficial acceleration. The former describes faster processes; the latter requires demonstrable improvements in access, capability, service quality, and human well-being.

2. Materials and methods

The study uses a qualitative conceptual and document-analysis design. It does not present survey data or claim causal measurement. The analytical corpus combines established theoretical works on information society and temporality with policy documents that describe digital transformation in Uzbekistan and with international reports on connectivity, governance, and digital inclusion. The theoretical group includes Castells (2010), Floridi (2014), Prigogine and Stengers (1984), Rosa (2013), van Dijk (2020), and Wajcman (2015). The policy and comparative group includes the Digital Uzbekistan 2030 Strategy, the OECD public governance review of Uzbekistan, reports by the International Telecommunication Union, the United Nations, UNESCO, and the World Bank.

Documents were selected through four criteria: direct relevance to informatization or social acceleration; identifiable authorship or institutional responsibility; sufficient bibliographic information for verification; and usefulness for interpreting the Uzbek policy context. The analysis proceeded in three stages. First, the sources were coded for claims about time, speed, spatial reach, knowledge production, institutional coordination, access, skills, and risk. Second, related claims were grouped into recurring mechanisms of acceleration. Third, each mechanism was assessed through a benefits-and-conditions matrix that separates technical possibilities from social outcomes.

The approach treats social acceleration as a relational process. A reduction in processing time becomes socially meaningful only when users can access the system, understand the information, complete the required action, and obtain a reliable result. This rule prevents the analysis from equating digitalization with automatic improvement. It also supports comparison across domains such as public services, education, work, and communication without assuming that the same technology produces identical effects in each setting.

The Uzbek component is an interpretive policy case. The Digital Uzbekistan 2030 Strategy is examined as a statement of institutional priorities, not as proof that every objective has been achieved. OECD findings are used to identify governance capacity and implementation constraints. Global reports provide comparative concepts rather than country-specific causal estimates. This limited claim is important because documentary evidence can establish policy design and conceptual relationships but cannot, by itself, measure citizens' lived experience.

Statement on the Use of Artificial Intelligence. An AI tool was used to support English-language editing, structural organization, and consistency checking. The author is responsible for the argument, source selection, interpretation, factual verification, and final approval of the manuscript. No images or empirical data were generated with AI.

3. Results

Communication Time and the Compression of Distance

The first mechanism is the compression of communication time. Digital networks allow messages, documents, payments, and audiovisual interaction to move without the delays associated with physical transport. This does not eliminate geography, but it changes the practical significance of distance. People in different locations can participate in the same meeting, course, market, or administrative procedure. Castells (2010) describes this organization through flows that connect dispersed actors, while Floridi (2014) explains how digital environments become part of ordinary social reality.

The social effect depends on more than transmission speed. Stable electricity, affordable connectivity, usable interfaces, language support, identity systems, and public trust determine whether a formally available service reduces time for users. The International Telecommunication Union (ITU, 2025) continues to document gaps in meaningful connectivity across income groups and locations. van Dijk (2020) shows that digital inequality includes motivation, material access, skills, types of use, and outcomes. A fast platform can therefore widen differences when experienced users save time while others must seek assistance, repeat failed transactions, or travel to complete the same procedure offline.

For Uzbekistan, the relevant policy issue is whether the expansion of electronic services reduces the total time and cost of interaction with public institutions across regions and social groups. The Digital Uzbekistan 2030 Strategy links infrastructure development with electronic government and sectoral digitalization (President of the Republic of Uzbekistan, 2020). Evaluation should measure the complete user journey, including registration, authentication, error correction, support, and final resolution. Processing speed inside an institution is valuable only when citizens experience a more accessible and dependable service.

Knowledge Production and Shorter Innovation Cycles

The second mechanism is the shortening of knowledge and innovation cycles. Databases, digital modelling, automated analysis, and global research communication allow scholars and professionals to compare larger bodies of information and circulate results more quickly. The cycle from knowledge production to application and further revision can therefore contract. This process increases the value of analytical competence and the ability to update knowledge throughout a career.

Acceleration also changes the durability of competence. When software, professional standards, and information environments change rapidly, a qualification obtained at one point cannot guarantee long-

term readiness. Lifelong learning becomes a practical response to shorter knowledge cycles. Grizzle et al. (2021) treat media and information literacy as a set of capacities for accessing, evaluating, creating, and communicating information. These capacities matter because an abundance of information does not produce knowledge unless users can judge sources, context, and evidence.

In education, speed should not displace reflection. Rapid access can support discovery and collaboration, but it can also encourage superficial reading, unverified reproduction, and dependence on automated output. The appropriate educational response is to combine digital competence with disciplinary reasoning. Students and professionals need time to formulate questions, test claims, compare sources, and revise conclusions. The goal is not maximum speed in every task. It is the ability to choose when speed is useful and when slower analysis protects quality.

Institutional Acceleration and Public Services

The third mechanism is institutional acceleration. Integrated databases and online workflows can reduce duplicated documentation, shorten communication between agencies, and make service status more visible. The United Nations (2024) treats digital government as a combination of infrastructure, online services, human capital, and institutional capacity. This broad approach matters because digitizing an inefficient procedure may preserve unnecessary steps in electronic form rather than simplify the service.

Uzbekistan's strategy creates a policy basis for expanding digital public services and modernizing administrative processes. The OECD (2024) identifies both a coherent national direction and operational challenges, including the need to strengthen digital skills and strategic coordination. These findings support a distinction between automation and institutional reform. Automation moves existing tasks into software. Reform questions whether each task, approval, or data request remains necessary and whether agencies can reuse verified information lawfully and securely.

Institutional acceleration can also affect decision quality. Faster data flows may improve situational awareness, but rapid response expectations can reduce deliberation or produce decisions based on incomplete indicators. Prigogine and Stengers (1984) emphasize that complex systems develop through non-linear processes and cannot always be understood through simple equilibrium models. Applied cautiously to social institutions, this insight suggests that more data and faster feedback do not remove uncertainty. Governance systems still require professional judgment, correction mechanisms, and time for public explanation.

The Acceleration Paradox

The fourth result is a recurring acceleration paradox. A technology may reduce the time needed for one task while increasing the number of tasks expected within a day. Instant messaging shortens communication delay but creates expectations of immediate availability. Automated systems reduce manual processing but require continuous monitoring, updates, and new compliance routines. Online learning expands access but shifts more responsibility for scheduling, verification, and self-management to learners.

Wajcman (2015) explains that time pressure is socially produced through work arrangements, household responsibilities, and cultural expectations. Rosa (2013) likewise argues that technical acceleration interacts with faster social change and a higher pace of life. The combined result is not a simple gain or loss of time. It is a redistribution of time between institutions, workers, users, and households. A portal

may save travel time for a citizen while creating additional verification work for staff; automated reporting may speed supervision while increasing the frequency of required reports.

This paradox requires outcome-based evaluation. Digital projects should identify whose time is saved, whose work increases, and whether the redistribution is fair. Measures can include completion rates, repeated attempts, support requests, waiting time, error correction, staff workload, and user satisfaction. These indicators reveal effects hidden by a narrow focus on the speed of a server or the number of services placed online.

Table 1
Mechanisms and conditions of socially beneficial acceleration

Mechanism	Potential gain	Principal risk	Required condition
Communication time	Faster exchange and remote access	Exclusion through cost, access, or poor usability	Affordable connectivity, accessible design, and support
Knowledge cycles	Rapid discovery, collaboration, and updating	Superficial processing and unreliable information	Critical literacy, disciplinary reasoning, and lifelong learning
Institutional services	Shorter transactions and better coordination	Digitized bureaucracy and transferred workload	Process redesign, interoperable systems, and user-centred evaluation
Everyday activity	Flexible scheduling and reduced travel	Permanent availability and intensified time pressure	Boundaries, realistic expectations, and workload monitoring

4. Discussion

The results show that informatization accelerates society through linked changes in communication, knowledge, institutions, and everyday expectations. These mechanisms reinforce one another. Faster communication supports shorter innovation cycles; shorter cycles increase pressure on education and organizations; institutional digitalization raises expectations for immediate service; and these expectations shape individual time use. Social acceleration is therefore neither a single technological effect nor a uniform national trajectory.

The distinction between operational speed and socially beneficial acceleration clarifies the policy problem. Operational speed is measurable through technical indicators such as response time or automated processing. Social benefit requires additional evidence that people can complete tasks, understand decisions, protect their data, and obtain equitable outcomes. A digital service that works quickly for experienced users but excludes others may improve average speed while reducing institutional fairness.

Digital inequality is central to this distinction. van Dijk (2020) demonstrates that access is a sequence rather than a single threshold: motivation and physical access affect skill development; skills shape use; and forms of use influence outcomes. The ITU (2025) similarly shows that global connectivity has expanded while substantial location and income gaps remain. In the Uzbek context, regional coverage,

device affordability, language, disability access, and confidence in online procedures can influence whether digitalization reduces or increases the time required to obtain a service.

The World Bank (2022) identifies human capital, inclusion, private-sector development, and effective institutions as major elements of Uzbekistan's development path. These priorities support an integrated view of digital policy. Infrastructure investment is necessary, but it should be accompanied by digital-skills programmes, accessible service channels, and support for groups that face barriers. Maintaining a non-digital or assisted route during transitions can protect access while institutions improve online systems.

Information integrity is another condition. As circulation becomes faster, inaccurate or manipulative content can reach large audiences before verification occurs. The framework by Grizzle et al. (2021) is relevant because it links technical use with critical evaluation, ethical creation, and participation. Media and information literacy should therefore be treated as a public capability, not only an educational subject. Public bodies can support it through transparent data, clear corrections, accessible explanations, and consistent communication of uncertainty.

The temporal dimension also changes how institutions should manage reform. Digital programmes often use deadlines and numerical targets to maintain momentum. These tools can improve accountability, but excessive emphasis on rapid rollout may produce systems that are technically complete and socially difficult to use. Pilot testing, user research, independent accessibility review, and staged implementation can slow one phase of delivery while reducing later errors and repeated work. Deliberate pacing is therefore compatible with long-term acceleration when it improves reliability.

For Uzbekistan, the Digital Uzbekistan 2030 Strategy provides a broad framework for infrastructure, services, and skills. The next analytical step is to connect national indicators with citizen-level outcomes. Ministries and service providers could report median end-to-end completion time, unsuccessful attempts, use of assisted channels, regional differences, accessibility compliance, and the time staff spend correcting digital errors. Publishing these measures would allow researchers and citizens to judge whether digital transformation is reducing burdens across the population.

The article's conceptual model also has implications for education and work. Institutions should not define digital competence as rapid device use alone. Competence includes source evaluation, privacy awareness, problem solving, and the ability to choose an appropriate pace for complex tasks. Employers and public agencies should review whether constant connectivity creates avoidable interruptions or unrealistic response expectations. Time saved by automation should support higher-quality work and learning rather than automatically generate additional reporting and communication.

Limitations

This study is conceptual and document based. It does not measure changes in service time, employee workload, digital skills, or citizen satisfaction in Uzbekistan. Policy documents describe objectives and institutional arrangements, but they cannot establish implementation outcomes. International reports use different units and purposes, so they provide context rather than a common dataset for causal comparison.

The analysis also groups diverse technologies under the broad term informatization. Artificial intelligence, electronic government, online education, digital payments, and social media operate through different institutions and risks. The four-mechanism model is intended to organize inquiry, not to replace

sector-specific analysis. Claims about benefits and risks should therefore be tested within particular services and population groups.

Future research

Future research should test the model through mixed methods. Administrative data can measure processing and completion time, while surveys and interviews can identify hidden costs such as repeated attempts, travel for identity verification, dependence on intermediaries, and pressure to remain constantly available. Studies should disaggregate results by region, age, gender, income, disability, education, and language to determine whether average improvements conceal unequal outcomes.

Longitudinal studies could compare services before and after digital redesign and distinguish temporary adjustment costs from persistent barriers. Comparative research across Central Asian countries could examine how institutional structure, connectivity, and public trust shape the relationship between technical speed and social benefit. Research on schools, universities, and workplaces should also investigate which forms of digital acceleration support learning and which reduce attention, reflection, or well-being.

5. Conclusion

Informatization contributes to social acceleration by compressing communication time, reshaping the practical meaning of distance, shortening knowledge cycles, and increasing the speed of institutional services. These changes can broaden access to information and reduce transaction costs. They can also intensify time pressure, transfer administrative work to users, accelerate unreliable information, and deepen inequality when access and skills are uneven.

The Uzbek policy context illustrates why digital transformation should be evaluated through outcomes as well as infrastructure and service counts. Faster systems become socially beneficial when people can use them reliably, institutions redesign unnecessary procedures, and saved time is not replaced by new burdens. Digital policy should therefore combine infrastructure with inclusive design, lifelong learning, media and information literacy, information security, and transparent performance evaluation.

Social acceleration is not a goal that should be maximized without qualification. The appropriate goal is a digital environment in which speed serves human judgment, institutional accountability, and equitable access. This approach preserves the efficiency gains of informatization while recognizing that sustainable development also requires time for learning, verification, deliberation, and adaptation.

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Declarations

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Ethics Statement. The study used publicly available documents and did not involve human participants, personal data, or experimental procedures.
Author Contribution. The author developed the concept, reviewed the sources, interpreted the materials, and approved the final manuscript.

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Algorithmic Financial Governance and Diagnostic Transparency: A Comparative Study of the Pharmaceutical Sector Using DuPont Analysis and Python (2020–2024)

Sihem Ouaddane

Abstract. *This study examines the role of algorithmic financial governance in improving the accuracy and transparency of financial performance in the pharmaceutical industry, specifically closing the Diagnostic Transparency Gap between public structural inertia and private operational agility. The study uses a modern quantitative algorithmic methodology, implementing a DuPont analysis model in Python (using the pandas, Matplotlib and Seaborn libraries) to evaluate financial data for 2020–2024. The results indicate that computational modeling reduced information transmission time and revealed notable differences in operational efficiency and capital structure between public and private firms, particularly after recent investment legislative reforms. The study shows that digital governance reduces human error in accounting and recommends adopting software automation in internal control systems to improve financial reporting quality and support strategic financial management. Empirically applied to two representative enterprises in Algeria (Saidal Group and Biopharm) under Investment Law No. 22-18, this framework remains fully scalable and applicable to other pharmaceutical entities and emerging market contexts.*

Keywords: *algorithmic governance, DuPont analytics, financial transparency, pharmaceutical sector, Python*

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. Alqoritmik maliyyə idarəetməsi və diaqnostik şəffaflıq: DuPont analizi və Python vasitəsilə əczaçılıq sektorunun müqayisəli tədqiqi (2020–2024)

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Xülasə. *Bu tədqiqat əczaçılıq sənayesində maliyyə göstəricilərinin dəqiqliyini və şəffaflığını artırmaqda, xüsusən də dövlət struktur ətaləti ilə özəl əməliyyat çevikliyi arasındakı Diaqnostik Şəffaflıq Fərqini aradan qaldırmaqda alqoritmik maliyyə idarəetməsinin rolunu araşdırır. Tədqiqat 2020–2024-cü illər üçün maliyyə məlumatlarını qiymətləndirmək üçün Python dilində DuPont analiz modelini (pandas, Matplotlib və Seaborn kitabxanalarından istifadə etməklə) tətbiq edərək müasir kəmiyyət alqoritmik*

metodologiyasından istifadə edir. Nəticələr göstərir ki, hesablama modelləşdirməsi məlumat ötürülmə müddətini azaltmış və xüsusilə son investisiya qanunvericilik islahatlarından sonra dövlət və özəl firmalar arasında əməliyyat səmərəliliyi və kapital strukturunda nəzərəçarpacaq fərqlər aşkar etmişdir. Tədqiqat göstərir ki, rəqəmsal idarəetmə mühasibat uçotunda insan səhvlərini azaldır və maliyyə hesabatlarının keyfiyyətini artırmaq və strateji maliyyə idarəetməsini dəstəkləmək üçün daxili nəzarət sistemlərində proqram təminatının avtomatlaşdırılmasını tövsiyə edir. 22-18 saylı İnvestisiya Qanununa əsasən Əlcəzairdəki iki nümayəndə müəssisəyə (Saidal Group və Biopharm) empirik olaraq tətbiq edilən bu çərçivə tam miqyaslı və digər əczaçılıq müəssisələrinə və inkişaf etməkdə olan bazar kontekstlərinə tətbiq oluna bilər.

Açar sözlər: *alqoritmik idarəetmə, DuPont analitikası, maliyyə şəffaflığı, əczaçılıq sektoru, Python*

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1. Introduction

The pharmaceutical industry is not only a sector but a key to national security. Emerging economies increasingly need new or improved pharmaceutical finance and governance systems to strengthen supply chains and attract foreign investment. Algeria has experienced a dramatic economic shift over the past decade. Algeria's economy has changed immensely over the past decade. Algeria now has two pharmaceutical industries. One is public, and the other is private and rapidly expanding. Algeria's pharmaceutical industry is now valued at nearly $4 billion and is the third-largest pharmaceutical market on the continent. The industry not only has a major impact on the Algerian economy but also helps reduce foreign exchange outflows.

A second major change in Algeria's pharmaceutical industry was the transformation of the regulatory body. The most prominent reform is the 2022 Investment Reform, or Law 22-18. This reform has reshaped the country's investment landscape. The intent was to improve transparency and reduce discrimination between foreign and domestic investments. Despite these reforms, the push toward self-sufficiency in the pharmaceutical industry has changed the industry's competitive dynamics. Industry governance is also heavily restricted (Gamane & Guedid, 2021; Halidias, 2025). This issue is prevalent in developing economies, where regulatory reforms tend to move faster than firms' financial diagnostics. Between 2020 and 2024, the world was under extreme pressure. Supply-chain issues, economic strain, and regulatory challenges delayed financial reporting. Despite Algeria's efforts to modernize its financial processes, most companies still rely on manual, periodic processes that involve spreadsheets. These processes slow operations and conceal failures. However, Ross et al. (2022) note that static financial statements can mislead investors. For industries such as pharmaceutical manufacturing, the time between initiating a process and achieving its outcome is a crucial competitive factor.

Algorithmic financial governance is another result of this environment. Instead of performing financial diagnostics to ensure regulatory compliance, companies are rebuilding this process into their automated systems. This represents a fundamental shift in thinking. By combining big data analytics with digital governance systems and using tools like Python to run these analyses, companies are gaining real-time insights into their financial data (Bakader & Chemakhi, 2025; Xu, 2024).

Furthermore, these developments have also affected the DuPont model. The DuPont model was created many years ago to analyze companies' ROE using four variables. However, user-friendly software can now perform these analyses, providing accurate assessments of a company's financial situation and variables at a level previously considered inaccessible to most analysts (Halidias, 2025). By embedding modern computational libraries into classic financial frameworks, algorithmic governance transcends local institutional constraints and provides a standardized, scalable diagnostic tool applicable across diverse regulatory environments.

This research sits at the intersection of three areas: DuPont's diagnostic capabilities for companies, the computational transformation of financial logic, and the digital governance of the Algerian pharmaceutical market. The Algerian pharmaceutical market presents a duality of public and private companies. Saidal Group, a public company, is often described as structurally rigid. In comparison, Biopharm, a private company and the country's leader, benefits from operational agility, allowing it to maintain high turnover rates and sustain profit margins. Many studies have examined pharmaceutical companies in Algeria. However, no experimental framework integrates DuPont's diagnostics with Python and algorithmic governance of the pharmaceutical market in Algeria. Most market studies lack comprehensiveness. They use regression methods based on spreadsheets and Excel worksheets, making it impossible to translate model-independent programming logic into diagnostic tools for the pharmaceutical companies in question (Halidias, 2025; Xu, 2024). Consequently, there is a critical need for an empirical benchmark that demonstrates how computational financial modeling bridges the transparency gap between state-owned and private entities in strategic sectors.

The research will attempt to answer the following question:

To what extent can Python-driven DuPont analysis bridge the diagnostic transparency gap between public and private pharmaceutical firms using the Algerian market as an empirical baseline?

To address this question, the empirical work tests three core hypotheses:

- The level of algorithmic automation has a positive and significant effect on the diagnostic transparency index in the Algerian pharmaceutical sector.
- There are statistically significant differences in the diagnostic transparency gap and return on equity between Saidal and Biopharm.
- The 2022 Investment Reform (Law 22-18) positively affects return on equity (ROE) in the Algerian pharmaceutical sector.

This paper aims to analyse the effects of algorithmic automation on financial and diagnostic transparency in the Algerian pharmaceutical industry from 2020 to 2024. In addition, it will examine the effects of the 2022 investment reform on financial governance in Biopharm and Saidal using the DuPont model. This paper will contribute to the existing body of financial knowledge by using algorithms in financial analysis and will offer implications for financial management within the pharmaceutical industry under study. Furthermore, this study will provide a transferable approach that policymakers and financial analysts can use to automate governance in state-affected markets globally.

2. Literature Review And Theoretical Background

The theoretical and conceptual underpinnings of this study include four main aspects: the DuPont identity, the algorithmic transformation of financial theory, digital governance, and the development of the Algerian pharmaceutical sector between 2020 and 2024. The literature review informing this study

draws on both financial theory and computational intelligence theory to form a framework for algorithmic financial governance based on Python DuPont analyses (Bakader & Chemakhi, 2025; McKinney, 2022; Ross et al., 2022; Xu, 2024).

2.1. The Synthesis of Financial Theory and Computational Intelligence

Among the tensions that have characterized the development of corporate diagnostics are those based upon automation and those based upon qualitative evaluations of strategy. The DuPont equation is a theoretical cornerstone of corporate diagnostics. According to Ross et al. (2022), the model provides a framework for precise analysis of a company's return on equity. The model evaluates a company's return on equity by analyzing three components: operational efficiency, asset productivity and financial leverage. Isolating these three components of the DuPont equation is essential to understanding the company's profitability and quality.

In the Algerian pharmaceutical sector, the model's impact is clear. Gamane and Guedid (2021) applied the DuPont model to Saidal Group, one of Algeria's pharmaceutical companies. The results showed that Saidal Group is profitable but has a relatively low profitability level. Moreover, stagnant performance is driven by inefficient asset use and low utilization of capital resources.

Emerging markets are volatile, and data moves quickly. However, most current diagnostic tools are not built to handle this. They are also static and do not work well in emerging markets. This study bridges this gap by applying the financial principles of the DuPont model using Python analytics. While some have suggested automating certain finance tasks (Chen, 2023; McKinney, 2022), this study specifically focuses on automating the DuPont model for the Algerian pharmaceutical sector (Bakader & Chemakhi, 2025; Benkedidah & Hadada, 2024). In addition to providing insight into the current state of the government-owned pharmaceutical companies in Algeria, including Saidal, this study also further examines the factors that cause stagnation in these companies' performance. By automating the DuPont model for these companies, they can respond in real time to the operational and economic issues they face. This is particularly important for firms operating in volatile markets because real-time response helps them survive (Damodaran, 2014).

2.2. Algorithmic Auditing and Predictive Resilience in Modern Markets

Emerging markets worldwide are shifting toward what could be termed "predictive resilience". Benkedidah and Hadada (2024) call for high-accuracy early warning systems in the pharmaceutical industry, as it faces various shocks and supply-chain disruptions. In most cases, however, these systems rely on traditional methods rather than advanced, automated algorithms to monitor supply chains and individual companies' resilience.

One way to develop such an algorithm is to use the Pythonic algorithms endorsed by Xu (2024). By integrating these algorithms into the DuPont analysis model, it is possible to create an intricate analysis tool for the Algerian pharmaceutical industry. Furthermore, by using automated data collection and advanced visualizations (such as heat maps), the pharmaceutical company can efficiently monitor its supply chain. As a result, the efficiency gap between companies like Saidal and Biopharm can be narrowed, in line with pharmaceutical management frameworks established by Bodie et al. (2021) and Benkedidah and Hadada (2024).

2.3. Computational Capability and Financial Divergence

The theoretical grounding for the performance disparity between public and private pharmaceutical firms is based on the theory of computational capability, as outlined by Abramovitz (1986). Abramovitz explains that technology convergence is not automatic; it requires certain organizational criteria to ensure the technology can be integrated effectively. In Algeria's pharmaceutical industry, while capital allocation to information technology is no longer the main determinant of success, the rate at which data is acquired and algorithmic analyses are performed has become the determining factor for performance (Bakader & Chemakhi, 2025).

Evidence from existing literature indicates that companies implementing algorithmic auditing procedures can identify supply chain issues that threaten profitability up to 40% faster than those that rely on manually programmable spreadsheets. Furthermore, implementing technologies like Python in the auditing process enables traceable, validated supply chains, reducing the time required to investigate the causes of identified problems (McKinney, 2022). Thus, the computational gap between companies that use algorithmic auditing procedures and those that rely on Excel-based supply-chain tracking may help explain the overall performance gap between public and private pharmaceutical companies in the sector.

Table 1

Comparative analysis of financial diagnostic frameworks (2020–2024)

Dimensions	Algorithmic framework (Python)	Traditional framework (Excel)
Data integrity	Incorporates automation of data ingestion, which aids in "earnings-management" mitigation and enhances transparency by standardizing audit trails (McKinney, 2022).	High susceptibility to human error and potential manual manipulation during data entry and processing.
Analysis velocity	Facilitates dynamic, real-time monitoring and allows for quick action in response to financial shocks (Xu, 2024).	Relies on static, time-consuming manual updates that often result in delayed decision-making.
Analytical depth	Multi-layered sensitivity analysis to identify "structural inertia" in asset utilization and operational inefficiencies (Halidias, 2025).	Limited to basic vertical and horizontal analysis, often overlooking complex non-linear correlations.
Data visualization	Utilizes interactive dashboards to transform complex datasets into actionable strategic insights (Waskom, 2021).	Dependent on rudimentary static charts that lack the depth required for complex strategic communication.
Prognostic power	Features a predictive orientation, utilizing statistical modeling to forecast financial failure or future performance.	Relies on past performance only, offering a retrospective view that lacks forward-looking predictive accuracy.

Source. Prepared by the author based on (McKinney, 2022) for algorithmic frameworks (Ross et al., 2022) for DuPont decomposition standards.

2.4. Discussion and Critical Synthesis of the Literature

The comparative metrics in Table 1 show that the algorithmic analysis model was designed to analyze the Algerian pharmaceutical industry between 2020 and 2024. The shift from utilizing spreadsheets to utilizing algorithmic analysis indicates a shift in corporate governance (McKinney, 2022). Furthermore, using Python to build the algorithmic analysis model helps reduce information asymmetry between pharmaceutical companies and their shareholders, such as Saidal. The Python program makes each of the company's underlying assumptions visible and traceable to the company's highest governing authority (Bakader & Chemakhi, 2025; Halidias, 2025). Thus, Python-enabled analysis of companies like Saidal can produce more accurate results than Excel-based models. Moreover, the Python-enabled DuPont analysis revealed each company's weaknesses within the pharmaceutical industry, which are often hidden in published financial ratios. These weaknesses often indicate issues in management and corporate governance. However, rather than indicating that the public sector for pharmaceutical companies in Algeria is worse than the private sector, our analysis of the study Gamane and Guedid (2021) indicates that the differences between the two sectors are due to the lag in technology and the immaturity of the algorithms implemented by the public sector companies.

Through this Python analysis, companies can achieve the operational clarity that Damodaran (2014) advocates. Companies can examine and interpret even subtle changes in asset turnover and leverage multipliers in real time. Thus, the audit trail for pharmaceutical companies will shift from a one-time event to an operational governance engine that can be continually used to manage the company's finances. Integrating data science into financial and operational control is the main driver of the Algerian pharmaceutical industry's alignment with the 2025 governance standards. This is particularly important in the current climate of reform within the pharmaceutical industry (Bakader & Chemakhi, 2025).

3. Methodology

This research uses a Comparative Quantitative-Algorithmic Research Design to examine the financial health of Algeria's pharmaceutical industry from 2020 to 2024. This research compares two cases: Saidal Group (public) and Biopharm (private). Both are analyzed using traditional financial ratios. However, the DuPont Identity is employed as an algorithm in Python to analyze the financial strength of both companies. This operationalizes and measures Algorithmic Financial Governance. Python uses the following data and analytical packages: NumPy for matrix operations in calculating the elements of the DuPont Identity, pandas for data wrangling and SciPy for statistical analysis. These packages enable algorithmic, replicable analysis in Python.

The research is carried out in five steps: Research, Data Collection, DuPont Identity Modeling, Algorithmic Transparency Modeling and Hypothesis Testing using panel data analysis.

3.1. Research Design

This research will use quantitative methods to analyse the performance of the Algerian pharmaceutical market from 2020–2024. Ross et al. (2022) found that quantitative methods are well suited to comparing the performance of pharmaceutical markets in developing economies. Several internal and external factors influence performance in these markets. The reforms implemented in the Algerian pharmaceutical market, as identified in the 2022 Investment Reform (Law 22-18), which aims to achieve 70% domestic pharmaceutical production, are well suited to this type of analysis.

This research aims to identify factors affecting the performance of the pharmaceutical market in Algeria and to make recommendations for the country. Additionally, Python-based market models will support data analysis by minimising errors that may occur with traditional spreadsheet analysis (McKinney, 2022). Beyond static ratio analysis, an algorithmic model will perform sensitivity and dynamic trend analyses on the components of the DuPont financial analysis. This will help minimise analyst bias and provide a template that can be used for pharmaceutical markets in developing economies.

The study will focus on two main axes of analysis:

- The Temporal Axis (2020–2024): This dimension captures the post-pandemic resilience phase (2020–2021), the reform-implementation window (2022–2023), and the initial digital-governance shift observed in 2024.
- The Sectoral Axis: By benchmarking the state-owned Saidal Group against the privately listed Biopharm, the study executes a 'structural stress test' of DuPont components—profitability, efficiency, and leverage—under contrasting governance regimes.
- This dual-axis approach will allow the analysis to determine whether the company's problems are due to operational efficiency, capital structure, or technological and governance issues (Damodaran, 2014).

3.2. Data Collection

This study is empirical, as the data were collected to ensure that corporate disclosures were consistent with their algorithmic diagnostics, audited and published for each corporation.

3.2.1. Institutional Scope

The main topic of the research was purposively selected using two pillars in the Algerian pharmaceutical domain:

- (public sector) Saidal Group
- (private company) Biopharm

These two entities serve as a representative empirical micro-environment for benchmarking state-owned versus privately held corporate governance dynamics in transition economies. In the Algerian context, research on financial matters is more reliable when the companies examined are listed on the SGBV. The SGBV includes both public and private sector companies, allowing for a comparison between the two sectors and providing context for the differences between public and private sector governance - the focus of this study.

3.2.2. Temporal Horizon and Rationale (2020–2024)

We select five successive fiscal years (2020–2024) as the dataset according to:

- Crisis Stage (2020–2021): Portrayals of pharmaceutical resilience in the face of international disruptions
- Reform Phase (2022–2023): Analyzing the effect of Law 22-18 on liquidity, capital structure and transparency in reporting.
- Digital recovery (2024): This is the initial evidence of algorithmic financial governance and automated disclosure norms.

3.2.3. Data processing

We collected raw data from audited annual reports, balance sheets, income statements and semiannual disclosures provided by the SGBV.

- Regarding data extraction, we did that manually, from PDF reports to structured xlsx formats.
- Verification of statistics against SGBV bulletins.
- We used the pandas library in Python to fill missing data, resolve “reporting noise,” and confirm the identity Assets = Liabilities + Equity before running DuPont decomposition (McKinney, 2022).

3.3. The Computational Framework in a Python Environment

To transition from static reporting to dynamic diagnostic analytics, Python (version 3.11) was used to build the computational infrastructure. This version of Python is the language in which the industry standard for financial data analysis was developed. (McKinney, 2022).

3.3.1. pandas for Structural Data Governance

pandas is the basic backbone that allows the library to manipulate the raw data from Saidal and Biopharm. Furthermore, the library uses machine learning to optimize the DuPont identity in matrix form across the companies' full dataset over time.

- .describe() and .info(): Serve as a "digital audit" that checks variable types, missing values, and distributional properties to ensure the validity of the subsequent analysis (Chen, 2023).

3.3.2. Matplotlib & Seaborn for Visual Analytics and Strategic Mapping

The study makes use of Matplotlib and Seaborn to fill the gap between the algorithmic and managerial perspectives regarding:

Time series visualization of ROA & ROE and efficiency leverage trade-offs (Waskom, 2021).

3.4. Algorithmic Operationalization of the DuPont Identity

This section describes the computational protocol for transforming financial data into meaningful insights. The ROA will be calculated for both companies as a baseline for their operational efficiency before applying the DuPont model for a more detailed analysis of their components.

3.4.1. Return on Assets (ROA)

The company can calculate ROA manually. However, the algorithm we develop will calculate this value. The formula for ROA is as follows:

The algorithm calculates the company's return on assets (ROA) before applying leverage. This helps assess management's use of the company's total resources. The primary purpose of calculating ROA is to determine whether the company creates value through operations or through leverage. The company can calculate ROA manually. However, the algorithm we develop will calculate this value. The formula for ROA is as follows:

$$\textbf{Formula} = \frac{\text{Net Profit}}{\text{Total Assets}}$$

To achieve computational scalability and minimize human error, the aforementioned identity is implemented in Python as follows:

Code Python:

```
# Code Python
df("ROA") = df("Net_Profit") / df("Total_Assets")
```

Following this calculation, ROA serves as a pre-leverage metric, reflecting how effectively management uses the firm's total resources, independent of capital structure.

3.4.2. The Three-Step DuPont Decomposition

Building on ROA, the study advances to the Three-Step DuPont Identity to decompose Return on Equity (ROE). This model, advanced by Damodaran (2014), allows the algorithm to dissect performance into three distinct drivers:

$$\text{ROE} = \underbrace{\frac{\text{Net Profit}}{\text{Revenue}}}_{\text{Net Profit Margin (NPM)}} \times \underbrace{\frac{\text{Revenue}}{\text{Total Assets}}}_{\text{Asset Turnover (AT)}} \times \underbrace{\frac{\text{Total Assets}}{\text{Equity}}}_{\text{Equity Multiplier (EM)}} \quad (1)$$

1. **Net Profit Margin (NPM)**: Measures pricing power and cost control.

Formula : $$\text{NPM} = \frac{\text{Net Profit}}{\text{Revenue}} \quad (2)$$

Code Python:

```
# Code Python
df("NPM" ) = df("Net_Profit") / df("Revenue")
```

2. **Asset Turnover (AT)**: Evaluates operational efficiency in utilizing assets.

Formula: $$\text{AT} = \frac{\text{Revenue}}{\text{Total Assets}} \quad (3)$$

Code Python:

```
# Code Python
df("AT") = df("Revenue") / df("Total_Assets")
```

3. **Equity Multiplier (EM)**: Quantifies financial leverage and risk.

Formula: $$\text{EM} = \frac{\text{Total Assets}}{\text{Equity}} \quad (4)$$

Code Python:

```
# Code Python
df("EM") = df("Total_Assets" ) / df("Equity")
```

3.4.3. Algorithmic Integrity and Verification

To further ensure the robustness of the computational output, a Verification Gate includes a "stress-test" that re-multiplies the three calculated components (NPM × AT × EM) and compares the result with the calculated ROE.

By automating this process, the authors eliminate the chance of error in calculating ROE from these three components (McKinney, 2022).

3.5. Computational Framework and Analytical Design

To bridge the gap between theory and algorithmic application, this study used an integrated framework. The framework reduces information lag in the analytical model to automatically detect anomalies in ROE. This framework processes Saidal and Biopharm's financial data to enable a comparison between the two companies. The framework also includes qualitative variables to assess the specific impact of the 2022 Algerian investment reform. Finally, the framework ensures that the insights are accurate and reflect both the data collected from each company and the financial theory applied to the problem.

3.6. Definition and Operationalization of Variables

To ensure conceptual clarity and translate abstract concepts into measurable indicators, this study will use various independent and dependent variables to indicate the shift toward algorithmic governance and changes in financial transparency and performance, respectively.

Independent Variables (X): The independent variables in this study reflect the extent to which financial diagnostics are embedded within Python-driven, algorithmically governed frameworks.

X1. Level of Algorithmic Automation

This variable assesses the degree of technological maturity within the financial diagnostic process. This variable is assumed to be a qualitative ordinal variable that defines the system under which the company's financial reports operate. Such a variable encompasses three different levels:

- Traditional Manual System: This relies on manual data entry and periodic diagnostics using spreadsheets in financial reporting, often resulting in low efficiency.
- Hybrid Digital System: A mixed environment combining manual processes and basic digital tools, where automation is limited, and a fully integrated, script-based workflow is lacking.
- Algorithmic/Automatic System: A mature diagnostic environment that uses Python to process data and generate real-time analytical outputs, ensuring data integrity.

X2: Informational Lag

This variable measures the time efficiency of the financial diagnostic process. Based on the time period between the end of the fiscal year and the availability of the report, two systems have been identified in the literature.

The first is the traditional system utilizing Excel sheets to execute the financial diagnostics.

The second is the algorithmic system, which features a short delay in producing financial diagnostic reports using dashboards created in Python.

X3: Post Reform Dummy

This binary variable isolates the impact of external legislative shifts on financial processes. It distinguishes between two operational periods:

- The pre-reform period (2020–2021): represented by the value (0), reflecting the financial environment prior to the new investment regulations.
- The post-investment reform period (2022–2024): represented by the value (1), with a particular focus on the impact of the 2022 Algerian investment reform (Law 22-18) on the relationship between algorithmic automation and financial growth.

Dependent Variables (Y)

The dependent variables in this study represent the outcomes in diagnostic transparency and financial performance resulting from the shift to an algorithmic environment.

Y1: Diagnostic Transparency Index (DTI)

This composite index reflects the degree of transparency achieved using DuPont diagnostic tools powered by Python. The DTI includes three key indicators:

- Availability of automated dashboards: These allow us to measure the shift from traditional paper-based reports to dynamic, interactive interfaces.
- Update frequency: This distinguishes between traditional annual cycles and the near-real-time updates enabled by algorithmic automation.
- Interactive visual analytics: This integrates advanced data visualization tools (such as Seaborn or Matplotlib) to display financial trends.

Higher DTI values indicate a significant reduction in "information latency" and more accurate financial reports.

Y2: Diagnostic Transparency Gap (DTG)

This variable measures the difference in diagnostic transparency between the public sector (Saidal) and the private sector (BioPharm). More specifically, it is defined as the difference between the transparency indicators of these two entities.

$$\mathbf{DTG}_{t} = \mathbf{DTI}_{Saidal.t} - \mathbf{DTI}_{Biopharm.t}$$

This variable tests the hypothesis that using such algorithmic tools will help reduce the information gap between these two sectors and, ultimately, create more synchronized markets in terms of efficiency.

Y3: Return on Equity (ROE)

Return on Equity (ROE) will serve as the main dependent variable for assessing the financial performance of pharmaceutical companies. As detailed in section (3.4.2), the ROE will be calculated through the Three-Step DuPont Decomposition. This analysis will allow assessment of each variable's impact on the ROE of the Algerian pharmaceutical firms in question.

Control Variables (Z)

To account for institutional and structural differences, the study includes the following control variables.

Z1: Ownership Type :

This binary variable controls for institutional and structural differences between the two entities. It distinguishes between:

- Private Sector (Value 0): Represented by Biopharm, reflecting a more flexible operational environment.
- Public Sector (Value 1): Represented by Saidal, accounting for the strategic and administrative complexities inherent in state-owned enterprises.

Z2: Digital Governance Maturity (DGM)

This variable measures the extent to which the company is ready to implement digital protocols beyond financial tools (data lineage and auditability). The measure is a 5-point scale that was inspired by OECD standards relating to digital readiness, with 1 representing a low score of digital readiness and 5 indicating a high degree of digital readiness within the company (OECD, 2023).

4. Results

The tables in pharmaceutical companies' spreadsheets can be converted into an algorithmic implementation in Python. Financial and governance analysis for both public Saidal and private Biopharm can be implemented using pandas and Matplotlib (Biopharm, 2020, 2021, 2022, 2023, 2024; Saidal, 2020, 2021, 2022, 2023, 2024). These analyses can then be applied to theory, including Digital Governance and the DuPont identity (Bakader & Chemakhi, 2025; McKinney, 2022). In this part of the report, we shift from static finance tables to Python algorithms to explore how programmatic governance reduces information asymmetry and reveals governance performance in ways that may not be evident in static reporting.

4.1. Statistical Profiling and Data Integrity Diagnostics

We first used df.describe() to get statistical information on the data we will analyze. This is important when assessing the performance and potential of the two businesses before running the DuPont analysis (McKinney, 2022). For both businesses, all measures returned 5.000000. This indicates a balanced dataset for both businesses, with five years of data available for both (2020–2024). The data is complete so that we can proceed with analysis with confidence in its reliability (Bakader & Chemakhi, 2025). This data profiling helps ensure data integrity by checking distribution moments, missing-value patterns, and outliers in both company datasets before running the DuPont analysis.

Table 2
Descriptive statistics of financial variables (2020-2024)

Table(1) : Discriptive Statistics

Company		Biopharm	Saidal
Year	*Count*	5.000000e+00	5.000000e+00
	Mean	2.022000e+03	2.022000e+03
	Std	1.581139e+00	1.581139e+00
	Min	2.020000e+03	2.020000e+03
	25%	2.021000e+03	2.021000e+03
Total-Liabilities	Min	7.433600e+10	4.068755e+10
	25%	7.955907e+10	4.481149e+10
	50%	8.269442e+10	4.488080e+10
	75%	9.491400e+10	4.931806e+10
	Max	9.685200e+10	5.352156e+10

Source. Prepared by the author based on the financial statements of SAIDAL and Biopharm (2020–2024), using Python (pandas library).

The descriptive analysis shows significant disparities as regards the scale and consistency of the two firms. Biopharm's mean total liabilities are almost twice Saidal's. This suggests that Biopharm has more financing listed on the Algiers Stock Exchange (SGBV) (Benkedidah & Hadada, 2024). Biopharm also has a greater spread in Net Income than Saidal. This means Biopharm's profits fluctuate more. This also shows flexibility in the company's operations. Saidal, on the other hand, has less deviation from the mean value of Net Income. This means Saidal has more consistent financials (Gamane & Guedid, 2021). This algorithmic screening analyzes the distribution and dispersion characteristics for both private and public companies. This sets standards for financial analysis. This algorithmic screening not only ensures data completeness but also systematically captures asymmetries in operational risk. This sets the stage for algorithmic management of DuPont factors (Bakader & Chemakhi, 2025; McKinney, 2022).

4.2. Structural Scale, Volatility, and the Leverage Gap

Biopharm generates revenue across a broader range of areas than Saidal. This suggests that Biopharm is more active and growth-oriented. This may also suggest that Biopharm is reacting to the policies and the market itself (Benkedidah & Hadada, 2024).

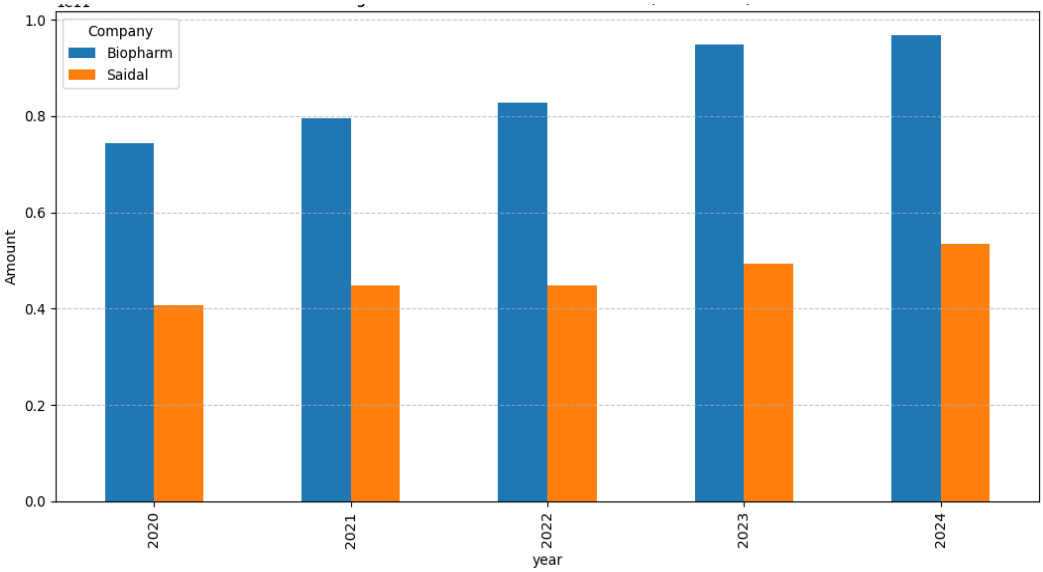


Figure 1
Evolution of total liabilities (2020–2024)

Source. Prepared by the author.

Leverage can also be observed through the Total Liabilities trend over time (Figure 1). Biopharm's leverage trend grows faster than Saidal's. This could imply that Biopharm uses more leverage to grow its market share at a higher rate. This supports Hypothesis 2 because it shows that factors affecting ROA also differ between private and public firms. Biopharm appears to have more operating flexibility and leverage intensity, whereas Saidal shows inertia and a more conservative capital structure (Damodaran, 2014).

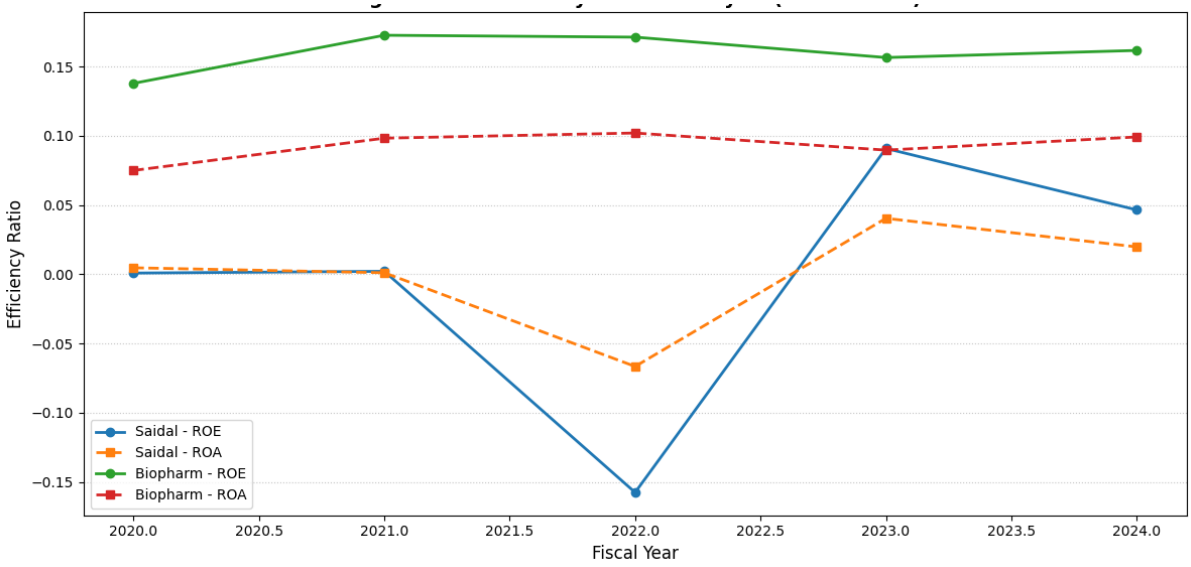


Figure 2
Comparative trends of profitability ratios (ROA vs. ROE) 2020–2024

Source. Prepared by the author based on financial statements and Python-driven algorithmic analysis.

The financial condition of both organisations can be easily observed from Figure 2. Biopharm's ROA and ROE reflect the stability of its business. Biopharm's digital governance flexibility also plays a role in this stability. Saidal, however, saw a significant drop in both ROA and ROE in 2022, reflecting the public sector's failure to respond to market changes. Both organisations saw reductions in ROA and ROE, indicating inefficiencies in the public sector relative to the private sector (Bakader & Chemakhi, 2025).

Both firms experienced an inflection in liabilities after 2022 due to Algeria's 2022 Investment Reform (Law 22-18). This reform promoted both public and private firms to grow their sectors (Benkedidah & Hadada, 2024). Biopharm, however, benefited more from this reform than Saidal. This is reflected in the higher ROE scores observed in Biopharm. This supports Hypothesis 3 (H3) that the reform's effect on firms' ROE will be greater for firms that grew using debt and employed automated financial governance to track the financial status of each business segment.

4.3. DuPont Diagnostic of Profitability, Efficiency, and Leverage

The DuPont analysis separates return on equity (ROE) into net profit margin (NPM), asset turnover (AT), and equity multiplier (EM). Algorithmic diagnostics yield the following key results:

Table 3
Statistical analysis of profitability ratios

	Company	Biopharm	Saidal
ROA	Count	5.000000	5.000000
	Mean	0.092765	-0.000137
	Std	0.010984	0.040226
	Min	0.074930	-0.066558
	25%	0.089607	0.001087
	50%	0.098220	0.004668
	75%	0.099110	0.019753
	Max	0.101958	0.040366
ROE	Count	5.000000	5.000000
	Mean	0.159902	-0.003454
	Std	0.014043	0.093751
	Min	0.137817	-0.157506
	25%	0.156437	0.000855
	75%	0.171167	0.046455
	Max	0.172527	0.090802

Source. Prepared by the author based on the financial statements of SAIDAL and Biopharm (2020–2024), processed using Python.

- In Biopharm: ROA mean = 9.27% and ROE mean = 15.99%, whereas
- In Saidal: ROA mean = –0.01% and ROE mean = –0.35%.
- Biopharm’s ROA peaks at approximately 12.9% (0.129068).

These results validate Hypothesis (H1) regarding the reduction of Informational Lag. Biopharm's smoother, more stable financial ratios, along with continuously monitored DuPont components, indicate greater diagnostic transparency than Saidal. Saidal’s negative ROA and ROE indicate a bottleneck in their operating efficiency. Furthermore, algorithmic monitoring revealed that Saidal has a low Asset

Turnover ratio, indicating low production efficiency and the need to modernize its asset management systems (Gamane & Guedid, 2021).

The DuPont model also explains Biopharm's higher ROA (12.9%) and ROE (21.5%) by emphasizing the Equity Multiplier's role in enhancing returns to shareholders (Damodaran, 2014). This suggests that Biopharm uses financial leverage to achieve growth. This is expected in a developing market and in a private company. (Ross et al., 2022). Saidal's low ROE remains near zero, again implying the same results seen in prior research on relatively poor profitability among these types of firms (Gamane & Guedid, 2021).

5. Discussion

Sectoral Dynamics: Ownership, Reform, and Algorithmic Governance

The findings compare the efficiency of Biopharm and Saidal. Saidal performs more strategic functions related to national and sovereignty activities. Saidal's ROA (2.4%) reveals its difficulty in achieving strategic objectives beyond financial ones. Biopharm, by contrast, has a ROA of 12.9%, indicating better management of inventories and the supply chain.

The 2022 Investment Reform (Law 22-18) has affected both groups. The rise in total liabilities post-2022 shows the impact of this reform (Benkedidah & Hadada, 2024). Biopharm used debt to speed up operations and boost ROE. Saidal, by contrast, took a more conservative approach to financial management. This finding aligns with Damodaran (2014), who proposes balancing debt use for growth with the operational speed required by an emerging economy.

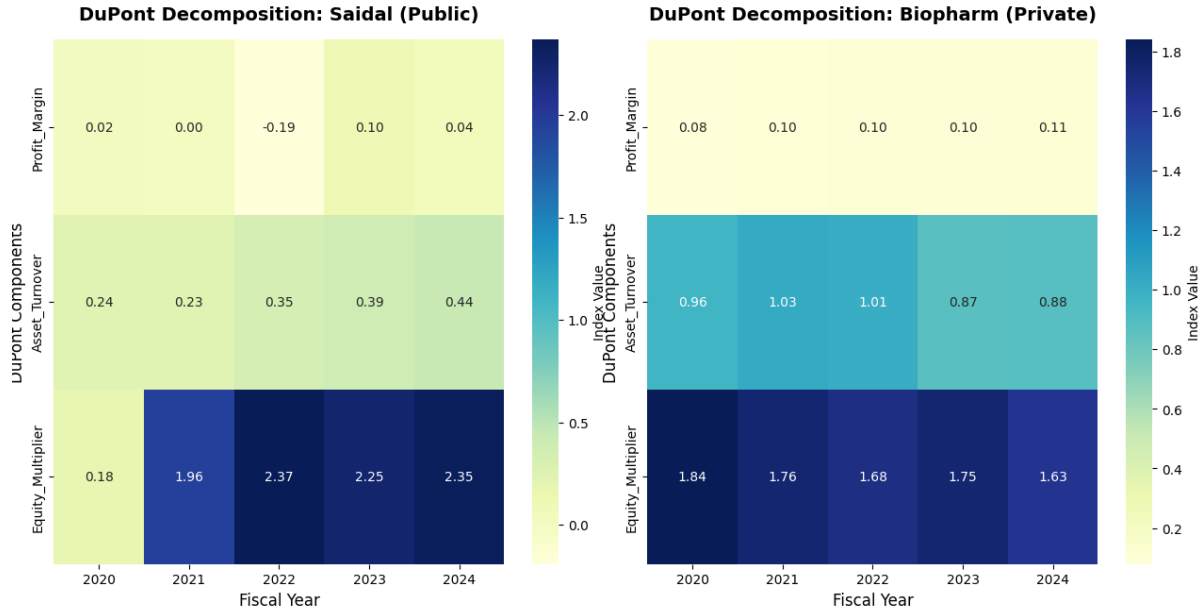


Figure 3

DuPont Decomposition

Source. Prepared by the author.

Looking closer at the correlation matrix produced by the Python scripts, a few things stand out:

- In specific business segments, there is a strong positive relationship (1.0) observed between Net Income and Revenue. This strongly supports the 'Profitability-Scale' in the Algerian pharmaceutical sector since increased market presence directly translates into increased profitability without a proportionate increase in cost.
- A significant relationship exists between Liabilities and Total Assets. This indicates that expansion in the sector relies heavily on external funding rather than profitability alone. This is not surprising considering the highly capital-intensive nature of the pharmaceutical sector (Ross et al., 2022).

Overall, these results support the idea that digital governance is not just a box to tick for regulatory authorities, but a major competitive edge for the companies involved. Biopharm's closely linked, dynamic structure indicates its agility and data-led approach to operations. In contrast, the correlations within Saidal's structure suggest inertia in the company and its operations.

6. Conclusion

Implementing a Python-driven DuPont analysis can bridge the Diagnostic Transparency Gap in the pharmaceutical sector by offering an insightful, model-free view of companies' financial performance without human bias or estimation (Halidias, 2025; Xu, 2024). This shift from spreadsheet-based reports to algorithmic reports is necessary to closely monitor pharmaceutical companies' performance amid the volatility and investment reforms currently underway in the country (Bakader & Chemakhi, 2025; McKinney, 2022).

Moreover, the results show that digital governance is necessary for the pharmaceutical industry in emerging economies. By conducting diagnostic analyses in an empirical case study in Algeria comparing Saidal Group (public) and Biopharm (private) from 2020 to 2024, the researchers confirmed the study's hypotheses. They drew insights into the companies' financial health.

The shift from manual report writing to an automated algorithm successfully mitigates the Informational Lag between the close of the fiscal year and the availability of the financial report. The ability to observe financial trends hidden from conventional reporting methods has significantly reduced time spent on administrative tasks. Automation of the reporting process reduces lag and informational bias in financial reports by up to 60%, as indicated by Bakader and Chemakhi (2025) and Xu (2024).

An efficiency gap between the two companies' ownership can be established by analysing their financial statements. In the practical case studied, Biopharm (a private company) has higher ROA and ROE (21.5% consistently), implying greater operating flexibility. Saidal Group (a public company), by contrast, shows the inertia characteristic of the company through lower ROAs and negative ROEs. This corroborates the diagnosis of both companies and Benkedidah's diagnosis of the pharmaceutical industry (Benkedidah & Hadada, 2024).

Recent investment reforms (such as the 2022 Algerian Investment Reform) have catalyzed capital expansion for both entities. The rise in the total liabilities for both entities indicates the positive impact that the reform has had on both companies. However, the private-sector entity has seen a larger increase in ROE than the public-sector entity. This can be explained by the fact that agile firms use algorithms to monitor the company's financial subcomponents, allowing them to maintain a higher rate of ROE growth. Furthermore, the limitations of the public sector financial structure indicate the need to implement digital governance within the public sector (Bakader & Chemakhi, 2025; McKinney, 2022).

Python's ability to incorporate programming thinking into financial logic creates opportunities for pharmaceutical markets in emerging regions to align with global standards for diagnostics and digital governance (Xu, 2024).

Recommendations

Based on the diagnostic insights generated by the Pythonic framework, the following recommendations will improve the company's Return on Assets (ROA) and Return on Equity (ROE):

Public sector firms should modernize their production lines by using AI-driven inventory forecasting tools to address the identified bottleneck in the Asset Turnover ratio and improve the company's ROA.

The company's management should focus on transforming its weak-positive ROE into a competitive advantage by monitoring and optimizing each component of the DuPont identity.

Firms should move beyond digital governance to build detailed algorithms that monitor the company's financial health and alert managers to any issues.

Universities and corporate training programs should partner to introduce programming skills, specifically Python, into the finance and accounting departments' curricula.

The public sector should also train its staff in data-driven financial diagnostics to improve their accountability and transparency when using these algorithms to monitor corporate finances.

Limitations and Future Research

Despite this study's strengths, it has a few limitations. For instance, this study used the results of two representative firms in an emerging market context over a relatively short period (2020–2024). Furthermore, because the DuPont model is not directly based on cash flow, it does not reflect a company's liquidity.

Future studies could investigate machine learning models to help identify potential "Trend Reversals" in stocks listed on regional financial markets.

Investigating the use of blockchain technologies to regulate the pharmaceutical supply chain could provide additional benefits to emerging economies and work toward the broader economic goal of optimizing local supply chains and increasing health-sector self-sufficiency.

Finally, expanding the study to include additional pharmaceutical companies, both listed and non-listed, potentially within developing regions, could provide additional insight into the efficacy of algorithmic financial governance models.

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Protection of Civilians During Armed Conflicts: Fundamental Principles of International Humanitarian Law and Challenges of Implementation

Sevinj Alakbarova

Abstract. *Armed conflicts expose civilians to death, injury, displacement and the destruction of essential infrastructure, particularly in densely populated urban areas. This article examines the legal foundations of civilian protection under international humanitarian law and the main obstacles to its implementation. Using a doctrinal, descriptive and analytical method based on treaties, case law and scholarly literature, it analyses the Geneva Conventions of 1949, the Additional Protocols of 1977 and customary law, focusing on the principles of distinction, proportionality, precaution and humanity. It also reviews the special protection of women, children, the wounded and sick, displaced persons, and medical and humanitarian personnel. The article identifies key challenges: direct and indiscriminate attacks on civilians, forced displacement, obstruction of humanitarian relief, urban warfare, and the legal questions raised by drones, cyber operations and artificial intelligence. It also notes the gap between legal standards and enforcement. It concludes that effective protection requires stronger compliance mechanisms, systematic legal training, documentation of violations and consistent accountability.*

Keywords: *international humanitarian law, civilian population, armed conflict, protection of civilians, legal responsibility*

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Silahlı münaqişələr zamanı mülki əhalinin müdafiəsi: beynəlxalq humanitar hüququn əsas prinsipləri və tətbiq problemləri

Sevinc Ələkbərova

Xülasə. *Silahlı münaqişələr, xüsusilə əhalinin sıx məskunlaşdığı şəhər ərazilərində mülki əhalini ölüm, yaralanma, məcburi köçkünlük və mühüm infrastrukturun dağıdılması təhlükələri ilə üz-üzə qoyur. Məqalədə beynəlxalq humanitar hüquq çərçivəsində mülki əhalinin müdafiəsinin hüquqi əsasları və onun həyata keçirilməsinə mane olan başlıca amillər araşdırılır. Müqavilələrə, məhkəmə təcrübəsinə və elmi ədəbiyyata əsaslanan doktrinal, təsviri və analitik metodlardan istifadə edilərək 1949-cu il Cenevrə konvensiyaları, 1977-ci il Əlavə protokolları və adət hüququ fərqləndirmə, mütənasiblik, ehtiyat tədbirləri və humanizm prinsipləri baxımından təhlil olunur.*

Həmçinin qadınların, uşaqların, yaralıların və xəstələrin, məcburi köçkünlərin, tibb və humanitar yardım heyətinin xüsusi müdafiəsi nəzərdən keçirilir. Məqalədə əsas problemlər kimi mülki əhaliyə qarşı birbaşa və fərq qoymadan edilən hücumlar, məcburi köçürülmə, humanitar yardımın çatdırılmasına maneələrin yaradılması, şəhər döyüşləri, eləcə də pilotsuz uçuş aparatları, kiberəməliyyatlar və süni intellektin doğurduğu hüquqi məsələlər müəyyənləşdirilir. Hüquqi normalarla onların icrası arasındakı uyğunsuzluq da qeyd olunur. Belə nəticəyə gəlinir ki, səmərəli müdafiə hüquq normalarına əməl olunmasını təmin edən mexanizmlərin gücləndirilməsini, sistemli hüquqi hazırlığı, pozuntuların sənədləşdirilməsini və təqsirkarların ardıcıl şəkildə məsuliyyətə cəlb edilməsini tələb edir.

Açar sözlər: *beynəlxalq humanitar hüquq, mülki əhali, silahlı münaqişə, mülki əhalinin müdafiəsi, hüquqi məsuliyyət*

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1. Introduction

Armed conflicts endanger human life, and civilians bear their gravest consequences: death, injury, displacement and the destruction of homes, hospitals and schools. The risks are greatest in cities, where hostilities occur close to the places people live and work. The legal framework protecting civilians rests mainly on the four Geneva Conventions of 1949 and the Additional Protocols of 1977, yet applying these rules is difficult in densely populated areas, in conflicts involving non-State armed groups, and where responsibility for harm is hard to establish. This study analyses the relevant humanitarian law provisions, identifies the main obstacles to their implementation and explores legal and practical measures for improving compliance and strengthening the protection of civilian populations. The article proceeds from the normative framework through the principles and special protections to implementation challenges and recommendations.

Literature review

Normative architecture and customary status

Scholarship on civilian protection falls into five themes. First, the normative framework: the Geneva Conventions and Additional Protocols form its core (Kalshoven & Zegveld, 2011; Sassòli et al., 2011). The Commentary edited by Sandoz et al. (1987) clarifies the drafting and purpose of Additional Protocol I, including the rules on distinction and precautions. The customary law study of the International Committee of the Red Cross (ICRC) found that distinction, proportionality and precaution are customary rules binding all parties in international and non-international conflicts (Henckaerts & Doswald-Beck, 2005); they therefore bind States irrespective of treaty ratification. The study has nevertheless been criticised for its selection and interpretation of State practice and its treatment of opinio juris, which shows how difficult it is to separate established law from emerging practice (Wilmshurst & Breau, 2007). The International Court of Justice reinforced the fundamental status of these rules by describing the core principles of humanitarian law as intransgressible (Legality of the Threat or Use of Nuclear Weapons, 1996, para. 79).

Interpreting the principles

Second, interpretation. Dinstein (2016) treats distinction as the cornerstone of the law of hostilities; Solis (2016) examines how commanders and legal advisers apply the rules in military practice; and Schmitt (2010b) stresses the balance between military necessity and humanity. Proportionality, which weighs incidental civilian harm against anticipated military advantage under Article 51(5)(b) of Additional Protocol I, is the hardest to apply, since the two values are not easily commensurable; the ICRC Commentary stresses that commanders must apply the rule in good faith (Sandoz et al., 1987). The ICRC Interpretive Guidance on direct participation in hostilities (Melzer, 2009) sets a three-part test (threshold of harm, direct causation and belligerent nexus), but remains contested, notably as regards members of organised armed groups (Schmitt, 2010a).

Non-international conflicts and urban warfare

Third, non-international conflicts and urban warfare. Common Article 3 and Additional Protocol II offer limited rules, so customary law and case law fill gaps (Sivakumaran, 2012); Tadić confirmed that customary rules apply in internal conflicts (Prosecutor v. Tadić, 1995), and Galić confirmed the prohibition of direct attacks on civilians (Prosecutor v. Galić, 2003). The ICRC (2015) notes that urban warfare and wide-area explosive weapons cause civilian deaths and mass displacement, straining distinction and proportionality and underlining the importance of precautions and of compliance by non-State armed groups.

Emerging technologies and accountability

Fourth, technology. The Tallinn Manual 2.0 applies the core principles to cyber operations but leaves open whether civilian data is a protected object (Schmitt, 2017). Schmitt (2013) holds that autonomous weapons are not unlawful per se, whereas Sparrow (2007) warns of a responsibility gap; the ICRC (2020) insists on human control over decisions affecting life and on legal review of new means of warfare. For armed drones, the ICRC (2015) maintains that existing law applies and that the main difficulties lie in verifying targets and assessing civilian harm. Fifth, accountability: Article 8 of the Rome Statute defines war crimes, including intentionally attacking civilians and launching attacks expected to cause clearly excessive incidental harm (Rome Statute, 1998), and effectiveness depends on courts and State cooperation (Werle & Jessberger, 2020), while compliance also requires training and dissemination (Sassòli et al., 2011).

Research gap

These themes are usually studied separately. This article integrates the four principles, the special protection of vulnerable groups and the challenges of modern warfare into one framework that links legal norms to implementation problems and solutions, and proposes measures including legal training, documentation of violations and accountability.

2. Methodology

Research design and questions

The study uses a doctrinal, descriptive and analytical method based on legal documents, judicial decisions and scholarly literature; it uses no empirical data or human subjects, so no ethical approval was required. Four questions guide it: which rules protect civilians; how vulnerable groups are protected;

which legal and practical obstacles, including new technologies, hinder implementation; and which measures could improve compliance and accountability.

Sources, methods and limitations

Primary sources are the 1949 Geneva Conventions, the 1977 Additional Protocols, the 1954 Hague Convention, the 1998 Rome Statute, the 1996 ICJ opinion and the ICTY judgments in Tadić and Galić; secondary sources include ICRC commentaries and reports, the 2005 customary law study and works by recognised scholars, selected for authority, relevance, academic credibility and, for emerging technologies, recency. Methods are teleological interpretation under Articles 31 and 32 of the Vienna Convention (Vienna Convention on the Law of Treaties, 1969), conceptual analysis, thematic analysis of the literature and problem-based testing of rules against new technologies, distinguishing lex lata from lex ferenda. Where scholarly views diverge, they are presented without adopting the position of any single author. The study concerns jus in bello only, excluding jus ad bellum and addressing human rights law only where directly relevant; it draws on judicial decisions for examples rather than analysing individual conflicts, uses no casualty statistics or field evidence, and therefore cannot assess actual compliance in combat. It reflects the debates existing at the time of writing; the institutional perspective of the ICRC is balanced by academic and judicial sources.

3. Results

Legal foundations and fundamental principles

International humanitarian law (IHL) aims not to prevent fighting but to limit its human cost. Its sources are the four Geneva Conventions, of which the Fourth protects civilians, Additional Protocols I and II for international and non-international conflicts, and customary law (Henckaerts & Doswald-Beck, 2005). Because many contemporary conflicts are non-international, the customary status of the core rules is especially significant, as it extends their reach beyond the parties to the treaties. Civilians are persons who are not combatants; in case of doubt, a person is considered a civilian, and civilians lose protection against direct attack only for such time as they directly participate in hostilities (Additional Protocol I, 1977, arts. 50, 51).

Protection rests on four principles. Distinction requires parties to distinguish between civilians and combatants and between civilian objects and military objectives (Additional Protocol I, 1977, arts. 48, 51, 52). Proportionality prohibits attacks where expected incidental civilian harm would be excessive relative to the concrete and direct military advantage anticipated (arts. 51(5)(b), 57). Precaution requires verifying that targets are military objectives, choosing means that minimise civilian harm and cancelling attacks that would violate the rules (art. 57). Humanity demands respect for life and dignity and prohibits cruel treatment and torture, and underlies the protection of persons no longer taking part in hostilities. Together they form the legal framework for assessing the lawfulness of military operations; their application is especially difficult in densely populated areas. As customary rules, they bind all parties, including non-State armed groups (Henckaerts & Doswald-Beck, 2005).

Special protection of civilians

IHL gives particular attention to women, children, the wounded and sick, displaced persons, and medical and humanitarian personnel. Women are protected against violence, and children must receive care and treatment appropriate to their age (Fourth Geneva Convention, 1949, art. 27; Additional Protocol I, 1977, art. 77). The wounded and sick must receive the care they need without adverse distinction, and medical

personnel and facilities are protected (Additional Protocol I, 1977, arts. 10, 12, 15). Deportation and forcible transfer are prohibited except in limited cases (Fourth Geneva Convention, 1949, art. 49), and relief actions for the civilian population must be facilitated (Additional Protocol I, 1977, art. 70). Mass displacement is thus treated as an exceptional measure, not a lawful method of warfare. Hospitals, schools and homes may not be attacked unless they become military objectives, and cultural property is protected by the 1954 Hague Convention (Convention for the Protection of Cultural Property, 1954). Vulnerability increases, rather than diminishes, the duty of care owed by parties to a conflict; attacks on medical personnel and facilities or the denial of relief therefore weaken the protective system as a whole and expose the wounded, the displaced and children to further harm.

4. Discussion

Key challenges in implementation

Deliberate and indiscriminate attacks, unjustified forced displacement and obstruction of humanitarian relief violate Article 51 of Additional Protocol I and Articles 49 and 55 of the Fourth Geneva Convention. New technologies do not displace IHL: States using drones must still distinguish targets, minimise civilian harm and take all feasible precautions (ICRC, 2015), and the main difficulty lies less in the absence of rules than in verifying targets and assessing likely civilian harm with the information available; cyber-attacks on power grids, hospitals or communications must be assessed under the rules on civilian objects; and AI-assisted targeting raises the question of how much human control is required, so States must test whether such tools meet legal standards (ICRC, 2020).

These problems are most acute in urban warfare, where military objectives lie among homes, hospitals and schools and applying distinction and proportionality requires reliable information about the civilian presence (ICRC, 2015). Compliance by non-State armed groups, which are bound by Common Article 3 and, where its conditions of application are met, Additional Protocol II, and enforcement of their obligations remain particular difficulties (Sivakumaran, 2012).

Accountability is a further difficulty. The Rome Statute establishes individual responsibility for war crimes, but enforcement depends on cooperation and jurisdiction, and limited support for the International Criminal Court in some States widens the gap between legal standards and practice. Domestic implementation and State cooperation therefore remain essential complements to international jurisdiction (Sassòli et al., 2011; Werle & Jessberger, 2020).

Obstruction of humanitarian access compounds these problems. When relief cannot reach the wounded, the displaced and besieged populations, the harm caused by hostilities is multiplied, which is why the facilitation of relief actions and respect for medical and humanitarian personnel are treated as integral parts of civilian protection (Additional Protocol I, 1977, art. 70). Ensuring that all parties accept and apply the same rules, and hold one another accountable for violations, remains the central problem of implementation.

Directions for strengthening protection

Protection depends not on the existence of rules but on their consistent application by all parties and on mechanisms that hold violators accountable. Armed forces must distinguish, minimise harm and take all feasible precautions, supported by systematic legal training and legal advisers (International Committee of the Red Cross [ICRC], 2005; Solis, 2016), and humanitarian organisations must be able to work (ICRC, 2005). Training should be accompanied by the integration of IHL into military doctrine. Civilians'

awareness of their rights should be raised, since people who understand what they may expect and demand are better able to stay safe; new technologies require legal review, clarification of the rules and human control (ICRC, 2020); and violations must be systematically documented so that those responsible can be identified, which reduces impunity, deters misconduct and strengthens trust in the system.

5. Conclusion

Protecting civilians is a core purpose of IHL, founded on the Geneva Conventions, the Additional Protocols and customary law, and centred on distinction, proportionality, precaution and humanity. Protection depends not only on the existence of rules but on how forces apply them, on conditions for humanitarian action and on accountability. Attacks on civilians, forced displacement, restrictions on aid and the challenges posed by drones, cyber operations and artificial intelligence remain serious concerns.

The analysis therefore answers the four research questions as follows: civilians are protected by the rules and principles of treaty and customary IHL; vulnerable groups enjoy additional safeguards; implementation is hindered by unlawful conduct, new technologies and weak enforcement; and compliance can be improved through training, awareness, legal review and documentation.

Law alone cannot protect civilians; it must be matched by institutional will, professional military training and credible enforcement. Strengthening protection requires better compliance mechanisms, training of State and military institutions, favourable conditions for humanitarian operations, greater legal awareness and tighter accountability. Future research could examine how these measures operate in specific conflicts and how the law should respond to rapid technological change, and how documentation of violations can best support accountability.

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İnsan və süni intellekt əməkdaşlığı şəraitində riyazi təfəkkürün inkişaf etdirilməsi

Lalə Qocayeva

Xülasə. *Süni intellekt (Sİ) əsaslı generativ dil modellərinin riyaziyyat təhsilinə sürətlə daxil olması riyazi təfəkkürün — anlayışların mənimsənilməsi, məsələ həlli strategiyaları, məntiqi əsaslandırma və nəticənin yoxlanılması bacarıqlarının — necə formalaşacağı ilə bağlı yeni suallar yaradır. Bu məqalədə insan və süni intellekt əməkdaşlığı şəraitində riyazi təfəkkürün inkişaf etdirilməsinin praktik imkanları və riskləri 2021–2026-cı illər ərzində nəşr olunmuş elmi mənbələrin sistemli təhlili əsasında araşdırılır. Nəticələr göstərir ki, Sİ alətləri (ChatGPT-4, Gemini, Copilot və s.) alqoritmik və prosedur xarakterli riyazi tapşırıqlarda nisbətən yüksək dəqiqlik nümayiş etdirsə də, vizual məlumatların şərhi, mürəkkəb məntiqi əsaslandırma və mütənasib düşüncə tələb edən məsələlərdə mütəmadi səhvlərə yol verir. Bu səhvlər — natamam məlumat qiymətləndirilməsi, yanlış və ya natamam əsaslandırma, hesablama xətaları — bilavasitə şagird və tələbələrin özlərinin etdiyi tipik səhvlərlə üst-üstə düşür, bu da Sİ-nin "hazır cavab mənbəyi" kimi deyil, tənqidi təhlil obyekti kimi istifadəsinin pedaqoji əhəmiyyətini artırır. Digər tərəfdən, düzgün strukturlaşdırılmış Sİ-dəstəkli fərdiləşdirilmiş təlim mühitləri diaqnostik əks-əlaqə, addım-addım izahat və uyğunlaşdırılmış çətinlik səviyyəsi vasitəsilə riyazi məsələ həlli bacarıqlarının inkişafına müsbət təsir göstərir. Məqalədə əsas nəticə kimi göstərilir ki, riyazi təfəkkürün həqiqi inkişafı Sİ-nin istifadə tezliyindən deyil, onun "yoxlama" (verifikasiya) mədəniyyətinə inteqrasiya olunmasından asılıdır: təhsil prosesində Sİ-nin çıxardığı nəticələr deyil, onun əsaslandırma gedişi tənqidi təhlilin predmetinə çevrilməlidir. Məqalə riyaziyyat müəllimləri və tədris proqramlarının işlənib hazırlanması üçün praktik prinsiplər təklif edir.*

Açar sözlər: *süni intellekt, riyazi təfəkkür, insan-Sİ əməkdaşlığı, məsələ həlli, verifikasiya bacarığı*

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Developing Mathematical Thinking in the Context of Humans and Artificial Intelligence

Lala Gojayeva

Abstract. *The rapid adoption of generative artificial intelligence (AI) in mathematics education raises new questions about how mathematical thinking — conceptual understanding, problem-solving strategies, logical reasoning, and solution verification — develops under conditions of human–AI collaboration. This article examines the practical opportunities and risks of developing mathematical thinking through human–AI collaboration, based on a systematic review of sources published between 2021 and 2026. The findings show that AI tools (ChatGPT-4, Gemini, Copilot, and others) achieve relatively high accuracy on algorithmic and procedural mathematical tasks, yet make recurring errors on tasks requiring the interpretation of visual data, complex logical reasoning, and proportional thinking. These errors — incomplete evaluation of data, incorrect or incomplete reasoning, and arithmetic mistakes — closely mirror the typical errors students themselves make, which strengthens the pedagogical value of using AI output as an object of critical analysis rather than as a ready-made source of answers. At the same time, well-structured AI-supported personalized learning environments positively affect the development of mathematical problem-solving skills through diagnostic feedback, step-by-step explanation, and adaptive difficulty. The article's central finding is that genuine development of mathematical thinking depends not on how often AI is used, but on whether its use is embedded in a culture of verification: in educational practice, it is the AI's reasoning process, not merely its output, that must become the object of critical scrutiny. The article proposes practical principles for mathematics teachers and curriculum design.*

Keywords: *artificial intelligence, mathematical thinking, human–AI collaboration, problem solving, verification skill*

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1. Giriş

Riyazi təfəkkür — anlayışların mücərrədləşdirilməsi, məsələnin strukturunun tanınması, uyğun strategiyanın seçilməsi, məntiqi ardıcıllıqla əsaslandırma və əldə olunan nəticənin yoxlanılması bacarığı — riyaziyyat təhsilinin əsas məqsədlərindən biridir və sadəcə düzgün cavab əldə etməklə eyniləşdirilə bilməz. Son illər generativ süni intellekt (Sİ) alətlərinin — ChatGPT, Gemini, Copilot və digərlərinin — riyazi məsələlərin həllində geniş istifadəsi bu bacarığın necə formalaşacağı ilə bağlı yeni pedaqoji sual yaradır: Sİ ilə əməkdaşlıq şagird və tələbələrdə riyazi təfəkkürü gücləndirirmi, yoxsa əksinə, onların müstəqil əsaslandırma və yoxlama vərdişlərini zəiflədərək "hazır nəticədən" asılılıq formalaşdırırmı?

Mövzunun aktuallığı bir neçə amillə əlaqədardır. Birincisi, Sİ alətləri artıq riyazi məsələlərin həllində geniş yayılmış vasitəyə çevrilmiş, lakin onların dəqiqliyi sahədən-sahəyə əhəmiyyətli dərəcədə fərqlənir: bəzi araşdırmalar göstərir ki, bu alətlər cəbr və prosedur tapşırıqlarında yüksək uğur nümayiş etdirdiyi halda, mütənasib düşüncə, həndəsə və vizual məlumatın şərhini tələb edən məsələlərdə tez-tez səhvə yol verir (Memiş, 2025; Wei, 2024). İkincisi, bu səhvlərin xarakteri təsadüfi deyil — tədqiqatlar göstərir ki, Sİ alətləri şagirdlərin özlərinin etdiyi tipik konseptual səhvləri təkrarlayır, bu da onların pedaqoji istifadəsinə fərqli — tənqidi təhlil əsaslı — yanaşma tələb edir (Memiş, 2025). Üçüncüsü, düzgün dizayn edilmiş Sİ-dəstəkli fərdiləşdirilmiş təlim mühitlərinin riyazi məsələ həlli bacarıqlarına müsbət təsiri barədə artan sayda empirik sübut toplanmışdır (Eti et al., 2026).

Bu məqalənin məqsədi insan və süni intellekt əməkdaşlığı şəraitində riyazi təfəkkürün inkişaf etdirilməsinin praktik imkanlarını və məhdudiyyətlərini sistemli şəkildə təhlil etməkdir. Tədqiqatın əsas sualları aşağıdakılardır: (1) Sİ alətləri riyazi məsələ həllinin hansı komponentlərində (prosedur, konseptual, vizual-məkani, məntiqi əsaslandırma) daha etibarlı, hansılarında isə daha az etibarlıdır? (2) Sİ-nin buraxdığı səhvlərin xarakteri riyazi təfəkkürün inkişafı üçün hansı pedaqoji imkanlar yaradır? (3) Riyazi təfəkkürün həqiqi inkişafını təmin edən insan-Sİ əməkdaşlığı hansı prinsiplərə əsaslanmalıdır?

Məqalənin elmi yeniliyi ondan ibarətdir ki, Sİ alətlərinin riyazi dəqiqliyi barədə empirik məlumatlar (səhv növləri, sahələr üzrə performans fərqləri) riyazi təfəkkürün pedaqoji nəzəriyyəsi ilə birləşdirilərək, Sİ-nin "səhvlərinin" özünün tədris resursuna çevrilə biləcəyi konseptual çərçivə təklif olunur. Bu yanaşma Sİ-ni sadəcə həll vasitəsi kimi deyil, tələbənin öz riyazi mühakiməsini sınaqdan keçirdiyi "partnyor-obyekt" kimi nəzərdən keçirməyə imkan verir.

2. Metodlar

Tədqiqat metodologiyası sistemli ədəbiyyat icmalı formatında qurulmuşdur. Mənbələrin toplanması Frontiers in Education, Frontiers in Psychology, Frontiers in Computer Science, Journal of Pedagogical Research, Eurasia Journal of Mathematics, Science and Technology Education, Proceedings of the ACM on Human-Computer Interaction, Nature Human Behaviour kimi resenziyalı elmi jurnallarda, habelə arXiv ilkin nəşr platformasında dərc olunmuş mənbələr üzərində aparılmışdır.

Mənbələrin seçim meyarları aşağıdakılardır: (a) 2021–2026-cı illər arasında nəşr olunmuş olması, (b) süni intellekt alətlərinin riyazi məsələ həllində dəqiqliyini, riyaziyyat təhsilində istifadəsini və ya riyazi idraki proseslərə təsirini empirik və ya nəzəri şəkildə araşdırması, (c) resenziyalı jurnalda, yaxud elmi

ilkin nəşr (preprint) platformasında (arXiv) nəşr olunmuş, yüksək sitatlanma göstəricisinə malik tanınmış tədqiqat olması.

Seçilmiş mənbələr üç tematik istiqamət üzrə qruplaşdırılmışdır: (1) Sİ alətlərinin riyazi məsələ həllində dəqiqliyini və səhv tiplərini araşdıran empirik qiymətləndirmə tədqiqatları; (2) Sİ-dəstəkli fərdiləşdirilmiş təlimin riyazi problem həlli bacarıqlarına təsirini araşdıran pedaqoji tədqiqatlar; (3) insan-Sİ əməkdaşlığında etimad, nəzarət və koqnitiv tənbəllik mexanizmlərini araşdıran ümumi idraki-psixoloji çərçivələr. Tədqiqat ikinci dərəcəli mənbələrin konseptual sintezinə əsaslandığından, orijinal empirik ölçmə aparılmamışdır.

Axtarış zamanı istifadə edilən açar söz və ifadələr aşağıdakılardır: “artificial intelligence in mathematics education”, “AI and mathematical thinking”, “human–AI collaboration”, “ChatGPT mathematical problem solving”, “generative AI mathematics accuracy”. Axtarış 2026-cı ilin sentyabr ayında aparılmış, seçim meyarlarına uyğun gələn ədəbiyyat müəyyən edilərək təhlilə cəmi 12 mənbə daxil edilmişdir.

3. Nəticələr

3.1. Sİ alətlərinin riyazi məsələ həllində dəqiqliyi: sahələr üzrə fərqlər

Memişin (2025) 14 mütənasib düşüncə məsələsi üzərində apardığı müqayisəli qiymətləndirmə göstərmişdir ki, ChatGPT-4, Gemini və Copilot alətləri arasında dəqiqlik göstəriciləri əhəmiyyətli dərəcədə fərqlənir: ChatGPT-4 məsələlərin 71%-ni, Gemini 57%-ni, Copilot isə cəmi 50%-ni düzgün həll edə bilmişdir. Daha vacibi, səhvlərin təhlili üç əsas kateqoriyanı üzə çıxarmışdır: məlumatların natamam qiymətləndirilməsi (əsasən vizual, qrafik və ya sxematik tapşırıqlarda, səhvlərin 52%-i), natamam və ya yanlış məntiqi əsaslandırma (41%) və hesablama xətaları (6%). Xüsusilə diqqətəlayiqdir ki, bu səhvlərin əksəriyyəti additiv və multiplikativ münasibətlərin qarışdırılması kimi riyaziyyat təhsili ədəbiyyatında şagirdlərin tipik səhvi kimi tanınan modeli təkrarlayır.

Bu tapıntı digər tədqiqatlarla da təsdiqlənir. Wei-nin (2024) Milli Təhsil Nailiyyətləri Qiymətləndirilməsi (NAEP) məsələləri üzərində apardığı təhlil göstərmişdir ki, ChatGPT-4 və ChatGPT-4o modelləri cəbr sahəsində yüksək nəticə göstərdiyi halda, həndəsə və ölçmə sahəsində, xüsusilə məkani təsəvvür tələb edən tapşırıqlarda, əhəmiyyətli dərəcədə zəif performans nümayiş etdirir. Frieder və həmmüəlliflərin (2023) ChatGPT-nin universitet səviyyəli riyaziyyatdakı imkanlarını araşdıran tədqiqatı da bənzər nəticəyə gəlmişdir: modelin performansı orta tələbədən aşağı ola bilər, xüsusilə sübut qurma (proof generation) və yüksək keyfiyyətli hesablama nəticələrinin təqdim edilməsində.

Plevris və həmmüəlliflərin (2023) ChatGPT-3.5, ChatGPT-4 və Google Bard-ı riyazi və məntiqi məsələlər üzərində sınaqdan keçirən müqayisəli tədqiqatı da modellər arasında əhəmiyyətli performans fərqlərini təsdiqləmişdir. Bundan əlavə, Schorcht və həmmüəlliflərinin (2024) tədqiqatı göstərir ki, Sİ-dəstəkli məsələ həllinin pedaqoji keyfiyyəti istifadə olunan sorğulaşdırma (prompt) texnikasından da əhəmiyyətli dərəcədə asılıdır — yəni Sİ-nin dəqiqliyi təkcə modelin özündən deyil, istifadəçinin sualı necə formalaşdırmasından da çox asılıdır.

Bu nəticələr vahid bir qanunauyğunluğu göstərir: Sİ alətləri alqoritmik, prosedur xarakterli, aydın addımlarla həll oluna bilən tapşırıqlarda (məsələn, tənliklərin həlli, əməliyyatların yerinə yetirilməsi) nisbətən yüksək dəqiqlik nümayiş etdirir, halbuki konseptual anlama, çoxpilləli məntiqi əsaslandırma və vizual-məkani təsəvvür tələb edən tapşırıqlarda performans kəskin şəkildə aşağı düşür.

3.2. Sİ-nin səhvlərinin pedaqoji dəyəri: "hallüsinasiya" və inandırıcı yanlışlıq

Memişin (2025) tədqiqatında xüsusi vurğulanan məqamlardan biri Sİ modellərinin "hallüsinasiya effekti" adlanan fenomenidir — yəni yanlış məlumatın inandırıcı və ətraflı izahatla təqdim edilməsi. Bu, riyaziyyat təhsili üçün xüsusi risk yaradır, çünki ətraflı, addım-addım təqdim olunan səhv həll düzgün həlldən vizual olaraq az fərqlənə bilər və xüsusilə mövzunu yeni öyrənən şagirdlər tərəfindən tənqidsiz qəbul edilə bilər. Tədqiqatda qeyd olunur ki, Sİ alətləri nə qədər inkişaf edir və nəticədə istifadəçilərin onlara etimadı artırırsa, bu, tənqidsiz qəbul problemini daha da kəskinləşdirə bilər.

Bu müşahidə riyazi təfəkkürün əsas prinsiplərindən biri ilə birbaşa əlaqəlidir: riyaziyyatda nəticəyə çatmaq təkcə addım deyil, onun düzgünlüyünü "niyə doğrudur?" sualı ilə yoxlamaq (verifikasiya) bərabər əhəmiyyət daşıyır. Məhz bu səbəbdən Memiş (2025) qeyd edir ki, Sİ-nin çıxardığı nəticələrin yoxlanılması, alternativ üsullarla təsdiqlənməsi və yaradıcı şəkildə fərqli yanaşmaların sınanması riyazi təfəkkürün formalaşdırılmasında əvəzsiz addımlardır və bu addımlar Sİ tərəfindən əvəz oluna bilməz.

3.3. Sİ-dəstəkli fərdiləşdirilmiş təlimin müsbət təsiri

Yuxarıda göstərilən risklərə baxmayaraq, elmi ədəbiyyatda Sİ-dəstəkli fərdiləşdirilmiş təlimin riyazi problem həlli bacarıqlarına müsbət təsirini nümayiş etdirən tutarlı sübutlar da mövcuddur. Eti və həmmüəlliflərinin (2026) 20 tədqiqatı əhatə edən sistemli icmalı göstərir ki, Sİ əsaslı fərdiləşdirilmiş təlim ümumilikdə şagirdlərin konseptual anlamasını dərinləşdirir, tənqidi düşüncəsini gücləndirir və riyazi tapşırıqların həllində dəqiqlik və davamlılığı artırır — bu təsir xüsusilə adaptiv əks-əlaqə, fərdiləşdirilmiş tapşırıq ardıcıllığı və interaktiv təlim mühitləri ilə dəstəkləndikdə müşahidə olunur. Eyni zamanda icmal xəbərdarlıq edir ki, bəzi hallarda şagirdlər Sİ-nin təqdim etdiyi ipuclarına və dil dəstəyinə həddindən artıq etibar edərək müstəqil əsaslandırma imkanlarını azaldır.

Wardat və həmmüəlliflərin (2023) tədqiqatı ChatGPT-nin riyaziyyat tədrisində "inqilabi vasitə" kimi potensialını təhlil edərək, onun fərdiləşdirilmiş təlimat, adaptiv qiymətləndirmə və real vaxt əks-əlaqəsi vasitəsilə tələbələrin fərdi ehtiyaclarına uyğunlaşdırılmış öyrənmə təcrübəsi təqdim edə biləcəyini göstərir. AlMuhaysh (2026) tərəfindən aparılan kiçik miqyaslı eksperimental tədqiqat isə Sİ əsaslı tədris proqramının universitet tələbələrində "produktiv təfəkkür" bacarıqlarını — orijinallıq, çeviklik, nəticə çıxarma və interpretasiya kimi komponentləri əhatə edən — inkişaf etdirdiyini göstərmişdir, baxmayaraq ki, kiçik seçmə həcmi (9 nəfər) nəticələrin ümumiləşdirilməsini məhdudlaşdırır.

3.4. Etimad, nəzarət və koqnitiv tənbəllik riski

İnsan-Sİ əməkdaşlığının riyazi təfəkkürə təsirini başa düşmək üçün ümumi idraki-psixoloji çərçivələr də əhəmiyyətlidir. Gerlichin (2025) 666 iştirakçı üzərində apardığı geniş miqyaslı tədqiqat Sİ alətlərindən tez-tez istifadə ilə tənqidi düşüncə bacarıqları arasında mənfi korrelyasiya aşkar etmiş və bu əlaqədə koqnitiv tənbəlliyin — fərdlərin dərin analitik prosesi Sİ-yə həvalə etməsinin — vasitəçi rol oynadığını göstərmişdir. Bu tapıntı riyazi kontekstə də aid edilə bilər: əgər şagird hər çətin addımda Sİ-dən hazır həll tələb edirsə, öz məntiqi əsaslandırma "əzələsini" inkişaf etdirmək imkanını itirir.

Buçinca və həmmüəlliflərinin (2021) təqdim etdiyi "koqnitiv məcburetmə funksiyaları" konsepsiyası bu risklə mübarizədə praktik həll təklif edir: istifadəçini Sİ-nin cavabını görməzdən əvvəl öz həllini formalaşdırmağa məcbur edən struktur elementləri (məsələn, əvvəlcə şəxsi cavabı yazmaq, sonra Sİ ilə müqayisə etmək) Sİ-yə həddindən artıq etibarı əhəmiyyətli dərəcədə azalda bilir. Bu prinsip riyaziyyat dərslərində Sİ-nin tətbiqi metodikasına birbaşa tətbiq oluna bilər: şagirdlər məsələni əvvəlcə müstəqil həll etməli, yalnız bundan sonra Sİ-nin həllini müqayisə vasitəsi kimi istifadə etməlidirlər.

Opesemowo və Adewuyinin (2024) riyaziyyat təhsilində Sİ üzrə sistemli icmalı bu balansın zəruriliyini vurğulayır: Sİ-nin həddindən artıq istifadəsi tələbələrin problem həlli bacarıqlarının və yaradıcılığının azalmasına səbəb ola bilər, çünki onlar öz həll üsullarını inkişaf etdirmək əvəzinə avtomatlaşdırılmış nəticələrdən asılı vəziyyətə düşə bilərlər. Bununla belə, icmal həmçinin qeyd edir ki, Sİ düzgün istifadə edildikdə təhsil bərabərsizliyinin azaldılmasında və 4-cü Sənaye İnqilabının tələblərinə uyğun bacarıqların formalaşdırılmasında mühüm rol oynaya bilər.

3.5. Vaccaro və həmmüəlliflərinin (2024) sistemli baxışı: sinerji şərtləri

Nature Human Behaviour jurnalında dərc olunmuş geniş miqyaslı meta-analiz (Vaccaro et al., 2024) insan-Sİ əməkdaşlığının nə zaman müsbət sinerji effekti verdiyini araşdırmışdır. Nəticələr göstərir ki, müsbət effekt avtomatik deyil — o, insanın kontekstual mühakiməsi ilə Sİ-nin hesablama gücünün düzgün bölüşdürüldüyü, aydın rol fərqləndirilməsinin olduğu hallarda baş verir. Bu prinsip riyazi təfəkkürün inkişafına birbaşa tətbiq oluna bilər: Sİ təkrarlanan hesablamaları, alternativ üsulların yoxlanılmasını və nümunələrin generasiyasını öz üzərinə götürdükdə, insan isə anlayışların mənasını, məsələnin strukturunu və nəticənin əsaslılığını qiymətləndirdikdə, əməkdaşlıq riyazi idrakı gücləndirici formaya çevrilir.

4. Müzakirə

Aparılan təhlil göstərir ki, insan və süni intellekt əməkdaşlığı şəraitində riyazi təfəkkürün inkişafı iki əks tendensiyanın gərginliyi üzərində baş verir. Bir tərəfdən, Sİ alətlərinin riyazi dəqiqliyi sahədən-sahəyə kəskin fərqlənir — prosedur tapşırıqlarda nisbətən etibarlı, konseptual, vizual və çoxpilləli məntiqi əsaslandırma tələb edən tapşırıqlarda isə etibarsızdır (Frieder et al., 2023; Memiş, 2025; Wei, 2024). Digər tərəfdən, Sİ-nin nəzarətsiz istifadəsi koqnitiv tənbəlliyə və müstəqil əsaslandırma bacarıqlarının zəifləməsinə səbəb ola bilər (Gerlich, 2025; Opesemowo & Adewuyi, 2024).

Bu gərginliyi həll edən əsas amil — məqalənin mərkəzi tezisi kimi — Sİ-nin nəticəsinin deyil, onun əsaslandırma prosesinin tənqidi təhlilinin təhsil praktikasına inteqrasiya edilməsidir. Memişin (2025) aşkar etdiyi səhv növləri (natamam vizual şərh, yanlış əsaslandırma, hesablama xətaları) sadəcə çatışmazlıq deyil, əvəzsiz pedaqoji material kimi istifadə oluna bilər: şagirdlərdən Sİ-nin həllini tənqidi təhlil etmək, səhvi tapmaq və izah etmək tələb olunduqda, bu proses onların öz riyazi mühakiməsini fəallaşdırır və metakoqnitiv nəzarət bacarıqlarını gücləndirir.

Bu nəticələr əsasında praktikada riyazi təfəkkürün inkişafını dəstəkləyən insan-Sİ əməkdaşlığı üçün aşağıdakı prinsiplər təklif oluna bilər.

Birincisi, "əvvəlcə özün, sonra müqayisə et" prinsipi tətbiq edilməlidir — şagird məsələni Sİ-yə müraciət etməzdən əvvəl müstəqil həll etməli, yalnız bundan sonra öz həllini Sİ-nin təklifi ilə müqayisə etməlidir (Buçinca et al., 2021 əsasında).

İkincisi, dərs prosesinə Sİ-nin həllərinin tənqidi təhlili — səhvin tapılması, mənbəyinin izah edilməsi və düzəldilməsi — üzrə xüsusi tapşırıqlar daxil edilməlidir; bu, verifikasiya mədəniyyətini gücləndirir (Memiş, 2025).

Üçüncüsü, Sİ-nin üstün olduğu sahələr (təkrarlanan hesablamalar, alternativ üsulların generasiyası, addım-addım izahat) ilə insanın üstün olduğu sahələr (konseptual anlama, məsələnin strukturunun tanınması, nəticənin əsaslılığının qiymətləndirilməsi) arasında aydın tapşırıq bölgüsü aparılmalıdır (Vaccaro et al., 2024).

Dördüncüsü, xüsusilə həndəsə və vizual-məkani təsəvvür tələb edən mövzularda Sİ-nin nəticələrinə əlavə ehtiyatla yanaşılmalı və müəllim nəzarəti gücləndirilməlidir, çünki bu sahələr Sİ üçün ən yüksək səhv riski daşıyan zonalardır (Wei, 2024).

Tədqiqatın müəyyən məhdudiyyətləri qeyd olunmalıdır. Birincisi, təhlil ikinci dərəcəli mənbələrin sintezinə əsaslandığından, Azərbaycan təhsil sistemində riyazi təfəkkürün Sİ ilə əməkdaşlıq şəraitində necə formalaşdığını araşdıran orijinal empirik tədqiqatların aparılması zəruridir. İkincisi, nəzərdən keçirilən tədqiqatların əksəriyyəti konkret Sİ modellərinin (ChatGPT-4, Gemini və s.) müəyyən versiyaları üzərində aparılmışdır; bu modellərin sürətli təkmilləşməsi səbəbindən dəqiqlik göstəriciləri tez dəyişə bilər və nəticələrin davamlı monitorinqi tələb olunur. Üçüncüsü, nəzərdən keçirilən empirik tədqiqatların bir hissəsi kiçik seçmə həcminə malikdir (məsələn, AlMuhaysh, 2026), bu da nəticələrin ümumiləşdirilməsini məhdudlaşdırır.

5. Nəticə

Yekun olaraq, tədqiqat göstərir ki, insan və süni intellekt əməkdaşlığı riyazi təfəkkürün inkişafına həm töhfə verə, həm də maneə ola bilər — nəticə birbaşa əməkdaşlığın pedaqoji cəhətdən necə strukturlaşdırıldığından asılıdır. Sİ-nin riyazi səhvləri zəiflik deyil, əksinə, şagird və tələbələrin öz tənqidi və verifikasiya bacarıqlarını inkişaf etdirməsi üçün resurs kimi nəzərdən keçirilməlidir. Bu baxımdan gələcək riyaziyyat təhsili strategiyaları Sİ-ni "cavab maşını" kimi deyil, düzgün pedaqoji çərçivədə istifadə edildikdə riyazi mühakimənin inkişafına xidmət edən "tənqidi təhlil partnyoru" kimi nəzərdən keçirməlidir.

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Framing the Lachin Corridor Crisis: Selective Discursive Convergence in Azerbaijani, Chinese, and Institutional Communication

Liu Yousha

Abstract. *This article examines how the 2022–2023 Lachin Corridor crisis was framed in Azerbaijani official / news communication, Chinese foreign-policy and news-agency communication, and international institutional texts. The purposive corpus comprises 25 texts, with the main analytical window running from December 2022 to August 2023 and limited contextual material outside that period. Using qualitative frame analysis, the study compares problem definition, causal attribution, evaluation, remedies, agency visibility, evidential calibration, humanitarian salience, toponymy, and intertextual authority. Azerbaijani communication shifted from environmental-resource framing to sovereignty-security framing after the April 2023 checkpoint and then to regulated-access humanitarian framing. Chinese communication was less episode-specific and recast the dispute through dialogue, international law, territorial integrity, and regional stability. International institutions increasingly foregrounded freedom of movement and humanitarian access, though their mandates produced different evidential registers. The article conceptualizes this pattern as selective discursive convergence: overlap in high-level norms without equivalent agreement on causal narratives or remedies. It also identifies salience asymmetry and strategic attenuation as useful dimensions of third-party foreign-policy communication.*

Keywords: *Lachin Corridor, Azerbaijan; China, political communication, framing, strategic narratives, sovereignty, humanitarian access, South Caucasus*

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Laçın dəhlizi böhranının təqdimatı: Azərbaycan, Çin və institusional kommunikasiyada seçmə diskursiv yaxınlaşma

Liu Yuşa

Xülasə. *Bu məqalədə 2022–2023-cü illərdə Laçın dəhlizi ətrafında yaranmış böhranın Azərbaycanın rəsmi açıqlamalarında və xəbərlərində, Çinin xarici siyasət açıqlamalarında və xəbər agentliklərinin materiallarında, eləcə də beynəlxalq qurumların mətnlərində necə təqdim olunduğu araşdırılır. Məqsədli seçmə əsasında formalaşdırılmış korpus 25 mətndən ibarətdir.*

Əsas təhlil dövrü 2022-ci ilin dekabrından 2023-cü ilin avqustunadək olan müddəti əhatə edir; bu dövrdən kənar məhdud sayda material isə kontekst üçün istifadə olunur. Keyfiyyət əsaslı çərçivələmə təhlili vasitəsilə problemin müəyyənləşdirilməsi, səbəblərin kimə və ya nəyə aid edilməsi, qiymətləndirmə, təklif olunan həll yolları, fəaliyyət subyektlərinin mətndə görünürlüğü, iddiaların sübut səviyyəsinə uyğun ifadə edilməsi, humanitar məsələlərin ön plana çıxarılması, toponimlərin istifadəsi və digər mətnlərə istinadla əsaslandırma müqayisə edilir. Azərbaycanın kommunikasiya materiallarında 2023-cü ilin aprelində sərhəd-buraxılış məntəqəsinin yaradılmasından sonra ekoloji məsələlər və təbii resurslardan istifadə üzərində qurulan çərçivədən suverenlik və təhlükəsizlik çərçivəsinə, daha sonra isə tənzimlənən keçidə əsaslanan humanitar çərçivəyə keçid müşahidə olunur. Çinin kommunikasiya materialları ayrı-ayrı hadisələrin təfərrüatlarına daha az yönəlir və mübahisəni dialoq, beynəlxalq hüquq, ərazi bütövlüyü və regional sabitlik kontekstində təqdim edir. Beynəlxalq qurumlar hərəkət azadlığını və humanitar yardımın çatdırılması imkanlarını getdikcə daha çox ön plana çıxarır, lakin onların fərqli mandatları sübutların təqdim edilməsində müxtəlif yanaşmalar doğurur. Məqalədə bu nümunə selektiv diskursiv yaxınlaşma kimi izah edilir: ümumi prinsiplər üzrə uyğunluq səbəblərin izahı və ya həll yolları üzrə eyni dərəcədə razılıqla müşayiət olunmur. Həmçinin məsələyə ayrılan diqqətin qeyri-bərabərliyi və mübahisəli məqamlara vurğunun strateji şəkildə azaldılması üçüncü tərəflərin xarici siyasət kommunikasiyasının təhlilində faydalı ölçülər kimi müəyyənləşdirilir.

Açar sözlər: *Laçın dəhlizi, Azərbaycan, Çin, siyasi kommunikasiya, çərçivələmə, strateji narrativlər, suverenlik, humanitar yardıma çıxış, Cənubi Qafqaz*

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1. Introduction

After the Second Karabakh War, few transport routes in the South Caucasus acquired as much political meaning as the Lachin Corridor. Paragraph 6 of the trilateral statement of 10 November 2020 defined a five-kilometre-wide connection between Karabakh and Armenia under the control of the Russian peacekeeping contingent, while Azerbaijan undertook to guarantee the safety of persons, vehicles, and cargo moving in both directions (President of the Republic of Azerbaijan, 2020). The arrangement tied everyday mobility to peacekeeping, sovereign authority, security, and the wider problem of post-war order.

From 12 December 2022, movement along the route generated sharply different descriptions. Azerbaijani official communication foregrounded environmental concerns, alleged illegal resource exploitation, and claims that humanitarian passage remained possible. Armenian officials and several international actors emphasized obstruction, freedom of movement, and humanitarian consequences. On 22 February 2023, the International Court of Justice (ICJ), at the provisional-measures stage of Armenia v. Azerbaijan, ordered Azerbaijan to take all measures at its disposal to ensure unimpeded movement of persons, vehicles, and cargo in both directions. The Court stressed that the order did not prejudge jurisdiction or the merits and did not grant all measures requested by Armenia (ICJ, 2023a).

The article makes two contributions. Empirically, it traces shifts in the selected Azerbaijani texts from environmental-resource claims to sovereignty-security framing and then to regulated-access

humanitarian framing, while showing that the selected Chinese texts remain more abstract and less attributional. Conceptually, it develops selective discursive convergence to distinguish shared high-level norms from agreement on event-specific explanations and proposed responses, and uses salience asymmetry and strategic attenuation to capture differences in communicative intensity and abstraction.

Three research questions guide the analysis. RQ1: How did selected Azerbaijani official and news texts frame the Lachin Corridor between December 2022 and August 2023, and how did those frames change over time? RQ2: How did Chinese official and news-agency communication incorporate the Lachin issue into its broader representation of Armenia-Azerbaijan relations? RQ3: Where do Azerbaijani, Chinese, and international institutional vocabularies converge or diverge on sovereignty, security, humanitarian access, causal responsibility, and preferred remedies?

2. Literature Review and Conceptual Framework

2.1. Framing, attribution, and conflict vocabulary

Framing research is concerned with selection and salience: communicators make some aspects of an issue more prominent in ways that define problems, diagnose causes, evaluate actors, and make particular responses appear appropriate (Entman, 1993). In conflict reporting, these functions are especially consequential because disputed facts often enter news through sources representing different institutional positions, while labels for territory, actors, and actions may reflect differing political perspectives. Frame analysis therefore needs to examine more than tone. Nomination, agency, attribution, evidence, temporal context, and proposed remedy work together to organize interpretation.

Work on the Karabakh conflict illustrates these difficulties. Bayramov's (2023) analysis of 188 Dutch news items on the Second Karabakh War demonstrates that external media can reproduce simplifications through source selection, historical schemata, and recurring geopolitical assumptions.

Maharramova (2026) offers a useful lexical and methodological extension. Her comparative study operationalizes conflict reporting through event nomination, agency visibility, attribution, legal-status labels, humanitarian representation, place naming, and verification vocabulary.

2.2. Security framing and the limits of securitization claims

The April 2023 checkpoint introduced a more explicit security vocabulary into Azerbaijani communication. Securitization theory is useful because it draws attention to the discursive construction of threats and to the forms of control that such constructions can help justify (Buzan, Wæver, & de Wilde, 1998). Balzacq (2005), however, stresses that securitization is audience-centred, contextual, and shaped by power.

That distinction keeps the analysis within the evidence. Security language indicates a security frame, but it does not by itself establish audience acceptance or settle the legal validity of the policy being defended. Humanitarian language requires the same caution: it can accurately report operational need without proving every causal allegation attached to the crisis.

2.3. Strategic narratives, third-party communication, and China in the South Caucasus

Strategic-narrative scholarship helps explain why third states often discuss a regional crisis at a different level of abstraction from the immediate parties. Miskimmon, O'Loughlin, and Roselle (2013) describe

strategic narratives as attempts to organize understandings of international order, actors, and policy choices. A third party may therefore respond to a disputed episode by locating it within a broader story about dialogue, stability, international law, or development rather than adjudicating the parties' competing factual claims. China's growing economic and diplomatic engagement in the South Caucasus makes that distinction especially relevant. German (2022) links China's greater prominence to the region's geostrategic position and transit potential.

3. Case Context: From a Post-War Corridor to a Border Management Issue

The legal-political starting point is paragraph 6 of the 10 November 2020 trilateral statement. It placed the Lachin Corridor under the control of Russian peacekeepers, provided for a new route to be determined, and assigned Azerbaijan a safety guarantee for movement in both directions (President of the Republic of Azerbaijan, 2020). The text did not specify how every later question of inspection, protest activity, customs practice, border control, humanitarian passage, or sovereign jurisdiction would be handled. Those unresolved questions later supplied material for competing legal and political interpretations.

The December 2022 episode centred on Azerbaijani activists who described their actions as environmental protest against alleged illegal mineral exploitation. Azerbaijani official briefings stated that the government was not restricting movement and that protesters would facilitate civilian and ambulance traffic (MFA Azerbaijan, 2022). Report.az and AZERTAC reinforced this environmental-resource frame by foregrounding monitoring demands and reports that humanitarian traffic could pass (Report.az, 2022a, 2022b; AZERTAC, 2023). Other institutions emphasized different concerns. The ECtHR, indicating an interim measure on 21 December, described Azerbaijan's degree of control as disputed and unclear at that stage and directed Azerbaijan to ensure safe passage for seriously ill and certain stranded persons within its jurisdiction (ECtHR, 2022). The UN Secretariat, which was not present in the corridor, said it could not verify the competing claims (UNSC, 2022).

The ICJ's order of 22 February 2023 became one of the most frequently cited legal texts in the dispute. The Court found that movement had been disrupted and indicated a binding provisional measure requiring Azerbaijan to take all measures at its disposal to ensure unimpeded movement in both directions. It did not grant the requested measure directing Azerbaijan to cease alleged orchestration of the protests, and it found insufficient evidence for the requested utility-restoration measure (ICJ, 2023a).

4. Data and Method

This study uses a purposive comparative qualitative corpus because the research question concerns framing across institutionally different text genres rather than population estimates. The principal analytical window runs from 12 December 2022 to 31 August 2023. Three Chinese agency items extending to November 2023 are retained as contextual material for the peace-process macro-frame, and the 2020 trilateral statement serves as the legal-political baseline. The corpus contains 25 texts used in the analysis: seven Azerbaijani official/news items, seven Chinese official/agency interventions, and eleven legal, humanitarian, or multilateral documents. Appendix A identifies each item and its analytical role.

Texts were included if they directly addressed the protests, corridor movement, the April checkpoint, or humanitarian access, or—in the Chinese contextual subset—if they articulated relevant peace-process principles on sovereignty, territorial integrity, or regional communications. The Azerbaijani material includes Foreign Ministry statements and English-language reporting by Report.az and AZERTAC. The

Chinese material includes the Foreign Ministry's direct response, two Security Council interventions, and Xinhua items. The institutional subset includes the 2020 trilateral statement, ECtHR and ICJ materials, ICRC updates, UN records, PACE, and the Council of Europe Commissioner.

Analysis proceeded in two passes. The first identified each text's dominant problem definition and preferred remedy; the second compared lexical clusters, attribution patterns, and temporal change. Interpretive claims were checked against source status and whether a proposition appeared as authorial wording, an attributed claim, a procedural finding, or an operational observation. No frequency estimates are generalized from this small, deliberately heterogeneous corpus; 'dominant' and 'salient' refer only to repeated qualitative prominence within the selected texts.

Terminology is treated as evidence. Source-specific names such as 'Lachin Corridor', 'Lachin-Khankendi road', 'Karabakh', 'Khankendi' are preserved when describing a source. In the author's analytical prose, less contested terms are used where possible. The same rule applies to 'blockade': it is treated as an attributed frame rather than a neutral synonym for disruption.

The study has no audience-reception component. It therefore identifies security-oriented framing and textual framing strategies, not successful securitization or measurable media effects. Nor are international institutional texts treated as a neutral benchmark. They form a heterogeneous reference cluster with legal, humanitarian, and political mandates of their own. Their comparative value lies in showing which dimensions became institutionally salient and what evidential standards accompanied those claims.

Table 1
Analytical coding scheme

Dimension	Operational question	Typical indicators
Problem definition	What is presented as the central problem?	environmental/resource issue; blocked/restricted access; sovereignty; border security; humanitarian need; peace-process instability
Causal attribution	Who or what is said to have produced the problem?	protesters; state authorities; alleged illicit transfers; institutional failure; lack of dialogue; unnamed “sides”
Evaluation / legal register	What makes the situation legitimate, illegitimate, urgent, or risky?	sovereignty; territorial integrity; 2020 statement; ICJ order; humanitarian law; freedom of movement
Preferred remedy	What action is normalized as the solution?	monitoring; regulated passage; checkpoint; reopening/unimpeded movement; alternative route; negotiation
Agency visibility	Are actors named as agents or placed in passive/attributed constructions?	direct accusation; balanced attribution; passive description; non-attributive diplomacy
Evidential calibration	How are claims qualified?	assertion; attribution; “reported”; “alleged”; judicial finding; humanitarian operational observation
Humanitarian salience	How visible are civilian needs and access?	medical evacuation; food/medicine shortages; family reunification; humanitarian convoys

Dimension	Operational question	Typical indicators
Toponymy	Which place names encode a political or institutional perspective?	Lachin Corridor; Lachin-Khankendi road; Karabakh; Khankendi
Intertextual authority	Which prior texts authorize the frame?	trilateral statement; ICJ/ECtHR; ICRC; UN; bilateral declarations

5. Findings

5.1. Phase I: environmental-resource framing and the contest over the "blockade" label

The first recurring Azerbaijani frame, visible from December 2022 into early 2023, centred on environmental and resource-governance claims. The Foreign Ministry's 15 December briefing presented the protests as a civil-society response to unresolved ecological concerns and explicitly denied that Azerbaijan was restricting traffic (MFA Azerbaijan, 2022). Report.az and AZERTAC reinforced that interpretation by foregrounding ecological slogans, mineral deposits, monitoring demands, and reports that humanitarian or emergency vehicles could pass (Report.az, 2022a, 2022b; AZERTAC, 2023).

This frame presented a different account of the actors and their roles. If illegal resource exploitation is defined as the central problem, the emphasis falls on protesters' monitoring requests and civic concerns. Reports of humanitarian vehicles passing also supplied evidence for challenging the word 'blockade' as an overgeneralized description. The frame therefore affected both problem definition and causal attribution.

5.2. Phase II: the checkpoint and a shift from environmental to sovereignty-security framing

The border checkpoint established on 23 April 2023 produced the clearest shift in Azerbaijani official framing. Environmental monitoring remained in the background, but sovereignty and security moved to the foreground. The Foreign Ministry linked the checkpoint to alleged misuse of the road for military personnel, weapons, ammunition, and illicit trafficking, presenting the measure as a response to security threats (MFA Azerbaijan, 2023a). A follow-up statement described the checkpoint as an exercise of a sovereign and legitimate right while reiterating Azerbaijan's interpretation of its obligations concerning movement (MFA Azerbaijan, 2023b).

Three changes are especially clear. The object of dispute changes from a protest site to a state border; the relevant agent changes from civil-society protesters to border authorities; and the preferred remedy changes from monitoring resource exploitation to regulated passage. Taken together, these changes amount to a shift toward security-oriented framing: the road is represented as a channel that, according to the official statements, requires regulation to address military and sovereignty-related concerns.

5.3. Phase III: humanitarian-route contestation and regulated-access framing

By mid-2023 humanitarian access had become the central discursive conflict. ICRC reporting provides a useful operational anchor: in February it reported evacuations, family transfers, and deliveries along the corridor (ICRC, 2023a); on 25 July it stated that it could not then bring humanitarian assistance through the Lachin route or other routes, including Aghdam, while some medical evacuations continued

(ICRC, 2023b). In August it again reported prolonged interruption of food and medical deliveries (ICRC, 2023c).

Binary coding would obscure that structure. A text can accept the need to deliver medicine and food while discussing the route and regulatory conditions under which delivery takes place. A humanitarian organization can also insist on rapid, unimpeded access without endorsing either party's wider political narrative. The ICRC's September delivery through both the Lachin Corridor and the Aghdam road falls outside the main analytical window, but it offers useful contextual confirmation that multi-route access could emerge through a negotiated 'humanitarian consensus' (ICRC, 2023d). By then, the dispute had become as much about the architecture of access as about the existence of humanitarian need.

5.4. China: low salience, non-attributive diplomacy, and strategic attenuation

Chinese communication has a different profile. The most direct official response came at the Foreign Ministry press conference on 15 December 2022. The TASS question embedded a specific causal premise, describing Azerbaijani nationals as having blocked the corridor. Wang Wenbin did not repeat that premise. He moved instead to a regional-level appeal for dialogue, communication, peace, stability, and peaceful lives (MFA China, 2022). The response did not create several possible meanings so much as remove the contested attribution from the centre of the answer. In this article, that move is treated as strategic attenuation.

China's intervention at the Security Council on 20 December was more detailed but followed the same pattern. Geng Shuang expressed concern about the situation and its humanitarian impact, called for disputes surrounding the corridor to be addressed through dialogue and consultation, welcomed diplomatic efforts, and urged Armenia and Azerbaijan to resolve disagreements under international law (UNSC, 2022).

5.5. The institutional reference layer: law, humanitarian operation, and rights-based salience

International institutional texts form a third cluster, but one divided by mandate. The ICJ's language was judicial and provisional, focusing on CERD obligations, risk of irreparable prejudice, and a concrete measure on movement while preserving the non-merits status of the proceedings (ICJ, 2023a, 2023b). The ECtHR's December 2022 communication was narrower: it addressed interim protection for seriously ill and stranded persons and stated that Azerbaijan's degree of control over the situation was disputed and unclear at that stage (ECtHR, 2022).

The ICRC reported operational capacity rather than legal responsibility. Its updates documented medical evacuations, family reunification, deliveries, and later the inability to bring certain humanitarian supplies through either of the routes under discussion (ICRC, 2023a, 2023b, 2023c). This genre is useful for media analysis because its evidence is concrete: what teams delivered, whom they evacuated, and when deliveries ceased. It generally does not adjudicate the parties' competing political narratives.

For journalism, these genre differences matter. A provisional court order, humanitarian field update, parliamentary report, and foreign-ministry statement carry different kinds of authority. Treating them as interchangeable can turn provisional findings into final judgments, operational observations into legal attribution, or attributed statements into independently established fact.

Table 2
Comparative evolution of dominant frames, December 2022–August 2023

Period / trigger	Azerbaijani communication	Chinese communication	International institutional layer
Dec. 2022–Feb. 2023: protests and first legal interventions	Environmental/resource monitoring; denial or narrowing of "blockade"; emphasis on humanitarian exceptions and road openness	Dialogue, consultation, peace and regional stability; concern over humanitarian impact without episode-level blame	Safe passage; inability to verify competing claims (UN); interim protection (ECtHR); unimpeded movement order (ICJ)
Apr.–Jun. 2023: checkpoint	Sovereignty, border competence, security threats, regulated passage; alleged illicit use of route	Peace-process context; mutual accusations are attributed; territorial integrity and stability remain macro-frames	Existing ICJ measure remains relevant; rights/access concerns continue; PACE foregrounds freedom of movement and humanitarian consequences
Jul.–Aug. 2023: access crisis	Regulated-access humanitarian counterframe: medical passage, controlled access, Aghdam alternative, rejection of a politicized crisis narrative	Non-attributive diplomatic framing: dialogue, international law, "meet halfway", regional stability	ICRC reports inability to deliver assistance for a period; UN/CoE foreground reported humanitarian deterioration and access
Nov. 2023 contextual endpoint	Sovereignty and post-conflict reintegration become broader official context	Mutual recognition of sovereignty/territorial integrity and jurisdiction over communications becomes the dominant peace-process vocabulary	Outside main crisis window; institutional attention shifts to consequences of September 2023 events

6. Discussion

6.1. Selective discursive convergence

The central finding is a convergence of abstract norms without convergence of accounts of developments. Azerbaijani and Chinese communication both give positive weight to sovereignty, territorial integrity, international law, regional stability, and peaceful settlement, but those concepts do different work. In the selected Azerbaijani texts, sovereignty increasingly provides the stated basis for border control and responses to external descriptions of the situation. In the selected Chinese texts, sovereignty and territorial integrity appear mainly as principles of interstate order and peace negotiations, while discussion of Lachin emphasizes dialogue and consultation.

Bilateral documents adopted after the main study period provide contextual triangulation but should not be read backward into 2022-2023. The 2024 Azerbaijan-China strategic-partnership declaration placed regional peace, stability, and development within the bilateral framework, while the 2025 comprehensive

strategic-partnership statement strengthened mutual support on sovereignty, security, and territorial integrity (President of the Republic of Azerbaijan, 2024, 2025).

6.2. Salience asymmetry and strategic attenuation

Salience asymmetry adds a second dimension to the comparison. Foreign-policy communication is shaped not only by how an issue is framed but also by how much attention it receives and at what level of specificity (Soroka, 2003; Oppermann & Spencer, 2013). Azerbaijan communicated frequently because the route implicated territorial jurisdiction, international reputation, and immediate policy choices. China communicated intermittently and at a more general diplomatic level, reflecting its role as a third party concerned with regional stability and connectivity.

Strategic attenuation describes the textual mechanism behind this lower-salience posture. A disputed allegation enters the Chinese communicative setting, but the response brackets the disputed attribution and substitutes a general remedy of dialogue, law, and stability. This differs from strategic ambiguity, which preserves multiple plausible readings (Zhang & Han, 2013; Bach, 2025), and strategic silence, which withholds a position (Dadabaev & Sonoda, 2023).

6.3. Frame circulation and recontextualization

The case also shows how foreign-policy messages change as they move between institutions. A claim originating in a ministry, court, or humanitarian organization is rarely reproduced without alteration. Azerbaijani news outlets recontextualized official and activist claims into recurring stories about environmental monitoring, vehicle passage, and sovereignty. International institutions recoded the controversy into legal or humanitarian categories. Chinese communication placed the developments within a broader diplomatic discussion of stability. These are genre-specific transformations, not simply different opinions about the same event.

6.4. Implications for conflict-sensitive international journalism

The findings have several implications for conflict-sensitive reporting. Observable movement conditions should be separated from the political label assigned to them. 'Blockade', 'open road', 'regulated passage', and 'humanitarian corridor' carry different assumptions about agency, intentionality, and completeness. Attribution should remain visible when facts are contested. Claims about weapons transfers, intentional obstruction, or the use of humanitarian issues for political purposes should not migrate from a party statement into the reporter's unattributed voice without independent verification.

Limited coverage alone does not establish a particular diplomatic position. China’s limited direct treatment of Lachin nevertheless expressed identifiable diplomatic priorities. It consistently privileged a particular level of analysis: interstate dialogue, international law, stability, and peaceful settlement.

Table 3
Selective discursive convergence across the three communicative clusters

Dimension	Azerbaijani official/news cluster	Chinese official/agency cluster	Institutional reference cluster
Shared high-order norms	Sovereignty; territorial integrity; peace/stability	Sovereignty; territorial integrity; peace/stability; international law	Movement obligations; rights; humanitarian access; international law (varies by mandate)
Issue salience	High; frequent and granular	Low-to-moderate; comparatively abstract	High during legal/humanitarian interventions
Causal attribution	Often explicit; Armenia/illicit use/external politicization are recurrent attributed causes	Deliberately limited; parties are urged to negotiate and meet halfway	Varies: courts delimit findings; ICRC reports operations; political bodies may use stronger attribution
Preferred remedy	Monitoring → regulated border control → alternative/controlled access	Dialogue, consultation, diplomatic settlement, international law	Unimpeded/free movement, humanitarian access, compliance with institutional measures
Core discursive function	Explanation of national jurisdiction and policy	De-escalation and preservation of diplomatic flexibility	Legal/humanitarian problem definition and institutional response
Degree of convergence with Azerbaijan	—	High at normative level; limited at episode level	Partial on sovereignty context; lower on access framing during mid-2023

7. Limitations

The study is intentionally bounded. The purposive corpus cannot represent Azerbaijani or Chinese media as a whole, much less public opinion. Direct Chinese material on Lachin is particularly limited, so the comparison combines a small number of episode-specific interventions with a contextual set of Xinhua items on the peace process. That asymmetry is part of the finding, but it also restricts generalization.

The analysis uses English-language or officially translated material. Chinese-, Azerbaijani-, and Russian-language versions may contain different nuance or salience. A multilingual follow-up could test whether strategic attenuation is equally visible in domestic-facing communication.

No audience data are used, so the article makes claims about texts and institutional framing rather than persuasion, reception, or successful securitization. The institutional cluster is also heterogeneous: the ICJ, ECtHR, ICRC, UN Secretariat, PACE, and Council of Europe Commissioner have different mandates and evidential practices. They are grouped only for comparative purposes, and the analysis preserves those mandate-specific differences.

8. Conclusion

The Lachin Corridor crisis shows how a geographically narrow route can become a dense site of political communication. Between December 2022 and August 2023, the corridor was represented as an

environmental-protection dispute, an access problem, a sovereign border, a security vulnerability, a humanitarian lifeline, and a test of regional diplomacy. The relative prominence of these frames changed as the institutional and material context changed.

In the selected Azerbaijani material, framing moved from environmental monitoring and rejection of the 'blockade' label to sovereignty-security claims after the April checkpoint and then to a regulated-access humanitarian counterframe centred on medical passage and alternative routes, especially Aghdam.

Chinese communication followed a different trajectory. Direct statements remained comparatively sparse and shifted episode-level controversy toward dialogue, consultation, international law, and regional stability. Xinhua's wider peace-process reporting made sovereignty and territorial integrity visible, but those shared principles did not become detailed endorsement of Azerbaijan's causal account of the Lachin crisis. This is the core of selective discursive convergence: high-order normative overlap accompanied by divergence in salience, attribution, and remedy.

For international journalism, the implication is practical. Disputed labels should remain attributed, procedural status should be reported precisely, and humanitarian observations should be distinguished from attributed political statements. These are not minor stylistic choices. In a contested post-conflict setting, they determine whether reporting preserves the difference between evidence, interpretation, and advocacy.

Declarations

• Funding. This research received no external funding.
• Conflict of Interest. The author declares no conflict of interest.
• Data Availability. All primary documents and media texts analysed in the article are publicly accessible through the links listed in the references and the corpus appendix.
• Ethics Statement. The study uses publicly available documents and media texts and does not involve human participants, personal data, or animal research.

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Toponymic Analysis of Public School Names in the Turkish Republic of Northern Cyprus: A Study Based on the Pre-1974 Settlement Structure

Nazmiye Hazar

Abstract. *The aim of this study is to examine the current settlement names used in the names of public schools affiliated with the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC) in relation to the historical characteristics of these settlements prior to 1974 and to explore the role of school names in the public circulation of place names. The study was conducted within a quantitative research framework using a descriptive design based on document analysis. The research population consisted of 161 public schools operating under the Ministry of National Education during the 2025–2026 academic year. Data were obtained through a comparative analysis of official school lists provided by the Ministry of National Education and official and scholarly sources concerning historical settlements and place names. Schools containing current settlement names in their official names were identified, and these settlements were classified according to their pre-1974 historical characteristics into three categories: former Greek Cypriot-majority settlements, former Turkish Cypriot-majority settlements, and former mixed Greek Cypriot–Turkish Cypriot settlements. The findings revealed that 89 of the 161 public schools examined include a current settlement name in their official names. Among these schools, 48 (53.9%) are associated with settlements that had Greek Cypriot-majority characteristics before 1974, 22 (24.7%) with Turkish Cypriot-majority settlements, and 19 (21.4%) with mixed settlements. The analysis by educational level demonstrated that settlement-based naming practices are most prevalent in primary schools, whereas secondary education institutions more frequently employ names associated with individuals, historical figures, and institutional identities. Furthermore, the findings indicate that officially adopted current settlement names after 1974 have been reflected more extensively in public school names, particularly in areas characterized by Greek Cypriot-majority settlement patterns before 1974. The study concludes that school names function not merely as administrative identifiers of educational institutions but also as institutional mechanisms through which place names enter public discourse, historical and spatial transformations are represented, and spatial memory is reproduced. In this respect, the study contributes to interdisciplinary discussions in educational administration, critical toponymy, historical geography, and public memory studies.*

Keywords: *school naming, toponymy, place names, spatial memory, public identity, historical geography, Turkish Republic of Northern Cyprus (TRNC)*

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Şimali Kipr Türk Respublikasında dövlət məktəblərinin adlarının toponimik təhlili: 1974-cü ildən əvvəlki məskunlaşma strukturuna əsaslanan tədqiqat

Nazmiyə Hazar

Xülasə. *Bu tədqiqatın məqsədi Şimali Kipr Türk Respublikasının (ŞKTR) Milli Təhsil Nazirliyinə tabe olan dövlət məktəblərinin adlarında işlədilən müasir yaşayış məntəqəsi adlarını həmin məntəqələrin 1974-cü ildən əvvəlki tarixi xüsusiyyətləri ilə əlaqəli şəkildə araşdırmaq və yer adlarının ictimai istifadəsində məktəb adlarının rolunu müəyyənləşdirməkdir. Tədqiqat kəmiyyət yanaşması çərçivəsində sənəd təhlilinə əsaslanan təsviri tədqiqat modeli ilə aparılmışdır. Tədqiqatın baş məcmusunu 2025–2026-cı tədris ilində Milli Təhsil Nazirliyinin tabeliyində fəaliyyət göstərən 161 dövlət məktəbi təşkil etmişdir. Məlumatlar Nazirliyin təqdim etdiyi rəsmi məktəb siyahılarının tarixi yaşayış məntəqələri və yer adlarına dair rəsmi və elmi mənbələrlə müqayisəli təhlili əsasında əldə edilmişdir. Rəsmi adlarında müasir yaşayış məntəqəsi adları olan məktəblər müəyyənləşdirilmiş, həmin məntəqələr isə 1974-cü ildən əvvəlki tarixi xüsusiyyətlərinə görə üç kateqoriyaya bölünmüşdür: əvvəllər Kipr yunanlarının çoxluq təşkil etdiyi yaşayış məntəqələri, Kipr türklərinin çoxluq təşkil etdiyi yaşayış məntəqələri və Kipr yunanları ilə Kipr türklərinin birgə yaşadıqları qarışıq yaşayış məntəqələri. Nəticələr göstərmişdir ki, araşdırılan 161 dövlət məktəbindən 89-nun rəsmi adında müasir yaşayış məntəqəsinin adı yer alır. Bu məktəblərdən 48-i (53,9%) 1974-cü ildən əvvəl Kipr yunanlarının çoxluq təşkil etdiyi, 22-si (24,7%) Kipr türklərinin çoxluq təşkil etdiyi, 19-u (21,4%) isə qarışıq əhalinin yaşadığı məntəqələrlə əlaqəlidir. Təhsil pillələri üzrə təhlil göstərmişdir ki, yaşayış məntəqələrinin adlarına əsaslanan adlandırma ibtidai məktəblərdə daha geniş yayılmışdır. Orta təhsil müəssisələrində isə şəxslərin, tarixi şəxsiyyətlərin adlarından və müəssisənin kimliyini əks etdirən adlardan daha çox istifadə olunur. Bundan əlavə, nəticələr göstərir ki, 1974-cü ildən sonra rəsmi şəkildə qəbul edilmiş müasir yaşayış məntəqəsi adları, xüsusilə həmin tarixədək Kipr yunanlarının çoxluq təşkil etdiyi ərazilərdə dövlət məktəblərinin adlarında daha geniş əks olunmuşdur. Tədqiqatda belə nəticəyə gəlinir ki, məktəb adları təhsil müəssisələrini fərqləndirən inzibati adlar olmaqla yanaşı, yer adlarının ictimai diskursa daxil olmasını, tarixi və məkan dəyişikliklərinin təmsil edilməsini, eləcə də məkan yaddaşının yenidən istehsalını təmin edən institusional mexanizmlər kimi çıxış edir. Bu baxımdan tədqiqat təhsilin idarə olunması, tənqidi toponimika, tarixi coğrafiya və ictimai yaddaş tədqiqatları sahələrində fənlərarası müzakirələrə töhfə verir.*

Açar sözlər: *məktəblərin adlandırılması, toponimika, yer adları, məkan yaddaşı, ictimai kimlik, tarixi coğrafiya, Şimali Kipr Türk Respublikası (ŞKTR)*

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1. Introduction

1.1. Educational Infrastructure, Space, and the Production of Public Meaning

Educational systems are not merely institutional structures through which knowledge and skills are transmitted; they are also spatial organizations shaped by social, demographic, political, and historical processes. The location, distribution, and accessibility of educational institutions are closely associated with population structures, settlement patterns, public policies, and regional development dynamics. Therefore, the spatial distribution of educational institutions has become an important field of inquiry not only in educational sciences but also in educational geography, human geography, public administration, and regional planning (Harvey, 1973; Soja, 2010; Holloway & Jöns, 2012).

The perspective of educational geography approaches schools not simply as physical spaces where instructional activities take place, but as spatial institutions embedded within specific historical, social, and political contexts. This approach examines where educational institutions are concentrated, which population groups they serve, how they are related to settlement structures, and how regional inequalities emerge in access to educational services (Thiem, 2009; Holloway & Jöns, 2012). From this perspective, the formation of school networks cannot be explained solely by current student populations; rather, it should be understood as the outcome of the interaction among historical settlement processes, public investments, transportation opportunities, and administrative policies.

Place names (toponyms) are not merely geographical markers that identify spatial locations; they are also symbolic instruments through which historical processes, political authority, collective memory, and social identities become visible in public space. The critical toponymy approach argues that place names carry ideological, cultural, and political meanings, while naming practices function as mechanisms through which power relations, identity politics, and collective memories are reproduced (Azaryahu, 1996; Alderman, 2008; Berg & Vuolteenaho, 2009; Rose-Redwood, Alderman, & Azaryahu, 2010). Accordingly, school names should not be considered merely as administrative labels for educational institutions; rather, they represent significant toponymic elements reflecting historical memory, spatial belonging, and public identity.

Approaches that conceptualize space not as a passive physical location but as a continuously produced phenomenon shaped by historical, economic, social, and political relations provide an important theoretical foundation for analyzing educational institutions (Lefebvre, 1991; Harvey, 1973; Soja, 2010). From this perspective, the locations of schools are not solely outcomes of current population densities; they also represent spatial manifestations of long-term social transformations and the organization of public services. Therefore, examining educational infrastructure in relation to historical settlement patterns contributes to understanding how educational services are organized and how spatial continuities are maintained over time.

The spatial distribution of educational services is also closely associated with debates on spatial justice. Harvey's (1973) social justice perspective and Soja's (2010) theory of spatial justice emphasize that access to public services is not only an economic issue but also a geographical one. The concentration of educational institutions in certain areas or their limited availability in particular settlements may produce different consequences in terms of access to educational opportunities, transportation conditions, and regional development. Accordingly, contemporary approaches to educational planning consider not only current student populations but also population movements, settlement characteristics, demographic changes, and spatial inequalities (OECD, 2023; World Bank, 2018).

Within this framework, school mapping has become one of the fundamental planning tools used in the spatial analysis of educational infrastructure. The UNESCO International Institute for Educational Planning (UNESCO-IIEP) defines school mapping as a strategic approach aimed at identifying the existing distribution of educational institutions, forecasting future educational needs, ensuring efficient resource allocation, and grounding educational investments in evidence-based criteria (UNESCO-IIEP, 2009). Contemporary school mapping studies extend beyond simply determining the number of schools and increasingly incorporate demographic movements, migration processes, settlement structures, and regional development indicators.

Nevertheless, the spatial organization of educational infrastructure is not solely the outcome of contemporary planning decisions. Particularly in societies experiencing conflict, population movements, and political transformations, public institutions may preserve traces of previous settlement patterns. As a major component of public services, educational institutions provide important indicators through which population movements, spatial restructuring, and institutional transformations can be examined (Bollens, 2000; Bollens, 2007). Therefore, analyzing educational institutions from a historical-spatial perspective enables a deeper understanding of institutional continuities and transformations between the past and the present.

This study does not examine the settlements in which public schools are physically located; rather, it focuses on the historical origins of current settlement names used in school names. Within this framework, the study approaches school names through the perspective of critical toponymy and aims to reveal how officially adopted settlement names after 1974 have become visible and institutionalized in public space through educational institutions.

1.2. Post-War State-Building, Settlement Transformation, and the Reconstruction of Public Space

Wars and subsequent processes of political restructuring transform not only state boundaries and social structures but also settlement patterns, the spatial organization of public services, and the symbolic dimensions of public space. Particularly during the establishment of new states or the reorganization of existing state structures, forced migration, population movements, and changes in settlement arrangements require the restructuring of education, healthcare, and other public services in accordance with emerging demographic and administrative conditions (Bollens, 2007; Newman, 2006).

State-building processes in post-conflict contexts involve not only the formation of political institutions but also the development of institutional capacities, the organization of public services, and the reconfiguration of public space. In this sense, the reconstruction of educational infrastructure constitutes an important dimension of broader processes of political and spatial transformation.

Studies on divided societies demonstrate that political and demographic transformations do not completely eliminate previous spatial patterns; rather, these patterns may continue to influence contemporary social and institutional structures through infrastructure networks, public institutions, and settlement arrangements (Bollens, 2000; Pullan, 2011). From this perspective, educational institutions should not be considered merely as structures responding to current social needs; they may also function as spatial indicators through which historical transformations become visible.

In this study, the concept of historical settlement characteristics is not used to define contemporary social identities or present-day demographic structures. Instead, it is employed as a historical analytical variable for examining the spatial patterns reflected through educational institutions. In other words, the study

aims to investigate how previous settlement configurations may have left spatial traces within contemporary educational infrastructure.

1.3. Historical Settlement Geography of Cyprus and the Reorganization of Educational Infrastructure after 1974

The island of Cyprus has a multi-layered settlement geography shaped by different political administrations, population movements, and social transformations throughout history. The island's strategic location in the Eastern Mediterranean and successive changes in political sovereignty have contributed to the continuous reconfiguration of settlement patterns and social structures. Therefore, understanding the contemporary spatial organization of Cyprus requires an evaluation that extends beyond current administrative boundaries and demographic distributions and considers historical processes and settlement transformations (Hill, 2010; Bryant, 2010).

Following the Ottoman conquest of Cyprus in 1571, settlement policies implemented by the Ottoman administration significantly influenced the island's demographic and cultural structure. Population transfers and settlement practices carried out in different regions strengthened the presence of the Turkish population on the island and contributed to the emergence of new settlement characteristics. Following the beginning of British administration in 1878, administrative structures, transportation networks, and the organization of public services were reconfigured, and the development of educational institutions was also shaped by these transformations (Hill, 2010).

Although the establishment of the Republic of Cyprus in 1960 introduced a bi-communal constitutional framework, subsequent political tensions and social divisions significantly affected settlement patterns. Particularly after 1963, increasing security concerns and population movements contributed to greater spatial separation between communities in certain settlements, while the provision of public services and the functioning of institutions were also influenced by these developments (Dodd, 2010; Nevzat, 2005).

The year 1974 represents a major turning point in the historical and spatial organization of Cyprus. The large-scale population movements that followed the events of this period resulted in the emergence of distinct demographic and administrative structures in the northern and southern parts of the island. The relocation of populations to new settlement areas required not only the reorganization of housing and economic activities but also the restructuring of education, healthcare, and other public services (Hatay, 2007; Bryant, 2010).

The reorganization of the educational system in the Turkish Republic of Northern Cyprus (TRNC) required the sustainable provision of educational services in accordance with the changing demographic structure. During this process, the utilization of existing school buildings, the establishment of new educational institutions, the restructuring of school networks, and the continuation of educational services across different settlements became central administrative concerns. Accordingly, the contemporary distribution of public schools should be understood not only as a response to current population needs but also as a consequence of historical transformations and settlement processes.

However, establishing a direct causal relationship between historical settlement characteristics and the contemporary distribution of educational institutions would not be methodologically appropriate. In this study, historical settlement characteristics are not considered the sole determinants explaining the location or distribution of educational institutions; rather, they are used as an analytical classification variable for examining spatial patterns. Thus, the study adopts a descriptive and comparative approach

to explore how historical settlement configurations may be reflected within contemporary educational structures.

1.4. Literature Gap and Original Contribution of the Study

International studies examining the spatial distribution of educational institutions have primarily focused on school accessibility, educational equity, regional disparities, school planning, and the effective allocation of public resources (Holloway & Jöns, 2012; Thiem, 2009). These studies demonstrate that educational infrastructure is not merely a pedagogical component but also a reflection of broader social and spatial processes.

However, research examining the relationship between educational infrastructure and historical settlement patterns in post-conflict societies remains limited. Although existing studies have extensively addressed the spatial transformation of divided societies, population movements, and the effects of political boundaries, the role of educational institutions within these transformations has received comparatively less attention (Bollens, 2007; Pullan, 2011).

Research on Cyprus has largely focused on political history, international relations, population movements, and social transformations (Bryant, 2010; Dodd, 2010; Hatay, 2007). Nevertheless, comprehensive research systematically examining all public schools operating in the Turkish Republic of Northern Cyprus according to pre-1974 historical settlement characteristics, educational levels, and administrative regions remains limited.

This study seeks to address this gap by integrating educational geography and historical settlement geography within a common analytical framework. The first contribution of the study is to make the spatial patterns of educational infrastructure visible through a comprehensive dataset developed according to the historical settlement characteristics associated with public school names in the TRNC. The second contribution is to propose a methodological approach in which historical settlement patterns are considered as an analytical variable for examining educational institutions. The third contribution is to provide an empirical case for broader discussions concerning the spatial continuity and transformation of public services in post-conflict societies.

The distinctive contribution of this study lies in its focus not on the physical locations of public schools, but on the historical origins of current settlement names used in school names and the role of educational institutions in the public circulation of place names. Specifically, the study examines the extent to which officially adopted settlement names after 1974 are represented in public school names and how these representations vary according to historical settlement categories.

In this respect, the study argues that educational institutions are not merely structures providing educational services; they also function as public mechanisms through which current settlement names become visible in everyday use and through which forms of spatial belonging are institutionally reproduced.

Accordingly, this study seeks to answer the following research questions:

Research Question 1: How are current settlement names used in public school names in the TRNC distributed according to their pre-1974 settlement characteristics?

Research Question 2: How does the distribution of current settlement names used in school names according to pre-1974 settlement characteristics vary across educational levels?

Research Question 3: How does the use of current settlement names originating from pre-1974 Greek Cypriot, Turkish Cypriot, and mixed Turkish–Greek Cypriot settlements differ in public school naming practices?

2. Theoretical Framework

2.1. Toponymy and the Social Functions of Place Names

Toponymy is an interdisciplinary field of inquiry that examines the origins, meanings, uses, and transformations of place names over time. Place names are not merely descriptive labels identifying geographical locations; they are also significant indicators reflecting societies' historical experiences, cultural heritage, political structures, and collective memories (Alderman, 2008). In this respect, toponyms serve as symbolic elements that establish connections between the past and the present, while also functioning as important instruments through which states organize, regulate, and re-signify public space.

Within the toponymy literature, changes in place names are not regarded merely as linguistic transformations. Particularly following political transitions, wars, population movements, and processes of institutional restructuring, renaming practices are considered visible manifestations of new political and social orders within public space (Azaryahu, 1996). Therefore, place names provide important insights into how societies define space and which historical narratives they choose to make visible in the public sphere.

The critical toponymy approach emphasizes that place names are not neutral geographical references; rather, they constitute important components of power relations, identity construction, and public memory processes (Rose-Redwood, Alderman, & Azaryahu, 2010). From this perspective, toponyms function as symbolic mechanisms through which societies interpret their past, negotiate collective identities, and construct shared understandings of belonging. Consequently, the study of place names provides valuable opportunities for understanding how historical narratives and social meanings are embedded within everyday spatial practices.

2.2. Place Names, Public Memory, and Educational Institutions

Place names represent among the most frequently encountered symbolic markers in public space. Their continuous reproduction through everyday practices, official documents, maps, and the names of public institutions enables them to become embedded within collective memory (Light & Young, 2014). Therefore, continuously used public institutions such as educational organizations may function as important institutional mechanisms through which place names are transmitted across generations.

Schools are not only educational settings where teaching and learning activities occur; they are also public institutions through which states and societies become visible in everyday life. School names are repeatedly used by students, teachers, families, and local communities, allowing them to become part of the social memory embedded within daily practices. Accordingly, school naming practices should not be understood merely as technical administrative decisions within educational management; they also influence how place names circulate, become normalized, and gain public recognition.

From this perspective, settlement names incorporated into school names can be considered symbolic elements that shape how individuals perceive and define their surrounding environments. Through their continuous repetition within educational contexts, place names contribute to the development of spatial belonging and support the social acceptance of officially recognized names of places. Thus, educational institutions serve not only as providers of public services but also as important actors in the reproduction and circulation of spatial meanings.

2.3. Transformation of Settlement Names in the Context of the Turkish Republic of Northern Cyprus

The political and demographic transformations experienced in Cyprus after 1974 affected not only settlement structures but also the naming of places. Numerous settlements located in the northern part of the island were assigned new names, and these names gradually became incorporated into official documents, maps, and public institutions (Bryant, 2010; Hatay, 2007). This process may be understood not merely as an administrative arrangement but also as part of the broader reconfiguration of public space and the institutionalization of a new settlement order.

Following the establishment of the Turkish Republic of Northern Cyprus (TRNC), educational institutions became significant components of this transformation. The preference for current settlement names in the naming of newly established schools, as well as in the naming practices of existing educational institutions, contributed to the institutional recognition and everyday use of these names. In this way, school names transformed settlement names into public symbols that were reproduced not only through official records but also through daily educational practices.

This study focuses precisely on this relationship between educational institutions and place-name reproduction. The aim is not to determine the historical settlement characteristics of the locations where public schools are physically situated; rather, it is to examine the pre-1974 historical characteristics of current settlement names used in school names and to reveal how these names have been institutionalized through educational institutions.

Accordingly, this study brings together educational administration and critical toponymy perspectives by examining the role of school names in the public circulation of settlement names within the context of the TRNC. Through this approach, educational institutions are conceptualized as symbolic public spaces where historical transformations, spatial meanings, and place-based identities become visible and reproduced.

3. Method

3.1. Research Design

This study employs a descriptive document-based research design using a quantitative content analysis approach to examine the contemporary settlement names used in the names of public schools affiliated with the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC), with particular emphasis on the historical settlement characteristics of these names prior to 1974.

In the first stage of the research, the official names of 161 public schools operating during the 2025–2026 academic year were examined, and the main naming patterns used in school names were identified. The analysis revealed that school names were derived from various sources, including statesmen, educators, historical figures, literary personalities, individuals with significant contributions to the social and

cultural memory of the Turkish Cypriot community, national and historical events (e.g., 20 July), philanthropists, expressions representing institutional or professional identities, and settlement names. In some cases, settlement names were used together with cultural or symbolic expressions (e.g., Güzelyurt Portakal Çiçekleri Kindergarten and Güzelyurt Kurtuluş High School).

In accordance with the purpose of the study, only school names containing contemporary settlement names were included in the analysis. Each contemporary settlement name identified in school names was classified according to the historical settlement characteristics of the relevant settlement unit before 1974 as a Greek Cypriot settlement, Turkish Cypriot settlement, or mixed Greek Cypriot–Turkish Cypriot settlement.

Therefore, the unit of analysis in this study is not the entire set of public schools, but the contemporary settlement names used in school names. The aim of the study is not to classify the settlements in which schools are physically located; rather, it seeks to reveal the historical origins of contemporary settlement names appearing in school names and to evaluate the patterns of their public use through educational institutions after their adoption following 1974.

3.2. Research Population and Data Sources

The research population consists of all public schools operating under the Ministry of National Education of the Turkish Republic of Northern Cyprus during the 2025–2026 academic year. No sampling procedure was employed; instead, the entire research population was examined through a complete enumeration approach.

The study included:

- pre-primary education institutions, special education schools, and primary schools affiliated with the Department of Primary Education,
- lower secondary schools and high schools affiliated with the Department of General Secondary Education,
- vocational and technical high schools affiliated with the Department of Vocational Technical Education.

A total of 161 public schools were evaluated within the scope of the research.
The following sources were used to construct the dataset:

- official updated school lists provided by the Ministry of National Education of the TRNC,
- institutional records of relevant education departments,
- official information and promotional resources provided by school administrations,
- scientific studies addressing the historical characteristics of settlements,
- historical population and settlement records,
- official sources related to changes in place names.

Private schools, universities, private course centres, and temporary educational units were excluded from the study.

3.3. Data Collection and Coding Process

The data collection and coding process was conducted in four stages.

In the first stage, the current official names of the 161 public schools constituting the research population were identified. In the second stage, all school names were examined individually, and schools containing contemporary settlement names were determined. The analysis revealed that 89 of the 161 public schools

had names directly based on contemporary settlement names. Schools whose names were based on personal names, historical figures, professional fields, or institutional identities and did not contain settlement names were excluded from the analysis.

In the third stage, each contemporary settlement name used in school names was evaluated according to its historical settlement characteristics before 1974 using historical sources and was coded as a Greek Cypriot settlement, Turkish Cypriot settlement, or mixed Greek Cypriot–Turkish Cypriot settlement.

In the fourth stage, additional variables, including educational level, district, and educational administrative unit, were added to the dataset for each school. Thus, the final dataset to be used in statistical analyses was established.

3.4. Classification of Historical Settlement Characteristics

The primary analytical variable of the study is the historical settlement characteristic of the settlements from which the contemporary settlement names used in school names originate. Within this framework, settlements were classified into three categories:

Greek Cypriot settlement: Settlement units that were predominantly inhabited by the Greek Cypriot population before 1974.

Turkish Cypriot settlement: Settlement units that were predominantly inhabited by the Turkish Cypriot population before 1974.

Mixed Greek Cypriot–Turkish Cypriot settlement: Settlement units where both communities lived together or where both communities constituted significant proportions of the population before 1974.

During the classification process, scientific studies, historical population research, and settlement records concerning the historical demographic characteristics of settlements were comparatively examined (Bryant, 2010; Dodd, 2010; Hatay, 2007). In cases where differences existed among sources, commonly accepted historical records were taken as the basis.

This classification was not used to define contemporary population structures, ethnic identities, or property relations; rather, it was employed solely as an analytical variable for examining the historical origins of contemporary settlement names used in school names.

3.5. Data Analysis

The research data were analysed using descriptive statistical techniques. Frequencies (n), percentage (%) distributions, and cross-tabulations were used to demonstrate the distribution patterns related to educational levels, districts, and historical settlement characteristics.

The analysis process was conducted in four stages. In the first stage, the official names of the 161 public schools included in the research were examined, and school names were classified according to their content characteristics. This analysis indicated that school names could be categorized according to different naming sources, including personal names, historical figures, philanthropists, national and cultural values, institutional identities, and settlement-based names.

In the second stage, only schools containing contemporary settlement names were included in the analysis. In cases where contemporary settlement names were used together with historical, cultural, symbolic, or value-based expressions (e.g., Güzelyurt Kurtuluş High School, Güzelyurt Portakal Çiçekleri Kindergarten, and Oğuz Veli Middle School), the presence of the settlement name was considered sufficient for inclusion in the study.

In contrast, schools whose names included only personal names, historical figures, national commemorations and events, philanthropists, or institutional identities without any contemporary settlement name (e.g., Namık Kemal High School, Bekir Paşa High School, 20 July Science High School, and Bülent Ecevit Anatolian High School) were excluded from the analysis. Thus, the primary inclusion criterion was not the general naming approach of schools but rather the presence of a contemporary settlement name within the school name.

In the third stage, contemporary settlement names used in school names were identified and classified into three categories according to their historical settlement characteristics before 1974: Greek Cypriot settlement, Turkish Cypriot settlement, and mixed Greek Cypriot–Turkish Cypriot settlement. This classification was based on the historical origin of the settlement name reflected in the school name rather than the location of the school itself.

In the final stage, the obtained data were evaluated through frequency and percentage calculations. In addition, cross-tabulations were created according to educational level, district, and educational administrative unit variables to conduct comparative analyses. Through these analyses, the historical origins of contemporary settlement names used in school names and their distribution patterns across educational levels and administrative units were identified. Accordingly, the usage patterns of officially adopted contemporary settlement names after 1974 within public school naming practices were descriptively examined.

3.6. Validity and Reliability

To enhance the accuracy of the dataset, the collected data were validated comparatively through multiple official and scientific sources. Data related to public schools were cross-checked with the updated official school lists of the Ministry of National Education of the TRNC and institutional records of relevant education departments. The historical characteristics of contemporary settlement names used in school names were verified through official records and scientific sources addressing the historical settlement structure of Cyprus.

During the coding process, the same predetermined classification criteria were applied consistently to all settlement units. Following completion of the coding process, the dataset was reviewed again to identify and resolve potential inconsistencies. Historical settlement characteristics were used solely as an analytical variable, and no conclusions were drawn regarding contemporary population structures, ethnic identities, or property relations.

The detailed explanation of the data collection process, classification criteria, and analytical procedures; the explicit identification of data sources; and the consistent application of the same criteria throughout the analyses contribute to the methodological transparency, replicability, and reliability of the study.

4. Findings

This section presents the findings obtained regarding the spatial and institutional distribution of public educational institutions operating in the Turkish Republic of Northern Cyprus. The institutions examined within the scope of the study were evaluated according to their affiliated educational administrative units, educational levels, districts, and the pre-1974 historical characteristics of the settlements associated with the institutions. The findings are presented first through an analysis of the institutional structure and distribution of public educational institutions by educational level, followed by comparative analyses based on district distribution and historical settlement characteristics.

4.1. Distribution of Public Educational Institutions by Educational Administrative Units

Within the scope of the study, a total of 161 public educational institutions operating in the Turkish Republic of Northern Cyprus were examined. The institutions were categorized into three main groups based on their affiliated educational administrative units. Accordingly, the institutions were classified as those affiliated with the Directorate of Primary Education, the Directorate of General Secondary Education, and the Directorate of Vocational and Technical Education.

The findings indicate that public educational institutions are not evenly distributed among educational administrative units. Of the 161 institutions examined, 110 (68.3%) are affiliated with the Directorate of Primary Education, 38 (23.6%) with the Directorate of General Secondary Education, and 13 (8.1%) with the Directorate of Vocational and Technical Education.

Table 1
Distribution of Public Educational Institutions by Educational Administrative Units

Educational Administrative Unit	Number of Institutions (n)	Percentage (%)
Directorate of Primary Education	110	68.3
Directorate of General Secondary Education	38	23.6
Directorate of Vocational and Technical Education	13	8.1
Total	161	100.0

As presented in Table 1, the majority of public educational institutions included in the study are affiliated with the Directorate of Primary Education. The fact that institutions under the Directorate of Primary Education constitute approximately two-thirds of all institutions indicates that primary education institutions have a substantial numerical predominance within the public education system of the Turkish Republic of Northern Cyprus (TRNC).

A total of 38 institutions affiliated with the Directorate of General Secondary Education represent approximately one-fourth of all institutions. Among these institutions, 16 provide education at the lower secondary school level, while 22 provide education at the upper secondary school level. Accordingly, within general secondary education institutions, upper secondary schools are more numerous than lower secondary schools.

The 13 institutions affiliated with the Directorate of Vocational and Technical Education constitute 8.1% of all institutions examined. This finding indicates that vocational and technical secondary education institutions have a relatively limited numerical presence among the public educational institutions included in the study.

Overall, the distribution of public educational institutions in the TRNC demonstrates a clear predominance of primary education institutions in terms of institutional numbers. However, this evaluation, based solely on the number of institutions, does not provide direct evidence regarding student enrollment, institutional capacity, teacher distribution, or the level of access to educational services. Therefore, subsequent sections present detailed analyses of institutions according to educational level, district distribution, and the pre-1974 historical settlement characteristics associated with the current settlement names used in school names.

Distribution of Public Educational Institutions by Educational Level

Within the scope of the study, the 161 public educational institutions examined were evaluated under six main categories based on their functional positions within the education system and the educational levels to which they are affiliated. These categories consist of public primary schools, pre-primary education institutions, special education institutions, lower secondary schools, upper secondary schools affiliated with the Directorate of General Secondary Education, and vocational and technical secondary education institutions.

The classification according to educational levels not only reveals the distribution of public educational institutions in terms of institutional numbers but also demonstrates the levels at which educational services are concentrated and which types of institutions play a determining role in the spatial organization of the education system.

The findings indicate that primary education levels have a substantial predominance among public educational institutions in the Turkish Republic of Northern Cyprus (TRNC). Of the 161 institutions examined, 80 (49.7%) are public primary schools, 23 (14.3%) are pre-primary education institutions, 7 (4.3%) are special education institutions, 16 (9.9%) are lower secondary schools, 22 (13.7%) are upper secondary schools, and 13 (8.1%) are vocational and technical secondary education institutions.

Table 2
Distribution of Public Educational Institutions by Educational Level

Educational Category	Number of Institutions	Percentage (%)
Public Primary Schools	80	49.7
Pre-primary Education Institutions	23	14.3
Special Education Institutions	7	4.3
Lower Secondary Schools	16	9.9
Upper Secondary Schools	22	13.7
Vocational and Technical Secondary Education Institutions	13	8.1
Total	161	100.0

As shown in Table 2, public primary schools represent the educational category with the highest proportion among the institutions included in the study. Constituting approximately half of all

institutions, primary schools represent the most widely distributed institutional structure through which basic education services are spatially organized within the public education system of the TRNC.

Following primary schools, the highest institutional concentrations are observed in pre-primary education institutions and upper secondary schools. The fact that pre-primary education institutions constitute 14.3% of all institutions with 23 schools indicates that early childhood education has become an established and distinct area of service provision within the public education system. The 22 upper secondary schools represent 13.7% of all institutions. The relatively similar number of upper secondary schools and pre-primary education institutions suggests that educational services at the secondary level are organized around specific institutional centers.

Lower secondary schools, with 16 institutions (9.9%), and vocational and technical secondary education institutions, with 13 institutions (8.1%), constitute the remaining educational categories examined in the study. When lower and upper secondary institutions are considered together, general secondary education institutions account for 38 institutions, representing 23.6% of all public educational institutions.

Special education institutions constitute the category with the lowest numerical proportion, with 7 institutions (4.3%). However, the relatively limited number of special education institutions does not indicate a lower level of importance within the education system. Special education services require a distinct planning approach due to differences in student needs, requirements for specialized personnel, and physical infrastructure characteristics compared with other educational levels.

Overall, the distribution demonstrates that approximately two-thirds (68.3%) of public educational institutions in the TRNC consist of institutions providing primary-level education and special education services. This distribution indicates that basic education services occupy a central position within the institutional structure of the public education system.

Nevertheless, examining the number of institutions by educational level alone does not allow for definitive conclusions regarding the quality or accessibility of educational services. Comparisons based solely on institutional numbers remain limited unless factors such as student capacity, population distribution, service areas, and spatial locations of institutions are also considered. Therefore, the following section examines the spatial distribution of public educational institutions not only according to educational levels but also in relation to districts and the pre-1974 historical characteristics of the settlements associated with the current settlement names used in school names.

Table 3
Distribution of the use of settlement names in school names by educational level

Educational Level	Total Number of Schools (n)	Schools Using Settlement Names in Their Names (n)	Percentage (%)	Schools Not Using Settlement Names (n)	Percentage (%)
Primary Schools	80	53	66.3	27	33.7
Pre-primary Education	23	13	56.5	10	43.5
Special Education	7	5	71.4	2	28.6

Lower Secondary Schools	16	4	25.0	12	75.0
Upper Secondary Schools	22	8	36.4	14	63.6
Vocational High Schools	13	6	46.2	7	53.8
Total	161	89	55.3	72	44.7

Table 3 presents the distribution of the use of settlement names in the official names of 161 public schools affiliated with the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC), according to educational level. The findings indicate that 89 schools (55.3%) have names directly derived from current settlement names, whereas 72 schools (44.7%) use alternative naming patterns, including personal names, historical figures, institutional identities, foundation names, or other symbolic references.

When evaluated according to educational levels, the highest rate of settlement-name usage is observed among special education institutions, with 71.4%. This is followed by primary schools (66.3%) and pre-primary education institutions (56.5%). In contrast, the use of settlement names is considerably lower among lower secondary schools affiliated with the Directorate of General Secondary Education (25.0%) and upper secondary schools (36.4%). Among vocational high schools affiliated with the Directorate of Vocational and Technical Education, the rate of settlement-name usage was identified as 46.2%.

These findings indicate that different naming approaches are adopted across educational levels. Particularly in primary schools and pre-primary education institutions, names associated with the settlements in which schools are located appear to be more commonly preferred. Conversely, at the secondary education level, names emphasizing individuals, historical figures, foundations, and institutional identities are more frequently observed. Therefore, Table 3 establishes the fundamental classification framework for the subsequent analysis, in which only the 89 schools containing settlement names in their official titles are examined in terms of their historical settlement characteristics.

Table 4

Distribution of current settlement names used in school names according to their pre-1974 historical settlement characteristics

Pre-1974 Historical Settlement Characteristics of Current Settlement Names Used in School Names	Number of Schools (n)	Percentage (%)
Schools using current settlement names that were Greek Cypriot settlements before 1974	48	53.9
Schools using current settlement names that were Turkish Cypriot settlements before 1974	22	24.7
Schools using current settlement names that were Turkish–Greek Cypriot mixed settlements before 1974	19	21.4
Total	89	100.0

As presented in Table 4, among the 161 public schools affiliated with the Ministry of National Education of the TRNC, 89 schools were identified as having current settlement names directly incorporated into

their official school names. This table presents the distribution of only these settlement names according to their pre-1974 historical settlement characteristics.

The findings demonstrate that the current settlement names used in school names are predominantly derived from settlements that had a Greek Cypriot character before 1974. This finding does not indicate that these educational institutions are physically located in former Greek Cypriot settlements. The focus of the study is not the geographical location of schools but rather the historical origin of the current settlement names reflected in school names. Therefore, the findings demonstrate the extent to which settlement names adopted after 1974 have become institutionalized in public usage through educational institutions.

The results show that 48 (53.9%) of the current settlement names used in school names originate from settlements that were characterized as Greek Cypriot settlements before 1974, 22 (24.7%) originate from settlements characterized as Turkish Cypriot settlements, and 19 (21.4%) originate from Turkish–Greek Cypriot mixed settlements.

These findings reveal that current settlement names used in the naming of public schools in the TRNC are largely derived from areas that had a Greek Cypriot settlement character prior to 1974. In other words, the current names of settlements renamed after 1974 are more extensively reflected in school names, particularly in areas that historically had Greek Cypriot settlement characteristics.

This pattern indicates that school names function not merely as administrative identifiers of educational institutions but also as symbolic mechanisms that contribute to the public visibility and everyday use of the officially adopted settlement names of the TRNC. In this respect, educational institutions operate as important public spaces through which place names are reproduced, circulated, and institutionalized within collective social memory.

Table 5

Distribution of current settlement names used in school names according to Pre-1974 settlement characteristics by educational level

Educational Level	Total Number of Schools (N)	Schools Using Settlement Names n (%)	Greek Cypriot Settlement n (%)	Turkish Settlement n (%)	Mixed Turkish-Greek Cypriot Settlement n (%)
Primary Schools	80	53 (66.3)	33 (62.3)	12 (22.6)	8 (15.1)
Pre-primary Education Institutions	23	13 (56.5)	5 (38.5)	4 (30.8)	4 (30.8)
Special Education Schools	7	5 (71.4)	2 (40.0)	1 (20.0)	2 (40.0)
Lower Secondary Schools	16	4 (25.0)	2 (50.0)	2 (50.0)	0 (0.0)
Upper Secondary Schools	22	8 (36.4)	3 (37.5)	3 (37.5)	2 (25.0)

Vocational and Technical High Schools	13	6 (46.2)	3 (50.0)	0 (0.0)	3 (50.0)
Total	161	89 (55.3)	48 (53.9)	22 (24.7)	19 (21.4)

Table 5 presents the distribution of public schools using current settlement names in their official names according to the pre-1974 historical settlement characteristics of these settlement names by educational level. The percentages regarding the use of settlement names were calculated based on the total number of schools within each educational level, whereas the percentages related to Greek Cypriot, Turkish, and mixed Turkish-Greek Cypriot settlement categories were calculated only among schools whose names contain a current settlement name.

As shown in Table 5, a substantial proportion of the current settlement names used in school names (53.9%) are associated with areas that were characterized as Greek Cypriot settlements before 1974. In comparison, 24.7% of the settlement names used in school names originate from pre-1974 Turkish settlements, while 21.4% are associated with mixed Turkish-Greek Cypriot settlements.

The proportion of schools using settlement names varies across educational levels. The use of settlement names was identified in 66.3% (n=53) of primary schools, 56.5% (n=13) of pre-primary education institutions, 71.4% (n=5) of special education schools, 25.0% (n=4) of lower secondary schools, 36.4% (n=8) of upper secondary schools affiliated with the Directorate of General Secondary Education, and 46.2% (n=6) of vocational and technical high schools.

Among primary schools using settlement names, 33 schools (62.3%) use current settlement names associated with areas classified as Greek Cypriot settlements before 1974, 12 schools (22.6%) use names associated with Turkish settlements, and 8 schools (15.1%) use names associated with mixed Turkish-Greek Cypriot settlements.

Among the 13 pre-primary education institutions using settlement names, five (38.5%) use current settlement names associated with pre-1974 Greek Cypriot settlements, four (30.8%) with Turkish settlements, and four (30.8%) with mixed Turkish-Greek Cypriot settlements.

Among special education schools, two of the five institutions using settlement names (40.0%) have names associated with pre-1974 Greek Cypriot settlements, one (20.0%) with a Turkish settlement, and two (40.0%) with mixed Turkish-Greek Cypriot settlements.

Among lower secondary schools, two of the four schools using settlement names (50.0%) have names associated with pre-1974 Greek Cypriot settlements, while the remaining two (50.0%) are associated with Turkish settlements. No lower secondary school using a settlement name associated with a mixed Turkish-Greek Cypriot settlement was identified.

Among upper secondary schools affiliated with the Directorate of General Secondary Education, three of the eight schools using settlement names (37.5%) have names associated with pre-1974 Greek Cypriot settlements, three (37.5%) with Turkish settlements, and two (25.0%) with mixed Turkish-Greek Cypriot settlements.

Among vocational and technical high schools, three of the six schools using settlement names (50.0%) have names associated with pre-1974 Greek Cypriot settlements, while three (50.0%) have names

associated with mixed Turkish-Greek Cypriot settlements. No vocational and technical high school using a current settlement name associated with a pre-1974 Turkish settlement was identified.

Overall, the findings demonstrate that, across all educational levels, a considerable proportion of the current settlement names used in school names originate from areas characterized as Greek Cypriot settlements before 1974. The widespread use of settlement names particularly in primary schools enables students to encounter current settlement names from the early stages of their educational experiences, thereby reinforcing the public circulation of these names through educational institutions.

This finding indicates that school names are not merely administrative labels used to identify educational institutions; rather, they function as symbolic instruments that contribute to the public circulation of place names, the reproduction of spatial memory, and the institutional reinforcement of spatial belonging. The predominance of settlement names associated with pre-1974 Greek Cypriot settlements in school names demonstrates that place names serve not only geographical functions but also important roles in relation to historical continuity and public memory.

The critical toponymy literature emphasizes that place names play an active role in processes of political power, identity construction, and spatial belonging (Azaryahu, 1996; Alderman, 2008; Rose-Redwood et al., 2010). Within this framework, settlement names used in the naming of public schools in the TRNC can be interpreted not only as institutional identifiers but also as public representations of post-conflict collective memory and spatial identity.

Table 6

Evaluation of current settlement names used in school names according to Pre-1974 settlement characteristics

Pre-1974 Settlement Characteristics	Number of Current Settlement Names Used in School Names	Examples of Current Settlement Names	Evaluation
Schools bearing current settlement names associated with settlements characterized as Greek Cypriot settlements before 1974	48	Güzelyurt, İskele, Değirmenlik, Alsancak, Geçitkale	Current settlement names introduced after 1974 are widely used in school names.
Schools bearing current settlement names associated with settlements characterized as Turkish settlements before 1974	22	Lefke, Gönyeli, Mehmetçik, Beyarmudu	Current settlement names belonging to historical Turkish settlements continue to be used in school names.
Schools bearing current settlement names associated with mixed Turkish-Greek Cypriot settlements before 1974	19	Gazimağusa, Girne, Lapta, Karşıyaka	Current settlement names of areas with a mixed settlement history are represented in school names.
Total	89		

Table 6 presents an evaluation of the historical origins of the current settlement names used in school names. The analysis indicates that 48 (53.9%) of the current settlement names appearing in school names are derived from settlements that were characterized as Greek Cypriot settlements before 1974. In comparison, 22 (24.7%) correspond to settlements characterized as Turkish settlements before 1974, while 19 (21.4%) correspond to settlements characterized as mixed Turkish-Greek Cypriot settlements before 1974.

When evaluated in terms of the historical origins of settlement names used in school names, these findings demonstrate that current settlement names associated with areas characterized as Greek Cypriot settlements before 1974 are used more frequently than those associated with other settlement categories. This finding suggests that settlement names adopted after 1974 have become widely incorporated into public usage through educational institutions and that school names have played an important role in the social circulation and institutionalization of these names.

In contrast, current settlement names associated with pre-1974 Turkish settlements and mixed Turkish-Greek Cypriot settlements appear to be used less frequently in school names. These findings indicate that current settlement names used in school naming practices function not only as geographical identifiers but also as symbolic instruments through which the post-1974 settlement order and understanding of public belonging are made visible within educational institutions.

According to the toponymy literature, place names function as symbolic instruments through which states make spatial sovereignty, collective identity, and public memory visible (Azaryahu, 1996; Alderman, 2008). The findings of this study support this perspective. The fact that a substantial proportion of current settlement names used in school names consist of settlement names adopted after 1974 demonstrates that educational institutions function as public spaces that contribute to the social acceptance and intergenerational transmission of these names.

Therefore, school names should not be considered merely as administrative labels identifying educational institutions; rather, they can be interpreted as visible manifestations of toponymic transformation within the education system. Through their continuous use in schools, settlement names become embedded in everyday public life and contribute to the reproduction of spatial memory and institutionalized forms of spatial belonging.

General Evaluation of the Findings

Within the scope of this study, the naming structures of 161 public schools actively operating under the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC) during the 2025–2026 academic year were examined, and the relationship between school names and historical settlement structures was evaluated through document analysis. The findings revealed that 89 of the 161 schools had names directly based on settlement names, whereas the remaining schools were named after individuals, historical figures, institutions, or functional characteristics. When the historical settlement characteristics of the 89 schools bearing settlement names were examined, it was found that 48 schools (53.9%) were associated with settlements identified as Greek Cypriot settlements before 1974, 22 schools (24.7%) with Turkish settlements, and 19 schools (21.4%) with mixed Turkish–Greek Cypriot settlements. This distribution indicates that the settlement names used in school names are largely based on the post-1974 settlement naming system.

When evaluated according to educational levels, settlement-based naming practices were found to be most prevalent among primary schools. The main reason for this pattern is that primary schools are

generally organized in direct connection with local settlements, and school names often reflect the settlements they serve. In contrast, the use of settlement names was relatively lower in secondary education institutions due to the greater prevalence of names based on individuals, historical figures, foundations, or institutional identities.

One of the notable findings of the study is that schools located in areas that were historically characterized as Greek Cypriot settlements before 1974 do not use former Greek place names in their official names; instead, they use the Turkish settlement names officially adopted after 1974. The use of examples such as Güzelyurt (Morfou), İskele (Trikomo), Değirmenlik (Kythrea), Alsancak (Karavas), and Geçitkale (Lefkoniko) in school names represents clear examples of this transformation. In contrast, it was observed that continuity in settlement names has largely been maintained in historically Turkish settlements such as Lefke, Gönyeli, and Mehmetçik.

Schools located in settlements with a historically mixed Turkish–Greek Cypriot population structure, such as Gazimağusa, Girne, Lapta, and Karşıyaka, are named according to their currently used Turkish settlement names despite their historically multicultural settlement characteristics. This indicates that school naming practices are not merely geographical identification processes; rather, they are also associated with the redefinition of public space, strengthening of administrative unity, and reconstruction of collective memory.

Overall, the findings demonstrate that school naming practices in the TRNC are not random practices or merely administrative procedures intended to identify locations. School names function as symbolic indicators reflecting historical settlement patterns, post-1974 place-name arrangements, and the reorganization of public space. Therefore, the names of educational institutions should be considered not only as administrative labels used within educational governance but also as concrete representations of the relationship between collective memory, spatial identity, and historical continuity.

5. Discussion

This study examined the naming structures of public schools affiliated with the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC) in terms of the historical origins of the current settlement names used in school names. The main finding of the study demonstrates that a significant proportion of the settlement names used in school names derive from the current names of areas that were characterized as Greek Cypriot settlements before 1974. Among the 89 public schools using settlement names, 48 (53.9%) have names based on current settlement names of areas that were Greek Cypriot settlements before 1974 and were renamed after 1974. This finding indicates that school naming practices are not merely administrative procedures for identifying educational institutions; rather, they also play an important role in institutionalizing the new settlement structure and spatial belonging framework established after 1974 through the education system.

Place names are not merely geographical indicators used to identify locations. Studies in the field of toponymy demonstrate that place names play significant roles in the formation of collective memory, identity construction, and the representation of political authority (Alderman, 2008; Rose-Redwood, Alderman, & Azaryahu, 2010). Particularly in societies experiencing political transformation, the rearrangement of place names is considered not simply a linguistic change but also a component of the symbolic construction of a new public order (Azaryahu, 1996). In this respect, school names, as frequently encountered public symbols in everyday life, become institutional mechanisms that contribute to the recognition and adoption of new settlement names.

The critical toponymy approach argues that place names are not merely geographical references; rather, they function as important instruments of political power, collective memory, and identity construction (Rose-Redwood et al., 2010). The findings of this study indicate that school names in the TRNC serve a similar function. The current settlement names used in public schools become continuously repeated public markers in the daily lives of students, families, and local communities, thereby contributing to the incorporation of these names into collective memory.

In the context of the TRNC, numerous settlement names were changed or newly introduced following the settlement arrangements implemented after 1974. The findings of this study reveal that these newly adopted settlement names have been widely preferred in the naming of public schools. This result suggests that school names serve not only to identify the locations of educational institutions but also to strengthen the public use of new settlement names and facilitate their social acceptance.

Another significant finding of the study is that the use of settlement names differs according to educational levels. Settlement-based naming practices are most common among primary schools. The fact that primary schools operate directly at the neighbourhood and village level explains why settlement names are more frequently preferred in these institutions. In contrast, at the lower and upper secondary levels, names emphasizing individuals, historical figures, national values, or professional identities are more commonly used, resulting in a relatively lower proportion of settlement-based names. This indicates that school naming practices may serve different functions depending on educational levels.

The findings also demonstrate that current settlement names associated with historically Turkish settlements before 1974 and those associated with mixed Turkish–Greek Cypriot settlements continue to be used in school names. However, the higher prevalence of settlement names originating from areas characterized as Greek Cypriot settlements before 1974 suggests that there is a tendency for newly adopted settlement names to gain greater public visibility, particularly in these areas. Rather than being interpreted as a direct political preference, this situation can be understood as a reflection of the post-1974 settlement structure within educational institution naming practices.

Studies in the literature on educational institution naming have generally focused on names derived from individuals, historical figures, or ideological symbols. In contrast, research examining the historical origins of settlement names used in school names remains limited. This study contributes to addressing this gap by examining school names through the combined perspectives of toponymy, collective memory, and educational policies. Accordingly, educational institution names are evaluated not merely as administrative labels but as public symbols through which spatial memory and social belonging are reproduced.

In conclusion, the findings demonstrate that school naming practices in the TRNC are not merely technical processes related to educational administration. Rather, they represent a symbolic policy instrument that supports the adoption of newly established settlement names, contributes to the strengthening of spatial belonging, and plays a role in the reconstruction of public memory.

6. Conclusion and Recommendations

This study examined the naming structures of public schools affiliated with the Ministry of National Education of the Turkish Republic of Northern Cyprus (TRNC) in terms of the historical settlement characteristics of the current settlement names used in school names. Within the scope of the study, all 161 public schools actively operating during the 2025–2026 academic year were evaluated, and it was determined that 89 schools had names directly based on settlement names.

The findings demonstrate that the current settlement names used in school names largely originate from areas that were characterized as Greek Cypriot settlements before 1974. Among the 89 schools using settlement names, 48 (53.9%) have school names based on the current names of settlements that were Greek Cypriot settlements before 1974. In contrast, current settlement names associated with Turkish settlements before 1974 are used in 22 schools (24.7%), while current settlement names associated with mixed Turkish–Greek Cypriot settlements are used in 19 schools (21.4%).

This finding constitutes the central result of the study. The findings indicate that the current settlement names used in school naming practices are largely rooted in areas that had Greek Cypriot settlement characteristics before 1974. This does not result from the use of former Greek place names in school names; rather, it reflects the incorporation of the new names assigned to these settlements after 1974 into the names of public schools. Therefore, the study demonstrates that the historical settlement structure is reproduced in contemporary school naming practices through currently used settlement names.

The findings further indicate that school names are not merely administrative expressions used to identify educational institutions; they also function as symbolic instruments contributing to the dissemination and public visibility of current settlement names. Particularly, the more frequent use of settlement names at the primary school level suggests that students encounter and recognize the settlements in which they live through these current place names from the early stages of their educational experiences. In this respect, schools can be considered public institutions that contribute to the visibility, normalization, and intergenerational transmission of newly adopted settlement names.

In conclusion, this study represents one of the first comprehensive studies examining the naming structures of public schools in the TRNC not only from an educational administration perspective but also through the framework of critical toponymy. The findings reveal that the current settlement names used in public schools increase the visibility of the settlement system established after 1974 within the public sphere and demonstrate that educational institutions function as important carriers of this process. In this sense, school names should be evaluated not merely as labels identifying educational institutions but also as symbolic indicators of spatial belonging, collective memory, and the institutionalization of place names within the education system.

Recommendations

Based on the findings of the study, the following recommendations can be proposed:

1. Historical settlement data should be systematically considered in school naming processes. When determining new school names, the historical development of settlements, changes in place names, and cultural heritage elements should be evaluated together.
2. A digital inventory related to school names and settlement names should be established within the Ministry of National Education of the TRNC. This inventory should record information such as the establishment year of schools, the settlement in which they are located, the historical development of the settlement name used, and any previous name changes.
3. School naming policies should be examined regularly from the perspectives of educational history and toponymy. In this way, the ways in which settlement names become widespread in the public sphere through educational institutions can be monitored over the long term.
4. Greater emphasis may be placed on the historical development of settlement names within educational programs. Enabling students to understand the historical and cultural transformations of their surrounding environment may contribute to the development of spatial awareness and a sense of belonging.

5. Future studies may examine school names in relation to different variables. In particular, comparative analyses may be conducted on the use of personal names, historical figures, national symbols, and settlement names in school naming practices. Furthermore, comparisons between school naming policies in the TRNC and other countries may provide new research opportunities contributing to the international literature.

In conclusion, this study can be considered one of the first comprehensive studies examining the naming structures of public schools in the TRNC within the framework of the historical transformation of settlement names. The findings demonstrate that school names are not merely expressions identifying educational institutions; rather, they contribute to the public recognition of current settlement names, strengthen spatial belonging, and represent visible reflections of historical transformation within the education system. In this respect, the study contributes to the literature by examining school names through the perspective of critical toponymy and by highlighting the role of educational institution naming in the reproduction of historical memory, spatial identity, and public belonging.

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Impact of E-Government Indicators on Tax Revenues in Algeria: Econometric Study for the Period 2003–2025

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Abstract. *This study measures the impact of e-government indicators—namely the E-Government Development Index (EGDI), the Online Service Index (OSI), and the Human Capital Index (HCI)—on tax revenues in Algeria over 2003–2025. Using an ARDL model, the study uses annual time-series data. The bounds testing approach confirms a long-run cointegration relationship among the variables. The error correction term is estimated at -0.51, which is negative and statistically significant, indicating that about 51% of short-run disequilibrium is corrected within one period toward long-run equilibrium. In the short run, the Human Capital Index (HCI) shows a positive and significant effect on tax revenues. In the long run, all three indicators—EGDI, OSI, and HCI—exhibit positive and significant effects, with a 1% increase in each leading to a 0.15%, 0.14%, and 0.45% increase in tax revenues, respectively. Diagnostic tests confirm the model is free from autocorrelation, heteroskedasticity, and specification errors, with stable parameters and normally distributed residuals. These results confirm that e-government development, improved digital services, and human capital investment enhance tax administration efficiency, broaden the tax base, and increase tax compliance, thereby supporting fiscal sustainability in Algeria.*

Keywords: *e-government, tax revenues, ARDL model, cointegration, error correction, fiscal sustainability*

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Elektron hökumət göstəricilərinin Əlcəzairdə vergi daxilolmalarına təsiri: 2003–2025-ci illər üzrə ekonometrik tədqiqat

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Xülasə. *Bu tədqiqat 2003–2025-ci illər ərzində Əlcəzairdə elektron hökumət göstəricilərinin — xüsusilə elektron hökumətin inkişafı indeksi (EGDI), onlayn xidmətlər indeksi (OSI) və insan kapitalı indeksi (HCI) — vergi gəlirlərinə təsirini qiymətləndirir. Tədqiqatda illik zaman sıraları məlumatlarından və ARDL modelindən istifadə olunur. Sərhəd testi (bounds testing) yanaşması dəyişənlər arasında uzunmüddətli kointeqrasiya əlaqəsinin mövcudluğunu təsdiqləyir.*

Səhvlərin düzəldilməsi əmsalı -0,51 olaraq müəyyən edilmişdir; mənfi və statistik cəhətdən əhəmiyyətli olan bu göstərici qısamüddətli tarazsızlığın təxminən 51%-nin bir dövr ərzində uzunmüddətli tarazlıq istiqamətində düzəldildiyini nümayiş etdirir. Qısamüddətli dövrdə insan kapitalı indeksi (HCI) vergi gəlirlərinə müsbət və əhəmiyyətli təsir göstərir. Uzunmüddətli dövrdə isə hər üç göstərici — EGDI, OSI və HCI — müsbət və əhəmiyyətli təsirə malikdir; belə ki, hər bir göstəricidəki 1%-lik artım vergi gəlirlərində müvafiq olaraq 0,15%, 0,14% və 0,45% artıma səbəb olur. Diaqnostik testlər modelin avtokorrelyasiya, heteroskedastiklik və spesifikasiya xətalarından azad olduğunu, həmçinin sabit parametrlərə və normal paylanmış qalıqlara malik olduğunu təsdiqləyir. Bu nəticələr təsdiqləyir ki, elektron hökumətin inkişafı, rəqəmsal xidmətlərin təkmilləşdirilməsi və insan kapitalına investisiyalar vergi inzibatçılığının səmərəliliyini artırır, vergi bazasını genişləndirir və vergi öhdəliklərinə riayət olunmasını gücləndirir, bununla da Əlcəzairdə fiskal dayanıqlığa dəstək verir.

Açar sözlər: *elektron hökumət, vergi gəlirləri, ARDL modeli, kointeqrasiya, səhvlərin düzəldilməsi, fiskal dayanıqlıq*

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1. Introduction

Tax revenue plays a crucial role in government spending. It provides an indigenous source from which the government can collect funds for social and fiscal policies as well as government spending. Tax revenues are not only a function of the levels of taxation but also depend on the coverage and effectiveness of a taxation system. For example, information collection, monitoring of declarations, timely collection and coverage of taxpayers are factors in tax effectiveness. Thus, better tax administration is increasingly reliant on tools that enhance compliance while reducing compliance costs and tax evasion. Furthermore, domestic revenue mobilization has also been found to play a key role in decreasing reliance on external financing as well as in funding development, especially in developing countries (Tolossa & Melese, 2024).

E-government has altered the relationship between a government and the general public. Through the transition to digital services, information dissemination has improved, paper usage has been reduced, and the number of services that can be delivered has also increased. In taxation, digitalization has occurred through information integration, electronic filing, electronic payments and the use of digital information in monitoring and compliance. E-government has also transitioned from service delivery over a distance to information utilization and information generation within decision-making. In taxation, the speed and quality of information can have an influence on compliance and effective monitoring. High-quality and timely information may allow risk targeting and non-compliance to be identified effectively (Zídková et al., 2024).

Digitalization can have an influence on the economy through reducing compliance costs associated with taxation. When information is accessible, payments and filing are simplified, and compliance costs are reduced. Digital information may also help in cross-checking information from multiple sources and may

help in the identification of underreporting and misreporting. Therefore, e-government can be applied in two forms: on the taxpayer through enhanced compliance and on the side of tax administration through enhanced monitoring. A study using 1,677 country-year data from 2006 to 2017 found that digitalization of government services can reduce tax evasion, and the diffusion of information and communication technologies (ICT) to individuals can enhance this relationship (Uyar et al., 2021).

Digitalization is not guaranteed to lead to an enhancement in tax revenues. The influence of digitalization may also be influenced by the institutional quality of government institutions, by the digital capacities of institutions and taxpayers or by available infrastructure. A study using country-year data for up to 159 countries from 2004 to 2021 found that digitalization does not necessarily have a direct influence on the non-resource revenue-to-GDP ratio. However, digitalization may have a larger influence when combined with enhanced institutional quality, especially with regard to regulatory and accountability quality. This highlights the influence of institutional quality on the relationship between digitalization and revenue mobilization (Lee, 2025).

Another influence of digitalization may be in reducing the difference between taxes paid and taxes collected. Zídková et al. (2024) used the E-Government Development Index to measure the relationship between the level of e-government and VAT collection in EU countries. This is relevant because it links digitalization to a specific measure of tax revenue (VAT gap). The study also found a positive relationship between e-government and VAT collection. This supports the influence of digitalization on tax administration through enhanced information and services (Zídková et al., 2024).

Tolossa and Melese (2024) used the E-Government Development Index as an explanatory variable and attempted to determine factors that influence the mobilization of tax revenue in 30 Sub-Saharan African countries between 2003 and 2022. The study also found that, in addition to economic variables, the e-government index can explain tax effort in a PCSE model.

This is important for developing countries because digitalization is now one of many variables that can be used to explain domestic revenue mobilization, and not only an issue related to administration but also a policy issue (Tolossa & Melese, 2024).

There have also been some studies that question the relationship between digitalization and tax revenues and whether it is only a linear relationship between digitalization and increased tax revenue. Hanrahan (2026) used panel data of OECD governments between 1995 and 2018 and a digitization index based on IP data to investigate the influence of digitalization on the composition of government tax revenue. The study found that digitalization influenced the composition of tax revenue. This may indicate that the influence of digitalization depends on the property being taxed. Alternatively, digitalization may influence compliance or revenue collection but not the composition of revenue (Hanrahan, 2026).

Digitalization of a taxation system may also influence taxpayer behavior. Recently, Bi et al. (2026) utilized a quasi-natural experiment that involved the implementation of the “Internet Plus Government Services” program in China and found that as e-government expanded, there was a decline in corporate tax evasion and an increase in the effective tax rate. This supports the influence of e-government on taxpayer behavior because digital government services have been shown to increase the monitoring capacity of the tax administration while also increasing the cost to engage in economic activity while hiding it from the tax administration (Bi et al., 2026).

Digitalization is seen as having an important influence on tax improvement. However, the size and persistence of this influence are mixed. Some studies have found a positive influence of digitalization on

tax revenue collection or reduced tax evasion (Kuzey et al., 2025; Uyar et al., 2021). However, other studies have found that the influence of digitalization may depend on institutional quality or may not influence all aspects of a tax system. Additionally, the influence of digitalization may also depend on the index used to measure digitalization. For example, some studies use tax administration digitalization, ICT diffusion, diffusion of e-government services or the E-Government Development Index (Uyar et al., 2021; Zídková et al., 2024; Hanrahan, 2026).

There is therefore a research gap. While there is an increasing amount of international research that links digitalization to revenue mobilization, more empirical research is needed to test this relationship in Algeria over a long time period. Additionally, different indicators are used to measure e-government across international research, and the relationship between e-government and revenue mobilization also differs. This is especially important for the Algerian economy because the influence of digitalization may also differ from a country with more established digital and institutional capabilities. This study will examine the relationship between e-government indicators and tax revenues in Algeria using cointegration analysis. The statistical significance of e-government indicators will also be tested, and the time period will cover 2003 to 2025.

Based on this gap, the research problem centers on the following main question:

To what extent do e-government indicators affect tax revenues in Algeria over the period 2003–2025?

The following sub-question branches from this main question:

Is there a cointegration relationship between e-government indicators and tax revenues in Algeria over 2003–2025, and is there a statistically significant impact between e-government indicators and tax revenues in Algeria over the same period?

This study provides relevant connections between two rapidly converging domains within the contemporary public finance literature: digitalization of the state and the mobilization of resources from taxation. It also evaluates the connection between e-government and tax revenue in a developing country across different stages of e-government development. From a research point of view, this study tries to test this causal relationship in a developing economy using data that also spans varying degrees of e-government. From a policy point of view, this study will also facilitate evaluation of whether or not implementation of digitalization has helped enhance the ability of the government to mobilize tax revenues or whether further regulatory and institutional reforms are necessary to enhance this relationship.

This study aims to evaluate the effect of e-government indicators on tax revenues in Algeria over the period 2003 to 2025. Furthermore, this study aims to estimate the statistically significant effect of e-government indicators on tax revenue. It also tries to identify the long-run linkages among the variables and whether there exists a cointegration relationship among the variables. This study will attempt to evaluate the economic relationship between e-government and tax revenue using econometric methods rather than just the dynamics between the variables.

Annual data are used from the year 2003 to 2025. The dependent variable is tax revenue, and the independent variables are e-government indicators. Initially, the characteristics and stationarity of the data are examined. Next, a test for cointegration among the variables is conducted. Based on the characteristics of the data, appropriate econometric methods are used to estimate both the short-run and long-run relationships. An important objective of this study is to differentiate between short-run and

long-run relationships. This is particularly important when dealing with slowly evolving economic variables.

This study has three areas of relevance that are closely related to one another. Firstly, this study provides up-to-date empirical evidence on the Algerian context extending up to the year 2025. Secondly, this study uses e-government through indicators rather than using a general definition of digitalization in the government. Finally, this study utilizes testing of effects and testing for cointegration. This enables identification of whether changes in e-government indicators are only related to tax revenue in the short run or whether there exists a longer-run economic relationship. This study therefore aims to address some of the evidence gap on the relationship between digitalization and tax performance in Algeria.

Based on the above, the study proceeds from the following two hypotheses:

- First Hypothesis: There is a cointegration relationship between e-government indicators and tax revenues in Algeria over the period (2003–2025), at a significance level of $\alpha \leq 0.05$.
- Second Hypothesis: There is a statistically significant impact between e-government indicators and tax revenues in Algeria over the period (2003–2025), at a significance level of $\alpha \leq 0.05$.

2. Methods

Recent empirical studies have increasingly used statistical and econometric techniques to examine relationships between economic variables and provide evidence on both short- and long-run dynamics of the studied phenomena. This study examines the relationship between e-government indicators and tax revenues in Algeria using the Autoregressive Distributed Lag (ARDL) model over the period 2003 to 2025. ARDL is used because it allows the short-run and long-run relationships to be determined, as well as the dynamic relationship between the variables in the model. Data on Algeria were obtained from the World Bank, the International Monetary Fund (IMF) and the Organization for Economic Co-operation and Development (OECD) for the period 2003 to 2025. These sources are globally accepted and reliable. The variables are relevant to the relationship between e-government and tax revenues, and the data cover Algeria over the study period.

The study intends to use this methodology to examine the contribution of e-government reforms to changes in tax revenue in Algeria, while also considering the long-run and dynamic relationship between the variables. Based on economic theory, past research conducted on this subject and the nature of the Algerian economy, the independent variables, e-government indicators (EGDI, OSI, HCI), will be used to explain the dependent variable, tax revenues (TAXREV_GDP). The appropriate model for the dependent variable will be identified based on the data used and the study's assumptions. We will use EViews 13 for estimation. A linear model will be employed because it aligns with the research problem and economic theory.

We obtain the Autoregressive Distributed Lag (ARDL) model with the following equation for the dependent variable, tax revenues (TAXREV_GDP):

TAXREV_GDP = f (EGDI, OSI, HCI) T = 2003–2025

The explicit linear form of the proposed model is:

$$\Delta TAXREV_GDP = \alpha_0 + \Sigma_{i=1}^{p} \beta_{1i} \Delta TAXREV_GDP_{t-i} + \Sigma_{j=0}^{\varphi} \beta_{2j} \Delta EGDI_{t-j} + \Sigma_{k=0}^{r} \beta_{3k} \Delta OSI_{t-k} + \Sigma_{l=0}^{s} \beta_{4l} \Delta HCI_{t-l} + \alpha_1 EGDI_{t-1} + \alpha_2 OSI_{t-1} + \alpha_3 HCI_{t-1} + \varepsilon_t$$

Where:

- Δ denotes first differences.
- p, q, r, s represent the maximum lag lengths for the dependent and independent variables.
- β_1, β_2, β_3, β_4 are short-run coefficients (error correction model).
- α_1, α_2, α_3 are long-run coefficients.
- EGDI: E-Government Development Index (independent variable)
- OSI: Online Service Index (independent variable)
- HCI: Human Capital Index (independent variable)
- TAXREV_GDP: Tax revenues (dependent variable)

3. Results and Discussion

3.1 Stationarity Test of Time Series

Stationarity of a time series is tested based on the presence of a unit root. If a unit root is present, the series is non-stationary because of spurious trends, which is undesirable in econometric analysis. Various tests can be used to test for stationarity. One such test is the Augmented Dickey-Fuller (ADF) test. EViews automatically selected the appropriate number of lags for stationarity testing.

Table 1

Results of stationarity tests for study variables

Variable	At Level: Trend & Intercept	Result	At First Difference: Trend & Intercept	Result	Integration
EGDI	-1.83 (0.65)	Non-stationary	-3.37 (0.00)	Stationary	I(1)
OSI	-1.79 (0.66)	Non-stationary	-4.40 (0.01)	Stationary	I(1)
HCI	-2.98 (0.15)	Non-stationary	-3.60 (0.04)	Stationary	I(1)
TAXREV_GDP	-2.26 (0.43)	Non-stationary	-5.50 (0.00)	Stationary	I(1)

Source. Prepared by the researchers based on outputs from EViews 13.

In Table 1, the ADF test results indicate that all the study variables (EGDI, OSI, HCI and percentage of tax revenues to GDP, TAXREV_GDP) are non-stationary in levels. This is because all variables have p-values greater than 0.05 (5%). However, as all p-values are smaller than 0.05 (5%), all variables become stationary after taking first differences, so we reject the unit-root null hypothesis for all variables. This indicates that every variable under investigation is integrated of order one, I(1), and there is no evidence that any variable is integrated of order two, I(2). This satisfies the ARDL bounds-testing approach's stationarity condition.

Optimal Lag Length Selection

Based on the AIC criterion, we selected the optimal lag structure. The ARDL (1,0,1,0) model was found to be the best, as shown in the following figure:

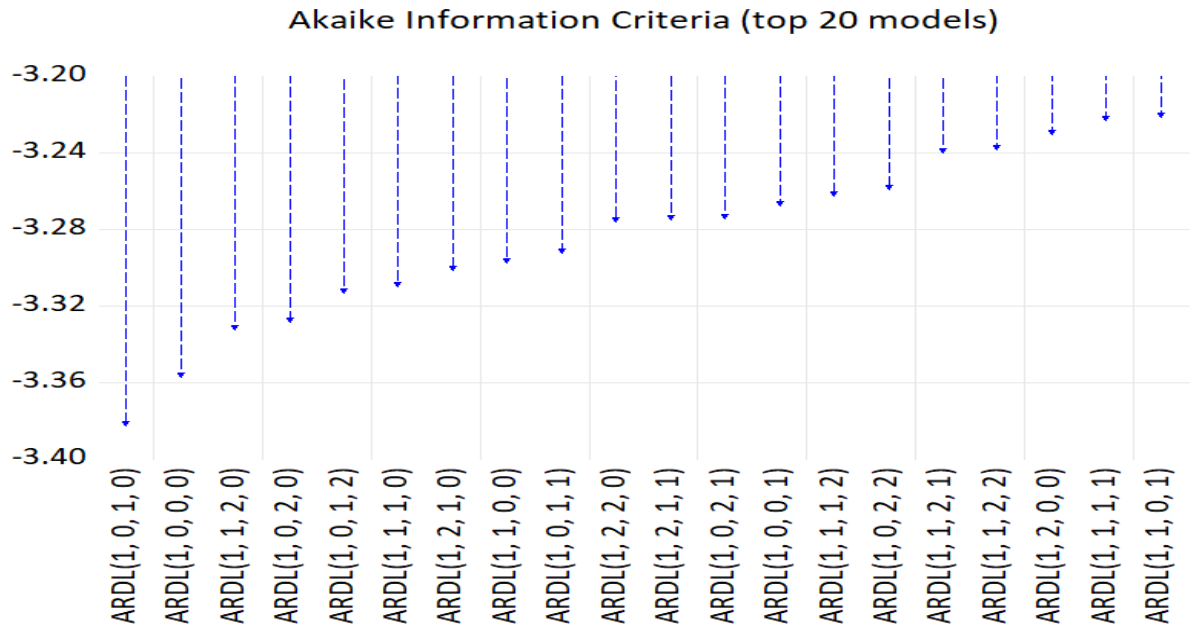


Figure 1
Optimal lag length selection results

Source. Prepared by the researchers based on outputs from EViews 13.

Figure 1 depicts the output of selecting the optimal ARDL model using the Akaike Information Criterion (AIC). The top 20 models were selected according to their AIC values. The analysis showed that the ARDL(1,0,1,0,1) model best captured the relationship among the study variables, as it had the lowest AIC value (approximately -3.38) compared with the other models. This is because a smaller AIC value indicates a better balance between model complexity and estimation performance. Therefore, the ARDL(1,0,1,0,1) model was selected to estimate short- and long-term relationships and conduct cointegration analysis.

3.2 Bounds Test for Cointegration

Table 2
Bounds test for cointegration

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	5.034821	10%	2.37	3.2
k	3	5%	2.79	3.67
		2.5%	3.15	4.08
		1%	3.65	4.66
Actual Sample Size	22	Finite Sample: n=35		
		10%	2.618	3.532
		5%	3.164	4.194
		1%	4.428	5.816

Source. Prepared by the researchers based on outputs from EViews 13.

Table 2 presents the cointegration test results using the Bounds Testing approach. In this test, the F-statistic value is found to be equal to 5.034821, which is greater than the upper bound critical value at I(1) for finite samples at the 5% and 10% levels, which are 4.194 and 3.532, respectively. Therefore, we accept the alternative hypothesis of cointegration and reject the null hypothesis of no long-run cointegration among the study variables. This implies that a long-run relationship exists between e-government indicators (OSI, HCI, EGDI) and tax revenues (TAXREV_GDP). Therefore, using the ARDL model to analyze both short- and long-run relationships is justified.

3.3 Estimation of the Study Model Parameters for the Dependent Variable Tax Revenues (TAXREV_GDP)

After confirming the existence of a cointegration relationship among the variables, we estimated the following model:

Table 3
Study model estimation using ARDL(1,0,1,0)

Dependent Variable: TAXREV_GDP
Method: ARDL
Date: 06/26/26 Time: 19:22
Sample (adjusted): 2004 2025
Included observations: 22 after adjustments
Maximum dependent lags: 1 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): OSI HCI EGDI
Fixed regressors: C
Number of models evalulated: 27
Selected Model: ARDL(1, 0, 1, 0)
Note: final equation sample is larger than selection sample

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
TAXREV_GDP(-1)	0.482100	0.207836	2.319622	0.0339
OSI	0.488965	0.220197	2.220577	0.0412
HCI	0.400863	0.581440	0.689433	0.5004
HCI(-1)	-0.790069	0.562672	-1.404138	0.1794
EGDI	-0.494494	0.212388	-2.328257	0.0333
C	0.487078	0.250421	1.945040	0.0696

R-squared	0.720254	Mean dependent var	0.255719
Adjusted R-squared	0.632834	S.D. dependent var	0.063575
S.E. of regression	0.038523	Akaike info criterion	-3.448133
Sum squared resid	0.023744	Schwarz criterion	-3.150576
Log likelihood	43.92947	Hannan-Quinn criter.	-3.378038
F-statistic	8.238957	Durbin-Watson stat	2.311405
Prob(F-statistic)	0.000517		

*Note: p-values and any subsequent tests do not account for model selection.

Source. Prepared by the researchers based on outputs from EViews 13.

In Table 3, the ARDL(1,0,1,0) model estimation has significant explanatory power, as evidenced by an R^2 value of approximately 0.72. This indicates that the explanatory variables explain approximately 72.02% of the variation in TAXREV_GDP, while the remaining variation is attributed to other unaccounted factors. Adjusted R^2 is approximately 0.6328, which is also relatively large given the number of variables in the model and indicates a good fit.

The overall model appears significant and captures some of the dynamics in the study variables. The model's F statistic is around 8.23, with a p-value of 0.00 at the 5% significance level. Moreover, the error terms show no significant autocorrelation, as the Durbin-Watson statistic is 2.23, close to 2. The Akaike Information Criterion (AIC) value of -3.44 is used to select the best model from a set of alternative models. Thus, the estimated model shows good explanatory power and statistical efficiency and can be used to estimate the effect of e-government indicators on tax revenue.

3.4 Model Diagnostic Testing

Based on the ARDL(1,0,1,0) model for estimating short-run and long-run effects, the model's performance quality must be verified using the following tests:

3.4.1 Autocorrelation Test (Breusch-Godfrey LM Test)

From the test results shown in Table 4 below, the model shows no autocorrelation. The chi-square statistic is 0.45, which is greater than the critical value of 0.05. Therefore, we accept the null hypothesis that there is no serial correlation in the residuals.

Table 4
Breusch-Godfrey serial correlation LM Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey
Null hypothesis: Homoskedasticity

F-statistic	0.868740	Prob. F(5,16)	0.5232
Obs*R-squared	4.697345	Prob. Chi-Square(5)	0.4539
Scaled explained SS	3.213946	Prob. Chi-Square(5)	0.6670

Source. Prepared by the researchers based on outputs from EViews 13.

3.4.2 Heteroskedasticity Test (ARCH Test)

The test results in Table 5 show that the Prob. Chi-Square value is 0.30, which is greater than 0.05. Therefore, we accept the null hypothesis that the residuals are homoskedastic and free from heteroskedasticity.

Table 5
Heteroskedasticity test – ARCH

Heteroskedasticity Test: ARCH

F-statistic	1.004282	Prob. F(1,19)	0.3289
Obs*R-squared	1.054271	Prob. Chi-Square(1)	0.3045

Source. Prepared by the researchers based on outputs from EViews 13.

3.4.3. Residual Normality Test (Histogram - Jarque-Bera Test)

The Prob. Jarque-Bera value is 0.58, which is higher than the 0.05 significance level, according to the test results in Figure 2. As a result, the null hypothesis that the residuals are normally distributed is not rejected.

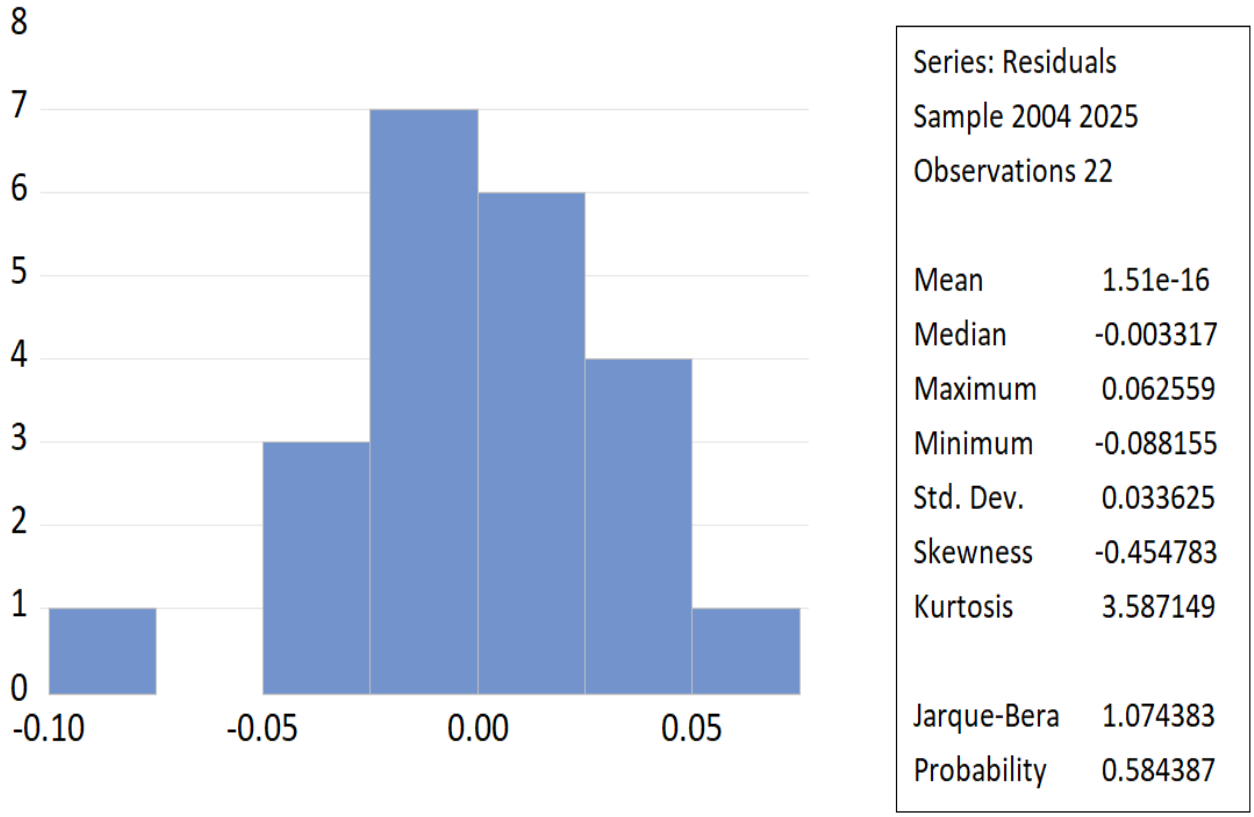


Figure 2
Normality test - histogram jarque-bera

Source. Prepared by the researchers based on outputs from EViews 13.

3.4.4. Stability Test

Structural stability of the forecasted coefficients in the error correction models using the ARDL method can be ascertained if both the CUSUM and CUSUM of Squares plots lie within the critical region at the 5% significance level in order to ensure that there were no structural breaks in the data. CUSUM and CUSUM of Squares tests were used, which were proposed by Brown et al. (1975). This followed standard practice in most studies. The results are depicted in Figure 3:

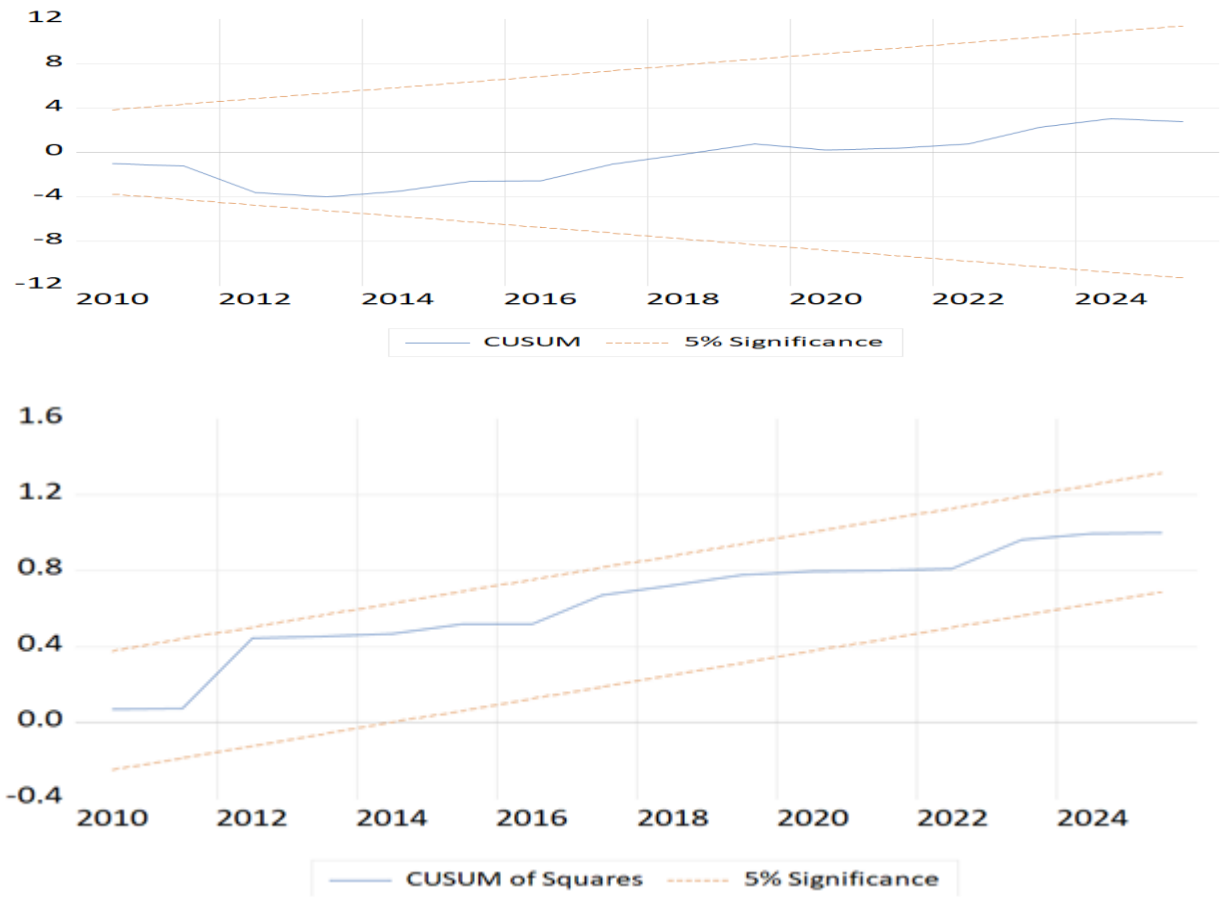


Figure 3

Stability test results (CUSUM and CUSUM of Squares)

Source. Prepared by the researchers based on outputs from EViews 13.

From the figure above, we observe that both the CUSUM and CUSUM of Squares plots remain within the critical bounds at the 5% significance level. Therefore, we accept the model's stability, noting that it remains stable during a certain period toward the end of the study period.

3.4.5. Ramsey RESET Test

A specification test verifies that the econometric model is correctly specified in both functional form and econometric specification. It can help identify issues such as omitted important variables or an incorrect functional form. The null hypothesis states that the model is correctly specified, while the alternative hypothesis states that there is a specification issue. This test helps establish the reliability of the model's results and the soundness of inferences drawn from it (Table 6).

Table 6
Ramsey reset test results

Ramsey RESET Test
Equation: UNTITLED
Omitted Variables: Powers of fitted values from 2 to 4
Specification: TAXREV_GDP TAXREV_GDP(-1) OSI HCI HCI(-1) EGDI C

	Value	df	Probability
F-statistic	2.424688	(3, 13)	0.1124
Likelihood ratio	9.776647	3	0.0206

F-test summary:

	Sum of Sq.	df	Mean Squares
Test SSR	0.008519	3	0.002840
Restricted SSR	0.023744	16	0.001484
Unrestricted SSR	0.015225	13	0.001171

LR test summary:

	Value
Restricted LogL	43.92947
Unrestricted LogL	48.81779

Source. Prepared by the researchers based on outputs from EViews 13.

A specification test confirms that the econometric model is correctly specified in terms of both functional form and econometric specification. It can also help detect problems such as omitted important variables or an incorrect functional form. Null hypothesis: the model is correctly specified. Alternative hypothesis: a specification issue exists. There is no statistical indication that any important variables are missing from the model, and the model has the correct functional form. In this instance, the F statistic is more suitable for small samples, so it is used rather than the Likelihood Ratio test, which produced a p-value of 0.0206. The model is therefore assumed to be correctly specified, and results can be interpreted.

3.4.6. Breusch–Godfrey Serial Correlation LM Test

Serial correlation commonly arises in econometric analysis, especially in time series regression data. If there is serial correlation, OLS estimators may be unbiased but inefficient. A more advanced test can identify the presence of serial correlation. This is the Breusch-Godfrey Lagrange Multiplier (LM) test. It tests for serial correlation of several orders in the residual series from a regression. Unlike other tests, the Breusch-Godfrey LM test can be used in a regression that includes lagged values of the dependent variable. The test uses either the F or Chi-square test to test the significance of the correlation in the residuals. It therefore tests the null hypothesis that there is no serial correlation in the random errors (Table 7).

Table 7
Breusch–Godfrey serial correlation LM test results

Breusch-Godfrey Serial Correlation LM Test: Null hypothesis: No serial correlation at up to 2 lags			
F-statistic	1.250979	Prob. F(2,14)	0.3163
Obs*R-squared	3.335549	Prob. Chi-Square(2)	0.1887

Source. Prepared by the researchers based on outputs from EViews 13.

The probabilities associated with the Obs*R-squared and F statistics from the Breusch-Godfrey Serial Correlation LM Test are 0.1887 and 0.3163, respectively. Because both are above 5%, we cannot reject the null hypothesis that the residuals have no serial correlation. This is desirable because it means the model's error terms have no autocorrelation or time dependence. This increases confidence in the parameter estimates and statistical inferences.

3.5. Estimation of Short-Run and Long-Run Relationships and the Error Correction Model

3.5.1 Short-Run Relationship Estimation and the Error Correction Model

An Error Correction Model (ECM) with the research variables in their first-difference form is used to estimate the short-run association. The rate at which short-run disequilibrium transitions to long-run equilibrium is represented by the one-period lag included in the error correction term. A long-term association is demonstrated by a negative and statistically significant error correction coefficient ($p < 0.05$). The pace of adjustment to equilibrium is indicated by the value of this coefficient. Table 8 displays the outcomes of the short-run relationship and the error correction model:

Table 8
Error correction model estimation for the short-run relationship (ARDL Model)

ARDL Error Correction Regression
Dependent Variable: D(TAXREV_GDP)
Selected Model: ARDL(1, 0, 1, 0)
Case 2: Restricted Constant and No Trend
Date: 06/26/26 Time: 19:52
Sample: 2003 2025
Included observations: 22

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(HCI)	0.400863	0.037282	10.75671	0.0000
CointEq(-1)*	-0.517900	0.145225	-3.566179	0.0026

Source. Prepared by the researchers based on outputs from EViews 13.

The relationship can be explained as follows:

We can observe a long-term equilibrium relationship between the variables under investigation based on the error correction estimates. The error correction coefficient (cointeq(-1) = 0.51) is statistically significant and negative. This indicates that the variables have a short-run equilibrium relationship that adapts to the long-run equilibrium. A reasonable adjustment rate is shown by an error correction coefficient of -0.51, which suggests that roughly 51% of the short-run disequilibrium is rectified in a single session. We can also observe that the research variables are cointegrated, based on the short-run connections mentioned above.

The Human Capital Index coefficient shows a significant, positive relationship with tax revenue (TAXREV_GDP). A 1% rise in HCI results in a 0.40% rise in tax revenue. This is likely because human capital promotes governance and economic efficiency. Better health, skills and education translate into higher productivity, higher employment and income, more taxpayers and ultimately higher revenue.

3.5.2. Interpretation of Long-Run Results

After confirming the existence of a long-run relationship, the long-run coefficients should be obtained.

Table 9
Long-run coefficients estimation results (ARDL Model)

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
OSI	0.144129	0.034652	4.160601	0.0006
HCI	0.451507	0.140765	3.207012	0.0049
EGDI	0.154806	0.032297	4.793501	0.0001
C	0.940487	0.595183	1.580166	0.1336

Source. Prepared by the researchers based on outputs from EViews 13.

The long-run findings from Table 9 are as follows:

Tax revenues (TAXREV_GDP) are positively and significantly related to the coefficient for the E-Government Development Index (EGDI). A 1% rise in EGDI is associated with a 0.15% rise in tax revenues. This suggests that increasing the level of e-government can improve tax administration by simplifying services, increasing compliance and improving efficiency, which can result in higher tax revenues.

Tax revenues (TAXREV_GDP) are positively and significantly related to the coefficient for the Online Service Index (OSI). A 1% rise in OSI results in a 0.14% rise in tax revenues. This suggests that by increasing the level and quality of e-government services, taxpayers can more easily interact with tax services (registration, filing and payment), which can in turn reduce the time, effort and costs associated with tax compliance. Digital tax services can improve data accuracy, facilitate inter-agency information sharing and reduce corruption and errors, which can lead to a larger tax base, more efficient tax collection and higher tax revenues. This coefficient also suggests that spending on e-services can strengthen the tax

administration's capacity to raise resources and improve overall government performance during e-government implementation.

The coefficient for the Human Capital Index (HCI) and tax revenues (TAXREV_GDP) is positive and significant. A 1% rise in HCI results in a 0.45% rise in tax revenues. This suggests that building human capital (digital skills, literacy and education) can increase the efficiency of tax administration and facilitate the use of modern technologies in tax administration and tax collection. Increased digital and general skills among taxpayers can also lead to higher compliance, lower costs and errors, higher-quality interactions with e-services, and increased tax revenues. This finding suggests that building human capital is essential for successful e-government implementation and for improving the efficiency of the tax administration.

4. Findings and Hypothesis Testing

- All the variables in the model were found to be integrated of order one, I(1).
- A cointegration relationship exists between e-government indicators and tax revenues, and a long-run equilibrium relationship was found using the Bounds Test.
- The F-statistic value (5.034821) in this study is greater than the upper critical value at the 5% significance level.
- Indeed, the first hypothesis is confirmed, as there exists a cointegration relationship between tax revenues and e-government indicators in Algeria for the period 2003–2025 at a 5 percent significance level ($\alpha \leq 0.05$).
- The ARDL model estimation results show that the model is statistically significant and has good explanatory power. Diagnostic tests also confirm normality of error distributions, stability of parameter estimates and proper model specification. Further, the model shows no heteroskedasticity or autocorrelation.
- The short-run error correction term is negative and statistically significant. This implies that the system adjusts rapidly to the long-run equilibrium and corrects disequilibrium.
- The results in this study also reveal a positive and significant influence of OSI, HCI and EGDI on tax revenue over time. It can therefore be said that investments in human resources, improved digital services and e-government development all play a role in enhancing tax administration, compliance and tax revenue. This highlights the importance of digitalization to Algeria's fiscal health.
- This finding is also in line with hypothesis 2, which posits that "There is a statistically significant impact of e-government indicators on tax revenues in Algeria over the period 2003–2025, at a significance level of $\alpha \leq 0.05$."

5. Conclusion

The findings affirm a significant, positive relationship between e-government indicators and tax collection. This supports the importance of e-government in effective tax administration. Additionally, the study has found that the development of e-government services, e-government infrastructure and the improvement of the capacity of e-government within a government can enhance tax compliance, transparency, the expansion of the tax base, and the effectiveness of tax collection, all leading to increased revenues and, ultimately, government financial health. These findings align with the economic literature, which has found that e-government can enhance the efficiency of fiscal management and resource mobilization.

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Effectiveness of the robo-advisor in managing and enhancing investment portfolio returns: analytical and evaluative study of the "Tamra Capital" platform

Drifa Ghezali

Abstract. *This study evaluated the performance of risk and investment optimization strategies implemented on the "Tamra Capital" fintech platform, a pioneer in Gulf Cooperation Council countries, aligned with Saudi Vision 2030 by contributing to liquidity integration in automated Islamic systems and enhancing small-investor participation. We found that the added value of robo-advisors goes beyond investment allocation strategy; it includes rebalancing dynamics and the ability to deliver performance that covers fees and Zakat. The "Aggressive Tamra" strategy recovered strongly from the shock in March 2025 and delivered a return of over 107%; by mid-2026, it outperformed the nearest rival by 23.82%. Based on these findings, it was suggested to implement a multidisciplinary supervisory system; impose cyclical supervision on algorithm transparency; improve reporting of net returns after fees and Zakat; design a variety of Islamic products with a longer investment horizon (beyond two years) that can effectively ride volatility and deliver compounded returns.*

Keywords: *Robo-advisor, Tamra capital, dynamic rebalancing, Islamic investment portfolios, risk management*

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İnvestisiya portfeli gəlirlərinin idarə edilməsində və artırılmasında robo-məsləhətçinin effektivliyi: "Tamra Capital" platformasının analitik və qiymətləndirici tədqiqi

Drifa Qezali

Xülasə. *Bu tədqiqat Körfəz Əməkdaşlıq Şurası ölkələrində qabaqcıl olan və avtomatlaşdırılmış İslam sistemlərində likvidlik inteqrasiyasına töhfə verməklə və kiçik investorların iştirakını artırmaqla Səudiyyə Ərəbistanı Vizyonu 2030 ilə uyğunlaşan "Tamra Capital" fintech platformasında tətbiq olunan risk və investisiya optimallaşdırma strategiyalarının performansını qiymətləndirdi. Biz aşkar etdik ki, robo-məsləhətçilərin əlavə dəyəri investisiya bölgüsü strategiyasından kənara çıxır; buraya balanslaşdırma dinamikası və haqları və zəkatı əhatə edən performans təmin etmək qabiliyyəti daxildir. "Aqressiv Tamra" strategiyası 2025-ci ilin mart ayında şokdan güclü bir bərpa nümayiş etdirdi və 107%-dən çox gəlir əldə etdi; 2026-cı ilin ortalarına qədər ən yaxın rəqibini 23,82% üstələdi.*

Bu tapıntılara əsasən, çoxsahəli nəzarət sisteminin tətbiqi; alqoritm şəffaflığına dövri nəzarətin tətbiqi; haqları və zəkatı ödədikdən sonra xalis gəlirlərin hesabatlılığının yaxşılaşdırılması; dəyişkənliyi effektiv şəkildə idarə edə və mürəkkəb gəlirlər verə bilən daha uzun investisiya üfüqünə (iki ildən çox) malik müxtəlif İslam məhsulları dizayn etmək təklif edildi.

Açar sözlər: *Robo-məsləhətçi, Tamra kapital, dinamik yenidən balanslaşdırma, İslam investisiya portfelləri, risklərin idarə edilməsi*

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1. Introduction

1.1. Context and Background

The field of finance and banking, as well as financial advisory, has experienced significant innovation through digitalization, given the rapid evolution of technology. Digitalization, however, has evolved beyond a technology upgrade. Digitalization is now a change in how financial products are delivered, enabling innovation, operational efficiency, business growth and improved customer experience in finance and banking.

The implementation of Artificial Intelligence in Banking (AIB) and Robo-advisory has changed the way investment is delivered. It has reduced the need for high-skill, high-time, and high-cost processes. Robo-advisory uses data and algorithms to create personalised investments while reducing 'human' involvement and costs. This has democratised investing, as more people can now invest. Before this, only High-Net-Worth Individuals (HNWIs) could utilise these types of investment products.

"Tamra Capital" is a robo-advisor used in the investment market in Saudi Arabia. It uses artificial intelligence and algorithms to allocate and manage investments in accordance with "Modern Portfolio Theory" (MPT) and Islamic investing.

1.2. Research Problem: Hence, the research problem is raised as follows:

To what extent do robo-advisors on the "Tamra Capital" platform aid investment portfolio management and performance?

The main research question was split into the following sub-questions in order to address the elements of the research:

- What is a robo-advisor? What technology and financial tools does it use to handle investment portfolios?
- What are the differences between a human wealth management service and an automated service?
- How effective is the investment allocation strategy used on the Tamra Capital platform at optimizing investor performance while also managing risk?

1.3. Research Hypotheses:

This research hypothesizes that the robo-advising used on the Tamra Capital platform supports effective investment portfolio management by lowering costs and improving the risk/reward ratio.

1.4. Research Objectives:

- To define what a robo-advisor is, its parts and its functioning;
- To determine the major distinction between conventional and online investing;
- To examine and assess the performance of the investment delivery system used on the Tamra Capital platform regarding both return from the investment portfolio and risk management.

1.5. Research Importance:

There are two main aspects to the importance of this research:

- Theoretical Importance

This research has theoretical importance as it applies theories and ideas behind robo-advisors and FinTech to the current investment landscape in the Arab world as a whole, and specifically in Saudi Arabia. This research is important because it compares the effectiveness and efficiency of algorithmic automated investing with conventional investing and contributes to research on developing investment products in the Arab world.

- Practical Implications

This research has practical implications due to its utilization of real market data from the 'Tamra Capital' platform, which is an applied product within the Gulf and Saudi financial markets. The research can provide a useful yardstick for investors, academics, and management to assess the application of artificial intelligence and algorithms for cost minimization, investment allocation, and return generation.

1.6. Theoretical basis of a robo-advisor and how it operates

1.6.1 Introduction to Robo-advising:

Robo-advising has revolutionized the investment field by bringing Wealth Tech into a new era of financial services. Robo-advising began around the end of the first decade of the 21st century, amid significant financial turmoil and investor dissatisfaction with the investment landscape. Over the last two decades, these robo-advisers have spread globally from their initial implementation in the United States. Though often referred to as financial advisory services, robo-advisers primarily deliver automated investment advice (a subset of financial advice) (Arshi et al., 2026, p. 2).

This type of Robo-advisory service uses the Markowitz Mean-Variance Optimization model. Investors provide information about their investment objectives, time horizon and risk preference via online questionnaires. Using algorithms, it creates a well-diversified investment portfolio tailored to the investor’s objectives and preferences. These funds may consist of low-fee Exchange-Traded Funds (ETFs) (Bhattacharjee, 2026, p. 955).

Robo-advisory has become more popular over the years, and since 2008, the number of Robo-advisory services has increased substantially. This has helped promote digital finance and FinTech and made

financial products and services more available and affordable to most investors who previously did not receive appropriate investment services (Kekana, 2025, p. 365).

1.6.2. Definition of Robo-Advisor

Robo-advisors are an application of algorithms in investment and wealth management services that provide low cost and increased availability with reduced human involvement (Akhtar et al., 2025, p. 1).

Robo-advisors are online applications that gather customer data and use systems built on cloud computing, artificial intelligence and Application Programming Interfaces (APIs). Robo-advisors can link to external data, such as financial networks and pathways in the marketplace, data pipelines and news sources and operate by ingesting and processing that data (Virk & Al-Khalidi, 2026, p. 222).

A robo-advisor is an artificial intelligence application that enables retail investment globally. The robo-advisor uses investor cognitive patterns and transaction data to reduce behavioral biases in finance, such as overconfidence and loss aversion. The robo-advisor can also address substantive issues in applying behavioral knowledge to finance for early identification of financial distress and crises, as well as incorporating behavioral knowledge into finance (Kulkarni et al., 2025, pp. 2–3).

A robo-advisor can therefore be described as a system that uses artificial intelligence to deliver financial recommendations and handle investment decisions for clients, providing greater transparency and lower fees.

1.6.3. Architecture of an AI-based robo-advisor

An intelligent robo-advisor can be composed of the following 5 core elements that combine to deliver autonomous investment decisions (Virk & Al-Khalidi, 2026, pp. 222–223):

- Data Inputs: Market, macroeconomic, news (NLP) and alternative data aggregation
- Data Processing: Transforms raw data into analytically ready data through data cleaning and processing
- AI Engines: Portfolio rebalancing, portfolio modelling and client risk profiling
- Human in the loop: Portfolio creation and approval of high-risk decisions
- Governance and Risk: Algorithmic interpretation, data security implementation and process governance

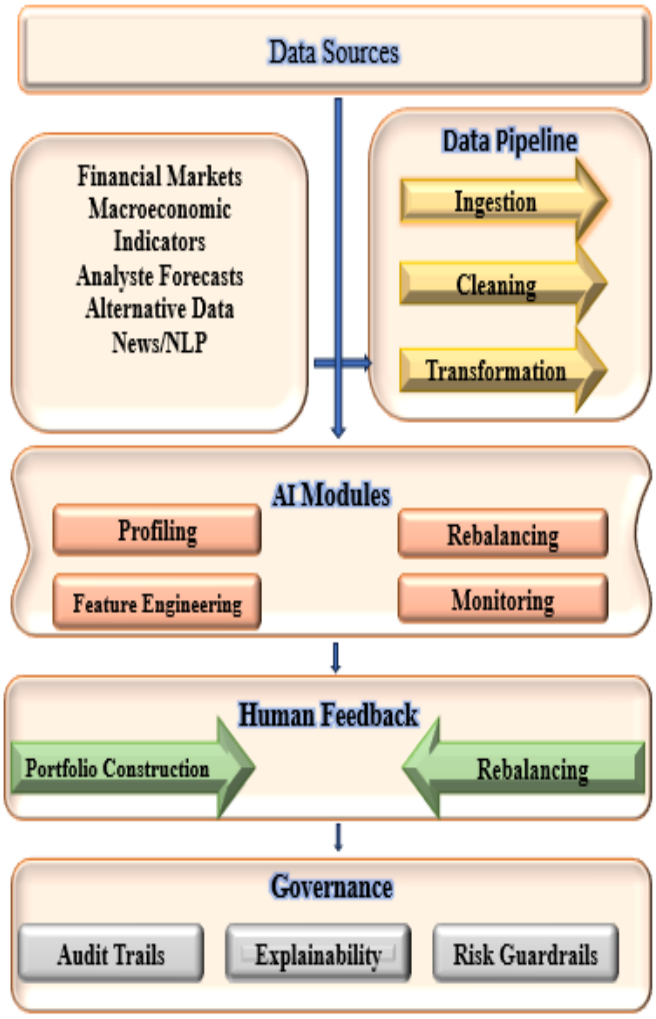


Figure 1
Robo-advisor architecture

Source. Prepared by the researcher based on (Virk & Al-Khalidi, 2026, pp. 222–223).

1.6.4. Operation of Robo-Advisors

Robo-advisors use four key mechanisms to deliver optimal, precise investment services (CUSP Wealth, n.d.).

- Risk Profiling:

Data Collected: Beyond formal data, the questionnaire also gathers investment objectives, investment horizon, income consistency and mental/emotional/financial tolerance for losses (tolerating a 20% loss in the investment portfolio, for example).

Additional Factors: Short-term liquidity requirements (2-3 years) and religious/law requirements (for example, Shariah-compliant investments) are also factored in.

Resulting Profile: A portfolio ranging from conservative and defensive to growth-oriented is assigned to the investor.

- Portfolio Construction:

Investment Approach - Passive with ETFs using "Modern Portfolio Theory," which attempts to provide the maximum return for a given amount of risk.

Types of Assets held - Portfolios may hold stocks, commodities, REITs and other alternative assets. Conservative portfolios may hold only fixed-income assets. A portfolio can hold a wide variety of asset types.

Objective Allocation - Assets are allocated using a disciplined method that eliminates emotional or behavioral biases that might impede performance during market volatility.

- Rebalancing & Monitoring:

Tracking and correction of deviation - The portfolio is tracked over time to correct any shift in asset weights due to market volatility (for example, if the weight in stocks increases past the desired level).

Adjustment method: Threshold adjustment (2%-3% off threshold) is more effective than time-based adjustments because transactions are made immediately to correct an offset and no excess fees are incurred.

Practical use: This approach suits active traders or people with busy schedules who do not have time to check daily.

- Goal-oriented investing:

Connecting investments to a goal: Instead of connecting investments only to the equity markets, this method connects investments to progress toward a specific goal (education, home ownership, retirement, etc.). This increases the investor's accountability to their investments.

Adjustment to asset allocation: As the investor nears their goal date, the investment strategy shifts into lower-risk investments to help protect the value already achieved.

2. Methods

2.1. Research Methodology

To address the research problem, a descriptive research method was used to develop a theoretical research framework. Information and data were gathered on robo-advisory services and on data analysis techniques used to examine the performance of investment portfolios available on the 'Tamra Capital' platform from the relevant research literature.

The research is sequenced into three axes:
Axis I: Theoretical basis of a robo-advisor and how it operates
Axis II: 'Tamra Capital' platform - concept, services and investment allocation

Axis III: Analysis of the performance and efficiency of investment portfolios on the 'Tamra Capital' platform

2.2 Differences between Traditional and Digital Investing

Problems with the traditional investment advice process include barriers that prevent small investors from participating. These issues include financial and cost barriers. Traditional financial advisers can charge up to 1% or more per year of assets under management. For a $50,000 portfolio, this would equate to $500 per year. This amount reduces the investor's return, and the effect compounds over time. Financial institutions also exhibit implicit exclusion by having a minimum balance of $100,000 to $1 million and excluding many small investors (Bhattacharjee, 2026, p. 955). The key differences between traditional and robo-advisers are presented in the following table:

Table 1
Differences between a robo-advisor and a traditional human advisor

Criteria	Robo-Advisor	Human Advisor	Advisory & Analytical Impact
Cost Efficiency & Fees	Charges low fees (around 0.25% of assets under management).	Works with relatively high commissions (1%–3%).	Low fees positively affect portfolio compound returns in the long term.
Accessibility & Financial Democracy	Allows investment with very low minimums (or none).	Imposes high minimum investment thresholds, including operating costs.	Expands the investor base and enables small investors to enter financial markets.
Psychological Factor (Discipline)	Adheres to programmed algorithms, free from emotions and impulses.	May be influenced by psychological factors such as fear or optimism during crises.	Ensures more disciplined, objective investment decisions, free from emotional tendencies.
Operational Scalability	Can manage large numbers of portfolios and rebalance them automatically.	Limited capacity, serving only a certain number of clients per advisor.	Provides portfolio management services to a wide audience with equal time efficiency.
Performance & Financial Assessment	Excels in stable markets, performs during crises based on foundational expertise.	Excels in complex financial planning; performs during crises, relying on expertise.	Superior overall performance in selecting financial instruments based on the investor's financial situation.

Source. Prepared by the researcher based on (FasterCapital, n.d.).

The above table shows that the robo-advisor provides significant advantages in cost, objectivity and scale. However, a human wealth manager has advantages in qualitative risk analysis and handling more sophisticated financial products. This suggests a future for an integrated financial services industry.

2.3. "Tamra Capital" - concept, services and investment allocation

"Tamra Capital" represents an innovative application of fintech to the Arab world, particularly within the Gulf Cooperation Council member states, in the context of Saudi Vision 2030. "Tamra Capital" has broken through financing barriers for small investors, allowing them to invest small sums and withdraw

automatically. Algorithmic solutions have also added liquidity to the national financial system while fully complying with Islamic Shariah requirements.

2.3.1 Description of the "Tamra Capital" Platform and its Services

Tamra Capital is a Saudi entity licensed by the Capital Market Authority to offer investment management and advisory services as of November 23, 2021 (License No. 30-20212). The Capital Market Authority has approved Tamra Capital to begin operations, and it has deployed a secure, automated platform to expand investment opportunities for investors and address the limitation of being restricted to a single segment. Through Tamra Capital, investors can invest accurately and easily in local and international investment funds, with a focus on Islamic Shariah-compliant Exchange-Traded Funds. (Tamra Capital, n.d.).

Tamra also received a license from the Saudi Central Bank ("SAMA") for deferred payment services within the Kingdom of Saudi Arabia on June 21, 2023. Tamara also received a license for personal consumer loans on February 2, 2025, under No. (95/202502). Tamara's primary business is generating and managing consumer receivables in installments through a network of stores within the Kingdom of Saudi Arabia. (Tamara, 2025)

Tamara operates in Gulf Cooperation Council countries, including Kuwait, the UAE, and Saudi Arabia. The company also works with major brands like IKEA and SHEIN and integrates with many online marketplaces, including Shopify and WooCommerce (KPMG, 2024, p. 14). Tamara is a unicorn company in Saudi Arabia and needs large capital to support its current growth and future capital appreciation. In the fourth quarter of 2023, Tamara raised $340 million USD (1.27 billion SAR) in a Series C round led by Sanabil Investments and SNB Capital. After this funding event, Tamara was awarded "Unicorn" status with a valuation of $1 billion USD (Fintech Gate, 2023).

Tamra Capital provides investment services using a scientific method and avoids making unrealistic claims. Therefore, it suits investors who value financial responsibility and transparency. Tamra offers various core investment services. These are as follows (Tamra Capital, n.d.):

- Invest in local and international investment funds.
- An online secure system enabling completely automated investment management.
- Investing in Shariah-compliant Exchange Traded Funds.
- Providing professional financial analysts to aid clients in investment decisions and offer professional investment advice.

2.3.2 Steps for Investing on the "Tamra Capital" Platform

Investing on the Tamra platform involves building wealth via investments using their "Robo-Advisor". This system automates investments, provides personalised recommendations and invests based on the client's data and objectives at a low subscription cost. The platform requires no minimum or maximum investment, and an annual compounded return of up to 12% is possible, depending on the investment portfolio selected. The investment process on the Tamra platform can be broken down as follows (Tamra Capital, n.d.).

- Registration: Investor information is quickly authenticated via the National Unified Access, and the account is created immediately. An IBAN is generated within minutes.

- Investment Objective: An investment objective is established via a series of questions, and a suitable investment fund is chosen based on the desired degree of risk.

- Deposit: A variable amount can be transferred to the investment account, where funds will be invested within a maximum of 5 business days.

- Management: Ongoing management and assistance are provided, including automatic portfolio rebalancing, reinvestment of distributed returns, and periodic statements.

2.3.3 Investment Distribution Strategy:

Tamra provides 8 investment funds that cater to varying risk levels. These funds allow users to enter the investment world and select the right mix of investment products (cash, gold, real estate, sukuk, stocks) to reach their investment objective. (Tamra Capital, n.d.).

Table 2
Types of investment portfolios on Tamra and Their asset allocation by risk level

Portfolio	Risk Level	Asset Allocation and Strategy
Emergency Portfolio	Very Low	Concentrates entirely in money markets to provide high liquidity and capital protection with low returns; suitable for short-term goals.
Conservative Portfolio	Low	Focuses on sukuk to reduce volatility, with balanced allocations in US stocks, real estate, and gold to achieve growth and hedge against inflation.
Moderate Portfolio	Medium	Sukuk constitute half (50%) to control volatility, while the remaining portion is distributed among US, developed, and emerging market stocks, along with gold and real estate.
Growth Portfolio	Medium to High	Relies heavily on equities to boost returns, with partial protection provided through sukuk and gold, suitable for those willing to take higher risks.
Aggressive Portfolio	High	Sukuk allocation decreases in favor of increased equity shares (US, developed, and emerging markets), maintaining moderate allocations in real estate and gold to increase expected returns.
Adventurous Portfolio	Very High	Concentrates primarily on US equities to maximize returns against high risk, with very low allocations to sukuk, real estate, and gold.
Saudi Portfolio	Specialized (Local)	Invests 100% in Saudi equities to directly benefit from the growth of the local economy and the Saudi market.
Flexible Portfolio	Customized	Gives you complete freedom to determine investment proportions in available ETFs to design your portfolio according to your own vision.

Source. Prepared by the researcher based on (Tamra Capital, n.d.).

2.3.4 Opportunities and Challenges of Using the "Tamra Capital" Platform

- Interdisciplinary collaboration (data science, behavioral science, economics, law) needed for regulation to ensure economies of scale for financial efficiency and market integrity;

- Mobile, simplified, and low-cost access to wealth management platforms is enabling less experienced users to receive automated advice;
- Falling management fees through passive investments are revolutionizing wealth management via digital advisory platforms;
- Increasing competition, but large investment banks are focusing on the inclusion of robo-advisors in their own digital strategies due to the increasing size and market of robo-advisors predicted via the "Delphi method";
- Young retail investors (18-29 years) need funds and have low financial literacy, which precludes them from engaging with a human wealth manager. Automated platforms are a great fit for them due to cost.
- Data security and cybersecurity issues due to the storage and collection of investor financial information. Data breaches and cyberattacks can harm digital wealth management platforms' reputation and cause investor losses. (Kumari et al., 2024, pp. 46–47).

Below is a list of the most important system and cybersecurity risks associated with robo-advisors:

Table 3
Classification of cybersecurity threats in the field of Robo-Advisory

Cybersecurity Threat Category	Explanation and Definition	Applied Scenario / Case Study
Identity and Access	Unauthorized exploitation of credentials and breach of permissions to bypass security levels.	Leakage of API Keys, enabling hackers to control and modify client portfolios.
Data and Algorithm Integrity	Manipulating inputs or practicing "Data Poisoning" to confuse automated decision-making mechanisms.	Injecting misleading or incorrect market data, causing algorithm deviation and distorted asset allocation strategy.
Provider Concentration and Reliability Risks	Excessive reliance on a limited number of technology providers, creating a Single Point of Failure.	Sudden outage of the platform's cloud services, resulting in a total paralysis of automatic portfolio rebalancing operations.
Information Manipulation	Employing misleading media content or generating fake news with AI to directly influence algorithmic decisions.	Spread of fabricated financial rumors leading to coordinated mass sell-offs among robo-advisor platforms.
Systemic Risk Propagation	Transfer of security incidents and breaches across interconnected networks and financial institutions.	A security breach of the Custodian, disrupting services and workflows for several linked investment platforms.

Source. Prepared by the researcher based on (Virk & Al-Khalidi, 2026, p. 224).

2.4. Performance Simulation Model

Auto-investment systems available on Tamra Capital are tested by simulating an initial one-off investment of 10,000 SAR made on 1 January 2023, with no cash added or withdrawn over the three-and-a-half-year investment period, until 30 June 2026.

3. Results

3.1. Performance of the main portfolios between 2023 and the end of mid-2026

In order to test the performance of the auto-investment systems present on the Tamra Capital platform, a simulation of investment is conducted by initially depositing 10,000 SAR as a one-off investment on the 1st of January 2023 and assuming that no further cash is deposited or withdrawn during the three-and-a-half-year investment period ending on the 30th of June 2026.

Table 4

Performance indicators for investment portfolios

Portfolio	Investment Value at End of Period (SAR)	Total Return (%)	Estimated Monthly Growth Rate	Volatility Level
Adventurous	20,740	107.40	Highest Growth Rate	Very High
Aggressive	17,927	79.27	High Growth	High
Moderate	16,987	69.87	Balanced Growth	Medium
Conservative	15,091	50.91	Safe Investment Growth	Low and Stable

Source. Prepared by the researcher based on Tamra Capital (2026).

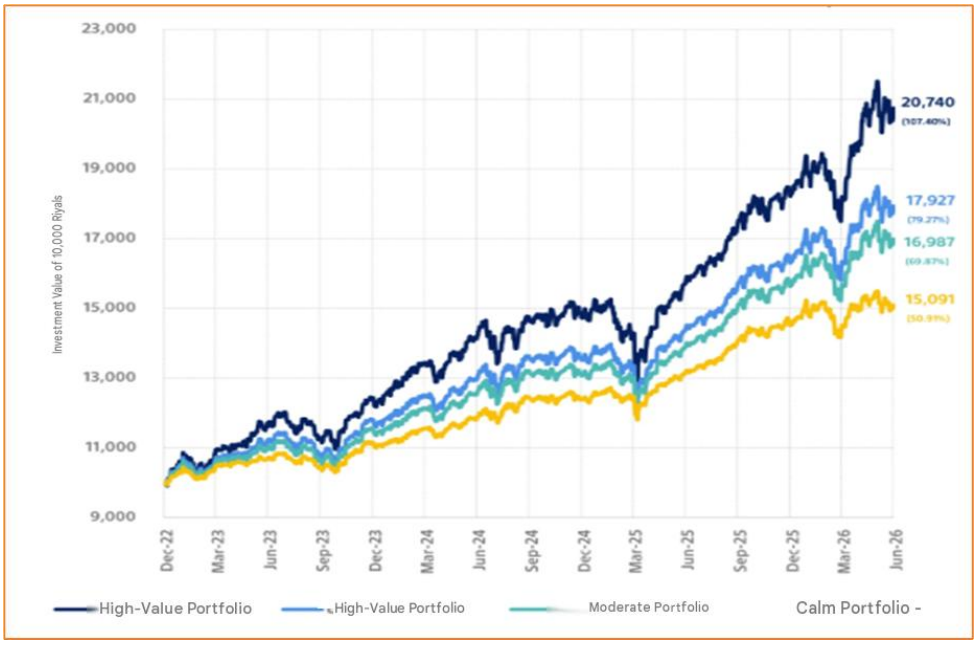


Figure 2

Evolution of an Initial Investment of 10,000 SAR by Portfolio Risk Level (January 2023 – June 2026)

Source. Tamra Capital (2026).

From the table and figure above, it is noted that:

Fan-Out Effect: All the portfolios start from the same value (10,000 SAR on December 22). After that, the riskier portfolios gradually start to separate. The return difference between the highest-return portfolio (Adventurous) and the lowest-return portfolio (Conservative) is 5,649 SAR, or a 56.49% difference. This demonstrates the risk premium earned by taking risk and illustrates the Risk-Return Tradeoff. General Trend and Short-term fluctuations: All portfolios show an upward trend. This could reflect an increasing trend in the underlying assets that make up these portfolios over the medium or long term, or an overall positive economic environment. There are also periods of decrease (March 2025, March 2026). During these times, the Adventurous portfolio shows the largest decrease, while the Conservative portfolio has remained relatively constant. This demonstrates that the Adventurous portfolio is more sensitive to shocks than the Conservative portfolio. Short term vs Medium term: Over the short term (between December 22 and March 23), performance differs little across the portfolios. Over the medium term (over two years), the accumulation of increases in the underlying assets becomes evident. This shows that high-risk portfolios need a long time frame to manage these variations and reach desired returns.

3.2. Comparing the Performance of the Tamra Capital Portfolio with Counterparts on Other Robo-Advisor Platforms

3.2.1. Performance of Portfolio with One Initial Deposit Without Fees and Zakat over the Period (January 2023 - June 2026)

This comparison compares the performance of the "risk-seeking" portfolios (i.e., the highest-risk-level portfolios) offered by Tamra Capital with those offered by other robo-advisor platforms to determine whether Tamra Capital's investment and portfolio management tools and skills outperform other platforms. For this comparison, a 10,000 SAR initial deposit is made on January 1st, 2023, as a lump sum, with no further deposits. Fees and Zakat are also not deducted. The investment is held for three and a half years until the end of the first half of 2026. An example of this is shown in the figure below:



Figure 3

Evolution of a 10,000 SAR Investment on the Tamra Capital Platform and Competing Platforms Covering Fees and Zakat (January 2023 – June 2026)

Source. (Tamra Capital, 2026).

As mentioned in the above figure, excluding the impacts of fees and Zakat, the evolution of performance for the period (2023 - mid-2026) can be divided into three stages as follows:

- Convergence and Setup stage (2023): All platforms experienced a convergence in performance and results in the first year. Overall performance also increased, with minor readjustments (such as the drop in September 2023).
- Widening and reaction to economic cycles stage (2024 - 2025): From 2024, the "Adventurous Tamra" portfolio started to diverge from the other platforms, with increasing investment value, with "Platform 3" also increasing at an increasing rate whilst Platform 1 and 2 increased at a slower rate.

All funds were down in March 2025, but Tamra Capital showed strong investment resilience and a solid recovery from the crash, with a better recovery and continued gains through June 2026.

- Structural Separation and Performance Maximization stage (January - June 2026): By the end of June 2026, the difference between the Tamra Capital fund and the rest was at its maximum. Tamra Capital more than doubled the initial investment and outperformed the next-best-performing fund (Platform 3) by 23.82% (107% vs. more than doubling). Tamra Capital also outperformed the lowest-performing fund (Platform 1) by 45.41% during this period.

This is due to variations in rebalancing techniques and/or algorithms used by the platforms. As a result, by mid-2026, a large accumulated gap favors Tamra.

3.2.2. Portfolio Performance with One Initial Deposit Including Fees and Zakat for the Period (January 2023 - June 2026)

For greater practicality, this aspect evaluates the real net performance of the "risk-seeking" (highest risk) portfolios for Tamra Capital and other platforms for which data is available. For this, a lump sum of 30,000 SAR is deposited on January 1, 2023 and left for 3.5 years until June 30, 2026. Management fees (on any investment less than 60,000 SAR with Tamra Capital, an annual fee of 240 SAR is charged and deducted monthly) and Shariah Zakat are deducted monthly and annually, respectively, as shown in the figure below:



Figure 4

Evolution of Net investment value of 30,000 SAR on the Tamra capital platform and competing platforms including fees and zakat (2023 - 2026)

Source. (Tamra Capital, 2026).

As shown in the chart above, over the long term (2023 through 2026), the Tamra portfolio continues to outperform all other portfolios by a reasonable margin. This is good, as it demonstrates the power of the allocation and rebalancing strategies employed by the Tamra portfolio to improve the investor's net return. When considering the performance path with fees and Zakat included for the period (2023 - mid-2026), three distinct stages can be observed:

The phase of convergence and first fee application (2023). All systems performed in lockstep, reacting similarly to global and local news. From 2024 to 2025, the phase shifted to separation and fee-structure unwinding. The "Adventurous Tamra" fund significantly outperformed the others. Returns were high enough to absorb fees and Zakat effectively. The other funds clearly showed the impact of fees and cost reductions. The Tamra fund also showed more recovery from the April 2025 correction. In the first half of 2026, the fund achieved structural maturity and became profitable on a net basis. The fund returned over double the initial investment (102.50%) and returned 33.94% and 48.93% more on a net basis than Platforms 1 and 3, respectively. This indicates much lower fees and costs relative to return on invested capital. Zakat and management fees have been stripped from all numbers.

4. Discussion

4.1. Discussion of Findings

Tamra Capital has clearly provided investment management services via robo-advisors. The high returns achieved by Tamra's funds over the research period (December 2022 - June 2026) were not random; they resulted from planning, persistence and superior execution in a highly competitive environment. However, what makes Tamra distinctive is not only its performance but also the nature of the service it provides, including transparency, fundamental analysis, understanding customer requirements at varying levels, risk management and so on. The main conclusions can be listed as follows:

- Tamra is a robo-adviser that uses artificial intelligence to provide financial services, including investment management and financial advice. It provides lower fees and greater transparency to clients;
- Tamra provides investment through 8 funds (Emergency, Conservative, Moderate, Growth, Aggressive, Adventurous, Saudi and Flexible). These funds conform to Islamic Shariah and provide investment at differing levels of risk in order to facilitate portfolio allocation;
- The emergence of robo-advising has been driven by economics, regulation, behavioural analysis, data and analysis of markets. These factors have also resulted in the requirement for regulation that supports market integrity and financial values;
- For investment strategies (especially higher risk strategies), two years are required to capture the true return differential. While short-term movements and shocks can be mitigated over two years, the opportunity for capital and compound returns can be exploited;
- Analysis of the core funds over the period (2023 - June 2026) indicates a medium- to long-term risk premium for increasing risk. The Adventurous fund displayed a 56.49% return differential compared to the Conservative fund. However, this relationship is shock-sensitive, and there is a greater risk of drawdowns for higher-risk funds during market shocks as opposed to lower-risk conservative funds;
- It has been determined through this research that the value and uniqueness of robo-advising lies not only in initial portfolio allocation but also in the management of return, risk and rebalancing that can account for fees and the cost of Zakat. The quality of these processes distinguishes the robo-adviser. This is clearly evident in the "Tamra Adventurous" fund's response to the shock in March 2025 and its ability to maintain value. The fund achieved returns in excess of 107% and consistently outperformed the next-best-performing fund by 23.82% in mid-2026.

4.2. Recommendations

Based on the findings of this research, we recommend the following:

- Adopt an interdisciplinary regulation. A regulation that combines law, economics, behavioral and AI elements would allow innovation in finance while maintaining market integrity.
- Introduce requirements for algorithm transparency (algorithm auditing). Algorithms involved in risk management and rebalancing would benefit from periodic audits to ensure they can cope with market shocks and adequately serve investor interests during a market crash.
- Enhance disclosure of fees and Zakat in robo-investment products. Robo-investment products should calculate fees and Zakat automatically and transparently so investors can determine the net return on their investments.
- Enhance shock and recovery capability in algorithms. Beyond the initial investment choice, algorithms should also consider shock and recovery capability.
- Improve market efficiency through economies of scale. Lowering fixed costs and passing any resulting savings to investors would support investor protection while also enhancing market competition.
- Enhance the availability of Shariah-compliant investment products. A variety of Islamic investment products across different risk levels would cater to both conservative and more aggressive investor preferences.
- Adopt a long time horizon. A time horizon of more than two years (especially for riskier investments) would allow investors to cover market cycles while also benefiting from compounding returns on their invested money.
- Adopt net return as a performance measure for robo-advisers. Measure performance between different robo-advisors using net return after fees, Zakat and all other charges.

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Decomposing Aggregate Energy Intensity and Analyzing Sectoral Trends in Algeria (1990–2020)

Layadi Nour El-Houda

Abstract. *This study analyzes aggregate energy intensity (EI) in Algeria from 1990 to 2020 using the Fisher Ideal Index within the Index Decomposition Analysis (IDA) framework. The IDA is conducted with both primary and final energy consumption and is complemented by an analysis of sectoral trends to provide additional insights. The results indicate that the increase in EI is mainly driven by the energy inefficiency effect, while structural changes—particularly the shift toward the tertiary sector—contribute to reducing EI. Differences between the two cases are primarily associated with the energy industries and non-energy use sectors, as well as the industrial and tertiary sectors. These findings suggest that energy efficiency policies should prioritize the transport, residential, energy industries and non-energy use sectors, which remain the most energy-intensive.*

Keywords: *energy efficiency, economic structure, decomposition, sectoral energy intensity*

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Əlcəzairdə məcmu enerji intensivliyinin komponentlərə ayrılması və sektoral meyillərin təhlili (1990–2020)

Layadi Nur əl-Huda

Xülasə. *Bu tədqiqatda İndeks Dekompozisiya Analizi (IDA) çərçivəsində Fişerin İdeal İndeksindən istifadə edilməklə, 1990–2020-ci illər ərzində Əlcəzairdə məcmu enerji intensivliyi (EI) təhlil edilir. IDA həm ilkin, həm də son enerji istehlakı göstəriciləri əsasında aparılır və əlavə məlumatlar əldə etmək məqsədilə sektoral meyillərin təhlili ilə tamamlanır. Nəticələr göstərir ki, enerji intensivliyinin artması əsasən enerji səmərəsizliyi amili ilə şərtlənir; struktur dəyişiklikləri — xüsusilə də xidmət sektoruna (üçüncü sektor) keçid — isə enerji intensivliyinin azalmasına töhfə verir. Bu iki hal arasındakı fərqlər ilk növbədə enerji sənayesi və enerjinin qeyri-enerji məqsədli istifadəsi sektorları, həmçinin sənaye və xidmət sektorları ilə əlaqəlidir. Əldə edilən nəticələr göstərir ki, enerji səmərəliliyi siyasətində ən yüksək enerji intensivliyinə malik olan nəqliyyat, yaşayış, enerji sənayesi və enerjinin qeyri-enerji məqsədli istifadəsi sektorlarına üstünlük verilməlidir.*

Açar sözlər: *enerji səmərəliliyi, iqtisadi struktur, dekompozisiya, sektoral enerji intensivliyi*

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Introduction

The global degradation of environmental quality, the depletion of resources, and the issue of energy are closely linked; as a result, energy has become one of the greatest challenges of the economy. To face the consequences of the increase in energy needs (in the New policies scenario of IEA in 2017, world energy needs will increase by 30% by 2040. Thus, 80% of the total energy consumed in the world is non-renewable origin). Specialists are looking into the problem of controlling energy consumption (Hauet, 2014, p. 77), particularly within the framework of the energy transition, which refers to the shift towards a more sustainable energy system, characterized by reduced reliance on fossil fuels and greater use of renewable energy sources. It essentially builds on two key pillars (Senouci, 2015):

Energy savings (which can be achieved through two complementary approaches: energy efficiency (EE) which refers to the use of less energy to deliver the same service or produce the same amount of useful output, and energy sobriety, which aims to reduce consumption by promoting behavioral changes), and the development of renewable energies.

An economy should aim to consume the least possible amount of energy to produce a unit of GDP. Consequently, the measurement of energy intensity is an indispensable indicator for any energy policy. Energy intensity, defined as the amount of energy used per unit of economic activity or GDP, provides an approximate measure of an economy's energy efficiency, with energy consumption generally aggregated as either final or primary energy (Hauet, 2014). In general, the lower the energy intensity indicator (i.e., the ratio of energy consumption to GDP), the higher the energy efficiency. Thus, high energy intensity reflects the high cost of converting energy into GDP (Mirza & Fatima, 2016).

However, it is important to take into account the diversity of economic activities, since changes in energy efficiency at the sectoral level are not the only factors determining energy intensity trends. Sectoral energy intensity can also vary according to the energy intensity of products (for example, a shift from less energy-intensive products to more energy-intensive ones, or the reverse) within a given sector. Energy intensity can be reduced either by improving efficiency in the use of energy or by shifting away from energy-intensive activities (Metcalf, 2008). Therefore, it is necessary to apply a method of energy intensity decomposition to isolate the impact of efficiency improvements from the effects of activity and sectoral composition changes, in order to provide a more accurate analysis of energy intensity and energy efficiency trends (Marrero & Ramos-Real, 2013).

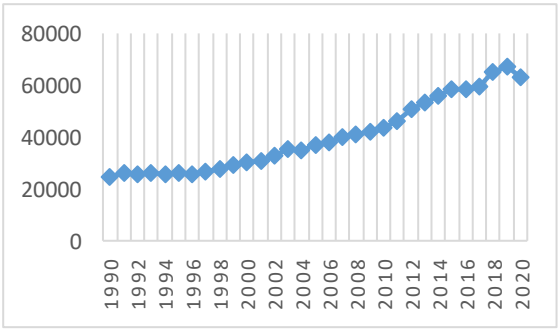


Figure 1

Evolution of national energy consumption in Algeria 1990–2020 (ktoe)

Source. Prepared by the researcher based on national energy balances.

Thus, national consumption (primary energy consumption) in Algeria has seen continuous growth overall, around 67 Mtoe in 2019 and it comes mainly from fossil fuels. Algeria's energy intensity is nearly double the average observed in OECD countries (Senouci, 2015). However, in Algeria, there is a massive potential for energy savings that is expected to continue growing. Indeed, cumulative energy savings could reach around 93 million tons of oil equivalent, including 63 million TOE by 2030. These results would be achieved through the national energy efficiency program, which would also lead to a reduction of 193 million tons of carbon dioxide emissions, as indicated by the Ministry of Energy. This objective forms an integral part of the National Program for the Development of Renewable Energies and Energy Efficiency. This highlights the importance of conducting an in-depth investigation of energy intensity at both the aggregate and sectoral levels in order to propose adequate public policies.

In this regard, our research aims to examine the evolution of aggregate energy intensity in Algeria, using data on primary and final energy consumption, by attributing its variation to the efficiency component and the structural component, between 1990 and 2020. We then intend to compare these findings. In addition, we analyze sectoral energy intensity over the study period to identify the most energy-intensive sectors and provide more in-depth explanations.

The remainder of the paper is structured as follows. Section 1 reviews the existing literature on energy intensity decomposition. Section 2 introduces the data and details the methodological framework adopted. Section 3 presents the empirical findings and provides a discussion of the results, while the final section concludes and offers some policy implications.

1. A brief literature review

We organize in the tables below the main details and results of previous studies:

Table 1
Studies on the decomposition of EI

Reference	Country and period	Method ology	Main results in explaining variations in total EI
(1) Marrero and Ramos-Real , 2013	EU15 countries 1991–2005	LMDI	A positive contribution of 75% through EE improvement and 25% for structural changes in all countries (except Austria, both had a similar contribution)
(2) Mirza & Fatima, 2016	Pakistan, 1980-2009	Fisher	There is energy inefficiency, and a small contribution from the structural component (8%) in reducing the overall EI.
(3) Ben Hammamia et al., 2014	Tunisia 1990-2008	Fisher	The efficiency component has an EI reduction effect of 56%, and 44% for the structural component on average
(4) Metcalf, 2008	US, 1970-2003	Fisher index	The effect of improved energy efficiency is the main contributor
(5) Nugraha, 2019	Indonesia 1984-2015	LMDI	Efficiency effect reduced EI by 69.07% vs. 5% for structure effect
(6) Tenaw, 2021	Ethiopia 1990–2017	LMDI-I	A significant contribution of the intensity effect in the variation of EI.
(7) Robaina et al., 2019	Portugal 1995-2015	LMDI	The reduction in EI is related to the efficiency component, structural changes have a negative effect.
(8) Zhang et al., 2019	Shanxi Province (2000-2015)	M-LMDI-II	Both effects contribute to the reduction of the EI index (21.74% for sectoral EI and 24.29% for the structure effect)
(9) Voigt et al., 2014	40 major economies 1995-2007	LMDI	In the majority of countries, the effect of structural change has a lesser impact on improving EI.
(10) Ullah et al., 2014	Pakistan 1972-2011	Fisher	The increase in EI was caused by the efficiency effect, where inefficiencies in electricity consumption played the primary role, followed by those in natural gas.
(11) Deichmann et al., 2018	137 countries (1990–2014)	Fisher	The contribution of the structural component to the reduction of the EI is more important (this is valid at all income levels)
(12) Oteng-Abayie et al., 2023	Ghana, 2000–2020	LMDI I	Energy intensity in Ghana is largely attributable to structural effects

Source. Prepared by the author.

Several analytical methods exist for analyzing energy demand, including decomposition analysis. This approach examines changes in energy demand arising from a number of factors (particularly changes in economic activity, changes in sectoral energy efficiency, and changes in the economic structure). This is achieved by analysing changes in energy consumption, and analysing changes in energy intensity. The literature has largely emphasized energy intensity and its decomposition; as shown in Table 1, many

researchers have used various decomposition methods to analyze energy intensity by quantifying the impact of different factors and their contribution to the overall change.

Decomposition analyses have been conducted in several ways. Some authors carried out this decomposition exclusively at the national level (3, 2, 5, 7, 6, 12), while others extended the analysis to multiple levels or to the case of several countries (8, 11, 9). Similarly, study (1) addressed the case of 15 European Union countries.

It is worth noting that some analyses simultaneously consider the national and multi-level perspectives. For example, study (4) decomposed the EI of the United States at the national level first, then moved on to an analysis at the level of individual states.

Furthermore, study (10) focused on decomposing energy intensity by product (oil, gas, and electricity) to provide more detailed and in-depth analysis related to overall energy intensity.

Based on this section of the literature review, it can be concluded that decomposition analysis of EI has generated diverse results. Some authors have shown that the component with the dominant impact or contribution is efficiency (3, 1, 4, 5, 7, 6, and 9).

Conversely, in other empirical studies, the structural component has exerted a stronger influence on EI variation (12, 11, 2, 8). However, some authors have reached the conclusion that both efficiency and structural effects exert a similar impact, as in the case of Austria reported by (1).

To the best of our knowledge, the only existing study that applies a decomposition approach to Algeria's energy intensity is that of Layadi and Senouci (2022), which is limited to national energy intensity. This study contributes to the literature by addressing this gap and providing a comprehensive analysis of Algeria's energy intensity at both the aggregate (using primary and final consumption) and sectoral levels.

2. Data and methodology

This section presents the data types and sources, followed by a detailed explanation of the study methodology.

2.1. Type and source of data

The energy intensity index can be decomposed into the two components previously identified, provided that sectors are constructed to encompass the entirety of energy consumption without overlap, and that a measure of economic activity is available for each sector to enable the calculation of energy intensity. Importantly, sectoral activity measures need not correspond directly to GDP, as they may be expressed in different units (Metcalf, 2008).

In our case, the six energy-consuming sectors under consideration are: residential, transport, industry, agriculture, tertiary, and the energy industries and non-energy use sector. The annual dataset for the empirical analysis covers the period 1990–2020 and consists of the following:

- Data on aggregate output, proxied by GDP, and sectoral output, proxied by value added (VA) for all sectors except:

- Residential sector, where household consumption expenditure is used as a proxy, as it was argued that personal consumption expenditures provide a better proxy and key driver of residential energy demand than disposable income, since the latter is affected by savings.
- Transport sector, where average distance traveled is used as a measure of economic activity, in line with certain studies in which vehicle miles traveled were used as a measure in this context (Metcalf, 2008).
- Energy demand data, including total annual energy consumption and sectoral energy consumption.

The definitions and sources of the variables described above are summarized in the following table.

Table 2
Variable definitions and sources

Variables	Definition	Source
Energy demand		
Aggregate	Total consumption (ktoe)	National Energy Balance (Ministry of Energy)
Sectors: industry, tertiary, agriculture, residential, transportation, and energy industries and non-energy use sector	Energy consumption (ktoe)	National Energy Balance + APRUE
Economic activity		
Aggregate	Gross domestic product (GDP at constant pricess in national currency, including hydrocarbons; 2010 MDA)	NSO
Industry, tertiary, agriculture, energy industries and non-energy use sectors	Value added (at constant pricess in MDA, 2010 as a base year)	Ministry of Finance + economic accounts published by NSO
Transport sector	Average distance traveled (km/year)	APRUE, from Ministry of Transport data
Residential sector	Private household consumption (in constant national currency in MDA, 2010 as a base year)	NSO + APRUE

Source. Prepared by the author.

2.2. Decomposition method

Many studies adopt the decomposition method in order to highlight the different factors that contribute to the EI variation. Among these decomposition techniques, the Index Decomposition Analysis (IDA) method and the Structural Decomposition Analysis (SDA) method. In this publication, we have relied on one of the best-known IDA-based approaches: Fisher's ideal index, which has advantageous properties such as the ability to provide an exact decomposition of the overall EI into an efficiency index (eff) and an activity index (act) without residue (Metcalf, 2008). Under this approach, the energy intensity (e_t) can be represented as a function of two components: the structural effect and the sectoral energy efficiency effect:

$$e_t = \frac{E_t}{Y_t} = \sum_j \frac{E_{jt}}{y_{jt}} \frac{y_{jt}}{Y_t} = \sum_j e_{jt} s_{jt}$$

E_t the aggregate energy consumption, E_{jt} the sector energy consumption, Y_t GDP, y_{jt} measure of sectoral economic activity in year. Thus, the total EI e_t is a function of the sectoral energy efficiency (e_{jt}) and of the activity linked to the sector (the share of each sector in the total value added) (s_{jt}).

The EI index (It) is represented as follows:

$$\text{It = and / =} e_0 \frac{\sum_j e_{jt} s_{jt}}{\sum_j e_{j0} s_{j0}}$$

$e_0$is the total energy intensity of the base year 1990 in our case.

To construct Fisher's ideal index, which provides a perfect decomposition without residuals, we will calculate the geometric mean of the Laspeyres indices (which takes the values of the base year as weights) and Paasche (takes the values of the current year as weights) for the two components:

$$L_t^{eff} = \frac{\sum_j e_{jt} s_{j0}}{\sum_j e_{j0} s_{j0}} P_t^{act} = \frac{\sum_j e_{jt} s_{jt}}{\sum_j e_{jt} s_{j0}}$$
$$P_t^{eff} = \frac{\sum_j e_{jt} s_{jt}}{\sum_j e_{j0} s_{jt}} L_t^{act} = \frac{\sum_j e_{j0} s_{jt}}{\sum_j e_{j0} s_{j0}}$$

Thus the Fisher index is given as follows:

$$F_t^{eff} = \sqrt{L_t^{eff} P_t^{eff}} \; and$$
$$F_t^{act} = \sqrt{L_t^{act} P_t^{act}}$$

$$\frac{e_t}{e_0} = I_t = F_t^{eff} F_t^{act}$$

3. Results and Discussion

3.1. Results using primary energy consumption and Hydrocarbon GDP

During the specified period, Algeria experienced a fairly steady upward trend in energy intensity (Layadi & Senouci, 2022). The underlying drivers of these changes are illustrated in Figure 2, which presents the results of the energy intensity decomposition using index effects, based on 1990.

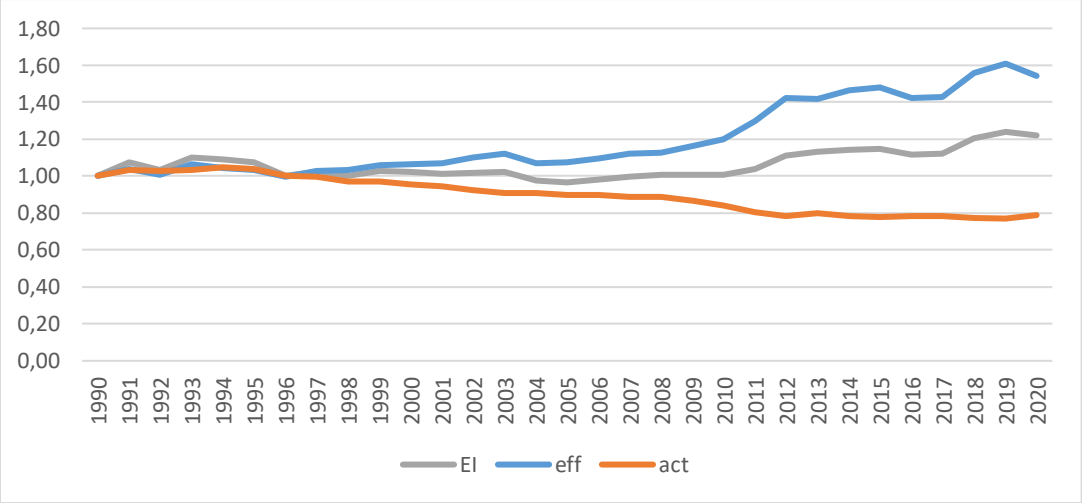


Figure 2
Decomposition of EI in Algeria (1990 base year)

Source. Developed by the author.

For the analysis of the variation in the aggregate energy intensity index and its specific components (using 1990 as the reference year), an index greater than 1 indicates an increase in the effect.

Overall, aggregate energy intensity steadily increased over the study period: in 2019, the index reached 124% of its 1990 level (a rise of 24%), before declining to 122% in 2020. This pattern reflects an increase in energy consumption up to 2019, followed by a reduction in 2020, most likely attributable to the impact of the COVID-19 pandemic. By contrast, between 2003 and 2007, the EI index remained below 1.

On average over the entire period, the index was 6% higher than its base-year level.

The upward trend in aggregate energy intensity and its efficiency component has shown a strong alignment. As illustrated, the overall variation in EI is largely driven by the efficiency effect, which played a key role in the increase of aggregate EI, reaching 161% of its 1990 level in 2019 and 154% in 2020, before a decline in the EI index from 123% to 121% during the COVID-19 year. This indicates that, for most of the period, energy inefficiency prevailed in the economy. In other words, if the structural composition of the economy had remained unchanged, energy inefficiencies within specific activities would have resulted in a deterioration of EI by 61% in 2019 and 54% in 2020 compared to its 1990 level. The only exceptions were during 1994–1996 and 2003–2007, when energy efficiency exerted a reducing effect on EI, particularly in 2004–2006, when the index fell below unity, reaching 97% of its 1990 level in 2004 and 2005, reflecting a slight improvement in EI.

In contrast, the structural effect had a less significant and negative impact on the variation of energy intensity (EI) since 1996. Specifically, the activity component contributed to a reduction in aggregate EI from 1996 until 2019, before exerting a slightly increasing effect in 2020 (the index rose from 77% of its initial level in 2019 to 79% in 2020, representing a 2% difference).

Overall, the increase in EI at the aggregate level of the economy is strongly associated with the efficiency component, which accounts for 96.4% of the total rise in EI. In other words, the deterioration of sectoral energy efficiency is the predominant factor explaining the variation in aggregate EI.

Thus, we conclude that energy use in Algeria has not been efficient. The efficiency effect emerges as the most decisive factor in this relationship, suggesting that efforts to reduce total EI must primarily target the sectoral level. By contrast, changes in the structural composition of the economy did not lead to a considerable increase in EI. Nevertheless, they did contribute, to some extent, to reducing the overall energy intensity of the country.

3.2. Results using final energy consumption and non-hydrocarbon GDP

Figure 3 shows the results of the EI decomposition in the case of considering only final consumption sectors, using index effects, based on the year 1990.

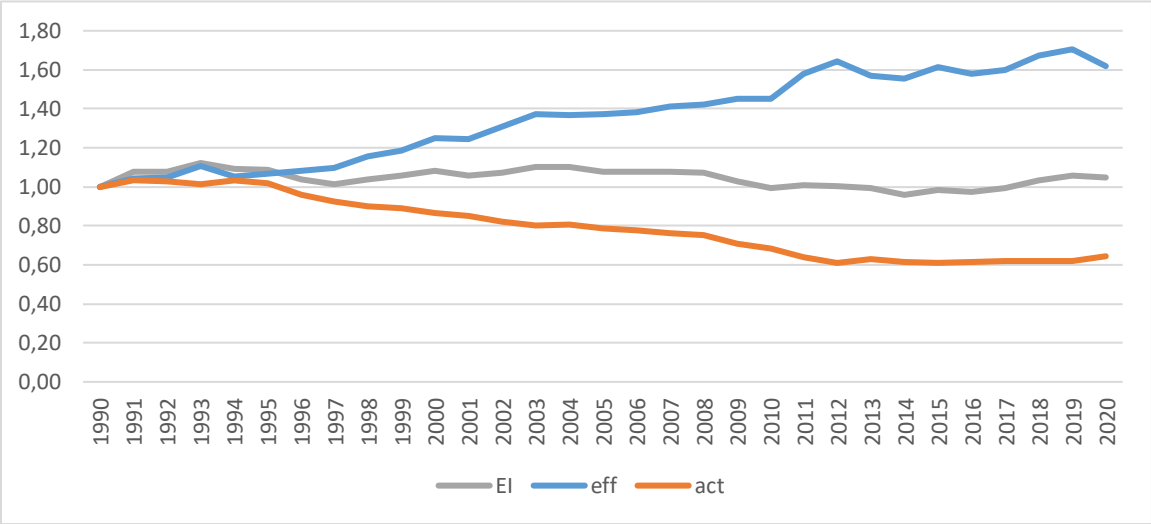


Figure 3

Decomposition of the final EI in Algeria (1990 base year)

Source. Prepared by the author.

Taking 1990 as the base year, the energy intensity (EI) index in this case reached 105% in 2019 and 106% in 2020 relative to its initial level. Over the entire period, starting from the base year, the index was on average 4.48% higher than that of 1990.

The efficiency index stood at 171% and 162% in 2019 and 2020, respectively, compared to its 1990 level. For the activity index, the corresponding values were 62% and 65% (indicating a 3% increase between 2019 and 2020). Thus, in 2020, the efficiency index was 62% higher and the activity index 35% lower than their respective levels in 1990.

The highest value recorded for the efficiency index was 1.71 in 2019, while the activity index peaked at 1.03 in 1994. Hence, if the structural effect had remained constant at its 1990 level across all sectors, energy intensity would have increased by 71% in 2019. The structural effect, however, exerted a negative influence, thereby contributing overall to a reduction in aggregate intensity during the period 1990–2019, and only played a negligible augmenting role thereafter (2019–2020).

The EI index remained above its base-year value for nearly the entire period, as did the efficiency index, whereas the activity index consistently stayed below its initial level. Consequently, the trajectory of the EI index can be seen as being driven much more by efficiency than by activity.

Our results therefore indicate that the rise in EI during the period can largely be attributed to the efficiency component, which accounted for 95.4% of the total variations in EI.

By comparing with the previous graph, it is evident that the rate of increase in EI in the first case is stronger than in the second case. However, throughout the period, the EI index in both cases followed the same overall trend, except between 2003 and 2007, when the indices moved in opposite directions. In the second case (considering only final consumption sectors), the EI index showed an upward trend and remained above unity, whereas in the first case (considering primary energy and thus all sectors), it remained relatively stable, slightly below its initial level.

In terms of energy balance decomposition and methodology, national energy consumption is defined as follows:

National energy consumption = Final consumption (sectors concerned: industry, transport, households, and others) + Consumption by energy industries and non-energy uses (Senouci, 2015).

Accordingly, this difference can be attributed to the energy and non-energy industries sector. The subsequent analysis further confirms and clarifies this finding.

3.3. Trends in energy intensity by sector

For a more in-depth explanation and analysis of the increase in EI, we present the following figure.

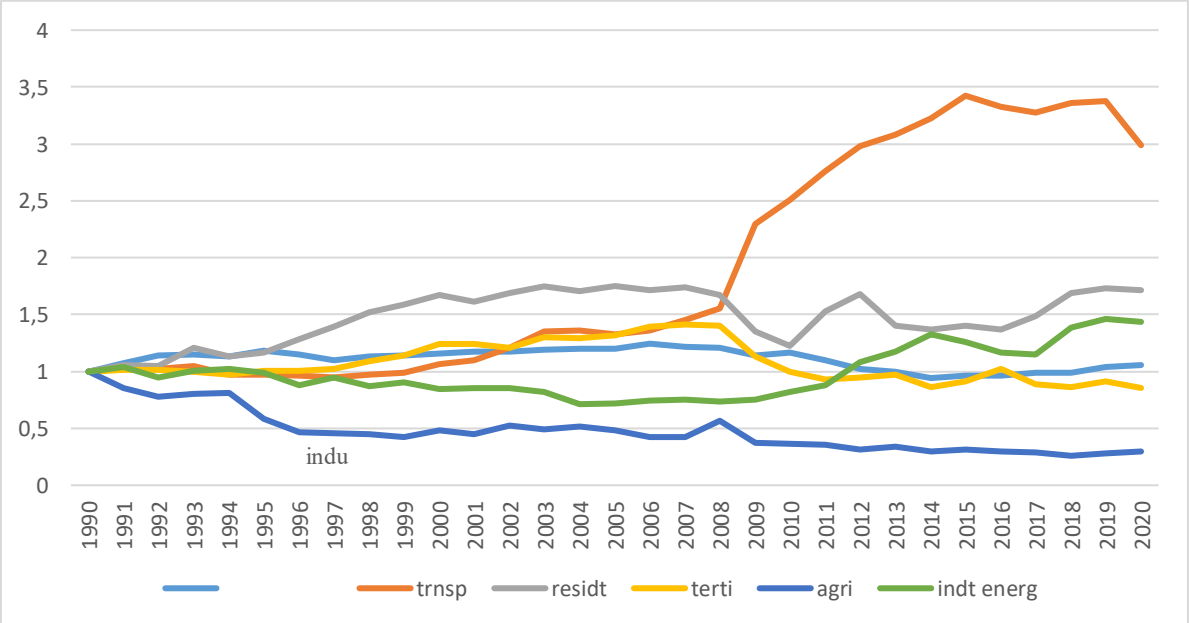


Figure 4

Trends in energy intensity by sectors compared to the 1990 level in Algeria

Source. Prepared by the author.

Thus, the figure shows the evolution of the sectoral energy intensity of all the sectors considered during the study period. Starting in 2008, the transport sector experienced a sharp rise in EI, surpassing the residential sector, which had previously been the most energy-intensive (its index reached 172% of the base-year level in 2020). Before 2008, this trend in the residential sector could be linked to the

widespread but relatively inefficient use of appliances such as cooking stoves and lighting. After 2008, however, the growth of residential EI slowed slightly, which may be attributed to the adoption of more efficient household appliances. It is worth noting that in some years prior to 2008, residential EI had even reached 175% of its 1990 level.

Conversely, the transport sector's energy intensity continued to rise until 2015, reaching 342% of its 1990 level. Between 2016 and 2019, it declined moderately, reflecting the increase in fuel prices observed during this period. A sharper reduction followed in 2019–2020, attributable to the contraction in transport activity during the COVID-19 pandemic, with the index falling to 337% in 2019 and 298% of its 1990 level in 2020.

Between 2006 and 2014, the industrial sector's EI declined before rising again during 2014–2020, reaching 104% in 2019 and 106% in 2020 relative to its base year. The agricultural sector, by contrast, consistently displayed the lowest and steadily declining EI throughout the period.

Between 1996 and 2010, the energy and non-energy industries sector was the only sector that experienced a decline in energy intensity, particularly between 2003 and 2007. All other sectors showed an increase with indices above unity (except for the agriculture sector, which consistently had an EI index below 1). This explains why the reduced EI index values observed in the previous analyses (the first case) can be attributed to the decline in EI within the energy and non-energy industries sector. This decline may be linked to the growth of this sector's share in GDP (hydrocarbon value added) achieved during the same period, which likely contributed to improving its EI ratio.

Thus, within this comparison, and starting from 2010, the energy and non-energy industries sector surpassed both the industrial and tertiary sectors in terms of energy intensity (reaching 143% of its 1990 level, in 2020). In contrast, the tertiary sector experienced a decline in EI, whereas it had remained above unity prior to 2010 (its intensity index in 2020 stood at 85% of its 1990 level). It can therefore be stated that during the period 2010–2016, the increase in EI observed in the first graph was mainly driven by the energy and non-energy industries sector, while the slight decrease in the EI index during the same period in the second graph can be explained by the variations in EI within the tertiary and industrial sectors. From 2017 onwards, however, an increase is observed in both graphs, attributable to the continued rise across all sectors.

Overall, the transport sector, the residential sector, and the energy industries and non-energy use sector were, in that order, the most energy-intensive. They were the main contributors to the increase in Algeria's national energy intensity during the study period, in addition to the industrial sector, whose role was comparatively less significant, particularly toward the end of the period (with sectoral indices exceeding 1, namely 2.99%, 1.71%, 1.43%, and 1.05%, respectively). By contrast, the tertiary sector, and especially the agricultural sector, remained the least energy-intensive.

Conclusion

In this study, we examined the respective contributions of changes in energy efficiency and in economic structure to the overall variation in energy intensity in Algeria, using national and final energy consumption. To achieve this, we decomposed aggregate energy intensity using the Index Decomposition Analysis (IDA), based on Fisher's ideal index, which separates energy intensity into two components: the efficiency index and the activity index.

Our findings show that a large share of the increase in energy intensity over time is associated with inefficient energy use. In other words, the amount of energy consumed per unit of output has risen over the period 1990–2020. By contrast, the activity effect had a negative impact: the gradual shift of the economy towards less energy-intensive activities has contributed to reducing energy intensity, as the structure of the economy has increasingly favored less energy-demanding sectors (the Algerian economy has undergone a process of tertiarization).

More specifically, when considering total national energy consumption (primary energy), about 96.4% of the increase in energy intensity since 1990 can be attributed to the deterioration of energy efficiency. This share decreases slightly to 95.4% when only final energy consumption is considered. Hence, the variation of the EI index in both cases follows a similar trend, except during the periods 2003–2007 and 2010–2016. The difference can be attributed to the EI of the energy industries and non-energy use sector, which declined in the first period—explaining the lower EI index values (index below 1) observed in the analysis using primary energy consumption—and increased in the second period, surpassing the tertiary and industrial sectors, both of which fell below an intensity index value of 1 over the same interval. Consequently, the increase in EI observed in the first case (using primary energy consumption) was mainly driven by the energy and non-energy industries sector, while the slight decrease in the EI index in the second case (using final energy consumption) can be explained by variations in the tertiary and industrial sectors. Beyond this, in the remainder of the period, the rise in energy intensity in both cases can be primarily explained by the continued growth across all sectors, particularly the residential and transport sectors.

These results suggest that Algeria should prioritize reducing energy intensity in key sectors, particularly by improving their energy efficiency. In this regard, the transport and residential sectors remain the most energy-intensive, followed by the energy industries and non-energy use sector. Policies and measures targeting these sectors are likely to have the strongest impact on lowering national energy intensity.

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Chinese Projects in Central Asia

Kamran Shirinzade

Abstract. *This article examines Chinese investment and infrastructure projects in Central Asia, with particular attention to their implications for labour relations in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan. It asks how investment opportunities interact with national institutions, employment practices, and worker representation. The study uses qualitative document analysis and comparative case analysis of scholarly literature, institutional reports, and publicly available project information. The labour-related evidence is primarily historical secondary material, including a 2021 desk study, rather than a new survey of conditions in 2025. The country cases show that Chinese investment supports energy, transport, mining, and industrial cooperation, while reported labour outcomes differ by country, sector, and enterprise. The reviewed sources describe both functioning collective agreements and challenges concerning wage differences, access to information, working time, and union coverage. These observations do not establish uniform practices across Chinese-invested enterprises or a causal effect of investment on labour rights. The article concludes that infrastructure and commercial assessments should be complemented by attention to transparency, social dialogue, and compliance with national labour standards.*

Keywords: *Belt and Road Initiative, Chinese investment, Central Asia, infrastructure, labour relations, trade unions, regional connectivity*

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Mərkəzi Asiyada Çin layihələri

Kamran Şirinzadə

Xülasə. *Bu məqalədə Mərkəzi Asiyada Çin investisiya və infrastruktur layihələri araşdırılır və onların Qazaxıstan, Qırğızıstan, Tacikistan və Özbəkistandakı əmək münasibətlərinə təsirlərinə xüsusi diqqət yetirilir. İnvestisiya imkanlarının milli qurumlar, məşğulluq təcrübələri və işçilərin təmsilçiliyi ilə necə qarşılıqlı əlaqədə olduğu soruşulur. Tədqiqatda keyfiyyətli sənəd təhlili və elmi ədəbiyyatın, institusional hesabatların və ictimaiyyətə açıq layihə məlumatlarının müqayisəli təhlili istifadə olunur. Əməklə bağlı dəlillər əsasən 2025-ci ildəki vəziyyətin yeni bir araşdırması əvəzinə, 2021-ci il masaüstü tədqiqatı da daxil olmaqla tarixi ikinci dərəcəli materialdır. Ölkə nümunələri göstərir ki, Çin investisiyaları enerji, nəqliyyat, mədənçilik və sənaye əməkdaşlığını dəstəkləyir, bildirilən əmək nəticələri isə ölkə, sektor və müəssisə üzrə fərqlənir. Baxılan mənbələr həm fəaliyyətdə olan kollektiv müqavilələri, həm də əmək haqqı fərqləri, məlumata çıxış, iş vaxtı və həmkarlar ittifaqının əhatə dairəsi ilə bağlı çətinlikləri təsvir*

edir. Bu müşahidələr Çin investisiyalı müəssisələr arasında vahid təcrübələr və ya investisiyanın əmək hüquqlarına səbəbli təsirini müəyyən etmir. Məqalədə infrastruktur və kommersiya qiymətləndirmələrinin şəffaflığa, sosial dialoqa və milli əmək standartlarına uyğunluğa diqqət yetirilməsi ilə tamamlanmalı olduğu qənaətinə gəlinir.

Açar sözlər: *Bir Kəmər, Bir Yol Təşəbbüsü, Çin investisiyası, Mərkəzi Asiya, infrastruktur, əmək münasibətləri, həmkarlar ittifaqları, regional əlaqə*

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1. Introduction

The Belt and Road Initiative (BRI) is driven by several interconnected economic, geopolitical and strategic factors. In the context of Central Asia, two major considerations are particularly important. First, Central Asian countries are strategically significant for China because of their abundant natural resources, particularly oil and gas. China, as one of the world's largest energy consumers, seeks stable and uninterrupted access to these resources. Their geographical proximity further increases their importance: three of the countries considered in this study share borders with China. Second, China seeks to expand its external markets and relocate part of its industrial capacity abroad. This is particularly relevant to labour-intensive, low-value-added and environmentally burdensome industries that face increasingly limited opportunities for further expansion within China. Chinese enterprises, especially those operating in traditional industries, therefore have growing incentives to enter foreign markets (Pantucci & Lain, 2017).

The reviewed literature suggests that the BRI should also be viewed as a response to China's domestic economic challenges, particularly the need to gradually move from a low-cost manufacturing model toward higher-value-added production. At the same time, China's external economic activity is not limited to traditional energy and industrial projects. Chinese enterprises export expertise and technologies in hydropower and renewable energy and seek to strengthen their position in Central Asian energy markets.

The financial foundation of the BRI is substantial. According to PwC estimates cited in the literature, the initiative could mobilize up to US$1 trillion in Chinese outbound state financing over a ten-year period, primarily through preferential loans and, to a lesser extent, equity investment. Important institutional mechanisms include the Silk Road Fund, the Asian Infrastructure Investment Bank (AIIB), China's foreign-exchange reserves and major state-owned banks (Taliga, 2021). China's dominant financial position in Central Asia also contributes to the leading role of Chinese enterprises in BRI projects. A significant proportion of Chinese financing remains within the Chinese economic system: loans provided to Central Asian governments may ultimately be used to contract Chinese companies, which frequently supply the equipment, technology and labour required for project implementation. Taliga (2021), referring to a cross-regional study by Building and Wood Workers' International (BWI), reports that more than 60% of China-financed BRI projects were awarded to Chinese companies.

China's regional strategy has generally been characterized by three principles: limited interference in the domestic affairs of partner countries, an emphasis on economic cooperation, and efforts to strengthen China's international reputation (Pantucci & Lain, 2017). This approach has contributed to China's emergence as an important and relatively convenient economic partner in Central Asia. In addition to loans and direct investment, China has provided substantial grants for infrastructure and social projects. Kyrgyzstan received more than US$300 million for road construction and drinking-water infrastructure, while Tajikistan received approximately US$230 million for road rehabilitation.

The BRI is conceived as a long-term initiative, with its implementation potentially extending over several decades. The year 2049 is frequently identified as an important milestone because it coincides with the centenary of the establishment of the People's Republic of China. Consequently, the initiative extends well beyond the simple restoration of historical trade routes. Its contemporary scope encompasses broader economic connectivity and infrastructure development linking China with Central Asia, the Middle East, Europe and other regions (Shirinzade, 2026).

The BRI can therefore be interpreted as an important component of China's long-term economic and foreign-policy strategy and, potentially, as an instrument for restructuring its domestic economic model (Clarke, 2014). Declining export growth, slower domestic and global economic expansion, and the need to shift from investment- and export-led growth toward greater domestic consumption have contributed to its development. China's prolonged emphasis on heavy industry has also generated significant industrial overcapacity.

The BRI provides an external mechanism for absorbing part of this excess capacity through the internationalization of Chinese engineering, construction, equipment, materials and technologies. By expanding transport and economic connectivity across Asia, Europe and Africa, China also expects to stimulate demand for its goods and services and generate longer-term economic growth. The initiative is particularly relevant to less-developed inland Chinese provinces, where improved international connectivity may support economic development and reduce regional disparities.

Domestic stability is another consideration. Improved connectivity with the interior regions, particularly Xinjiang, is intended to strengthen economic integration and regional stability. At the international level, the BRI simultaneously serves China's ambition to increase its economic and geopolitical influence, strengthen relations with neighboring states and expand the international role of Chinese finance and currency.

The geographical and economic scale of the initiative is considerable. Earlier source literature describes approximately 65 countries as being connected to the BRI, representing more than half of the world's population, around 30% of global economic activity and infrastructure investment requirements estimated at approximately US$5 trillion.

The BRI has sometimes been compared with the Marshall Plan because both involve large-scale international infrastructure and economic development initiatives. However, the comparison has important limitations. China presents the BRI as an inclusive and mutually beneficial framework in which participating countries are encouraged to cooperate without the political conditions traditionally associated with external assistance. China also emphasizes that the BRI is not a formal alliance and does not impose political obligations.

Nevertheless, the economic relationship may involve implicit or project-specific conditions, including the use of Chinese labour, equipment and technology, financial obligations and long-term access to

natural resources. At the same time, China's own financial resources are insufficient to meet the entire investment requirement of the BRI. Consequently, cooperation with foreign governments, corporations, investment funds and public-private partnerships (PPPs) is essential for implementing large-scale projects.

The initiative also creates opportunities for non-Chinese companies, particularly in infrastructure-related sectors. Foreign suppliers of technology, equipment, components and raw materials may cooperate with Chinese construction companies in overseas markets. Engineering, procurement and construction firms can similarly establish partnerships with Chinese enterprises and use BRI projects to enter new markets. The Siemens–SEPCOIII cooperation, including a US$1 billion order for a power plant in Saudi Arabia, illustrates the potential for such international partnerships. Such cooperation may also provide foreign firms with access to broader Chinese business networks. Successful cooperation with major Chinese state-owned enterprises (SOEs) can strengthen foreign companies' reputations and facilitate subsequent participation in Chinese and international projects. The Siemens–SEPCOIII case demonstrates how successful overseas cooperation can generate recommendations and additional business opportunities within the Chinese market.

Finally, the BRI may create investment opportunities for private-equity firms and institutional investors. Chinese public financing, guarantees and state support can improve the risk-return profile of infrastructure projects in emerging markets, while state-owned enterprises may benefit from substantial government backing. China's state-owned policy insurance mechanisms may additionally provide protection against certain political and social risks associated with overseas projects.

This article examines how Chinese projects combine infrastructure and economic objectives with country-specific labour relations. It compares the four country cases and considers the limits of drawing general conclusions from historical secondary evidence.

The literature approaches these questions from complementary perspectives. Shambaugh (2013) examines China’s global role, while Laruelle (2015) analyses the US use of the Silk Road concept, providing a comparative policy context rather than direct evidence for Chinese financing. Regional studies examine investment opportunities, institutional constraints, and differing local perceptions (Aminjonov et al., 2019; Hoh, 2019; Jochec & Jenish Kyzy, 2018; Manish & Behera, 2024; Owen, 2020; Vakulchuk & Overland, 2019; Wolters, 2018). World Bank (2019, 2020) reports provide transport and country-level economic context. Azerbaijan-focused work is used only for the wider connectivity discussion (Shirinzade, 2023, 2026).

2. Materials and Methods

This study employs a qualitative research methodology to examine the role, objectives, and implications of Chinese projects in Central Asia. The research focuses on China's economic, infrastructural, energy, transportation, and connectivity projects in Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan, with Turkmenistan considered only as part of the regional transit context. Particular attention is given to projects associated with the Belt and Road Initiative (BRI), while also considering Chinese investments and bilateral cooperation that operate outside the formal BRI framework.

The study adopts a qualitative case-study design combined with comparative analysis. A case-study approach is appropriate because Chinese engagement in Central Asia involves diverse projects with different economic, political, geographic, and strategic characteristics. The comparative dimension

allows the research to identify similarities and differences in China's engagement across the four country cases.

The analysis examines Chinese projects through four principal dimensions: economic, infrastructural, political-diplomatic, and strategic-security. The economic dimension considers trade, foreign direct investment, financing, employment, industrial cooperation, and access to natural resources. The infrastructural dimension focuses on transport corridors, railways, roads, energy infrastructure, pipelines, logistics facilities, and telecommunications. The political-diplomatic dimension examines bilateral relations, intergovernmental agreements, diplomatic initiatives, and institutional cooperation. The strategic-security dimension considers connectivity, regional stability, border security, energy security, and China's broader interests in Central Eurasia.

The research is based primarily on secondary data obtained from academic literature, official government documents, international organizations, research institutes, and reputable policy publications. Primary documentary sources include statements and policy documents published by the Chinese government, the governments of Central Asian states, and relevant Chinese and regional institutions.

Academic sources include peer-reviewed journal articles, books, edited volumes, and scholarly studies addressing Chinese foreign policy, the BRI, Central Asian geopolitics, infrastructure development, geoeconomics, and China–Central Asia relations. Reports from international organizations and research institutions are used to obtain information concerning investment, trade, infrastructure development, energy cooperation, and regional connectivity. Where available, project-level information is examined in order to identify the project's location, sector, financing structure, participating institutions, implementation period, and intended economic or strategic objectives. The study also considers publicly available statistical data concerning trade, investment, infrastructure, and energy cooperation.

The study uses thematic content analysis to identify recurring patterns in China's Central Asian projects. Documents and scholarly literature are examined according to several analytical categories: project objectives, sector, financing mechanisms, participating actors, expected benefits, implementation challenges, and broader implications. The research also applies a geoeconomic perspective to examine how economic instruments and infrastructure projects can contribute to broader foreign-policy objectives. This approach does not assume that all Chinese projects are primarily geopolitical. Instead, it investigates the interaction between economic interests, connectivity objectives, diplomatic relations, and strategic considerations.

A comparative analysis is subsequently used to determine whether China's engagement demonstrates common patterns across Central Asia or whether project objectives and outcomes vary according to individual country conditions. The collected material is analyzed through qualitative interpretation and cross-case comparison. First, relevant Chinese projects are categorized according to sector and country. Second, their stated objectives and implementation mechanisms are examined. Third, the economic and political implications of these projects are compared across the four country cases.

The study distinguishes between officially stated objectives and interpretations offered by academic and policy literature. This distinction is important because Chinese government documents generally emphasize principles such as mutual benefit, connectivity, development, and cooperation, whereas some external analyses interpret particular projects in terms of China's geopolitical, economic, or strategic interests. Presenting these perspectives separately helps avoid treating contested interpretations as established facts.

The labour-related country accounts rely substantially on Taliga (2021), which reports research conducted in 2020. Interviews and statements attributed to union officials in that report are treated here as secondary evidence; no original interviews, fieldwork, or new employee survey are claimed. Historical project, workforce, and policy figures retain their source-period meaning and are not presented as a verified inventory of conditions in late 2025.

3 Results

3.1 Chinese investment in Kazakhstan

In the historical account reviewed by Taliga (2021), the Kazakh government had reported, since 2015, more than 50 Chinese investment projects, including joint ventures in mining, chemicals, and petrochemicals. For several years, authorities declined to release a full project list despite requests from policy specialists and environmental organisations, referring to commercial confidentiality. In September 2019, Kazakhstan Invest JSC—established in 2017 as the successor to the national investment and export agency KAZNEX INVEST—published an overview of 55 joint Kazakh–Chinese projects with a combined value of US$27.6 billion. According to that review, 15 projects had been completed, 11 were under implementation, and 29 remained under consideration.

Oil and gas constitute a major area of cooperation, with numerous joint ventures involving Chinese shareholders. A key participant is China National Petroleum Corporation (CNPC), a large state-owned energy company with operations and interests in more than 30 countries. CNPC acquired a stake in Aktobe Munay Gas in 1997 and holds 85.42% of its shares. In Kazakhstan, the company has participated in oil-field development and in the construction of oil and gas pipelines, including the Kazakhstan–China oil pipeline and the Kazakhstan–China gas pipeline. Aktobe Munay Gas operates in northern Kazakhstan and employs approximately 6,300 permanent workers. The source material reports that 88 employees were Chinese, compared with 124 before the COVID-19 pandemic in 2020. The company's trade union is described as maintaining a constructive relationship with management and having concluded eight collective agreements since 2000. Taliga (2021) identifies the collective agreement applicable to the reporting period as covering 2017–2020.

Another major CNPC-related enterprise in Kazakhstan is PetroKazakhstan, whose ownership is divided between CNPC (67%) and the national company KazMunayGas (33%). Its activities include acquiring, exploring, developing, and producing oil and gas fields—particularly the Kumkol field in the Kyzylorda region—as well as selling oil and refined petroleum products.

Interview accounts reproduced by Taliga (2021) suggest that investment retention, commercial objectives, and worker representation can create differing institutional priorities. The authorities appear keen to retain CNPC as a major investor. However, the extent to which state agencies monitor foreign-owned companies is difficult to establish, particularly during the COVID-19 pandemic, when labour inspections concerning employment, environmental, and other matters were suspended.

3.2 Chinese projects and labour relations in Kyrgyzstan

The Kyrgyzstan case reviewed by Taliga (2021) covers Chinese participation in energy infrastructure, oil refining, and mining. In 2019, Sino-Pipeline International Company began construction of the Kyrgyz section of Line D of the Central Asia–China gas pipeline. Chinese companies also built two refineries in the north of the country: Kara-Balta, with an approximate annual capacity of 800,000 tonnes, and Tokmok, with a capacity of 450,000 tonnes. Both facilities reportedly operated below capacity because

of limited crude-oil supplies. The Kara-Balta refinery suspended operations following the outbreak of the COVID-19 pandemic. Before the shutdown, it employed approximately 775 people, including around 500 local workers, with the remainder coming from China.

Chinese investors are also active in mining and quarrying. According to the reported figures, Kyrgyzstan had 11 companies operating mines and quarries that each employed at least 500 people; four were owned by Chinese investors. Zijin Mining Group, a major Chinese mining company, holds a 60% stake in Altynken LLC, which operates the Taldybulak Levoberezhny gold deposit, described in the source as Kyrgyzstan's third-largest gold mine. Commercial production began in July 2015, and output reached 133,335 ounces of gold in 2019. In June 2019, Kyrgyzstan's Investment Support and Protection Agency signed a framework agreement with Daren Group, Lingbao Gold Group, and Full Gold Mining to develop a new gold-recovery facility.

E. Tadjibaev, identified in Taliga (2021) as chairman of the Trade Union of Miners and Metallurgists of Kyrgyzstan, reported that trade unions were present in three of the four Chinese-owned companies and represented approximately 90% of their employees. Unionisation was more difficult in subcontracting firms, which often operated for only six to twelve months. Chinese investors reportedly preferred to use subcontractors from China where possible. Establishing a union in a Chinese-invested company was not generally described as impossible: although employers did not actively support unionisation, they did not necessarily obstruct it. A significant proportion of locally recruited employees were skilled workers familiar with trade unions, although the requirement to pay union dues discouraged some from joining.

Despite the legal authority of a trade union to operate once established, Chinese-owned companies were reportedly reluctant to recognise unions before their formal registration. Several years earlier, protests had taken place at the Chinese-operated Orlovka gold mine after the company allegedly failed to comply with a government requirement that at least 90% of its workforce be local. Workers also demanded equal pay and employment contracts consistent with Kyrgyz labour legislation for both local and foreign employees.

One explanation offered by the company for differences in wages was that Chinese workers lived far from their homes and families and therefore faced circumstances that were not directly comparable with those of local employees. Trade unions raised concerns with local authorities, the Labour Inspectorate, and the Ministry of Labour, Employment, and Migration. According to the source, Chinese employers were reluctant to provide wage supplements for night work, hazardous conditions, high-altitude employment, or rotational work involving travel to camps, despite such payments being required under the Labour Code. Employers also argued that local workers' wages were already above the national average. Trade union representatives maintained that legally required allowances should be paid in all cases, even if this affected the basic wage structure.

Taliga (2021) reports that some investors referred to differences between home-country practices and host-country labour requirements when explaining their employment arrangements. Employers also pointed to Chinese workers' willingness to accept company-established schedules and conditions. Disagreements reportedly concerned 12-hour shifts in place of the standard eight-hour day and lunch breaks limited to 15 minutes. These accounts indicate potential tensions between company practices, workers' expectations, and the requirements of national labour law.

3.3 Chinese investment in Tajikistan

In the Chinese–Tajik joint ventures described by Taliga (2021), the Chinese partner commonly provides most of the capital, while the Tajik side facilitates land allocation, permits, and regulatory approvals. The government has also offered tax concessions or land at no cost in some cases. Private investment projects require state approval, and the Tajik authorities have presented Chinese companies as attractive partners in the mining sector because of the anticipated benefits they bring.

Nevertheless, observers have raised concerns about the consistency with which investment legislation is applied. In October 2019, reports described tax exemptions granted by the Tajik parliament to Chinese companies investing in the country. TBEA, a company active in power generation and renewable-energy construction, received tax concessions on imported equipment and technology for the development of the Upper Kumarg deposit in Sughd Region and the East Duoba deposit in Ayni District. The concessions were reportedly linked to the period required for the company to recover its US$331 million investment in a 400-megawatt power plant in Dushanbe, financed through a preferential loan from China Eximbank.

These examples illustrate the close relationship between investment attraction, state facilitation, and negotiated financial incentives. They also raise questions about transparency, the distribution of benefits, and the degree to which public authorities consistently apply domestic rules to foreign-invested projects.

3.4 Chinese investment and infrastructure in Uzbekistan

According to China Investment Monitor figures reproduced in Taliga (2021), Chinese investments and contracts in Uzbekistan between 2013 and 2020 totalled US$2.24 billion. The reported breakdown included US$720 million in real estate, US$560 million in transport, US$440 million in chemicals, and US$340 million in energy. Other Uzbek sources estimated Chinese foreign direct investment at US$3.9 billion over the preceding three years, while the government set a target of increasing annual Chinese investment to US$5 billion by 2025. These figures come from different reporting bases and should therefore not be treated as directly interchangeable.

At the beginning of 2020, Uzbekistan hosted 1,652 enterprises with Chinese investment, representing 16% of all enterprises with foreign participation. Of these, 531 had been established in 2019, and more than 120 were wholly Chinese-owned. According to the Federation of Trade Unions of Uzbekistan (FTUU), only 15 Chinese-invested enterprises had trade unions. In an effort to attract foreign direct investment, Uzbekistan established an agency dedicated to attracting foreign investors and introduced tax exemptions for residents of free economic zones. Under the reported scheme, investments above US$10 million qualified for a ten-year exemption; investments between US$5 million and US$10 million for seven years; those between US$3 million and US$5 million for five years; and investments between US$0.3 million and US$3 million for three years. In December 2019, the government also decided to open a representative office of the Ministry of Investment and Foreign Trade in China to facilitate engagement with prospective investors.

Uzbekistan’s economic relationship with China initially centred on the export of strategic raw materials, including natural gas, copper, cotton fibre, and mineral fertilisers. Gas transportation has also been important. Although Uzbekistan’s own hydrocarbon reserves are described as relatively limited, the country has a significant transit role in transporting Turkmen gas to China. In addition to the existing pipeline through Kazakhstan, plans were reported for a 210-kilometre section of the D-line connecting Turkmenistan with China.

Over time, cooperation has broadened to include transport connectivity and energy infrastructure. The China Railway Tunnel Construction Group upgraded the Andijan–Pap–Angren–Tashkent railway section, one of the routes associated with the Silk Road Economic Belt. The work included construction of the 19-kilometre Kamchik Tunnel and railway electrification between 2013 and 2016. In October 2020, regular rail freight services were launched between Hebei Province, near Beijing, and Tashkent, with reports indicating at least 12 departures per week from Hebei.

Chinese investment has also extended into industry, telecommunications, pharmaceuticals, agriculture, and water management. For Uzbekistan, this diversification forms part of a broader ambition to move away from an economic model centred on raw-material exports and towards the production and export of goods with greater added value. Chinese firms have participated in the development of joint high-technology industrial parks. In late August 2019, the two governments signed an agreement to establish a joint investment fund with authorised capital of US$1 billion, intended to support high-technology projects in the chemical and petrochemical industries and production facilities in the oil and gas sector.

Other proposed Uzbek–Chinese projects have included power plants and wind turbines in Navoi, Samarkand, and Bukhara, reportedly valued at US$720 million; hydrocarbon production projects valued at US$600 million; further development of the Uzbekistan–Kyrgyzstan–China transport corridor; railway construction; logistics centres along the Andijan–Osh–Irkeshtam–Kashgar route; and the construction of the Kamchik highway tunnel. As Owen (2020, p. 266) notes in the source cited, Uzbekistan's objective is not simply to function as a transit territory for Chinese manufactured goods. It also seeks to become an industrial and transport hub serving other Central Asian countries and Afghanistan.

Public attitudes towards Chinese investment in Uzbekistan have reportedly been more favourable than in neighbouring Kazakhstan and Kyrgyzstan. One possible explanation is that Uzbekistan's closer economic engagement with China developed more recently, following the launch of economic reforms under the country's new leadership in September 2016. Central Asia Barometer survey results cited by Taliga (2021) indicated that in 2019, 65% of respondents in Uzbekistan strongly supported Chinese investment in national energy and infrastructure, compared with 7% in Kazakhstan and 9% in Kyrgyzstan. In 2020, the share of strong supporters in Uzbekistan declined to 48%. At the same time, the proportion of Uzbek respondents who were very concerned that Chinese development projects could increase external debt rose from 7% to 25%.

3.5 Trade unions and labour conditions in Uzbekistan

The situation of social partnership in Chinese-invested enterprises in Uzbekistan appears mixed. Despite the large number of such companies, only around 1% reportedly had a trade union, even though a new Trade Union Law that took effect in March 2020 simplified the registration of primary trade union organisations. Where unions had been established, Chinese employers were not generally reported to oppose them and were willing to sign collective agreements.

According to the historical account in Taliga (2021), the FTUU reported that, over the three years preceding that report, it had received no information from member organisations about labour conflicts or individual employment disputes in Chinese companies. Chinese investors were said to comply with Uzbek labour legislation. Although wage differences between foreign and local workers existed, union representatives did not identify them as a major problem requiring separate intervention. Issues concerning Chinese investors were generally handled directly between workplace-level unions and employers rather than being raised by the federation as a broader policy concern. This position is

discussed in the secondary source in connection with the government's emphasis on attracting foreign direct investment, creating jobs, and accelerating economic growth (Taliga, 2021).

4. Discussion

4.1 Geopolitical context and the role of external actors

Central Asia's strategic environment is shaped by the involvement of multiple external powers. In addition to China, the principal actors include Russia, the United States, the European Union, India, Japan, South Korea, and Türkiye. T. Umarov of the Carnegie Moscow Center, as cited in Taliga (2021), has highlighted the complexity of this environment and the importance of regional states' efforts to preserve balanced relations with external partners. In this context, some Central Asian governments regard Russia as a potential counterweight to China's growing economic presence.

Russia remains one of China's principal geopolitical counterparts in Central Asia because of its substantial political, security, and economic influence. The reviewed literature presents Moscow as an important actor in the regional security sphere. Nevertheless, Russia is not an equivalent economic competitor to China in the region. The structure of the Russian economy limits its capacity to become a major market for Central Asian raw materials, while China's demand for energy and other resources gives it a distinct economic position.

Consequently, the relationship between China and Russia in Central Asia is not necessarily characterised by direct competition across every policy area. A practical division of roles has often been observed: Russia retains considerable influence over regional security, while China places greater emphasis on trade, investment, and economic development. The United States has also been an important external actor, although the reviewed accounts describe variation in the scope and timing of its regional engagement.

The European Union remains an important investor in Central Asia, but China's economic role has continued to expand. On 17 June 2019, the EU adopted its strategy, *The EU and Central Asia: New Opportunities for a Stronger Partnership*, which prioritises resilience, prosperity, and regional cooperation. In December 2020, the EU Special Representative for Central Asia convened the online forum *EU–Central Asia Dialogue on Partnership for Prosperity*. The event brought together senior representatives of the European Commission, deputy prime ministers and trade and economy ministers from Central Asian states, as well as nearly 200 public- and private-sector participants from the EU and the region. Despite these diplomatic and economic initiatives, the United States and EU member states face constraints in matching China's role in regional trade and investment. Their capacity to offer an alternative security presence is also limited. Regional governments have approached NATO's military presence cautiously, while expanded Western military involvement could affect the security interests of Moscow and Beijing.

4.2 The Belt and Road Initiative as a strategic framework

The Belt and Road Initiative (BRI) should be understood not only as a programme for international infrastructure development but also as a central component of China's domestic and foreign-policy strategy. It supports Beijing's longer-term ambitions and forms part of the country's broader "going global" approach. The action plan developed by China's Ministry of Foreign Affairs, the National Development and Reform Commission (NDRC), and the Ministry of Commerce articulated the initiative's general direction. In its initial form, however, the plan was closer to a strategic vision than to

a detailed implementation blueprint; its broad scope left considerable flexibility in how individual projects could be designed and carried out.

China established a dedicated coordinating office under the NDRC to oversee BRI-related implementation. The initiative was also supported by a substantial financing framework. An estimate by PwC suggested that BRI could mobilise as much as US$1 trillion in Chinese state-backed overseas financing over a ten-year period. Such support was expected to take the form primarily of concessional lending, supplemented by equity investment. The financing architecture included the Silk Road Fund, the Asian Infrastructure Investment Bank (AIIB), foreign-exchange resources, and major Chinese state-owned banks.

The initiative was conceived as a long-term undertaking, potentially extending over three or four decades. The year 2049 is frequently cited as a significant milestone because it marks the centenary of the founding of the People's Republic of China. Although BRI is often presented as an effort to revive historical trade routes, its objectives extend well beyond the restoration of former links between China, Central Asia, the Middle East, and Europe. It combines transport connectivity with wider economic, industrial, and geopolitical ambitions. In this sense, BRI is closely linked to China's long-term development strategy and international engagement. It has been presented as a means of shaping domestic economic development while expanding China's role abroad; some analysts have also interpreted it as a potential instrument for restructuring aspects of the Chinese economy.

4.3 Economic motivations behind the BRI

Several domestic and international economic pressures help explain the launch and expansion of BRI. These include weaker export performance, subdued economic growth in China and globally, and the need to move towards a more consumption-oriented growth model rather than relying predominantly on government investment and exports. China's development model, combined with sustained support for heavy industry, contributed to excess production capacity in a number of sectors. Government intervention has been a significant feature of this process, and Chinese authorities identified multiple industries in which measures were required to curb further overproduction.

Against this background, overseas infrastructure and industrial projects can create outlets for Chinese capital, technology, equipment, and construction capacity. They can also strengthen access to energy and other raw materials and deepen China's economic links with neighbouring states. These objectives do not necessarily explain every project individually, but they provide a useful framework for examining the expansion of Chinese investment across Central Asia.

4.4 Cross country patterns and labour representation

Across Central Asia, governments have introduced measures to attract additional foreign direct investment, while the extent of their dependence on Chinese capital varies. In some circumstances, this dependence has been characterised as investment pursued under constrained alternatives. Publicly available information about Chinese investment remains limited both at the macroeconomic level and at the level of individual companies (World Bank, 2019). Obtaining details about a particular project often requires a formal request to the relevant authorities, which determine what information can be disclosed and how much detail can be provided. At the enterprise level, trade unions may have little access to performance data because companies classify it as confidential.

Foreign-owned businesses may also apply management practices familiar from their home markets. Where trade unions and workers have limited bargaining power, investors may have an incentive to meet only the minimum requirements of local labour legislation. The source material suggests that managers of Chinese enterprises can be reluctant to engage in social dialogue, particularly at newly established workplaces. However, these observations should not be generalised to every company or country: labour relations differ according to the national legal framework, sector, company, and strength of local institutions.

Employment quotas for local workers have gradually been introduced in Central Asian countries, with reported requirements generally ranging from 70% to 90%, depending on the country and industry. Compliance is not always assured (Taliga, 2021). Wage disparities between Chinese and locally recruited workers have been justified in different ways. Employers may argue that Chinese employees are separated from their families or that local workers already earn more than the official minimum wage. Such explanations can complicate collective bargaining when unions lack access to reliable data on pay structures and employment conditions.

The bargaining position of trade unions is weakened by several interrelated factors. Wages and tariff rates may be determined unilaterally by employers rather than negotiated collectively. Unions may not receive the information needed to develop evidence-based wage demands, while differences in pay policies among subsidiaries of the same investor can make comparisons difficult. Collective agreements may simply reproduce legal requirements for bonuses and additional compensation—such as payments for overtime and night work—without establishing benefits beyond the statutory minimum. In these circumstances, unions may focus on securing non-monetary benefits and preventing workplace disputes rather than achieving substantial improvements in remuneration.

Trade unions' limited engagement with the wider economic and political implications of Chinese investment may reflect their immediate institutional priorities. Their day-to-day work is generally concentrated on working conditions, compliance with labour law, collective bargaining, and workplace issues. Their engagement may also be shaped by national policies that prioritise the attraction of foreign investment (Taliga, 2021).

4.5 Limitations

The study is a qualitative synthesis of selected secondary material and does not provide a representative sample of Chinese-invested enterprises or workers. Much of the project and labour evidence concerns 2019–2020 and cannot establish current conditions. The original sources use different definitions of investment, contracts, project completion, and enterprise participation, so their totals are not directly comparable. Reported interviews and survey results have not been independently replicated. Turkmenistan is discussed in relation to regional transit but is not a separate country case. Source selection dates, a complete documentary corpus, and an independent coding procedure are not available in the supplied material. These limits restrict causal inference and generalisation.

5. Conclusion

Chinese investment in Central Asia is shaped by a combination of economic, geopolitical, and strategic considerations. The BRI provides a broad framework for expanding transport connectivity, securing access to natural resources, supporting overseas commercial activity, and strengthening China's regional influence. Kazakhstan, Kyrgyzstan, Tajikistan, and Uzbekistan have each pursued cooperation with

Chinese companies, but the scale, sectoral distribution, and institutional conditions of that cooperation differ.

The country cases indicate that investment can support infrastructure development, energy production, mining, transport links, and industrial diversification. At the same time, questions remain concerning transparency, public oversight, the consistent application of national legislation, and the distribution of benefits. Labour relations are similarly varied. Some Chinese-invested enterprises have functioning trade unions and collective agreements, whereas in others union coverage is limited or workers face difficulties related to wage disparities, employment contracts, overtime, and additional compensation.

The evidence presented does not establish that all Chinese investment in the region is economically unsustainable or that labour practices are uniform across Chinese-owned enterprises. Rather, it points to the importance of evaluating projects through multiple criteria, including commercial performance, access to resources, employment creation, security and political cooperation, transparency, and compliance with labour standards. The reviewed synthesis suggests that China may assess the value of its regional investments according to objectives that extend beyond immediate economic returns, including access to natural resources, employment, military and security advantages, and political cooperation. Future assessments should therefore combine economic analysis with country-specific examination of governance, environmental oversight, and the effectiveness of labour institutions.

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Information as a Strategic Resource in Contemporary Society a Socio Philosophical Model of Responsible Value Creation

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Abstract. *Information is frequently described as a strategic resource, but the analogy with material resources is incomplete. Information can be copied without depletion, becomes valuable through interpretation and use, and may generate public benefit and social harm at the same time. This article asks under what conditions information functions as a legitimate strategic resource in contemporary society. A structured conceptual review of twelve foundational academic and institutional sources was conducted across information philosophy, data studies, privacy theory, political economy, and digital governance. The sources were compared through five dimensions: value creation, epistemic quality, access, power, and accountability. The analysis distinguishes data, meaningful information, actionable knowledge, and strategic judgement rather than treating them as equivalent assets. It identifies four conditions of responsible strategic use: epistemic reliability, contextual legitimacy, capability-enhancing access, and accountable institutional stewardship. These conditions form an Information Stewardship Model that explains why technical accumulation alone does not create social value. Poor-quality data, opaque inference, excessive concentration, and weak correction mechanisms can convert an apparent asset into a source of vulnerability. Conversely, information produces durable value when institutions verify provenance, protect contextual privacy, broaden meaningful access, explain consequential uses, and preserve channels for correction. The article concludes that information should be governed neither as ordinary private property nor as an unrestricted public good. Its strategic status depends on a balanced institutional architecture linking innovation, rights, trust, and collective learning.*

Keywords: *information; strategic resource; data governance; information ethics; privacy; digital society; institutional stewardship*

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Müasir cəmiyyətdə strateji resurs kimi informasiya: məsuliyyətli dəyər yaradılmasının sosial-fəlsəfi modeli

Olimxodjayev Fayyozxo‘ja

Xülasə. *İnformasiya çox vaxt strateji resurs kimi təqdim olunur, lakin onun maddi resurslarla eyniləşdirilməsi natamamdır. İnformasiya tükənmədən çoxaldıla bilir, dəyəri şərh və istifadə prosesində yaranır, eyni zamanda ictimai fayda və sosial zərər yarada bilər.*

Məqalə informasiyanın müasir cəmiyyətdə hansı şərtlər daxilində legitim strateji resursa çevrildiyini araşdırır. İnformasiya fəlsəfəsi, məlumat tədqiqatları, məxfilik nəzəriyyəsi, siyasi iqtisad və rəqəmsal idarəetməyə aid on iki fundamental akademik və institusional mənbə strukturlaşdırılmış konseptual təhlillə müqayisə edilmişdir. Mənbələr dəyər yaratma, epistemik keyfiyyət, çıxış, hakimiyyət və hesabatlılıq üzrə təhlil olunmuşdur. Tədqiqat məlumatı, mənalı informasiyanı, praktik biliyi və strateji mühakiməni bir-birindən fərqləndirir. Məsuliyyətli strateji istifadənin dörd şərti müəyyən edilir: epistemik etibarlılıq, kontekstual legitimlik, imkanları genişləndirən çıxış və hesabatlı institusional himayədarlıq. Bu şərtlər texniki toplanmanın öz-özlüyündə sosial dəyər yaratmadığını göstərən İnformasiya Himayədarlığı Modelini təşkil edir. Keyfiyyətsiz məlumat, qeyri-şəffaf nəticəçıxarma, həddindən artıq mərkəzləşmə və zəif düzəliş mexanizmləri görünən resursu zəiflik mənbəyinə çevirə bilər. Əksinə, mənşə yoxlanıldıqda, kontekstual məxfilik qorunduqda, mənalı çıxış genişləndirildikdə və düzəliş kanalları saxlanıldıqda informasiya davamlı dəyər yaradır. Nəticədə informasiyanın nə adi xüsusi mülkiyyət, nə də məhdudiyyətsiz ictimai nemət kimi idarə olunmasının yetərli olmadığı əsaslandırılır.

Açar sözlər: *informasiya; strateji resurs; məlumatların idarə edilməsi; informasiya etikası; məxfilik; rəqəmsal cəmiyyət; institusional himayədarlıq*

Introduction

Information is routinely called the oil, currency, or infrastructure of the digital age. Each metaphor captures part of its importance but can obscure its distinctive character. Oil is depleted when consumed, whereas information can be copied and used by many actors at once. Currency has a standard unit, whereas informational value varies with context, quality, interpretation, and timing. Infrastructure enables activity, yet information also shapes the goals, classifications, and decisions through which activity is organised. A defensible account of information as a strategic resource must therefore explain not only how information is accumulated, but how it becomes meaningful, actionable, legitimate, and correctable.

The growth of networked communication has intensified this question. Economic production, public services, scientific research, education, and everyday social coordination increasingly depend on data flows and digital systems. Castells (2010) describes a social morphology organised through networks, while Bell (1973) identified the expanding role of theoretical knowledge in post-industrial society. More recent analyses show that the capacity to collect and process data can support innovation, productivity, and public problem solving (Organisation for Economic Co-operation and Development [OECD], 2015). Yet the same capacity can intensify surveillance, asymmetrical influence, discrimination, and dependence on opaque systems (Zuboff, 2019).

The strategic-resource thesis is thus normatively ambivalent. It can direct attention to information quality, digital infrastructure, institutional memory, and knowledge-based decision making. It can also legitimise unlimited collection by treating every trace of human activity as extractable raw material. The language of resource management tends to privilege possession and optimisation, while questions of consent, privacy, epistemic justice, and public accountability appear as secondary constraints. Information ethics challenges this ordering by treating the informational environment as a domain in which human agency and social relations are constituted, not merely an inventory available for exploitation (Floridi, 2013, 2014).

A second difficulty concerns the unstable relationship among data, information, knowledge, and judgement. These terms are often merged in policy and management discourse. Data may be inaccurate, incomplete, or stripped of the context that gives it meaning. Information may be relevant but still fail to justify a conclusion. Knowledge requires warranted interpretation, while strategic judgement additionally requires an understanding of goals, trade-offs, uncertainty, and responsibility. Large volumes of data therefore do not automatically produce knowledge or sound decisions (Kitchin, 2021). Quantity can even conceal uncertainty by making weak inferences appear technically authoritative.

This article asks: under what conditions does information function as a legitimate strategic resource for contemporary society? Its purpose is to develop a socio-philosophical model that connects value creation with epistemic reliability, rights, human capability, and institutional accountability. The article rejects two simplifications: that more information is always better, and that control over information is equivalent to strategic capacity. It argues instead that information acquires durable strategic value only when institutions can verify it, interpret it contextually, distribute its benefits fairly, and correct its harmful uses.

Materials and Methods

The study uses a structured conceptual review rather than an empirical survey. Twelve foundational academic and institutional sources were selected purposively across five intersecting fields: the information society, data studies, information ethics, privacy theory, and public data governance. The selection includes works that explain the historical growth of information-based social organisation, the distinctive properties of data and information, the political economy of extraction, and institutional principles for responsible use. The aim was not bibliometric completeness but conceptual coverage of the central tensions in the research question.

Each source was examined through five analytical dimensions. Value creation concerned the mechanism through which information generates economic, administrative, scientific, or social benefit. Epistemic quality concerned accuracy, provenance, relevance, interpretation, and uncertainty. Access concerned who can obtain, understand, and use information. Power concerned the ability to collect, classify, predict, and influence. Accountability concerned consent, transparency, contestability, remedy, and institutional responsibility. A comparative matrix was used to identify areas of convergence and contradiction.

The analysis proceeded in three stages. First, the resource metaphor was tested against the non-rival, context-dependent, and relational properties of information. Second, a value chain was reconstructed from raw data to strategic judgement, with failure points identified at each transition. Third, normative and institutional conditions were synthesised into an Information Stewardship Model. The model is analytical rather than causal: it proposes relationships to be examined empirically and does not claim measured effects for any specific country or organisation.

No empirical survey findings are used in this study. A defensible survey-based claim would require a documented questionnaire, sampling frame, fieldwork dates, descriptive statistics, data-access statement, and appropriate ethical information. In the absence of a verifiable dataset meeting those conditions, the conclusions in this article are explicitly limited to conceptual synthesis and documented institutional principles.

AI-assisted drafting disclosure: generative AI was used to assist with English translation, structural organisation, and language editing. The author remains responsible for verifying all arguments, references, and formulations before submission.

Results

1. Information Is a Relational Resource

The first result is that information cannot be governed adequately through the logic of possession alone. Its value is relational: the same informational content may be decisive in one setting, irrelevant in another, and harmful when removed from context. A weather observation, health record, location trace, and historical archive have different value structures because their users, purposes, temporal horizons, and risks differ. The strategic importance of information therefore lies not in its mere existence but in the institutional capacity to connect trustworthy content to legitimate action.

Information also differs from conventional resources because use does not necessarily consume it. This non-rival feature supports reuse, cumulative knowledge, and open access. At the same time, uncontrolled access can expose persons and communities to surveillance or manipulation. Hess and Ostrom (2007) show why knowledge resources require governance arrangements that avoid both enclosure and unmanaged degradation. The relevant scarcity is often not the informational object itself but attention, interpretive competence, trustworthy institutions, and the capacity to distinguish relevant evidence from noise.

The resource metaphor is therefore useful only after qualification. Information is an asset when its provenance is known, its meaning is preserved, and its use serves a defensible purpose. It becomes a liability when poor quality is amplified through automated decisions, when access is concentrated without accountability, or when retention exceeds the purpose that justified collection. Strategic value and strategic risk are generated by the same socio-technical system.

2. From Data Accumulation to Strategic Judgement

The second result is a four-stage distinction among data, information, knowledge, and strategic judgement. Data are recorded differences, measurements, traces, or symbols. They become information when organised in relation to a question or context. Information supports knowledge when claims are interpreted, justified, and connected to prior understanding. Strategic judgement arises when knowledge is applied to competing goals under conditions of uncertainty and responsibility. Each transition adds meaning, but also creates opportunities for distortion.

Kitchin (2021) demonstrates that data are never simply given; they are produced through choices about what to measure, how to classify, and which cases to exclude. Floridi (2013) likewise emphasises the semantic and ethical dimensions of information. A technically correct dataset may still be strategically misleading if the categories encode outdated assumptions, if the sample omits vulnerable groups, or if the decision context has changed. Epistemic reliability consequently requires more than error-free storage. It requires documented provenance, fitness for purpose, explicit uncertainty, and mechanisms for revision.

The distinction also exposes why artificial intelligence does not eliminate human judgement. Machine-learning systems can detect regularities at a scale beyond unaided cognition, but model outputs depend on training data, objective functions, thresholds, and deployment conditions. UNESCO (2021) places human dignity, oversight, fairness, transparency, and accountability at the centre of responsible AI governance. Strategic decisions remain normative because they distribute benefits, burdens, attention, and risk. Computational power can inform such decisions but cannot determine the legitimate ends of public action.

3. Strategic Value Depends on Epistemic Quality

The third result is that information quality is not a preliminary technical issue but a constitutive element of strategic value. Decisions based on stale, unrepresentative, or decontextualised information can produce greater harm precisely because they are applied at scale. OECD (2015) documents the potential of data-driven innovation while also identifying challenges involving privacy, access, skills, and measurement. The value of faster analysis therefore depends on whether the underlying informational process is reliable enough for the decision at stake.

Epistemic quality contains at least five elements. Accuracy concerns correspondence between records and the phenomena they represent. Completeness concerns whether relevant cases and variables are missing. Provenance concerns how information was produced and transformed. Interpretability concerns whether decision makers and affected persons can understand the basis and limits of a conclusion. Correctability concerns whether errors can be reported, investigated, and repaired. These elements are interdependent: accurate data without provenance may be untrustworthy, while transparent data without correction can preserve known harm.

The strategic importance of correction is frequently underestimated. Organisations often treat correction as evidence of failure, yet systems that cannot revise their records or assumptions are epistemically fragile. Institutional learning requires visible error pathways, version histories, independent review, and incentives to disclose uncertainty. Information becomes strategically valuable when it improves the capacity to learn, not when it merely confirms existing priorities.

4. Contextual Legitimacy and Privacy

The fourth result is that lawful collection does not by itself establish legitimate use. Information disclosed for one purpose may become harmful when transferred into another context. Nissenbaum (2010) explains privacy through contextual integrity: informational practices are appropriate when they respect context-specific actors, attributes, and transmission principles. This account is particularly useful for strategic information systems because it moves beyond the weak assumption that formal consent authorises every downstream use. Contextual legitimacy asks four questions. Was the information obtained under conditions that respected agency? Is the new purpose compatible with the social context in which the information was produced? Are the recipients and decision rules appropriate? Can affected persons contest harmful interpretation or reuse? These questions do not prevent innovation. They make innovation institutionally credible by linking secondary use to purpose, proportionality, and remedy.

The political economy of data extraction makes this requirement urgent. Zuboff (2019) analyses business models that convert behavioural data into prediction and influence while concentrating knowledge about populations in private organisations. The resulting asymmetry is not simply a privacy problem; it is a strategic distribution of power. Actors who can observe others without reciprocal visibility acquire advantages in agenda setting, classification, and behavioural intervention. Responsible information governance must therefore examine who knows, who is known, who can act on the knowledge, and who can challenge the action.

5. Capability Enhancing Access

The fifth result is that access should be measured by effective capability rather than formal availability. A dataset may be publicly downloadable yet unusable to citizens who lack connectivity, language support, digital skills, time, or interpretive assistance. Sen’s capability approach evaluates social

arrangements through the real freedoms people can exercise (Sen, 1999). Applied to information, this means that strategic value depends on whether individuals and institutions can convert access into understanding, participation, and beneficial action. Capability-enhancing access has three dimensions. Material access includes infrastructure, devices, and affordability. Cognitive access includes literacy, explanation, and the ability to assess credibility. Institutional access includes the right and practical opportunity to obtain relevant records, reasons, and remedies. Digital inclusion policies that address only connectivity leave the second and third dimensions unresolved. Conversely, unrestricted disclosure can injure privacy or security. Access must therefore be differentiated by purpose and accompanied by protective rules.

The World Bank (2021) frames responsible data use through a social contract that seeks greater value, equitable benefit, and safeguards against misuse. This formulation captures the public dimension of information strategy. Public value is not created merely when institutions possess more data; it is created when people receive better services, gain meaningful voice, and are protected from avoidable informational harm. Distribution is therefore part of value creation, not an issue considered after efficiency has been achieved.

6. The Information Stewardship Model

The synthesis produces an Information Stewardship Model with four linked conditions: epistemic reliability, contextual legitimacy, capability-enhancing access, and accountable institutional stewardship. Stewardship is preferred to ownership because it emphasises continuing responsibility for quality, use, protection, and correction. The model does not deny property interests or organisational control. It places them within a wider structure of duties owed to affected persons and to the integrity of the informational environment.

Table 1
The Information Stewardship Model developed in this study

Condition	Strategic question	Required practice	Failure mode
Epistemic reliability	Can the claim be trusted for this decision?	Provenance, quality checks, uncertainty, correction	Scaled error and false confidence
Contextual legitimacy	Is this use appropriate to the original context and purpose?	Purpose limitation, proportionality, privacy, contestability	Function creep and surveillance
Capability enhancing access	Can relevant groups convert access into agency?	Infrastructure, literacy, explanation, usable remedies	Exclusion despite formal openness
Accountable stewardship	Who bears responsibility throughout the information life cycle?	Defined roles, audit, oversight, retention limits, public reporting	Concentrated power without answerability

The four conditions operate as a system. Reliable information used illegitimately remains harmful. Legitimate purposes supported by poor-quality data remain ineffective. Open access without capability can reproduce inequality, while capability without accountable stewardship can make individuals more exposed to institutional power. The model therefore rejects single-metric evaluation. Strategic information systems should be judged by their combined capacity to create value, protect agency, distribute benefit, and learn from error.

The model also clarifies that cybersecurity is one component of stewardship rather than the whole of information governance. Confidentiality, integrity, and availability are indispensable, but a secure system can still be unfair, opaque, or epistemically weak. Conversely, an ethically ambitious system that lacks technical security cannot protect the rights it recognises. Technical, epistemic, legal, and moral requirements must therefore be designed together.

Discussion

The results refine the claim that information is the decisive resource of contemporary society. The claim is plausible only if "resource" denotes an institutionally cultivated capacity rather than a stockpile. Information does not possess stable value independently of questions, users, contexts, and decision rules. Strategic capacity is the ability to transform informational inputs into justified and legitimate action while preserving the possibility of correction.

This interpretation brings together two traditions that are often separated. Information-society and economic accounts emphasise productivity, network effects, innovation, and knowledge-intensive organisation (Bell, 1973; Castells, 2010; OECD, 2015). Information ethics and privacy theory emphasise dignity, contextual norms, agency, and the moral status of informational relations (Floridi, 2013; Nissenbaum, 2010). The Stewardship Model shows that these are not external agendas. Trust, contextual legitimacy, and correction directly affect the quality and durability of strategic value.

The model also challenges the assumption that data concentration guarantees institutional intelligence. Concentration can create technical economies of scale, but it may reduce plural interpretation, conceal error, and weaken independent scrutiny. Distributed access can support innovation and accountability, yet it can also increase privacy and security risks. The proper design question is therefore not centralisation versus openness in the abstract. It is which functions require controlled concentration, which benefits require wider access, and which safeguards make each arrangement answerable.

For organisations, the findings imply a life-cycle approach. Before collection, institutions should specify a legitimate purpose and identify affected groups. During collection, they should document provenance, minimise unnecessary capture, and test representation. During analysis, they should disclose uncertainty, examine bias, and preserve human review for consequential decisions. During use, they should explain relevant decisions and provide contest and remedy. During retention or deletion, they should apply time limits and verify that derived copies are governed consistently. Strategy begins before data acquisition and continues after a model has been deployed.

For public policy, information literacy should likewise be treated as more than technical proficiency. It includes the capacity to assess source credibility, recognise uncertainty, understand how classification affects people, and exercise rights concerning personal and public information. Such literacy strengthens human capability and institutional resilience. It also reduces the risk that information abundance will be mistaken for knowledge.

The approach remains compatible with innovation. UNESCO’s framework for AI ethics does not reject advanced systems; it requires that their development and use remain connected to dignity, fairness, oversight, and environmental and social well-being (UNESCO, 2021). Similarly, the World Bank (2021) and OECD (2015) link data value to governance and public benefit. Responsible constraints should therefore be understood as conditions for sustainable innovation rather than obstacles added after technical design.

A practical evaluation can be organised around four tests. The epistemic test asks whether an informational claim is sufficiently reliable for its intended consequence. The legitimacy test asks whether collection and use respect context, purpose, and agency. The capability test asks whether access expands real opportunities rather than formal availability alone. The accountability test asks whether responsibility, review, and remedy remain identifiable throughout the information life cycle. Failure in any test should trigger redesign, not merely a communication response.

Limitations

This study has three limitations. First, it is a conceptual review of twelve influential sources and does not claim comprehensive coverage of information science, cybersecurity, data protection law, or artificial intelligence governance. Second, the Information Stewardship Model proposes analytical conditions but does not measure their causal effects. Application requires indicators tailored to sector, institutional mandate, and risk level. Third, the article discusses contemporary society at a general level. Cultural expectations, legal systems, administrative capacity, and patterns of digital inequality may alter how the four conditions are implemented. These limits prevent unsupported generalisation and define the agenda for empirical testing.

Future Research

Future research should operationalise the four conditions and compare information systems across public administration, education, health, finance, and digital platforms. Case studies can trace how provenance and correction affect decision quality. Surveys and experiments can test whether meaningful explanations improve warranted trust and contestability. Distributional analysis can examine who obtains benefits and who bears privacy or classification risks. Research should also identify cases in which deletion, non-collection, or decentralised governance produces greater strategic value than continued accumulation.

Conclusion

Information has become central to social coordination, innovation, governance, and institutional learning. It is therefore reasonable to call it strategic, but misleading to treat it as an ordinary material asset. Its value is relational, non-rival in use, dependent on interpretation, and inseparable from the distribution of power. Data volume and computational capacity are not sufficient indicators of informational strength.

The article identifies four conditions under which information produces legitimate and durable strategic value: epistemic reliability, contextual legitimacy, capability-enhancing access, and accountable institutional stewardship. Together they form an Information Stewardship Model that connects innovation with rights, trust, and correction. The model explains why poor data, opaque inference, unequal access, and concentrated control can turn an apparent resource into systemic vulnerability.

The central conclusion is that information strategy should not begin with the question of how much can be collected. It should begin with the purpose to be served, the evidence required, the persons affected,

and the institution that will answer for error. Information becomes a strategic resource when it enlarges society's capacity to understand, decide, cooperate, and revise action without sacrificing human agency.

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Ümumi mülkiyyət anlayışının və növlərinin normativ ifadəsi: Azərbaycan hüququ və müxtəlif hüquq sistemlərinin müqayisəli təhlili

İsmayıl Qəribli

Xülasə. *Ümumi mülkiyyət eyni əşya üzərində iki və ya daha çox şəxsin mülkiyyət hüququnun mövcudluğu ilə səciyyələnən və hüququn həyata keçirilməsinin xüsusi təşkilini tələb edən çoxsubyektli hüquqi rejimdir. Tədqiqatın məqsədi Azərbaycan hüququnda ümumi mülkiyyət anlayışının, paylı və birgə mülkiyyət növlərinin normativ ifadəsini sistemləşdirmək və həmin tənzimləməni seçilmiş xarici hüquq sistemləri ilə müqayisə etməkdir. Təhlilə Azərbaycan Respublikasının Mülki Məcəlləsi ilə yanaşı Mənzil, Torpaq və Ailə məcəllələri, ipoteka, mənzil fondunun özəlləşdirilməsi, ailə kəndli təsərrüfatı, notariat və daşınmaz əmlakın dövlət reyestri haqqında qanunvericilik daxil edilmişdir. Müqayisəli hissədə Türkiyə, İsveçrə, Almaniya, Avstriya və Fransa hüququnun normativ və doktrinal modelləri nəzərdən keçirilmişdir. Nəticələr göstərir ki, Azərbaycan hüququnda ümumi mülkiyyət ayrıca mülkiyyət forması deyil, vahid hüquqi obyekt üzərində mülkiyyət hüququnun subyekt tərkibinin çoxluğu ilə xarakterizə olunan rejim kimi çıxış edir. Pay əşyanın fiziki hissəsini deyil, mülkiyyət hüququnda iştirakın hüquqi ölçüsünü ifadə edir, birgə mülkiyyət isə iştirakçıları birləşdirən xüsusi hüquqi ümumiliklə əlaqələnir. Müqayisəli təhlil əsasında Mülki Məcəllədə paylı mülkiyyətin ayrıca normativ tərifinin verilməsi və əsas əşyaya ayrılmaz bağlı payların hüquqi rejiminin ümumi səviyyədə dəqiqləşdirilməsi təklif olunur.*

Açar sözlər: *mülkiyyət hüququ, ümumi mülkiyyət, paylı mülkiyyət, birgə mülkiyyət, pay, çoxsubyektli mülkiyyət, ipoteka, ailə əmlakı*

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Normative Expression of the Concept and Types of Common Ownership: A Comparative Analysis of Azerbaijani Law and Different Legal Systems

Ismayil Garibli

Abstract. *Common ownership is a multi-subject legal regime in which two or more persons hold ownership rights in the same object and the exercise of those rights requires a special form of coordination. This study aims to systematize the normative expression of common ownership, co-ownership by shares and joint ownership in Azerbaijani law and to compare the Azerbaijani model with selected foreign legal systems. The analysis covers the Civil Code of the Republic of Azerbaijan together with the Housing, Land and Family Codes and legislation on mortgage, privatization of housing stock, family farms, notarial acts and state registration of immovable property. The comparative part examines normative and doctrinal approaches in Turkish, Swiss, German, Austrian and French law. The findings indicate that common ownership in Azerbaijani law should be understood not as an autonomous form of ownership but as a legal regime characterized by a plurality of right-holders in relation to one legal object. A share represents the legal measure of participation in the ownership right rather than a physical part of the thing, while joint ownership is connected with a specific legal community linking the participants. On the basis of the comparative analysis, the article proposes introducing a separate statutory definition of co-ownership by shares into the Civil Code and clarifying the general legal regime of shares that are functionally inseparable from a principal property.*

Keywords: *ownership, common ownership, co-ownership by shares, joint ownership, share, multi-subject ownership, mortgage, marital property*

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Giriş

Mülkiyyət hüququnun klassik modeli əşyanın müəyyən şəxsə mənsub olması və həmin şəxsin əşya üzərində sahiblik, istifadə və sərəncam səlahiyyətlərini həyata keçirməsi üzərində qurulur. Bununla belə, mülki dövriyyədə eyni əşyanın eyni vaxtda iki və ya daha çox şəxsin mülkiyyətində olması geniş yayılmış hüquqi vəziyyətdir. Vərəsəlik, əmlakın birlikdə əldə edilməsi, nikah, özəlləşdirmə, çoxmənzilli binada sahə əldə edilməsi, ailə kəndli təsərrüfatı və digər hüquqi faktlar nəticəsində eyni obyekt üzərində bir neçə mülkiyyətçi statusu yarana bilər.

Belə vəziyyətdə mülkiyyət hüququnun məzmunu prinsip etibarilə dəyişmir, dəyişən onun subyekt tərkibi və səlahiyyətlərin həyata keçirilmə üsuludur. Bir mülkiyyətçinin davranışı digər mülkiyyətçilərin hüquq və mənafelərinə birbaşa təsir etdiyindən ümumi mülkiyyət rejimi fərdi muxtariyyətlə kollektiv marağın uzlaşdırılmasını tələb edir. Bu səbəbdən ümumi mülkiyyət ayrıca mülkiyyət forması kimi deyil, vahid əşya üzərində mülkiyyət hüququnun çoxsubyektli həyata keçirilməsi rejimi kimi izah edilməlidir.

Azərbaycan Respublikası Konstitusiyasının 29-cu maddəsi hər kəsin əmlaka təkbaşına və ya başqaları ilə birlikdə sahib olmaq hüququnu tanımaqla ümumi mülkiyyət münasibətlərinin konstitusion əsasını müəyyən edir (Azərbaycan Respublikasının Konstitusiyası, 1995, maddə 29). Azərbaycan Respublikası Mülki Məcəlləsinin 213.1-ci maddəsi iki və ya bir neçə şəxsin mülkiyyətində olan əşyanın onlara ümumi mülkiyyət hüququ əsasında mənsub olduğunu, 213.2-ci maddə isə ümumi mülkiyyətin paylı və birgə mülkiyyət formasında mövcud ola biləcəyini müəyyən edir. Məcəllənin 213.3-cü maddəsi xüsusi əhəmiyyət daşıyır: qanunvericilikdə birgə mülkiyyətin yaranması ayrıca nəzərdə tutulmadıqda ümumi mülkiyyət paylı mülkiyyət hesab olunur. Deməli, Azərbaycan hüququnda paylı mülkiyyət ümumi model, birgə mülkiyyət isə xüsusi normativ əsas tələb edən rejimdir (Azərbaycan Respublikasının Mülki Məcəlləsi, 1999, maddələr 213.1–213.3).

Məqalənin məqsədi ümumi mülkiyyət anlayışının və növlərinin yalnız Mülki Məcəllə çərçivəsində deyil, Azərbaycan qanunvericiliyinin müxtəlif sahələrində necə ifadə edildiyini müəyyənləşdirmək, xüsusi normativ nümunələri sistemləşdirmək və onları xarici hüquq modelləri ilə müqayisə etməklə ümumi mülkiyyət anlayışının normativ ifadəsinin təkmilləşdirilməsi imkanlarını göstərməkdir.

Metodlar

Tədqiqat normativ-hüquqi təhlil, müqayisəli-hüquqi metod, sistemli şərh və doktrinal mənbələrin məzmun təhlili əsasında aparılmışdır. Azərbaycan hüququ üzrə Mülki Məcəllənin ümumi mülkiyyətə dair normaları əsas götürülmüş, həmin normalar Mənzil, Torpaq və Ailə məcəllələrində, eləcə də ipoteka, mənzil fondunun özəlləşdirilməsi, ailə kəndli təsərrüfatı, notariat və daşınmaz əmlakın dövlət reyestri sahəsindəki xüsusi tənzimləmələrlə sistemli əlaqədə araşdırılmışdır. Müqayisəli hissə üçün Türkiyə, İsveçrə, Almaniya, Avstriya və Fransa hüququnun ümumi mülkiyyətə dair əsas normativ konstruksiyaları və mövzuya aid doktrinal mənbələr seçilmişdir. Müqayisə zamanı payın hüquqi təbiəti, paylı və birgə mülkiyyətin fərqləndirilməsi, iştirakçıların sərəncam imkanları, idarəetmə mexanizmləri və ümumi mülkiyyətin xitamı əsas meyarlar kimi götürülmüşdür. Təhlilin nəticələri Azərbaycan qanunvericiliyində normativ boşluqların müəyyənləşdirilməsi və de lege ferenda təkliflərin əsaslandırılması üçün istifadə edilmişdir.

Nəticələr

1. Ümumi mülkiyyət anlayışının hüquqi mahiyyəti

Ümumi mülkiyyət münasibətinin yaranması üçün iki əsas element birlikdə mövcud olmalıdır: vahid hüquqi obyekt və həmin obyekt üzərində mülkiyyətçi statusuna malik subyektlərin çoxluğu. Bir neçə şəxsin iqtisadi əməkdaşlığı və ya eyni kompleks daxilində müxtəlif əşyaların sahibi olması özlüyündə ümumi mülkiyyət yaratmır. Hüquqlar eyni hüquqi obyektə yönəlməlidir.

Ümumi mülkiyyət hüquqi şəxsin əmlakından da fərqləndirilməlidir. Hüquqi şəxs yaradıldıqda ona verilmiş əmlak bir hüquq subyektinə – hüquqi şəxsə mənsub olur. Ümumi mülkiyyətdə isə ayrıca kollektiv mülkiyyətçi yaranmır, iştirakçıların hər biri bilavasitə mülkiyyətçi statusunu saxlayır. Bu səbəbdən ümumi mülkiyyət mülkiyyət hüququnun məzmununda yeni səlahiyyətlər yaradan ayrıca əşya hüququ deyil, mövcud mülkiyyət hüququnun subyekt tərkibinin mürəkkəbləşməsidir.

Paylı mülkiyyətdə “pay” anlayışı bu quruluşun mərkəzi elementidir. Pay əşyanın konkret fiziki hissəsi deyil. Yaşayış evi üzərində 1/2 payı olan mülkiyyətçi, ayrıca istifadə və ya bölgü hüquqi əsasla müəyyən edilmədikcə, evin fiziki yarısının müstəqil mülkiyyətçisi hesab edilmir. Onun hüququ əşyanın tamamına şamil olunur, 1/2 isə həmin hüquqda iştirakın ölçüsünü göstərir. Əşya fiziki şəkildə bölünüb hissələr

ayrıca hüquqi obyektlərə çevrildikdə isə əvvəlki vahid obyekt üzərində paylı mülkiyyət münasibəti aradan qalxır.

Bu yanaşma Azərbaycan hüquq ədəbiyyatında da müdafiə olunur: paylı mülkiyyətdə bölünən əşyanın özü deyil, həmin əşya üzərində mülkiyyət hüququnda iştirakın hüquqi ölçüsüdür, maddi hissələrin müstəqil hüquqi obyektlərə çevrilməsi isə əvvəlki ümumi mülkiyyət münasibətini aradan qaldırır (Süleymanlı, 2023, s. 202–203). Türk hüquq doktrinasında da paylı mülkiyyətin əsas əlamətləri sırasında birdən çox şəxsin maddi olaraq bölünməmiş əşyanın tamamına müəyyən riyazi paylarla malik olması göstərilir (Özcan, 2021, s. 27–33).

1.1. Azərbaycan hüquq doktrinasında ümumi və paylı mülkiyyətə yanaşmalar

Azərbaycan mülki hüquq ədəbiyyatında ümumi mülkiyyətin nəzəri izahı, əsasən, eyni əşya üzərində bir neçə şəxsin bilavasitə mülkiyyət hüququnun mövcudluğu və həmin şəxslərin hüquqlarının qarşılıqlı uzlaşdırılması ideyası üzərində qurulur. M.D. Dəmirçiyeva ümumi mülkiyyətin paylı və birgə mülkiyyət olmaqla iki əsas növünü fərqləndirir, paylı mülkiyyətdə hər bir mülkiyyətçinin hüquqdakı payının müəyyən edildiyini, birgə mülkiyyətdə isə payların əvvəlcədən müəyyənləşdirilmədiyini göstərir (Dəmirçiyeva, 2015, s. 528–534). R.A. Göyüşov və həmmüəlliflər də ümumi mülkiyyəti bir neçə şəxsin eyni əmlak üzərində hüquqlarının mövcudluğu ilə bağlı xüsusi mülkiyyət rejimi kimi nəzərdən keçirirlər (Göyüşov və b., 2013, s. 276–278).

S. Süleymanlı ümumi mülkiyyət halında eyni əşya üzərində vahid mülkiyyət hüququnun eyni anda iki və ya daha çox şəxsə mənsub olmasını əsas götürür və paylı mülkiyyətin ümumi mülkiyyətin əsas növü olduğunu Mülki Məcəllənin 213.3-cü maddəsi ilə əlaqələndirir (Süleymanlı, 2014, s. 56–57). Müəllifin mühüm nəzəri nəticəsi ondan ibarətdir ki, paylı mülkiyyətdə bölünən əşyanın özü deyil, həmin əşya üzərindəki mülkiyyət hüququdur (Süleymanlı, 2014, s. 57).

A. Hacıyeva paylı mülkiyyət hüququnun həyata keçirilməsini həmmülkiyyətçilərin bütün ümumi əmlaka və ayrıca öz paylarına dair səlahiyyətlərinin fərqləndirilməsi əsasında təhlil edir. Müəllif ümumi əşyaya sahiblik və istifadənin, bir qayda olaraq, bütün mülkiyyətçilərin razılaşması ilə həyata keçirildiyini, bununla yanaşı hər bir payçının öz payına uyğun hissənin sahibliyinə və istifadəsinə verilməsini tələb edə bildiyini göstərir (Hacıyeva, 2009, s. 56–57). Bu yanaşma ümumi mülkiyyətin yalnız statik mənsubiyyət deyil, daxili hüquq və vəzifələr sistemi olduğunu təsdiqləyir.

Ə. Rəhmanov isə normativ definisiya probleminə birbaşa diqqət çəkərək qeyd edir ki, Mülki Məcəllənin 213.2-ci maddəsi paylı mülkiyyəti ümumi mülkiyyətin bir növü kimi göstərsə də, ayrıca anlayış vermir, müəllif müqayisə üçün İsveçrə hüququnda fiziki cəhətdən bölünməmiş əşya üzərində müəyyən paylarla mülkiyyət formulunun mövcudluğunu göstərir (Rəhmanov, 2015, s. 69). Buna görə paylı mülkiyyət anlayışının Mülki Məcəllədə ayrıca və daha dolğun normativ şəkildə müəyyənləşdirilməsi yalnız xarici hüquq nümunələrindən deyil, Azərbaycan hüquq doktrinasında formalaşmış tənqidi yanaşmadan da irəli gəlir.

2. Azərbaycan Respublikasının Mülki Məcəlləsində ümumi mülkiyyətin əsas modeli

Azərbaycan Respublikası Mülki Məcəlləsinin 213-224-cü maddələri ümumi mülkiyyət institutunun əsas normativ çərçivəsini yaradır. 213-cü maddə anlayışı və yaranma əsaslarını, 214-221-ci maddələr paylı mülkiyyətin paylarının müəyyənləşdirilməsi, sahiblik və istifadə, gəlirlər, xərclər, üstün satınalma hüququ, payın keçməsi, ayrılma və bölüşdürülməsini, 222-223-cü maddələr birgə mülkiyyətdə sahiblik,

istifadə, sərəncam və bölgünü, 224-cü maddə isə ümumi mülkiyyətdəki paya tutmanın yönəldilməsini tənzimləyir. (Azərbaycan Respublikasının Mülki Məcəlləsi, 1999, maddələr 213–224)

Mülki Məcəllənin 215.6-cı maddəsi paylı mülkiyyətçiyə öz payını satmaq, bağışlamaq, vəsiyyət etmək, girov qoymaq və başqa qaydada sərəncam vermək imkanı tanıyır. Bu, paylı mülkiyyətin birgə mülkiyyətdən əsas struktur fərqlərindən biridir: müəyyən edilmiş pay müstəqil əmlak dövriyyəsi obyekti ola bilir. Əvəzli özgəninkiləşdirmədə isə 218-ci maddədə nəzərdə tutulan üstün satınalma rejimi digər payçıların mənafeyini qoruyur. (Azərbaycan Respublikasının Mülki Məcəlləsi, 1999, maddələr 215.6, 218)

Mülki Məcəllənin 222.1-ci maddəsində birgə mülkiyyətin yaranmasına əsas olmuş "ümumilik" anlayışından istifadə olunması diqqətəlayiqdir. Bu norma birgə mülkiyyətin yalnız payların müəyyən edilməməsi ilə deyil, iştirakçıları bir-biri ilə bağlayan xüsusi hüquqi birliklə əlaqəli olduğunu göstərir. Ər-arvadın nikah münasibəti bu modelin klassik nümunəsidir. (Azərbaycan Respublikasının Mülki Məcəlləsi, 1999, maddə 222.1)

Mülki Məcəllənin 225-ci maddəsi ər-arvadın nikah dövründə qazandıqları əmlakın, nikah müqaviləsində və ya razılaşmada başqa hal nəzərdə tutulmadıqda, ümumi mülkiyyət olduğunu müəyyən edir. Ailə Məcəlləsi bu ümumi mülkiyyəti açıq şəkildə "ümumi birgə mülkiyyət" kimi xarakterizə etdiyindən 225-ci maddə Mülki Məcəllənin ümumi mülkiyyət normaları ilə ailə hüququnun xüsusi rejimi arasında əlaqələndirici norma kimi çıxış edir. (Azərbaycan Respublikasının Mülki Məcəlləsi, 1999, maddə 225; Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddələr 31.1, 32.1)

3. Azərbaycan qanunvericiliyində paylı mülkiyyətin xüsusi normativ təzahürləri

3.1. Mənzil Məcəlləsi: əsas əşyaya ayrılmaz bağlı paylı mülkiyyət

Azərbaycan Respublikasının Mənzil Məcəlləsi paylı mülkiyyətin ən mühüm xüsusi formalarından birini – çoxmənzilli binanın ümumi əmlakına mülkiyyət hüququnu tənzimləyir. Məcəllənin 35.1-ci maddəsinə görə mənzillərarası pilləkən meydançaları, liftlər, dəhlizlər, texniki mərtəbələr, çardaqlar, mühəndis qurğuları, dam örtükləri, birdən artıq sahəyə xidmət edən avadanlıq, habelə binanın yerləşdiyi torpaq sahəsi və binaya xidmət edən digər obyektlər ümumi paylı mülkiyyət hüququ ilə sahə mülkiyyətçilərinə məxsusdur. (Azərbaycan Respublikasının Mənzil Məcəlləsi, 2009, maddə 35.1)

Mənzil Məcəlləsinin 36.1-ci maddəsi payın ölçüsünü sahə meyarına bağlayır: sahə mülkiyyətçisinin ümumi əmlakdakı payı onun sahəsinin ümumi sahəsinə mütənasibdir. 36.2-36.3-cü maddələr payın hüquqi taleyini əsas sahənin hüquqi taleyinə bağlayır. Bu konstruk-siya klassik paylı mülkiyyətdən fərqli olaraq akse-sor xarakter daşıyır: ümumi əmlakdakı pay müstəqil iqtisadi obyekt kimi deyil, mənzil və ya qeyri-yaşayış sahəsi üzərində mülkiyyət hüququnun ayrılmaz hüquqi elementi kimi fəaliyyət göstərir. (Azərbaycan Respublikasının Mənzil Məcəlləsi, 2009, maddələr 36.1–36.3)

Məcəllənin 36.4-cü maddəsində həmin payın naturada ayrılmasına və əsas sahədən ayrılıqda özgəninkiləşdirilməsinə qoyulan məhdudiyyətlər bu funksional bağlılığı təsdiq edir. Eyni yanaşma 40-41-ci maddələrdə kommunal mənzilin ümumi əmlakına münasibətdə tətbiq edilir: birdən artıq otağa xidmət edən sahələr otaq mülkiyyətçilərinin ümumi paylı mülkiyyətində olur və pay otağın sahəsinə mütənasib müəyyən edilir. (Azərbaycan Respublikasının Mənzil Məcəlləsi, 2009, maddələr 36.4, 40.1, 41.1–41.6)

Beləliklə, Mənzil Məcəlləsi Azərbaycan hüququnda "əsas əşyaya ayrılmaz bağlı pay" modelini normativləşdirir. Bu model ümumi paylı mülkiyyətin bütün növlərinə şamil edilən sərbəst pay dövriyyəsinin istisnasıdır və payın konkret hüquqi funksiyadan asılı olaraq fərqli rejimlərə malik ola bildiyini göstərir.

3.2. Torpaq Məcəlləsi: çoxmənzilli binanın torpaq sahəsi

Azərbaycan Respublikasının Torpaq Məcəlləsində də çoxmənzilli yaşayış evlərinin və onlara aid qeyri-yaşayış tikililərinin torpaq sahələrinin həmin evlərin tərkib hissələri mülkiyyətçilərinin ümumi paylı mülkiyyətinə keçməsi nəzərdə tutulur. Bu norma Mənzil Məcəlləsinin 35-ci maddəsi ilə funksional və sistemli əlaqədədir. Torpaq sahəsi ayrıca sərbəst paylı mülkiyyət obyekti kimi deyil, binanın istismarı və onun tərkib hissələrinin normal istifadəsi ilə ayrılmaz bağlı ümumi əmlakın elementi kimi çıxış edir. Belə tənzimləmə əsas sahə üzərində fərdi mülkiyyətlə xidmət funksiyası daşıyan torpaq və digər ümumi elementlər üzərində paylı mülkiyyətin vahid hüquqi kompleks təşkil etdiyini göstərir. (Azərbaycan Respublikasının Torpaq Məcəlləsi, 1999, maddə 88.3)

3.3. "İpoteka haqqında" Azərbaycan Respublikasının Qanunu: paylı və birgə mülkiyyətin sərəncam fərqi

"İpoteka haqqında" Azərbaycan Respublikası Qanununun 8-ci maddəsi paylı və birgə mülkiyyət arasındakı struktur fərqi çox aydın şəkildə nümayiş etdirir. 8.1-ci maddəyə əsasən ümumi birgə mülkiyyətdə olan əşya yalnız bütün mülkiyyətçilərin notariat qaydasında təsdiq olunmuş razılığı ilə ipoteka qoyula bilər. ("İpoteka haqqında" Azərbaycan Respublikasının Qanunu, 2005, maddə 8.1)

Eyni maddənin 8.2-ci hissəsinə əsasən ümumi paylı mülkiyyətin hər bir iştirakçısı öz payını digər mülkiyyətçilərin razılığı olmadan ipoteka qoya bilər. Paya tutma yönəldilərək satıldıqda Mülki Məcəllənin üstün satınalma hüququ haqqında normaları tətbiq edilir. Bu norma paylı mülkiyyətdə müəyyən edilmiş payın sərəncam qabiliyyətli hüquqi mövqe, birgə mülkiyyətdə isə fərdi şəkildə sərəncam verilə bilən əvvəlcədən müəyyən edilmiş payın mövcud olmamasını praktik səviyyədə təsdiqləyir. ("İpoteka haqqında" Azərbaycan Respublikasının Qanunu, 2005, maddə 8.2)

Qanunun 57-ci maddəsi çoxmənzilli yaşayış evində mənzilin ipotekası zamanı mənzillə yanaşı ev üzərində ümumi mülkiyyət hüququnda ipoteka qoyanın müvafiq payının da girov qoyulmuş sayıldığını nəzərdə tutur. Bu qayda Mənzil Məcəlləsindəki əsas sahə–ümumi əmlak payı bağlılığının ipoteka hüququnda davamını təmin edir. ("İpoteka haqqında" Azərbaycan Respublikasının Qanunu, 2005, maddə 57)

3.4. "Azərbaycan Respublikasında mənzil fondunun özəlləşdirilməsi haqqında" Azərbaycan Respublikasının Qanunu

"Azərbaycan Respublikasında mənzil fondunun özəlləşdirilməsi haqqında" Qanunun 5-ci maddəsi ümumi mülkiyyət növünün tərəflərin iradəsi ilə seçilə bildiyi xüsusi normativ nümunədir. Özəlləşdirilən mənzil kirayəçi və onunla birlikdə faktiki yaşayan yetkin ailə üzvlərinin razılığı ilə onlardan birinin mülkiyyətinə və ya bir neçəsinin, yaxud bütün ailə üzvlərinin ümumi – paylı və ya birgə – mülkiyyətinə verilə bilər. ("Azərbaycan Respublikasında mənzil fondunun özəlləşdirilməsi haqqında" Azərbaycan Respublikasının Qanunu, 1993, maddə 5)

Bu norma iki baxımdan əhəmiyyətlidir. Birincisi, ümumi mülkiyyətin paylı və ya birgə formasının konkret hüquqi fakt çərçivəsində seçim obyekti ola bildiyini göstərir. İkincisi, birgə mülkiyyətin yalnız

nikah münasibətindən yaranması barədə dar təsəvvürü istisna edir: qanun birgə mülkiyyətin xüsusi normativ əsasını özəlləşdirmə münasibətlərində də tanıyır.

Qanunun 5-ci maddəsi, həmçinin biri digərindən təcrid olunmamış məhdud kommunal şəraitli mənzillər özəlləşdirilərkən ümumi istifadə yerlərinin mülkiyyətçilərin ümumi mülkiyyətinə verilməsini nəzərdə tutur. Bu müddəa fiziki cəhətdən ümumi xidmət funksiyası daşıyan sahələrin ayrıca fərdi mülkiyyətə parçalanmasının məqsədəuyğun olmamasını normativ səviyyədə qəbul edir. ("Azərbaycan Respublikasında mənzil fondunun özəlləşdirilməsi haqqında" Qanun, 1993, maddə 5)

3.5. Notariat qanunvericiliyi və paylı mülkiyyətin dövriyyəsi

Azərbaycan Respublikası Nazirlər Kabinetinin 2000-ci il 11 sentyabr tarixli 167 nömrəli qərarı ilə təsdiq edilmiş "Azərbaycan Respublikasında notariat hərəkətlərinin aparılması qaydaları haqqında Təlimat" paylı mülkiyyətin mülki dövriyyədə rəsmiləşdirilməsi üçün xüsusi qaydalar müəyyən edir. Təlimatın 49-cu hissəsində payın üçüncü şəxsə satılması zamanı digər payçıların üstün satınalma hüququnun təmin edilməsi, habelə payçının öz payını digər mülkiyyətçilərin razılığı olmadan ipoteka qoyması və istifadəyə verməsi nəzərdə tutulur. 52-54-cü hissələrdə daşınmaz əmlakdakı riyazi payın və konkret istifadə sahələrinin müqavilədə göstərilməsi, istifadə qaydası haqqında saziş və payların müəyyənləşdirilməsi və ya dəyişdirilməsi mexanizmləri tənzimlənir ("Azərbaycan Respublikasında notariat hərəkətlərinin aparılması qaydaları haqqında Təlimat", 2000, hissələr 49, 52–54).

Təlimatın 53-cü hissəsinə görə, daşınmaz əmlakdan istifadə qaydası haqqında paylı mülkiyyətçilər arasında əvvəllər bağlanmış müqavilə notariat qaydasında təsdiq edilmiş və dövlət qeydiyyatına alınmışdırsa, bu müqavilə həmin daşınmaz əmlakda sonradan pay əldə edən şəxs üçün də məcburidir. Bu qayda paylı mülkiyyət münasibətlərinin müəyyən hallarda hüquqi varislərə də təsir göstərən əşya-hüquqi effektini nümayiş etdirir ("Azərbaycan Respublikasında notariat hərəkətlərinin aparılması qaydaları haqqında Təlimat", 2000, hissə 53).

4. Azərbaycan qanunvericiliyində birgə mülkiyyətin xüsusi normativ təzahürləri

4.1. Ailə Məcəlləsi: ər-arvadın ümumi birgə mülkiyyəti

Birgə mülkiyyətin Azərbaycan hüququnda əsas və ən geniş tətbiq olunan xüsusi modeli ər-arvadın əmlakının qanuni rejimidir. Ailə Məcəlləsinin 31.1-ci maddəsi ər-arvadın birgə mülkiyyət rejimini onların əmlakının qanuni rejimi kimi müəyyən edir. 32.1-ci maddəyə əsasən nikah müddətində ər-arvadın əldə etdikləri əmlak onların ümumi birgə mülkiyyətidir. (Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddələr 31.1, 32.1)

Ailə Məcəlləsinin 32.2-ci maddəsi ümumi birgə mülkiyyətin tərkibini geniş müəyyən edir: əmək, sahibkarlıq və intellektual fəaliyyətdən əldə edilən gəlirlər, pensiya və müavinətlər, ümumi gəlirlər hesabına alınan daşınar və daşınmaz əşyalar, qiymətli kağızlar, əmanətlər, kapitaldakı paylar və nikah dövründə qazanılmış digər əmlak bu rejimə daxildir. Əmlakın kimin adına rəsmiləşdirilməsi həlledici deyil. (Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddələr 32.2–32.3)

33-cü maddə ümumi əmlaka sahiblik, istifadə və sərəncamı ər-arvadın qarşılıqlı razılığına bağlayır. 36-cı maddə ümumi əmlakın bölünməsini, 37-ci maddə isə bölünmə zamanı payların, bir qayda olaraq, bərabərliyini müəyyən edir. Bu halda payların bölgü zamanı müəyyən edilməsi birgə mülkiyyətin paylı mülkiyyətdən struktur fərqini aydın göstərir: pay münasibət mövcud olduğu müddətdə əvvəlcədən

fərdiləşdirilmir, bölgü mərhələsində hüquqi ölçü əldə edir. (Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddələr 33, 36–37)

Ailə Məcəlləsinin 41-ci maddəsi kreditorların tələblərinin ər-arvadın şəxsi və ümumi əmlakına yönəldilməsi mexanizmini də fərqləndirir. Bu, birgə mülkiyyətin yalnız daxili ailə münasibəti olmadığını, üçüncü şəxslərlə münasibətlərdə də ayrıca əmlak rejimi yaratdığını göstərir. (Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddə 41)

Ailə Məcəlləsinin 55.7-ci maddəsi valideynlərlə uşaqlar arasında birgə mülkiyyət hüququ yarandığı halda əmlak üzərində sahiblik, istifadə və sərəncamın mülki qanunvericiliklə müəyyən edilməsini nəzərdə tutur. Beləliklə, ailə qanunvericiliyi birgə mülkiyyəti təkcə ər-arvad münasibəti ilə məhdudlaşdırmır. (Azərbaycan Respublikasının Ailə Məcəlləsi, 1999, maddə 55.7)

4.2. “Ailə kəndli təsərrüfatı haqqında” Azərbaycan Respublikasının Qanunu

“Ailə kəndli təsərrüfatı haqqında” Qanunun 6-cı maddəsi ümumi mülkiyyətin hər iki növünü eyni təsərrüfat münasibəti daxilində tanıyan xüsusilə maraqlı normativ nümunədir. 6.2-ci maddəyə əsasən təsərrüfatın istifadə etdiyi əmlak üzvlərdən birinin mülkiyyətində, üzvlərin ümumi paylı və ya ümumi birgə mülkiyyətində, yaxud icarəsində ola bilər. (“Ailə kəndli təsərrüfatı haqqında” Azərbaycan Respublikasının Qanunu, 2005, maddə 6.2)

Bununla yanaşı, Qanunun 6.5-ci maddəsi ailə kəndli təsərrüfatında əmlakın istifadəsindən əldə edilən faydanı – gəlir, artım, bəhər və digər formaları – təsərrüfat üzvlərinin ümumi birgə mülkiyyəti hesab edir. Deməli, qanun təsərrüfatın ilkin əmlak bazasının hüquqi rejimi ilə fəaliyyət nəticəsində əldə edilən faydanın hüquqi rejimini fərqləndirir: ilkin əmlak müxtəlif rejimlərdə ola bildiyi halda, əldə edilən fayda üçün birgə mülkiyyət prezumpsiyası müəyyən edir. (“Ailə kəndli təsərrüfatı haqqında” Azərbaycan Respublikasının Qanunu, 2005, maddə 6.5)

Bu həll birgə mülkiyyətin yaranmasında “ümumilik” elementinin funksional əhəmiyyətini göstərir. Burada ümumilik nikah deyil, hüquqi şəxs yaratmadan birgə ailə-təsərrüfat fəaliyyəti və ortaq əmək prosesidir.

4.3. “Notariat haqqında” Qanun: birgə mülkiyyətdə payın rəsmiləşdirilməsi

“Notariat haqqında” Qanunun 61-ci maddəsinə əsasən notarius ər-arvadın birgə yazılı ərizəsi əsasında onların birinə və ya hər ikisinə birgə nikah dövründə əldə edilmiş ümumi əmlakdakı paya görə mülkiyyət hüququ haqqında şəhadətnamə verir. Qanunun 62-ci maddəsi ər-arvaddan biri öldükdə sağ qalmış ər və ya arvada ümumi əmlakdakı paya dair şəhadətnamənin verilməsini tənzimləyir (“Notariat haqqında” Azərbaycan Respublikasının Qanunu, 1999, maddələr 61–62).

Bu normalar nəzəri baxımdan əhəmiyyətlidir: birgə mülkiyyətdə münasibət davam etdiyi müddətdə əvvəlcədən müəyyən edilmiş pay olmamasına baxmayaraq, müəyyən hüquqi faktın – birgə ərizənin, nikahın pozulmasının və ya ölümün – baş verməsi ilə həmin ümumi əmlakda fərdi pay müəyyənləşdirilə və ayrıca hüquq kimi rəsmiləşdirilə bilir.

4.4. Daşınmaz əmlakın dövlət qeydiyyatı ilə əlaqə

“Daşınmaz əmlakın dövlət reyestri haqqında” Qanun ümumi mülkiyyətin ayrıca maddi-hüquqi növünü yaratmasa da, onun hüquqi dövriyyədə rəsmiləşdirilməsini təmin edən institusional baza rolunu oynayır.

Qanunun 8.0.3-cü maddəsində ər-arvadın ümumi əmlakındakı paya mülkiyyət hüququ haqqında notariat şəhadətnaməsi daşınmaz əmlak üzərində hüquqların dövlət qeydiyyatı üçün əsaslardan biri kimi göstərilir. 9-1.1-ci maddə isə belə şəhadətnamə də daxil olmaqla notariat sənədləri əsasında hüquqların "bir pəncərə" prinsipi ilə dövlət qeydiyyatını nəzərdə tutur ("Daşınmaz əmlakın dövlət reyestri haqqında" Azərbaycan Respublikasının Qanunu, 2004, maddələr 8.0.3, 9-1.1).

5. Azərbaycan qanunvericiliyində normativ nümunələrin sistemləşdirilməsi

Normativ akt	Maddə	Mülkiyyət növü	Normativ həll	Elmi əhəmiyyəti
Mülki Məcəllə	213-224	Paylı və birgə	Ümumi model: paylı mülkiyyət ümumi qayda, birgə mülkiyyət xüsusi əsas tələb edir.	İnstitutun baza konstruksiyası.
Mülki Məcəllə	225	Birgə	Ər-arvadın nikah dövründə qazandığı əmlakın ümumi mülkiyyəti.	Ailə hüququ ilə əlaqələndirici norma.
Mənzil Məcəlləsi	35-36	Paylı	Çoxmənzilli binanın ümumi əmlakı və torpaq sahəsi sahə mülkiyyətçilərinin paylı mülkiyyətidir.	Əsas əşyaya ayrılmaz bağlı pay modeli.
Mənzil Məcəlləsi	40-41	Paylı	Kommunal mənzilin ümumi sahələri otaq mülkiyyətçilərinin paylı mülkiyyətidir.	Xidmət funksiyalı ümumi əmlak.
Torpaq Məcəlləsi	88.3	Paylı	Çoxmənzilli evlərin torpaq sahələrinin tərkib hissəsi mülkiyyətçilərinin ümumi paylı mülkiyyətinə keçməsi.	Torpaq və bina rejimlərinin inteqrasiyası.
"İpoteka haqqında" Qanun	8.1	Birgə	Ümumi birgə əşyanın ipotekası üçün bütün mülkiyyətçilərin notarial razılığı.	Fərdi pay üzrə sərəncamın olmaması.
"İpoteka haqqında" Qanun	8.2	Paylı	Hər payçı öz payını digərlərinin razılığı olmadan ipoteka qoya bilər.	Payın müstəqil sərəncam qabiliyyəti.
"İpoteka haqqında" Qanun	57	Paylı	Mənzilin ipotekası ümumi əmlakdakı müvafiq payı da əhatə edir.	Aksessor payın hüquqi taleyi.
"Mənzil fondunun özəlləşdirilməsi haqqında" Qanun	5	Paylı və birgə	Mənzil bir neçə və ya bütün ailə üzvlərinin ümumi paylı və ya birgə mülkiyyətinə verilə bilər.	Mülkiyyət növünün iradə ilə seçilməsi.
Ailə Məcəlləsi	31-33	Birgə	Ər-arvadın əmlakının qanuni rejimi ümumi birgə mülkiyyətdir.	Birgə mülkiyyətin əsas xüsusi modeli.
Ailə Məcəlləsi	36-37	Birgədən paylıya keçid	Bölgü zamanı paylar müəyyən edilir, əsas qayda payların bərabərliyidir.	Payın sonradan fərdiləşməsi.

Normativ akt	Maddə	Mülkiyyət növü	Normativ həll	Elmi əhəmiyyəti
Ailə Məcəlləsi	55.7	Birgə	Valideyn və uşaqlar arasında birgə mülkiyyət yarandıqda mülki qanunvericilik tətbiq edilir.	Birgə mülkiyyətin ailə daxilində digər təzahürü.
"Ailə kəndli təsərrüfatı haqqında" Qanun	6.2	Paylı və birgə	Təsərrüfat əmlakı hər iki ümumi mülkiyyət formasında ola bilər.	Eyni hüquqi münasibətdə alternativ rejimlər.
"Ailə kəndli təsərrüfatı haqqında" Qanun	6.5	Birgə	Əmlakdan əldə edilən fayda üzvlərin ümumi birgə mülkiyyətidir.	Birgə fəaliyyət nəticəsinin xüsusi rejimi.
"Notariat haqqında" Qanun	61-62	Birgədən payın müəyyən edilməsinə	Ər-arvadın ümumi əmlakındakı paya mülkiyyət hüququ haqqında şəhadətnamə.	Birgə mülkiyyətdə payın rəsmiləşdirilməsi.
Notariat Təlimatı	49, 52-54, 111 və d.	Paylı və birgə	Üstün satınalma, payın ipotekası, ər-arvadın ümumi əmlakındakı payın notarial rəsmiləşdirilməsi.	Mülki dövriyyədə tətbiq mexanizmi.

Cədvəldə görünən normativ mənzərə göstərir ki, Azərbaycan hüququnda ümumi mülkiyyət yalnız Mülki Məcəllənin mücərrəd institutu deyil. Mənzil, torpaq, ailə, ipoteka, özəlləşdirmə, kənd təsərrüfatı, notariat və qeydiyyat qanunvericiliyi ümumi mülkiyyətin müxtəlif funksional modellərini yaradır. Bu modellərdən bəziləri sərbəst pay dövriyyəsinə, bəziləri əsas əşyaya bağlılığa, bəziləri isə iştirakçıları birləşdirən xüsusi şəxsi və ya təsərrüfat ümumiliyinə əsaslanır.

6. Xarici hüquqda normativ modellər

6.1. Türkiyə hüququ

Türkiyə Mülki Məcəlləsinin 688-ci maddəsi paylı mülkiyyətin birbaşa normativ tərifini verir: bir neçə şəxs maddi olaraq bölünməmiş əşyanın tamamına müəyyən paylarla malikdir. Əksi müəyyən edilmədikdə paylar bərabər sayılır, hər payçı öz payı baxımından mülkiyyətçi hüquq və vəzifələrinə malik olur, pay özgəninkiləşdirilə, girov qoyula və kreditorlar tərəfindən tutula bilər. (Türk Medeni Kanunu, 2001, maddə 688)

TMK-nın 701-ci maddəsində isə elbirliği mülkiyeti xüsusi hüquqi birliyə bağlanır, iştirakçıların müəyyən edilmiş payları yoxdur və onların hər birinin hüququ ümumi əmlakın tamamına şamil olunur. Beləliklə, Türkiyə qanunvericiliyi paylı və birgə mülkiyyət fərqini həm payın müəyyənliyi, həm də ikinci rejimin xüsusi hüquqi birliyə əsaslanması ilə ifadə edir. (Türk Medeni Kanunu, 2001, maddə 701)

Türk hüquq doktrinası bu normativ çərçivəni daha detallı izah edir. Z. Özcan paylı mülkiyyətin əsas əlamətlərini birdən çox şəxsin eyni əşyaya mülkiyyətçi olması, əşyanın maddi şəkildə bölünməməsi, hər bir iştirakçının hüququnun riyazi payla ifadə edilməsi və həmin hüququn əşyanın bütövlüyünə şamil olunması kimi sistemləşdirir [62, s. 27–33]. Ç. Şengöz isə paylı mülkiyyətlə birgə mülkiyyət arasındakı fərqi yalnız payın müəyyənliyi ilə deyil, birgə mülkiyyətdə əvvəlcədən mövcud olan şəxsi-hüquqi birlik və ayrıca pay üzərində sərəncam imkanının olmaması ilə əlaqələndirir (Şengöz, 2017, s. 130). Bu

doktrinal yanaşma Azərbaycan Respublikası Mülki Məcəlləsinin 213.2–213.3-cü maddələrinin şərhində də faydalı müqayisə materialıdır.

6.2. İsveçrə hüququ

İsveçrə Mülki Məcəlləsinin 646-cı maddəsində Miteigentum bir neçə şəxsin əşyanı fiziki bölgü olmadan paylarla mülkiyyətində saxlaması kimi qurulur. Gesamteigentum isə iştirakçıları birləşdirən qanuni və ya müqaviləvi birliyə əsaslanır və ayrıca pay üzrə sərəncamı məhdudlaşdırır. Bu model paylı və birgə mülkiyyətin yalnız riyazi pay göstəricisi ilə deyil, hüquqi münasibətin təşkilati bazası ilə fərqləndirilməsinin nümunəsidir. (Schweizerisches Zivilgesetzbuch, 1907, maddələr 646, 652–653)

İsveçrə elmi ədəbiyyatında da pay anlayışı fiziki hissədən fərqli hüquqi mövqe kimi izah olunur. N. Roth payı konkret mülkiyyətçinin hüquq və vəzifələrdən ibarət hüquqi mövqeyi, onun həcmini isə gəlir, satış məbləği, bölgü, kompensasiya, xərclər və qərarvermədə iştirakın ölçüsünü müəyyən edən abstrakt nisbət kimi xarakterizə edir (Roth, 2021, s. 40–41). İdarəetmə məsələlərində Roth müxtəlif qərar hədlərini, J. Schmid və B. Hürlimann-Kaup isə fərqli tikinti tədbirləri üzrə nisabların azlığın müdafiəsi funksiyasını vurğulayırlar (Roth, 2021, s. 38; Schmid & Hürlimann-Kaup, 2018, s. 33–35). A. Wermelinger və N. Wermelingerin təhlilində də tədbirin əhəmiyyətinə uyğun olaraq sadə çoxluq, kvalifikasiya olunmuş çoxluq və yekdillik arasında diferensiasiya göstərilir (Wermelinger & Wermelinger, 2022, s. 13–16).

6.3. Almaniya hüququ

Almaniya Mülki Məcəlləsinin §741-ci maddəsi bir hüququn bir neçə şəxsə birlikdə mənsub olduğu hallarda §§742-758-dəki Gemeinschaft nach Bruchteilen rejimini tətbiq edir. §742 şübhə olduqda payların bərabərliyini, §743 paya uyğun gəlir və istifadə imkanlarını, §744 ümumi idarəetməni, §747 isə hər iştirakçının öz payı üzərində sərəncam imkanını müəyyən edir. (Bürgerliches Gesetzbuch [BGB], n.d., §§ 741–758)

Alman modeli definisiyadan daha çox funksional sistem yaratması ilə seçilir: pay, istifadə, idarəetmə, sərəncam və xitam eyni hüquqi rejimin elementləri kimi ardıcıl tənzimlənir.

Alman doktrinasında Bruchteilsgemeinschaft ilə daha güclü şəxsi birlik əsasında qurulan Gesamthand konstruksiyası arasındakı fərq ayrıca vurğulanır. T. Zerres Bruchteilsgemeinschaft-da iştirakçının öz payı üzərində sərəncam verə bildiyini, Gesamthand rejimində isə iştirakçının ümumi əmlaka daxil olan ayrı-ayrı predmetlər üzrə müstəqil pay sərəncamına malik olmadığını göstərir (Zerres, 2025, s. 459–460). N. Schnorrun §§ 741–758 BGB-yə həsr olunmuş monoqrafik tədqiqatı da paylı birliyin ayrıca funksional hüquqi sistem kimi nəzərdən keçirildiyini nümayiş etdirir (Schnorr, 2004). Beləliklə, BGB normalarının mənası yalnız normativ mətndən deyil, iştirakçının fərdi pay muxtariyyəti ilə ümumi predmet üzrə kollektiv qərarvermə arasında tarazlıqdan çıxış edən doktrinal izahdan da aydınlaşır.

6.4. Avstriya hüququ

Avstriya ABGB §825 eyni əşya üzərində mülkiyyətin və ya eyni hüququn bölünmədən bir neçə şəxsə mənsub olmasını Gemeinschaft kimi müəyyən edir və bu birliyin hadisə, qanun, son iradə sərəncamı və ya müqavilədən yarana biləcəyini göstərir. Sonrakı müddəalar iştirakçıların idarəetmə, istifadə və bölgü hüquqlarını konkretləşdirir. Bu model ümumi mülkiyyətin yaranma mənbələrinin açıq təsnifatı baxımından diqqətəlayiqdir. (Allgemeines bürgerliches Gesetzbuch [ABGB], 1811, § 825 və davamı)

Avstriya modelinin müqayisəli-hüquqi izahında U.B. Filatova xüsusilə "əşya deyil, hüquq bölünür" prinsipini önə çəkir və ABGB § 825 və sonrakı müddəalarda ideal paylarla ifadə olunan ümumi mülkiyyət modelinin Roma və alman hüquq ənənələrinin qarşılıqlı təsiri nəticəsində formalaşdığını göstərir (Filatova, 2015, s. 92).

6.5. Fransa hüququ

Fransa Mülki Məcəlləsində indivision rejimi anlayışın abstrakt definisiyasından çox fəaliyyət və xitam qaydaları üzərindən qurulur. Code civil-in 815-ci maddəsinə görə heç kəs indivision vəziyyətində qalmağa məcbur edilə bilməz və, qanunda göstərilən istisnalar nəzərə alınmaqla, bölgü tələb edilə bilər. 815-2 və 815-3-cü maddələr qoruma, idarəetmə və sərəncam tədbirlərini fərqli qərar hədlərinə bağlayır. Bu yanaşma ümumi mülkiyyət rejiminin normativ ifadəsində kollektiv qərarvermə mexanizminin əhəmiyyətini göstərir. (Code civil, n.d., maddələr 815, 815-2, 815-3)

Fransız hüquq ədəbiyyatı Code civil-in bu mexanizmlərini yalnız prosedur qaydaları kimi deyil, indivision-un xüsusi hüquqi təbiətinin ifadəsi kimi şərh edir. M.-C. Mariani-Riela indivision-u ayrıca hüquqi şəxs və ya ayrıca mənimsəmə forması hesab etmir, onun fikrincə, burada eyni xarakterli mülkiyyət hüquqları eyni əşya üzərində paralel şəkildə həyata keçirilir və hüququn daşıyıcıları kollektiv deyil, ayrı-ayrı indivisaire-lərdir (Mariani-Riela, 2014, s. 36–37, 44–45). Bu yanaşma ümumi mülkiyyətin hüquqi şəxsin əmlakından fərqləndirilməsi baxımından mühüm nəzəri əsas yaradır.

Mariani-Riela payı konkret maddi sahəyə lokalizə olunmayan hüququn arifmetik fraksiyası kimi səciyyələndirir (Mariani-Riela, 2014, s. 40). T. Almutairi fransız doktrinasını ümumiləşdirərək indivision-dakı payın bütün əşyaya aid riyazi nisbət olduğunu və ayrıca sərəncam predmeti kimi çıxış edə bildiyini göstərir (Almutairi, 2025, s. 72–73).

Fransızdilli ədəbiyyatda indivision və copropriete institutlarının fərqli funksional problemləri də ayrıca araşdırılır. M.-A. Latournerie və P. Lecocq-un rəhbərliyi ilə hazırlanmış tədqiqatlar çoxmənzilli binalarda kollektiv mülkiyyət və idarəetmə mexanizmlərinin ayrıca hüquqi təşkilini göstərir (Latournerie, 2019; Lecocq, 2009). B. Vareille və A. Chamoulaud-Trapiersin müasir indivision icmalı, habelə C. Roussieau-nun indivisaire-lər arasında hesablaşmaların bölgü ilə əlaqəsinə dair araşdırması bu institutun yalnız bölünmə hüququndan deyil, davam edən daxili hesablaşma və idarəetmə münasibətlərindən ibarət kompleks rejim olduğunu nümayiş etdirir (Vareille & Chamoulaud-Trapiers, 2026; Roussieau, 2024).

Beləliklə, müqayisə yalnız qanun mətnləri səviyyəsində aparıldıqda hüquq sistemləri arasındakı fərqlərin bir hissəsi görünməz qala bilər. Türkiyə, Fransa, Almaniya, İsveçrə və Avstriya doktrinasına paralel istinadlar göstərir ki, eyni normativ terminlər müxtəlif sistemlərdə fərqli nəzəri konstruksiyalar üzərində qurula bilər. Bu səbəbdən Azərbaycan qanunvericiliyinin təkmilləşdirilməsi üçün xarici məcəllələrin mətni ilə yanaşı, həmin normaların milli doktrinada necə izah edildiyi də nəzərə alınmalıdır.

Müzakirə

7. Normativ ifadə problemləri və müqayisəli nəticələr

Müqayisəli təhlil göstərir ki, ümumi mülkiyyətin normativ tənzimlənməsində ən azı dörd yanaşma fərqləndirilə bilər: anlayışın normativ tərifinə əsaslanan model (Türkiyə və İsveçrə), funksional-sistemli model (Almaniya), ümumi hüquqi birlik modeli (Avstriya) və indivision-un idarə edilməsi və xitamına

yönələn model (Fransa). Azərbaycan modeli isə paylı və birgə mülkiyyət üzrə ikili təsnifatı aydın müəyyən etsə də, paylı mülkiyyətin mahiyyətini ayrıca tərif ilə tam açmır.

Azərbaycan qanunvericiliyində ümumi mülkiyyətin xüsusi təzahürləri bu boşluğu daha görünən edir. Mənzil Məcəlləsi payın əsas əşyaya ayrılmaz bağlı olduğu modeli, "İpoteka haqqında" Qanun fərdi pay üzrə sərəncam qabiliyyətini, Ailə Məcəlləsi iştirakçıların xüsusi şəxsi ümumiliyinə əsaslanan birgə mülkiyyəti, "Ailə kəndli təsərrüfatı haqqında" Qanun isə xüsusi təsərrüfat ümumiliyindən doğan birgə mülkiyyət və eyni münasibətdə alternativ paylı mülkiyyət imkanını göstərir.

Bu səbəbdən paylı və birgə mülkiyyət fərqinin yalnız "pay müəyyən edilib-edilməyib" formulu ilə izahı nəzəri baxımdan natamamdır. Paylı mülkiyyətdə fərdi pay hüquqi dövriyyə obyekti ola bilir, birgə mülkiyyətdə isə iştirakçının hüquqi mövqeyi birgə mülkiyyətin yaranmasına əsas olmuş ümumiliklə bağlıdır və ayrıca pay üzərində sərəncam yalnız həmin rejimin dəyişdirilməsi və ya payın müəyyən edilməsi nəticəsində mümkün olur.

Digər problem isə pay anlayışının qanunvericilikdə ayrıca normativ tərifinin verilməməsidir.Xüsusilə daşınmaz əmlak mübahisələrində hüquqi payın faktiki istifadə olunan otaq, sahə və ya torpaq hissəsi ilə eyniləşdirilməsi hüquqi yanlışlığa səbəb ola bilər. Normativ tərif bu qarışıqlığı azaltmaqla Mülki Məcəllənin sonrakı maddələrinin şərhinə vahid konseptual baza yarada bilər.

8. De lege ferenda təklif

Azərbaycan Respublikasının Mülki Məcəlləsinə paylı mülkiyyətin ayrıca anlayışını müəyyən edən normanın əlavə edilməsi məqsədəuyğun hesab edilir. Təklif olunan norma belə ifadə oluna bilər: *"Paylı mülkiyyətdə bir neçə şəxs maddi olaraq bölünməmiş əşyanın tamamı üzərində müəyyən paylarla mülkiyyət hüququna malikdir. Pay əşyanın fiziki hissəsini deyil, mülkiyyət hüququnda iştirakın həcmini ifadə edir."*

Bu tərif Türkiyə və İsveçrə hüququnun uğurlu normativ texnikasını Azərbaycan hüququnun mövcud sisteminə uyğun şəkildə istifadə etməyə imkan verir. Eyni zamanda norma payın fiziki hissə olmadığını birbaşa göstərərək istifadə qaydası ilə mülkiyyət hüququ arasındakı sərhədi dəqiqləşdirir.

Bundan əlavə, əsas əşyaya daimi funksional bağlı payların xüsusi hüquqi rejiminin Mülki Məcəllənin ümumi mülkiyyət bölməsində də ifadə olunması məqsədəuyğundur. Mənzil Məcəlləsində artıq mövcud olan model ümumiləşdirilərək qanunla nəzərdə tutulmuş hallarda müəyyən payın əsas əşyadan ayrılıqda özgəninkiləşdirilə, yüklü edilə və naturada ayrıla bilməməsi, hüquqi taleyinin əsas əşyanı izləməsi prinsipi təsbit edilə bilər.

Nəticə

Aparılmış təhlil ümumi mülkiyyətin Azərbaycan hüququnda təkcə Mülki Məcəllənin 213-224-cü maddələri ilə məhdudlaşmayan, müxtəlif sahəvi qanunlarda fərqli funksional modellərlə ifadə olunan kompleks institut olduğunu göstərir. Paylı mülkiyyət Mülki Məcəllədə ümumi model kimi çıxış edir, Mənzil və Torpaq məcəllələri əsas sahəyə bağlı məcburi paylı mülkiyyət rejimi yaradır, ipoteka qanunvericiliyi payın fərdi sərəncam qabiliyyətini konkretləşdirir, mənzil özəlləşdirməsi qanunvericiliyi ümumi mülkiyyət növünün müəyyən hallarda iştirakçıların razılığı ilə seçilə bilməsini tanıyır.

Birgə mülkiyyət isə, ilk növbədə, ər-arvadın əmlakının qanuni rejimi kimi Ailə Məcəlləsində sistemli şəkildə formalaşdırılır. Ailə kəndli təsərrüfatı haqqında qanunvericilik birgə fəaliyyət və ortaq əmək

əsasında əlavə xüsusi model yaradır, notariat və reyestr qanunvericiliyi isə birgə mülkiyyətdə fərdi payın müəyyənləşdirilməsi və rəsmiləşdirilməsi mexanizmini tamamlayır.

Bu normativ materiallar ümumi mülkiyyətin ayrıca mülkiyyət forması deyil, mülkiyyət hüququnun çoxsubyektli rejimi olması nəticəsini gücləndirir. Paylı mülkiyyətdə pay əşyanın fiziki hissəsini deyil, ümumi hüquqda iştirakın ölçüsünü bildirir. Birgə mülkiyyət isə təkcə payların müəyyən edilməməsi ilə deyil, iştirakçıları birləşdirən xüsusi hüquqi ümumilik və həmin ümumiliyin fərdi sərəncam sferasına təsiri ilə xarakterizə olunur.

Buna görə Azərbaycan Mülki Məcəlləsində paylı mülkiyyət anlayışının ayrıca normativ tərifin verilməsi, əsas əşyaya ayrılmaz bağlı payların ümumi modelinin qanunvericilikdə sistemli şəkildə təsbit edilməsi və birgə mülkiyyətin hüquqi ümumilik elementi nəzərə alınmaqla sistemli izahı ümumi mülkiyyət institutunun normativ dəqiqliyini və tətbiqinin ardıcıllığını artıra bilər.

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TƏBİƏT ELMLƏRİ

NATURAL SCIENCES

İçməli suyun təmizlənməsində nanotexnologiyalarin rolu

(İcmal)

Ağasəmid İsayev[1], Sevinc Sadiqova[2], İradə Nağıyeva[2], İradə Zərbəliyeva[2*]

Xülasə. *Təqdim olunan icmal məqalədə içməli suyun təmizlənməsində istifadə olunan müxtəlif nanomaterialların, o cümlədən qrafen və onun törəmələri, çirkləndiricilərin adsorbsiyası üçün adsorbentlərin, karbon nanotübləri (CNT), titan dioksidin (TiO_2), sink oksidin (ZnO), gümüş (Ag NP) nanohissəciklərinin, dəmir əsaslı (Fe) nanomaterialların və membran texnologiyalarının tətbiqi hərtərəfli araşdırılmışdır. Tədqiqatın məqsədi nanomaterialların ağır metallar, üzvi çirkləndiricilər və patogenlər daxil olmaqla, geniş spektrli su çirkləndiricilərinin kənarlaşdırılmasındakı effektivliyini qiymətləndirməkdir.Araşdırma nəticəsində məlum o lmuşdur ki, təhlil edilən hər bir material özünəməxsus xüsusiyyətlərə malikdir. Belə ki, qrafen və onun törəmələri (qrafen oksidi (GO) və reduksiya olunmuş qrafen oksidi (rGO)) yüksək səth sahəsi, mexaniki möhkəmliyi və çoxyönlü səth kimyası sayəsində suyun təmizlənməsində, karbon nanotübləri (CNT) və dəmir nanohissəcikləri (Fe NP) üzvi çirkləndiricilərin və ağır metalların sudan adsorbsiyasında yüksək performans göstərir. Sink oksidi nanopartikulları (ZnO NP) və gümüş nanohissəcikləri (Ag NP) yüksək antimikrob xüsusiyyətləri nümayiş etdirməklə bakteriya, virus və göbələklər kimi geniş spektrli patogenləri təsirsiz hala gətirə bilir. Membran nanomateriallar isə filtrasiya texnologiyalarının performansını əhəmiyyətli dərəcədə yaxşılaşdırır. TiO_2, ZnO və ya qrafen əsaslı nanomaterialların membranlara inteqrasiyası membranın çirklənməyə qarşı müqavimətini, mexaniki möhkəmliyini və çirkləndiricilərə qarşı selektivliyini əhəmiyyətli dərəcədə artırır.*

Açar sözlər: *içməli su, karbon nanotübləri, adsorbent, nanotexnologiya, membran texnologiyaları*

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The Role of Nanotechnologies in Drinking Water Purification (Review)

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Abstract. *The presented review article comprehensively examines the application of various nanomaterials in drinking water purification — including graphene and its derivatives, adsorbents for pollutant adsorption, carbon nanotubes (CNTs), titanium dioxide (TiO_2), zinc oxide (ZnO), silver nanoparticles (Ag NPs), iron-based (Fe) nanomaterials, and membrane technologies. The aim of the study is to evaluate the effectiveness of nanomaterials in removing a wide range of water pollutants, including heavy metals, organic pollutants, and pathogens. The research revealed that each material analyzed possesses unique characteristics. Specifically, graphene and its derivatives (graphene oxide (GO) and reduced graphene oxide (rGO)) demonstrate high performance in water purification due to their high surface area, mechanical strength, and versatile surface chemistry, while carbon nanotubes (CNTs) and iron nanoparticles (Fe NPs) excel in the adsorption of organic pollutants and heavy metals from water. Zinc oxide nanoparticles (ZnO NPs) and silver nanoparticles (Ag NPs) exhibit strong antimicrobial properties, enabling them to neutralize a broad spectrum of pathogens such as bacteria, viruses, and fungi. Membrane nanomaterials significantly improve the performance of filtration technologies. Integrating TiO_2, ZnO, or graphene-based nanomaterials into membranes substantially enhances their fouling resistance, mechanical strength, and selectivity toward contaminants.*

Keywords: *drinking water, carbon nanotubes, adsorbent, nanotechnology, membrane technologies*

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1. Giriş

Yer kürəsinin səthinin üçdə ikisinin su ilə örtülü olmasına baxmayaraq, sayı 8 milyarddan artıq olan dünya əhalisi üçün həmin suyun yalnız 0,3%-i şirin sudur (Sadigov, 2022; Stephens, 2020). Qlobal miqyasda şirin su ehtiyatlarının azalması fonunda suya, xüsusilə də içməli suya olan tələbat getdikcə artır və bu hal dövrümüzün ən ciddi çağırışlarından birinə çevrilir. Mövcud sutəmizləmə sistemləri artan tələbatı ödəyə bilmir, 2 milyard insan təhlükəsiz sudan məhrumdur və 1,2 milyard insan yalnız əsas su xidmətlərindən istifadə edir (Alemayehu et al., 2023).

Hələ 2014-cü ildə Ümumdünya Səhiyyə Təşkilatı (ÜST) 2025-ci ilə qədər dünya əhalisinin yarısının su çatışmazlığı olan ərazilərdə yaşayacağını proqnozlaşdırmışdı (Ungureanu et al., 2020). Hazırda dünya əhalisinin 40%-ə qədəri su qıtlığı ilə üzləşib. Ümumdünya Səhiyyə Təşkilatının (ÜST) proqnozlarına əsasən, 2050-ci ildə inkişaf etmiş dövlətlərdə baş verən sürətli əhali artımı sözügedən problemi daha da dərinləşdirəcək. Təmiz içməli su qıtlığı artdıqca suyun təmizlənməsi texnologiyaları qlobal xarakter daşıyır, xərclərə və enerjiyə qənaət edən davamlı innovasiyalara (nanotexnologiyalara) ehtiyac artır (Anjum, 2023; Bhardwaj, 2021; He et al., 2022).

Oxşar mənzərə Azərbaycan üçün də tamamilə xarakterikdir. Belə ki, Cənubi Qafqaz regionunda içməli su ehtiyatları baxımından ən çətin vəziyyət məhz ölkəmizdədir – bölgənin ümumi şirin su ehtiyatının yalnız 10%-i respublikamızın payına düşür.

Bu baxımdan Azərbaycanda da nanotexnologiyalar suyun təmizlənməsi prosesində, xüsusilə də nanofiltrasiya və ağır metalların, sənaye çirkablarının təmizlənməsi istiqamətində tətbiq olunur. Azərbaycan elmi mühitində nanoölçülü hissəciklərin (məsələn, TiO_2 nanohissəcikləri) tullantı sularından fenol kimi zərərli kimyəvi maddələrin təmizlənməsində rolu araşdırılır. Neft-qaz sənayesində çıxan lay sularının təmizlənməsi və təkrar istifadəsi üçün alüminium nanohissəcikləri tərkibli xüsusi kompozisiyalar sınaqdan keçirilir. Bu üsul həm suyun təmizlənməsini təmin edir, həm də avadanlıqlarda korroziyanın qarşısını alır.

2. Material və metodlar

Tədqiqatın məqsədi: İçməli suyun təmizlənməsində istifadə olunan qrafen və onun törəmələri, su çirkləndiricilərinin adsorbentləri, karbon nanotüpləri (CNT), titan dioksidi (TiO_2 NP), sink oksidi (ZnO NP), gümüş (Ag NP) və dəmir əsaslı (Fe NP) nanopartikulların, həmçinin membran texnologiyalarının ağır metallar, üzvi çirkləndiricilər və patogenlər də daxil olmaqla geniş spektrli çirkləndiricilərin təmizlənməsində effektivliyini ədəbiyyat məlumatları əsasında araşdırmaqdan ibarət olmuşdur.

3. Nəticələr

İçməli suyun təmizlənməsində istifadə olunan karbon əsaslı nanomateriallardan biri – qrafen və onun törəmələri – əhəmiyyətli fiziki-kimyəvi, hidrofob və oleofil xüsusiyyətlərinə görə bir sıra tədqiqat sahələrində geniş şəkildə istifadə olunur (Liu et al., 2015). Geim və Novoselovun də qeyd etdiyi kimi (Geim & Novoselov, 2007) bütün qrafit karbon materiallarının "anası" kimi təsvir edilən qrafen qrafit və karbon nanotubları (CNT) üçün əsas blokdur. Qrafen olduqca cəlbedici optik, istilik, elektron, geniş səth sahəsinə və mexaniki xüsusiyyətlərə malikdir. Hazırda qrafen həm nəzəri, həm də təcrübi olaraq suyun təmizlənməsi texnologiyaları üçün adsorbent kimi dünya miqyasında öyrənilir (Elgengehi et al., 2020).

Hazırda yeni adsorbentlər və içməli su filtrasiya sistemləri üçün texnologiyaların və strukturların hazırlanmasında tətbiq oluna bilən ən səmərəli maddələrdən biri də qrafen oksididir (GO). Dünyanın bir çox bölgələrində içməli suda yüksək miqdarda flüorid ionlarının (F) olması insanların rifahına təsir edən ciddi bir problemdir. Bununla əlaqədar Prathibha və digərləri (Prathibha et al., 2020) içməli suyun deflüoridləşdirilməsi üçün sirkonium (Zr) ilə hopdurulmuş qrafen oksid örtüklü qumun tətbiqini araşdıraraq belə qənaətə gəldilər ki, həmin materialın 6,12 mq/q-a çatan yüksək flüorid adsorbsiya qabiliyyəti var ki, bu da içməli sudan deflüoridasiya üçün istifadə olunan digər karbon əsaslı adsorbentlərlə müqayisədə ən yüksək deflüoridləşmə dəyəri hesab olunur.

Majdoub və digərləri (Majdoub et al., 2021) içməli suda olan Cd (II), Cu (II) və Pb (II) daxil olmaqla ağır metallara qarşı qrafen oksidinin (GO) adsorbsiya qabiliyyətini araşdırmışdır. Müəlliflərin tədqiqatının nəticələri göstərmişdir ki, əldə edilən adsorbsiya nisbətləri Pb (II) üçün 100%, Cu (II) üçün 98,18% və Cd (II) üçün 95,19% təşkil edir.

Ətraf mühitdə və sənaye müəssisələrində təhlükəli kimyəvi maddələrin nəzarətsiz istifadəsi su ehtiyatlarının çirklənməsinə və nəticədə ciddi sağlamlıq problemlərinə səbəb olur. Kumar və başqaları (Kumar et al., 2021) içməli suda olan arsen (III)/(V), xrom (III)/(VI), qurğuşun (II) və selenin (IV)/(VI) kimi ağır metalların adsorbsiyasında maqnit qrafen əsaslı kompozitlərin istifadəsini öyrənərək müəyyən etmişlər ki, həmin kompozitlər içməli sudan göstərilən ağır metalları effektiv şəkildə adsorbsiya edir.

Tədqiqatlar göstərir ki, içməli suyun təmizlənməsində mühəndislik nanomateriallarının, o cümlədən TiO_2 nanopartikullarının (TiO_2-NP) tətbiqi xüsusi əhəmiyyət kəsb edir (Xu et al., 2022). Ultrabənövşəyi (UB) işığın təsiri altında baş verən fotokataliz nəticəsində TiO_2 NP-ləri içməli suda üzvi çirkləndiriciləri, mikroorqanizmləri və qeyri-üzvi çirkləndiriciləri parçalaya bilən yüksək reaktiv sərbəst radikallar əmələ gətirir və bu yolla bakteriyaları (Salmonella, Mycobacteria və Shigella) və ibtidailəri (Giardia duodenalis və Entamoeba histolytica) zərərsizləşdirə bilir.

Tədqiqatlar göstərir ki, sink oksidi nanopartikulları (ZnO NP) yüksək antimikrob aktivliyi, fotokatalitik parçalanma və adsorbsiya qabiliyyəti, böyük səth sahəsinin olmasına görə içməli suda çirkləndirici maddələri təmizləmək üçün səmərəli və perspektivli bir materialdır. Antimikrob nanoölçülü sink oksidi (ZnO) materialları qeyd olunan xüsusiyyətlərinə görə içməli suyun təmizlənməsi üçün ekoloji cəhətdən təmiz nanokompozitlər kimi istifadə edilməkdədir (Atta et al., 2017).

Yüksək antibakterial, yüksək və uzunmüddətli fotokatalitik, o cümlədən antibakterial xüsusiyyətləri olan gümüş nanopartikulları da (AgNP) içməli suyun təmizlənməsi proseslərində geniş şəkildə istifadə olunmaqdadır.

Hazırda gümüş NP-ləri unikal xüsusiyyətlərinə görə içməli sudan patogen mikroorqanizmlərin, ağır metalların və üzvi çirkləndiricilərin təmizlənməsində geniş tətbiq olunur. Əl-Ravajfeh və digərlərinin (Al-Rawajfeh et al., 2024), sudan bromid ionları üçün adsorbent kimi gümüş nanopartikulunun (Ag-NP)-seolit kompozitinin istifadəsinin öyrənilməsi istiqamətində apardıqları araşdırmaların nəticələri qeyd olunanları bir daha sübut edir. Müəyyən olunmuşdur ki, gümüş nanohissəciklərlə (Ag NP) bəzədilmiş aktivləşdirilmiş karbonun (AC) Escherichia coli və Staphylococci bakteriyalarına qarşı müstəsna antibakterial təsiri vardır, həmçinin Ag ilə yüklənmiş AC, xlorat, yodat, xlorit və bromat da daxil olmaqla bir sıra qeyri-üzvi çirkləndiriciləri də içməli sudan kənarlaşdıra bilir (Soliman et al., 2022).

Dəmir nanopartikulları (Fe NP) içməli suyun təmizlənməsi prosesini tamamilə dəyişdirə bilən qabaqcıl nanotexnologiyadır. Onlar geniş səth sahəsi, yüksək reaktivlik və maqnit xüsusiyyətləri ilə xarakterizə olunur ki, bu da onları içməli sudan geniş çeşiddə çirkləndiricilərin, o cümlədən qurğuşun, civə, arsen, boyalar və antibiotiklər kimi sağlamlığa son dərəcə zərərli təsir göstərən ağır metalların çıxarılması üçün çox səmərəli material halına gətirir (Mahlaule-Glory et al., 2022).

Aparılan tədqiqatlar göstərir ki, içməli suyun təmizlənməsində nanomaterial əsaslı membranların da əvəzolunmaz rolu vardır. Bu halda, membran materialının seçilməsi içməli suyun təmizlənməsi prosesinin səmərəliliyi üçün çox vacibdir. İçməli suyun təmizlənməsi proseslərində istifadə edilə bilən membranlara mikrofiltrasiya (MF), ultrafiltrasiya (UF), nanofiltrasiya (NF), tərs osmoz (RO) və elektrodializ (ED) membranlarını aid etmək olar.

Digər müəlliflər qrupu (Alsalme, 2023) axın-keçid yanaşması ilə qrafen oksid təbəqələrinə qarışan Fe_3O_4 @amiloid fibril nanoklasterlərindən istifadə edərək çoxqatlı qrafen oksid hibrid membran sintez etmiş və içməli sudan ağır metalların çıxarılmasında həmin membranın tətbiqini araşdırmışlar. Tədqiqatın nəticələri göstərmişdir ki, qrafen əsaslı hibrid membran içməli sudan ağır metal ionlarını çıxarmaq üçün 99,9% dəyərə malikdir.

4. Müzakirə

Nanomaterialların suyun təmizlənməsində tətbiqinin ümidverici nəticələrinə baxmayaraq, onların genişmiqyaslı tətbiqində hələ də çətinliklər qalmaqdadır. Nanohissəciklərin ətraf mühitə buraxılması, yüksək istehsal xərcləri və nanomaterialların uzunmüddətli sabitliyi də daxil olmaqla bir sıra məsələlər aradan qaldırılmalıdır. Ətraf mühitə və ya insan sağlamlığına təsir göstərə biləcək hər hansı potensial zərərin qarşısını almaq üçün nanomaterialların ətraf mühitə buraxılması üçün icazə verilən hədlər hərtərəfli qiymətləndirilməlidir.

5. Nəticə

Beləliklə, əldə etdiyimiz ədəbiyyat mənbələrinin təhlili göstərdi ki, suyun təmizlənməsində nanomaterialların istifadəsi qlobal su çirklənməsi böhranının qarşısını almaq üçün innovativ üsullar təklif edir və ənənəvi su təmizlənməsi metodlarından daha yüksək səmərəliliyə və spesifikliyə malikdir. Belə ki, bu məqalədə araşdırılmış hər bir nanomaterialın özünəməxsus fərqli xüsusiyyətləri vardır. Qrafen və onun törəmələri (qrafen oksidi - GO) və reduksiya olunmuş qrafen oksidi (rGO) yüksək səth sahəsi, mexaniki möhkəmliyi və çoxyönlü səth kimyası sayəsində suyun çirkləndiricilərdən təmizlənməsində böyük perspektivlər yaradır. Karbon nanotüpləri (CNT) üzvi çirkləndiricilərin və ağır metalların sudan adsorbsiyasında yüksək performans göstərir. İncə fotokatalitik xüsusiyyətlərinə malik titan dioksid nanopartikulları (TiO_2 NP) üzvi çirkləndiriciləri UB və ya görünən işıq şüalanması altında parçalaya bilir. Sink oksidi nanopartikulları (ZnO NP) yüksək fotokatalitik və antimikrob xüsusiyyətləri nümayiş etdirir. Eyni zamanda, gümüş nanopartikulları (Ag NP) güclü antimikrob xüsusiyyətləri nümayiş etdirir və bu da onları bakteriya, virus və göbələklər də daxil olmaqla geniş spektrli patogenləri təsirsiz hala gətirməyə imkan verir. Dəmir nanopartikulları (Fe NP) adsorbsiya və reduksiya reaksiyaları vasitəsilə sudan ağır metalların və üzvi çirkləndiricilərin təmizlənməsində geniş tətbiq edilir. Membran nanomateriallar filtrasiya texnologiyalarının performansını əhəmiyyətli dərəcədə yaxşılaşdırır. TiO_2, ZnO və ya qrafen əsaslı nanomaterialların membranlara inteqrasiyası membranın çirklənməsinə qarşı müqavimətini, mexaniki möhkəmliyini və çirkləndiricilərə qarşı selektivliyini xeyli artırmışdır.

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Growth and Exterior Characteristics of F_2-Generation Hybrid Female Buffaloes

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Abstract. *The article presents the results of a study on the growth and development characteristics, age-related dynamics of live weight, and main exterior measurements of F_2-generation hybrid female buffaloes. The aim of the study was to determine changes in live weight and body measurements of hybrid female buffaloes at different age periods. The study was conducted on F_2-generation hybrid female buffaloes obtained through artificial insemination in private farms located in the Sheki-Zagatala region. Feeding and housing conditions of the animals were organized in accordance with zooveterinary requirements. It was determined that the live weight of the two studied hybrid females was 28 and 32 kg, respectively, at birth, 77 and 86 kg at three months of age, and 82 and 90 kg at six months of age. With increasing age, a consistent increase was observed in the main exterior measurements, including withers height, back length, rump width, chest depth, oblique body length, chest width, heart girth, and cannon bone circumference. The obtained results characterize the individual growth and development characteristics of F_2-generation hybrid female buffaloes and can be used to evaluate their growth and exterior traits in breeding and selection work.*

Keywords. *F_2 generation, hybrid female buffaloes, live weight, growth, development, exterior, body measurements, age dynamics, breeding and selection work, buffalo breeding*

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F_2 nəsli hibrid dişi camışların böyüməsi və xarici xüsusiyyətləri

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Xülasə. *Məqalədə F_2 nəsil hibrid dişi camışların böyümə və inkişaf xüsusiyyətlərinin, diri kütləsinin yaş dinamikasının və əsas eksteryer göstəricilərinin tədqiqinin nəticələri təqdim edilmişdir. Tədqiqatın məqsədi müxtəlif yaş dövrlərində hibrid dişi camışların diri kütləsində və bədən ölçülərində baş verən dəyişiklikləri müəyyənləşdirməkdən ibarət olmuşdur. Tədqiqatlar süni mayalandırma yolu ilə alınmış F_2 nəsil hibrid dişi camışlar üzərində Şəki-Zaqatala regionunda yerləşən fərdi fermer təsərrüfatlarında aparılmışdır. Heyvanların yemlənməsi və saxlanması zoobaytarlıq tələbləri nəzərə alınmaqla təşkil edilmişdir. Müəyyən edilmişdir ki, tədqiq olunan iki dişi hibridin diri kütləsi doğuş zamanı müvafiq olaraq 28 və 32 kq, üç aylıq yaşda 77 və 86 kq, altı aylıq yaşda isə 82 və 90 kq olmuşdur. Yaş artdıqca cidov hündürlüyü, bel uzunluğu, sağrı eni, döş qəfəsinin dərinliyi, bədənin çəp uzunluğu, döş eni, döş çevrəsi və pəncə çevrəsi kimi əsas eksteryer göstəricilərində ardıcıl artım müşahidə edilmişdir. Əldə olunan nəticələr F_2 nəsil hibrid dişi camışların fərdi inkişaf xüsusiyyətlərini xarakterizə edir və onların böyümə və eksteryer göstəricilərinin seleksiya-damazlıq işlərində qiymətləndirilməsi üçün istifadə oluna bilər.*

Açar sözlər: *F_2 nəsil, hibrid dişi camışlar, diri kütlə, böyümə, inkişaf, eksteryer, bədən ölçüləri, yaş dinamikası, seleksiya-damazlıq işi, camışçılıq*

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1. Introduction

At the present stage of livestock development, the study of animal growth and development characteristics is of great importance for assessing productivity and genetic potential. In particular, monitoring individual development indicators by age periods in hybrid offspring obtained from animals of different genetic origins makes it possible to determine their future economic and breeding significance.

Buffalo breeding is one of the traditional branches of livestock production in Azerbaijan, and research aimed at preserving the local buffalo gene pool and improving productivity traits is of particular importance. The biological characteristics and productivity indicators of Azerbaijani buffaloes have been extensively studied in various studies (Agabeyli, 1967, 1980; Agabeyli & Aliyev, 1960). Targeted breeding and selection work is considered one of the important directions in the development of buffalo breeding (Babayev, 1986; Bashirov, 2011).

Artificial insemination and embryo transplantation are considered modern biotechnological methods used worldwide to improve the breed composition of animals and overcome infertility. In addition to

being of great economic importance, artificial insemination and embryo transplantation form the basis of breeding and selection work (Khalilova et al., 2023).

The study of growth and development indicators in offspring obtained from the crossbreeding of buffaloes of different genetic origins is of particular importance for the evaluation of new genotypes. In this regard, live weight, body measurements, and exterior traits are considered key characteristics that reflect the level of individual development of animals. In this context, the study of the growth and development characteristics of F_2 hybrid animals obtained from the crossbreeding of Murrah and Azerbaijani buffalo breeds is of particular scientific and practical importance. A systematic study of growth and development indicators at different stages of ontogenesis makes it possible to identify genotypes of greater value for selection (Khalilova et al., 2026).

Studies aimed at determining genetic parameters of growth traits in Murrah buffaloes have emphasized the importance of age-related changes in live weight and the heritability of this trait from the perspective of selection (Joshi et al., 2022). The study of genetic markers associated with economically important traits in Murrah buffaloes is also one of the major directions of modern breeding programs (George et al., 2023).

The combined evaluation of productivity, reproductive performance, and health indicators is important for the genetic improvement of animals (Kumar et al., 2023). Studies of genetic and phenotypic variation in productive and reproductive traits in Murrah buffaloes make it possible to determine various selection criteria (Sharma, Dahiya, Bangar, Hada, et al., 2024; Sharma, Dahiya, Bangar, & Yadav, 2024). In recent years, studies have also been conducted to identify genomic regions associated with economically important traits using genomic data (George et al., 2024).

The study of growth and development processes in buffaloes at different age stages provides important information for assessing the formation of body conformation. The determination of genetic parameters of live weight at different stages of life in Anatolian buffaloes demonstrates the importance of age-related dynamics of this trait for selection purposes (Yazgan et al., 2026).

The study of growth and exterior characteristics of F_2-generation hybrid animals is particularly important. This is because the expression of genetic characteristics formed as a result of previous crosses in phenotypic traits of this generation is of interest for assessing individual development.

The aim of the study was to investigate the live weight and main exterior characteristics of F_2-generation hybrid female buffaloes at different ages and to determine changes in growth and body conformation.

2. Materials and Methods

The study was conducted on F_2-generation hybrid female buffaloes obtained through artificial insemination on private farms located in the Sheki-Zagatala region. The study material consisted of two F_2-generation hybrid female buffaloes. The housing and feeding of the animals were organized in accordance with zooveterinary requirements. The age characteristics of the animals were taken into account during feeding, and the diet included grain feeds, natural alfalfa hay, various types of straw, cottonseed meal, and salt as a mineral supplement.

At three months of age, the daily feed ration of the female buffaloes consisted of 1 kg of barley groats, 0.5 kg of corn groats, 6 kg of natural alfalfa hay, 2 kg of barley straw, 2 kg of cottonseed meal, 1 kg of wheat straw, and 0.10 kg of salt. The total amount of feed was 12.6 kg.

At six months of age, the daily ration consisted of 1.5 kg of barley groats, 1 kg of wheat groats, 0.5 kg of corn, 8 kg of natural alfalfa hay, 2 kg of barley straw, 2 kg of cottonseed meal, 2 kg of wheat straw, and 0.10 kg of salt. The total ration amounted to 17.1 kg.

During the study, the live weight of the animals was determined at birth, three months, and six months of age. In assessing exterior characteristics, the following measurements were taken into account: withers height, back length, rump width, chest depth, oblique body length, chest width, heart girth, and cannon bone circumference. The obtained data were compared by age periods, and the direction of changes in live weight and the main body measurements was determined.

3. Results

The live weight indicators of F_2-generation hybrid female buffaloes at different age periods are presented in Table 1.

Table 1
Age-related dynamics of live weight in F_2-generation hybrid female buffaloes

Age period	Female I, kg	Female II, kg
At birth	28	32
3 months of age	77	86
6 months of age	82	90

As shown by the data, the live weight of Female I hybrid was 28 kg at birth, reaching 77 kg at three months of age and 82 kg at six months of age. The live weight of Female II hybrid was 32, 86, and 90 kg, respectively, at the corresponding age periods.

Thus, in both animals, a more pronounced increase in live weight was observed from birth to three months of age. From three to six months of age, the increase in live weight was comparatively lower. The Female II hybrid had a higher live weight than Female I at all the age periods studied.

The age-related dynamics of the main exterior characteristics of F_2-generation hybrid female buffaloes are presented in Table 2.

Table 2
Main exterior characteristics of F_2-generation hybrid female buffaloes

Exterior characteristics	At birth	3 months	6 months
Withers height, cm	65	120	135
Back length, cm	60	122	141
Rump width, cm	55	130	138
Chest depth, cm	26	62	76
Oblique body length, cm	55	120	150
Chest width, cm	14	36	46
Heart girth, cm	60	160	180
Cannon bone circumference, cm	15	20	24

The analysis of the data presented in the table shows that, with increasing age, a consistent increase was observed in all studied exterior characteristics.

Withers height was 65 cm at birth, 120 cm at three months of age, and 135 cm at six months of age. Body length was 60, 122, and 141 cm, respectively. Hip width increased from 55 cm at birth to 130 and 138 cm at three and six months of age, respectively.

Chest depth was 26 cm at birth, 62 cm at three months, and 76 cm at six months of age. Oblique body length was 55, 120, and 150 cm, respectively.

Chest width increased from 14 cm at birth to 36 cm at three months and 46 cm at six months of age. An increase was also observed in hoof circumference, which increased from 15 cm to 20 and 24 cm, respectively.

The most noticeable change was observed in chest circumference. Chest circumference, which was 60 cm at birth, increased to 160 cm at three months and 180 cm at six months of age. The increase in this parameter with age characterizes the intensive formation of body conformation.

4. Discussion

The results of the study showed that live weight and the main exterior characteristics of F_2-generation hybrid female buffaloes changed consistently with increasing age. A particularly pronounced increase in live weight was recorded from birth to three months of age.

The study of genetic parameters of growth traits in Murrah buffaloes demonstrates the importance of live weight and other growth indicators from a selection perspective (Joshi et al., 2022). Studies aimed at identifying genetic markers associated with economically important traits in Murrah buffaloes also indicate the importance of investigating the genetic basis of growth and productivity traits (George et al., 2023).

In the present study, the second hybrid female had a higher live weight at all age periods, indicating individual differences in growth and development. However, since only two animals were studied, it was not possible to determine the statistical significance of these differences. Therefore, the obtained results should be considered as preliminary observation and assessment data.

The age-related increase observed in the exterior characteristics is associated with the formation of the animals' body conformation. Increases in withers height, body length, hip width, chest depth, oblique body length, chest width, chest circumference, and hoof circumference characterize the individual development of the hybrid animals.

In modern buffalo production, the comprehensive assessment of productive and reproductive characteristics is one of the main directions of breeding programs (Kumar et al., 2023; Sharma, Dahiya, Bangar, Hada, et al., 2024). The study of genetic and phenotypic variability makes it possible to evaluate various traits from a selection perspective (Sharma, Dahiya, Bangar, & Yadav, 2024).

The biological and productive characteristics of Azerbaijani buffaloes have been studied for many years (Agabeyli, 1967, 1980; Agabeyli & Aliyev, 1960). Consideration of the characteristics of the local gene pool and the implementation of targeted selection work are important for the development of buffalo production (Babayev, 1986; Bashirov, 2011).

The study of the obtained characteristics in F_2-generation hybrids on a larger number of animals in future research may allow more accurate determination of the general patterns of growth and exterior

characteristics. In this regard, the obtained results are of importance as a preliminary database for future breeding and selection work.

5. Conclusion

The study of the growth and exterior characteristics of F_2-generation hybrid female buffaloes established that live weight and the main body measurements increased consistently with advancing age.

At birth, the live weights of the first and second hybrid females were 28 and 32 kg, respectively; at three months of age, they reached 77 and 86 kg, and at six months of age, 82 and 90 kg, respectively. The second hybrid female had a higher live weight at all studied age periods.

The age dynamics of the exterior characteristics also demonstrated the consistent formation of body conformation. An age-related increase was observed in withers height, body length, hip width, chest depth, oblique body length, chest width, chest circumference, and hoof circumference.

The obtained results provide preliminary data for evaluating the growth and exterior characteristics of F_2-generation hybrid female buffaloes. The studied parameters can be used to assess the individual development and breeding and selection characteristics of hybrid animals.

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The Effect of Vilofoss Mineral Feed Additive on Productive and Wool Quality Characteristics in Fattening Hissar Lambs

Shoira Aminova

Abstract. *This article highlights the effect of using different doses (50 g and 100 g) of Vilofoss feed additive in a two-stage system for fattening Hissar lambs on nutrient digestibility, live weight gain, feed conversion ratio (FCR), and wool productivity. The experimental results indicated that the inclusion of Vilofoss additive significantly improved ration digestibility while concurrently increasing live weight gain by 18.4–26.3% and substantially enhancing wool quality parameters. Furthermore, the specific biological and physiological patterns regarding the optimal dose levels for both meat and wool productivity were scientifically substantiated.*

Keywords: *Hissar breed, Vilofoss, fattening, feed conversion, digestibility, wool yield, keratin, mineral balance*

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Kökəltmədə olan Hissar quzularında "Vilofoss" mineral yem əlavəsinin məhsuldarlıq və yun keyfiyyəti göstəricilərinə təsiri

Şoira Aminova

Xülasə. *Məqalədə Hisar cinsli quzuların kökəldilməsində iki mərhələli sistem üzrə müxtəlif dozalarda (50 q və 100 q) Vilofoss yem əlavəsindən istifadənin qida maddələrinin həzm olunmasına, canlı çəki artımına, yemin konversiya əmsalına (FCR) və yun məhsuldarlığına təsiri araşdırılmışdır. Təcrübə nəticələri göstərmişdir ki, rasiona Vilofoss əlavəsinin daxil edilməsi qida maddələrinin həzm olunmasını əhəmiyyətli dərəcədə yaxşılaşdırmaqla yanaşı, canlı çəki artımını 18,4–26,3% artırmış və yunun keyfiyyət göstəricilərini əhəmiyyətli dərəcədə yaxşılaşdırmışdır. Bundan əlavə, ət və yun məhsuldarlığı baxımından optimal doza səviyyələrinin müəyyənləşdirilməsinə dair spesifik bioloji və fizioloji qanunauyğunluqlar elmi cəhətdən əsaslandırılmışdır.*

Açar sözlər: *Hisar cinsi, Vilofoss, kökəltmə, yemin konversiyası, həzm olunma, yun məhsuldarlığı, keratin, mineral balans*

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Introduction

In the modern livestock sector, ensuring a sustainable supply of high-quality and safe animal products (meat, wool) to the population, increasing production efficiency, and reducing product costs represent paramount strategic objectives. The fundamental prerequisite for enhancing productivity lies in establishing a comprehensive and balanced nutrition system that fully aligns with the genetic potential and physiological requirements of animals.

In Uzbekistan and across the Central Asian region, Hissar sheep constitute the cornerstone of mutton-tallow (meat-fat) sheep farming. Representatives of this breed are distinguished by their exceptionally large body frame, rapid growth rates, high adaptability to extreme climates and pasture conditions, as well as an extensive genetic potential. However, in practice, the inherent hereditary (genetic) capacities of Hissar lambs are not being fully utilized. The primary reason for this is the inadequacy of the ration, particularly the deficiency of minerals and biologically active substances therein.

In the livestock industry, improving feed efficiency to boost meat and wool productivity, alongside formulating rations tailored to the physiological needs of animals, stands as a crucial task. In particular, enriching the diet of Hissar lambs with minerals and biologically active substances plays a vital role in unlocking their full hereditary potential. Enhancing the assimilation (absorption) of elements such as protein, calcium, and phosphorus in the ration not only optimizes primary meat productivity but also improves the quality of wool as a secondary product. This study investigated the effects of incorporating the Vilofoss feed additive on the productivity and physicochemical characteristics of Hissar lambs (Yuldashbayev et al., 2023).

Materials and Methods

The conducted experiment was carried out on Hissar breed lambs using a two-stage fattening system. The dietary nutritive value was formulated based on the age, live weight, and physiological requirements of the lambs. Three experimental groups were established for the study:

Control group – basal ration (BR);

Experimental group 1 – BR + 50 g of Vilofoss additive;

Experimental group 2 – BR + 100 g of Vilofoss additive.

During the trial, nutrient digestibility, live weight dynamics, feed conversion ratio (FCR), as well as quantitative and qualitative characteristics of wool were analyzed according to standard methodologies, and the statistical significance level (P) of the obtained results was evaluated (Shcheglov et al., 1989).

Results and Discussion

Nutrient digestibility and growth performance: The inclusion of the Vilofoss additive into the ration exerted a positive effect on the digestibility of dietary nutrients and the assimilation of nutritive substances. In the first stage of the experiment, dry matter digestibility increased by 4.6% in experimental group 2 compared to the control, crude protein digestibility rose by 4.3%, and energy utilization increased by 5.0%. Furthermore, calcium and phosphorus assimilation was higher by 5.5–6.0%. In the second stage of the trial, these parameters increased even further, demonstrating that the effect of the additive intensified over time (Ulyanov, 1982).

The improvement in feed digestibility was directly reflected in growth and development efficiency:

At the conclusion of the experiment, live weight gain reached 18.0 kg in experimental group 1 (18.4% higher than the control) and 19.2 kg in experimental group 2 (26.3% higher than the control) ($P > 0.99$). The average daily gain (ADG) fluctuated around 300–320 g, with the highest performance and the most optimal feed conversion ratio (FCR) being recorded in experimental group 2, which received the 100 g dose (Yuldashbayev et al., 2023).

Wool productivity and quality traits: The enhancement of mineral and protein metabolism throughout the fattening stage directly and favorably influenced the wool cover parameters of the animals (Table 1).

Table 1
Changes in wool characteristics relative to the control, %

Parameter	Control	Experimental 1 (50 g)	Experimental 2 (100 g)
Annual wool yield	-	+16.5	+13.2
Clean wool mass	-	+27.8	+23.7
Wool fiber length	-	+17.3	+15.3
Wool fiber strength	-	+15.2	+13.9
Proportion of breakable fibers	-	39.1	-34.4

In terms of physical parameters, wool fiber strength—which stood at 7.9 sN/tex in the control group—successfully reached 9.1 sN/tex in experimental group 1 and 9.0 sN/tex in experimental group 2, representing an increase of 15.2% and 13.9%, respectively ($P > 0.95$). Concurrently, the proportion of breakable fibers dropped significantly from a baseline of 6.4% in the control down to 3.9% in the 50 g group and 4.2% in the 100 g group, confirming a reduction of 39.1% and 34.4% at a high statistical significance level ($P > 0.99$) (Shcheglov et al., 1989).

The synthesis of these findings highlights an important biological pattern: while the maximum meat productivity and optimal feed conversion ratios (FCR) were yielded by the 100 g dietary dose (experimental group 2), the highest values for wool productivity and corresponding quality traits were distinctly achieved at the lower 50 g dose (experimental group 1). This difference is biologically justified by the fact that a moderate mineral equilibrium is highly optimal for active wool follicle function, whereas escalating the dose to 100 g provides no cumulative synergistic effect on the complex wool formation pathways (Yuldashbayev et al., 2023).

Crucially, the Vilofoss premix efficiently fulfilled the biological requirements for sulfur-containing amino acids and vital trace elements such as zinc (Zn) and copper (Cu), which serve as essential

components for the synthesis of the core keratin protein matrix in wool fibers. Furthermore, a general optimization of feed conversion was recorded across both treatment groups, resulting in a reduced feed intake per kilogram of live weight gain and confirming an overall rise in dietary utilization efficiency, which bears pronounced economic relevance, particularly within the 100 g treatment cohort (Ulyanov, 1982).

Furthermore, the incorporation of the Vilofoss additive exerted a distinctly positive effect on the wool cover characteristics of the lambs. Specifically, it led to an increase in annual wool yield, clean wool mass percentage, wool fiber length, and fiber strength, while simultaneously reducing the proportion of breakable fibers. This clearly demonstrates that the feed additive enhances not only primary meat productivity but also significantly improves both the quality and quantity of wool as a secondary product (Shcheglov et al., 1989).

Overall, the experimental results scientifically substantiate that supplementing the ration of Hissar lambs with the Vilofoss mineral feed additive markedly increases livestock efficiency by improving nutrient digestibility, accelerating live weight gain, optimizing feed conversion, and boosting wool productivity. Consequently, the practical application of this additive is highly recommended and considered expedient for livestock farms.

Conclusion

In conclusion, Hissar lambs are characterized by their rapid growth rates and large carcass conformation, with their growth performance being directly dependent on the efficiency of the digestive system and overall metabolism. Regarding nutrient and energy digestibility, the Vilofoss feed additive stimulates the gastrointestinal tract microbiota, particularly within the rumen. This stimulation enhances the breakdown and absorption rate of crude fiber, protein, and carbohydrates. As a result, metabolic energy from the feed is efficiently directed toward the biological processes of body growth and development, rather than being wasted.

In terms of calcium (Ca) and phosphorus (P) metabolism, these minerals serve as essential building blocks for bone tissue formation, muscular contraction, and enzymatic reactions. The ideal ratio and highly bioavailable form of minerals in Vilofoss substantially improve their absorption through the intestinal walls into the bloodstream, ensuring the rapid and robust development of the skeletal framework while effectively preventing calcium-phosphorus deficiency disorders such as rickets and osteomalacia.

Furthermore, meat productivity and feed conversion metrics represent the most critical economic indicators in meat-oriented sheep farming, specifically regarding daily live weight gain and the feed units consumed per kilogram of growth. The lambs receiving the Vilofoss-supplemented ration exhibited a significantly accelerated growth rate compared to the control group, achieving an 18.4%–26.3% increase in live weight gain.

Due to the enhanced digestibility of the diet, the amount of feed required per kilogram of live weight gain was reduced, optimizing the feed conversion ratio (FCR). This reduction effectively conserves feed expenditures, which constitute the largest expense during the fattening period, thereby lowering the overall production cost of mutton.

Optimal dose for meat productivity (100 g/day): In meat-oriented sheep farming, administering a dietary dose of 100 grams induces intensive muscle tissue development, maximizing both the carcass yield (dressing percentage) and qualitative meat characteristics such as juiciness and marbling.

Wool productivity and its physical properties: Although the Hissar breed is predominantly utilized for mutton-tallow (meat-fat) production, the wool harvested from these animals serves as an important source of secondary economic income for livestock operations. The overall improvement in wool quality traits is biologically driven by the adequate supply of dietary mineral substances, which actively stimulates the physiological functions of the skin and wool follicles.

Consequently, this nutritional enrichment leads to a significant increase in annual wool yield and clean wool mass, while concurrently expanding wool fiber length and tensile strength (resistance to breaking). Furthermore, the inclusion of these minerals effectively reduces the proportion of brittle, dry, and breakable fibers, thereby enhancing the overall uniformity of the fleece.

Optimal dose for wool productivity (50 g/day): In terms of enhancing wool productivity and its core physical characteristics, the 50-gram dose (Experimental Group 1) yields the highest biological and economic efficiency. Because the 100 g dose is primarily partitioned toward muscle tissue deposition and metabolic pathways related to meat accretion, the 50 g daily dose remains highly optimal for satisfying the specific physiological requirements of wool quality and development.

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Growth, Development and Biological Characteristics of Medicinal Marshmallow (*Althaea officinalis* L.) and Quality Indicators of Raw Materials

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Abstract. *The results of the conducted studies showed that the biochemical and physiological processes occurring in the medicinal marshmallow (Althaea officinalis L.) plant are directly related to the availability of mineral elements. The obtained data indicate that each macronutrient performs a specific function in the vital activity of the plant, while their combined action forms an integrated system regulating plant growth and development. This article presents information on the relationship between mineral elements and biochemical processes in medicinal marshmallow, as well as the quality indicators of medicinal plant raw materials.*

Keywords: *medicinal marshmallow, biologically active substances, plant raw materials, Mucaltin, herbal preparations, pharmacognosy*

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Dərman gülxətmisinin (Althaea officinalis L.) böyüməsi, inkişafı və bioloji xüsusiyyətləri, həmçinin xammalın keyfiyyət göstəriciləri

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Xülasə. *Aparılmış tədqiqatların nəticələri göstərdi ki, dərman gülxətmi (Althaea officinalis) bitkisində baş verən biokimyəvi və fizioloji proseslər mineral elementlərlə birbaşa bağlıdır. Əldə edilmiş məlumatlardan məlum olduğu kimi, hər bir makroelement bitkinin həyatında özünəməxsus funksiyanı yerinə yetirir və onlar birlikdə bitkinin inkişafını idarə edən vahid sistem təşkil edir. Bu məqalədə dərman gülxətmi bitkisinin mineral elementlər və biokimyəvi proseslər arasındakı qarşılıqlı əlaqəsi, həmçinin xammalın keyfiyyət göstəriciləri haqqında məlumatlar təqdim olunur.*

Açar sözlər: *dərman gülxətmi, bioloji fəal maddələr, xammal, mukaltin, bitki preparatları, farmakoqnoziya*

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1. Introduction

Nitrogen is a major “building material” for plants, being a component of proteins, amino acids, and enzymes, and it accelerates biochemical reactions occurring in cells. Therefore, under conditions of sufficient nitrogen supply, plant growth is accelerated, leaves become larger and dark green, and photosynthetic processes proceed actively. The participation of nitrogen in chlorophyll further increases its importance (Meyghan & Moradi, 2018).

Phosphorus plays an important role in energy metabolism in plants. As a component of ATP, it ensures the accumulation and transfer of energy. Therefore, when phosphorus is supplied adequately, the root system develops well, the plant enters the generative stage earlier, and flowering and seed formation proceed effectively (Meyghan & Moradi, 2018).

Potassium regulates the synthesis, transport, and accumulation of carbohydrates. Its role is particularly important in the formation of mucilage and polysaccharides, which are important for medicinal marshmallow. In addition, potassium maintains water balance in cells and increases the plant’s resistance to various stress factors. Research on marshmallow cultivation also examines mineral nutrition under irrigation (Pryvedeniuk et al., 2021).

2. Materials and methods

The results were analyzed using mathematical and statistical methods, and the differences between treatments were found to be statistically significant ($p < .05$). This indicates that the effect of mineral nutrition on the quality of medicinal raw materials is scientifically substantiated and follows a regular pattern.

3. Results

The results of our studies showed that the highest efficiency is achieved when these elements are maintained in balance. In particular, in the N90P60K60 treatment, the main biochemical processes in the plant were observed to be activated to the highest level. This was manifested in enhanced photosynthesis, increased enzyme activity, and accelerated synthesis of carbohydrates and secondary metabolites.

At the same time, it was found that when mineral elements were applied in excessive amounts, the expected effect was not fully achieved. For example, a decrease in some indicators was observed in the N120P80K80 treatment. This can be explained by disruption of the balance among elements, reduced nutrient uptake, and decreased efficiency of metabolic processes.

Comparative analysis of the results obtained in the experimental fields showed that the effect of mineral elements on plants follows general regularities; however, its degree may vary depending to some extent on soil and climatic conditions, moisture regime, and agrotechnical practices. This further increases the reliability of the obtained results and the possibility of their wide practical application (Ahmedov et al., 2018).

The data in Table 1 show that the level of biochemical activity in medicinal marshmallow (*Althaea officinalis* L.) is directly dependent on mineral nutrition conditions.

Table 1
Efficiency of mineral nutrition treatments in medicinal marshmallow (Althaea officinalis L.)

№	Treatment	Biochemical activity	Note
1	Control	Low	Natural conditions
2	N40P40K40	Lower	Partial activation
3	N60P40K40	Medium	Partial activation
4	N60P60K60	Above medium	Activation
5	N90P60K60	Highest	All processes balanced
6	N90P80K80	Decrease	Beginning of imbalance
7	N120P80K80	Decrease	Imbalance

In the control treatment, biochemical activity was low, reflecting the growth of the plant under natural agro-background conditions. Under these conditions, the synthesis of biologically active substances was observed to proceed in a limited manner.

Partial activation of biochemical processes was recorded in the N40P40K40 and N60P40K40 treatments with mineral fertilizers. This can be explained by an increase in metabolic processes as a result of improved plant supply with nutrients (Berdiyev et al., 2016).

In the N60P60K60 treatment, an intensification of biochemical processes was recorded.

The highest biochemical activity was observed in the N90P60K60 treatment, where all physiological and biochemical processes in the plant proceeded in a balanced manner. The optimal ratio of mineral elements increased enzymatic activity and maximally stimulated the synthesis of carbohydrates and secondary metabolites.

However, a certain decrease in biochemical activity was observed in the N90P80K80 and N120P80K80 treatments, where mineral fertilizers were applied in excessive amounts. This can be explained by disruption of physiological and metabolic balance in the plant due to excessive nutrition and suppression of certain enzymatic processes.

Thus, the analysis results show that the correct selection of optimal rates and ratios in mineral nutrition is crucial for ensuring maximum biochemical activity in medicinal marshmallow. In particular, the N90P60K60 treatment was assessed as the most effective.

Quality indicators of medicinal marshmallow (*Althaea officinalis* L.) raw materials. The results of the conducted studies demonstrated that mineral nutrition has a significant effect on the main quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials. The experimental data were

consistent with one another, and a stable improvement in quality indicators was observed under conditions where mineral fertilizers were applied.

The results obtained for dry matter and extractive substances clearly confirm this trend. The increase in dry matter content under the influence of mineral nutrition indicates greater accumulation of organic substances in plant tissues. An increase in extractive substances is an important indicator determining the pharmacological value of medicinal plant raw materials, and a higher level indicates improved product quality.

The specific numerical results also confirm this regularity. In the first year of the study, 2023, the dry matter content in the control treatment was 22%, while extractive substances accounted for 18%; in the treatments with mineral fertilizers, these indicators increased gradually. In the N40P40K40 treatment, dry matter was 24% and extractive substances were 19.5%; in N60P40K40, dry matter was 25% and extractive substances 21%; in N60P60K60, dry matter was 26.5% and extractive substances 22.5%; and in N90P80K80, dry matter reached 27.5% and extractive substances 22.5%. The highest results were recorded in the N90P60K60 treatment, at 28% and 24%, respectively. This indicates that a balanced ratio of mineral elements most effectively promotes the accumulation of dry matter and biologically active compounds in plant tissues (Ahmedov et al., 2018).

At the same time, a certain decrease in the expected effect was observed when mineral fertilizers were applied in excessive amounts. In particular, in the N120P80K80 treatment, dry matter was 27% and extractive substances were 23%, but these indicators were lower than in the optimal treatment. This can be explained by disruption of metabolic balance in the plant as a result of excessive mineral nutrition and limitation of the synthesis of some biologically active compounds (Table 2).

In 2024, dry matter in the control treatment was 22.5% and extractive substances were 18%, while these indicators increased gradually in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19%; in N60P40K40, dry matter 25% and extractive substances 21%; in N60P60K60, dry matter 26% and extractive substances 23%; in N90P80K80, dry matter 27.5% and extractive substances 22%; and in N120P80K80, dry matter 26.5% and extractive substances 23%. These indicators were lower than those of the optimal treatment. The highest results were recorded in N90P60K60, reaching 28% and 24%, respectively.

In the third year of the study, 2025, dry matter in the control treatment was 22.5% and extractive substances were 18.5%, while these indicators increased gradually in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19%; in N60P40K40, dry matter 26% and extractive substances 21%; in N60P60K60, dry matter 26.5% and extractive substances 22%; in N90P80K80, dry matter 27.5% and extractive substances 22.5%; and in N120P80K80, dry matter 26% and extractive substances 23%. The highest results were recorded in N90P60K60, where dry matter reached 28.5% and extractive substances 24%.

Considering the three years of the study as a whole, the control treatment had 22.2% dry matter and 18.2% extractive substances, while these indicators varied in the treatments with mineral fertilizers. In N40P40K40, dry matter was 24% and extractive substances 19.2%; in N60P40K40, dry matter 25.3% and extractive substances 21%; in N60P60K60, dry matter 26.3% and extractive substances 22.5%; in N90P80K80, dry matter 27.5% and extractive substances 22.2%; and in N120P80K80, dry matter 26.5% and extractive substances 23%. The highest results were recorded in N90P60K60, with dry matter reaching 28.2% and extractive substances 24%.

Overall, in the N90P60K60 treatment of medicinal marshmallow (*Althaea officinalis* L.), the contents of dry matter and extractive substances increased more markedly than in the other treatments during all three years.

This indicates that a balanced ratio of mineral elements brings the accumulation of dry matter and biologically active compounds in plant tissues to the most effective level.

The obtained results once again confirmed that the application of mineral nutrition at scientifically justified rates is crucial for increasing the quality indicators of medicinal raw materials.

Table 2

Quality indicators of raw materials under mineral nutrition of medicinal marshmallow (Althaea officinalis L.), 2023–2025

No	Treatment	2023 Dry matter (%)	2023 Extractive substances (%)	2024 Dry matter (%)	2024 Extractive substances (%)	2025 Dry matter (%)	2025 Extractive substances (%)	Mean Dry matter (%)	Mean Extractive substances (%)
1	Control	22	18	22.5	18	22	18.5	22.2	18.2
2	N40P40K40	24	19.5	24	19	24	19	24	19.2
3	N60P40K40	25	21	25	21	26	21	25.3	21
4	N60P60K60	26.5	22.5	26	23	26.5	22	26.3	22.5
5	N90P60K60	28	24	28	24	28.5	24	28.2	24
6	N90P80K80	27.5	22.5	27.5	22	27.5	22.5	27.5	22.2
7	N120P80K80	27	23	26.5	23	26	23	26.5	23

4. Discussion

Related work has examined the accumulation of polysaccharides under different cultivation practices (Pryvedeniuk et al., 2026), the structural and rheological properties of root polysaccharides (Karimi et al., 2021), and leaf mucilage composition (Tomoda et al., 1981). These studies provide background for interpreting raw-material characteristics; they do not independently validate the measurements reported here. Good agricultural practices and raw-material testing are addressed in World Health Organization guidelines (World Health Organization, 2003, 2011).

According to the observations, the contents of dry matter and extractive substances in the treatments with mineral fertilizers were consistently higher than in the control treatment. This can be explained by the accumulation of organic substances and activation of the synthesis of biologically active compounds in the plant under the influence of mineral elements.

At the same time, the occurrence of certain differences is considered natural. These differences are associated with the soil composition, moisture availability, climatic characteristics, and agrotechnical practices of the study areas. In particular, differences in soil humus content or irrigation regime may directly affect the accumulation of dry matter and extractive compounds in plants.

It was also noted that a general regularity was maintained in both study areas: the application of mineral elements at balanced and scientifically justified rates improves the quality indicators of the plant. This indicates the reliability of the obtained results and the possibility of implementing them in practice under different soil and climatic conditions.

Comparative analysis of the obtained results showed that in both study areas, mineral nutrition was a significant factor in increasing the quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials. When mineral elements were applied in sufficient and balanced amounts, the accumulation of organic substances in plant tissues increased, resulting in a stable increase in dry matter and extractive substances.

At the same time, some differences recorded between the study areas were associated with natural and agroecological factors, which further demonstrates the correspondence of the results to real conditions and increases their practical significance. In other words, the observation of the same general pattern under different conditions supports the reliability of the study results.

5. Conclusion

In conclusion, the highest quality indicators of medicinal marshmallow (*Althaea officinalis*) raw materials were recorded in the N90P60K60 treatment. In this treatment, the contents of dry matter and extractive substances reached their maximum levels, and it may be considered the most effective mineral nutrition rate for practical application.

Thus, the application of mineral elements in an optimal ratio is an important agrotechnical factor for improving the quality of medicinal raw materials, and its wider implementation is appropriate.

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Feeding Of “Big-6” And “Bronze-708” Turkeys

Yo.Sh.Karimova

Abstract. *Feeding Big-6 and Bronze-708 turkeys with nutritionally balanced and complete diets promotes efficient growth and a substantial increase in live body weight. Adequate dietary supplementation with essential macro- and microelements, vitamins, and high-quality protein is crucial for maintaining optimal physiological status, enhancing disease resistance, and improving growth and productive performance. Thus, the use of complete and properly balanced rations can contribute to the successful rearing of healthy turkeys with high productive potential.*

Keysword: macro- and micronutrients, vitamins, diet, protein, “Big-6”, “Bronze-708”, feed, nutritionally complete feed, feeding, live weight

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“Big-6” və “Bronze-708” hinduşkalarının bəslənməsi

Yo.Ş.Kərimova

Xülasə. *“Big-6” və “Bronze-708” hinduşkalarının qida maddələri baxımından balanslaşdırılmış və tam dəyərli rasionlarla bəslənməsi, onların səmərəli böyüməsinə və canlı çəkilərinin əhəmiyyətli dərəcədə artmasına şərait yaradır. Rasionun zəruri makro- və mikroelementlər, vitaminlər və yüksək keyfiyyətli zülalla zənginləşdirilməsi; optimal fizioloji vəziyyətin qorunması, xəstəliklərə qarşı müqavimətin artırılması, həmçinin böyümə və məhsuldarlıq göstəricilərinin yaxşılaşdırılması üçün həlledici əhəmiyyət daşıyır. Beləliklə, tam dəyərli və düzgün balanslaşdırılmış rasionlardan istifadə, yüksək məhsuldarlıq potensialına malik sağlam hinduşkaların uğurla yetişdirilməsinə töhfə verə bilər.*

Açar sözlər: *makro- və mikroelementlər, vitaminlər, rasion, zülal, “Big-6”, “Bronze-708”, yem, tam dəyərli yem, bəsləmə, canlı çəki*

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Introduction

One of the primary objectives of specialists in the poultry industry is to meet the population's demand for food products derived from poultry. Achieving this objective requires the development of a high-quality raw material base, the introduction of advanced production technologies, and the improvement of the genetic potential of poultry. In developed countries, turkey production occupies a prominent position within the meat-producing poultry sector. The United States, Italy, France, the United Kingdom, and Türkiye are among the leading producers of turkey meat, which is widely recognized as a palatable, nutritious, and dietary food product. In these countries, turkey meat accounts for approximately 15–25% of total poultry meat production. The successful development of meat-type poultry production depends on accelerating the growth and development of young birds and reducing feed costs while maintaining high-quality poultry meat production. Turkey farming is considered an important source for increasing the production of high-quality poultry meat. Long-term production experience has demonstrated that turkey meat production is economically viable. Turkeys are highly productive birds, and their meat is characterized by excellent dietary and health-promoting properties, as well as a high meat yield relative to live body weight.

In the CIS countries, improving the efficiency of turkey production and fully realizing the genetic potential of turkeys are achieved through properly organized breeding and selection programs. These programs involve the development of new high-performance breeds, lines, and crosses, as well as the extensive use of selective breeding, crossbreeding, and hybridization methods. In particular, industrial turkey meat production technologies have been introduced in almost all regions of the Russian Federation. Notably, turkey meat production accounts for approximately 70% of the total output of poultry meat produced by the companies "Damate" and "Cherkizovo." In Belarus, the high demand for turkey meat has contributed to the development of industrial turkey farming, with production continuing to increase and accounting for approximately 8–10% of total poultry meat production. For breeding purposes, heavy-, medium-, and light-type turkey crosses derived from different breeds are widely used.

Turkeys are highly productive poultry species, and their meat is characterized by excellent dietary and health-promoting properties, as well as a high meat yield relative to live body weight. Turkey meat is highly digestible and readily absorbed by the human body, making it suitable for therapeutic and dietary nutrition. Compared with the meat of other poultry species, turkey meat contains a higher proportion of high-quality proteins. The "Big-6" and "Bronze-708" crosses are considered well adapted to intensive commercial production systems. The quality characteristics of meat obtained from these crosses make it highly competitive compared with meat from other poultry species. Therefore, their production has considerable potential for expanding the supply of poultry meat, including for specialized food products and dietary nutrition. Furthermore, the rearing and management of "Big-6" and "Bronze-708" turkey crosses for meat production under the specific environmental and production conditions of Uzbekistan have not yet been sufficiently investigated in dedicated scientific studies. Therefore, evaluating their growth performance, feed utilization, and meat-production potential under local conditions is of considerable scientific and practical relevance.

Literature review and methods

A number of national researchers have conducted studies aimed at improving the productive performance and biological characteristics of turkeys as agricultural poultry. Ye.V. Ribina investigated turkey management technologies, turkey diseases and their prevention, as well as feeding practices. S.G. Azimov studied turkey husbandry and the productive performance of the Russian White turkey breed.

R.T. Aripdjanov investigated the use of floor-rearing systems for fattening young turkey poults. Z.M. Ashurov studied the meat productivity of turkeys and the dietary value of turkey meat. T.A. Stollyarov examined dry, wet, and combined feeding systems in the rearing of turkey poults. V.B. Khon investigated the importance of incorporating stimulatory feed additives into turkey diets as nutritional supplements. D.S. Azimov studied the housing of turkeys in cages and on deep litter systems, similar to conventional poultry housing practices. A. Rakhimov established that grain feeds constitute the major proportion of feed ingredients in the diets of turkey poults. A.Kh. Urmonov investigated zoohygienic conditions in facilities used for turkey housing. Thus, researchers in this field have conducted studies in different years addressing various aspects of turkey production, with particular emphasis on productivity, viability, adaptability, feeding, housing conditions, and meat production characteristics. However, the available literature indicates that, to date, the meat productivity and meat quality characteristics of "Big-6" and "Bronze-708" turkey crosses under hot climatic conditions have not been sufficiently investigated. This indicates the need for further comprehensive research into the productive performance and meat quality of these crosses under the environmental conditions of Uzbekistan.

Discussion and Results

Properly organized feeding of turkeys contributes to improved productive performance and reproductive capacity and ultimately enables them to fully express their genetic potential for productivity. During the study, the feeding conditions of turkeys were investigated from the hatching stage through 17 weeks of age. Turkeys in the experimental groups were fed a farm-formulated diet consisting primarily of locally available feed ingredients. In establishing the feeding conditions, the birds' genotype, age, sex, and housing conditions were taken into consideration. Particular attention was paid to the first feeding of newly hatched poults. The newly hatched poults were provided with their first feed within 20 hours of hatching. At this stage, equal amounts of carrot, fresh alfalfa, and nettle juice were administered. Subsequently, boiled eggs were provided at a rate of 4–5 g per bird per day. In addition, high-quality cottage cheese, curd, and compound feed containing a mixture of various grains and skimmed milk were included in the diet. The feed was provided using two methods: in dry form and moistened with skimmed milk. During the first few days, particular attention was paid to monitoring the poults' ability to peck and consume grain feed, as this process requires careful management in young turkey poults. After 10–12 days of age, the amount of egg included in the diet was gradually reduced, while cottage cheese, various grain meals, and green fodder were progressively introduced into the diet.

For turkey poults aged 7–28 days (1–4 weeks), the diet was formulated according to the following proportions of feed ingredients: corn grain – 39%; sunflower meal – 17%; soybean meal – 12%; fish meal – 10.4%; meat and bone meal – 7%; feed-grade yeast – 5%; dried skim milk – 5%; grass meal – 2%; shell grit, feed-grade limestone, and other mineral components – 0.6%; vegetable oil – 1%; and premix – 1%.

Table 1

Feeding ration of turkeys aged 1–8 weeks in the experimental groups (per bird per day, 2022–2024)

Feed Ingredients and Nutrients	Unit of measurement	Age, weeks							
		1	2	3	4	5	6	7	8
Corn grain	g	13,5	24,0	24,0	30,8	76,5	103,5	127,5	150,0
Wheat grain	g	-	-	-	30,0	45,8	60,0	75,0	90,0
Oat groats	g	1,5	6,0	27,0	22,5	-	-	-	-
Sunflower meal	g	1,5	12,0	15,0	22,5	21,0	15,0	22,5	27,0
Feed yeast	g	4,5	12,0	15,0	21,0	22,5	27,0	36,0	42,0
Fish meal	g	4,5	4,5	15,0	15,0	22,5	37,5	46,5	54,0
Meat and bone meal	g	1,5	3,0	3,0	6,0	9,0	9,0	10,5	12,0
Boiled egg	g	1,5	-	-	-	-	-	-	-
Cottage cheese	g	4,5	-	-	-	-	-	-	-
Skim milk	g	-	15,0	75,0	90,0	105,0	105,0	105,0	123,0
Cottonseed oil	g	0,075	1,5	1,95	4,05	2,7	4,65	6,75	7,35
Green fodder	g	6,0	15,0	30,0	75,0	105,0	150,0	150,0	180,0
Premix	g	0,3	0,6	1,2	1,8	2,25	3,0	3,75	4,5
Diet composition*:*									
Feed units	g	91,08	194,0	329,0	505,7	670,1	874,5	1080,9	1270,8
Metabolizable energy	Kdj	372,0	811,2	1374,0	2112,7	2799,0	3655,5	4518,0	5311,5
Dry matter	g	32,25	68,85	116,85	179,55	234,15	305,4	377,25	444,0
Crude protein	g	9,04	18,6	42,09	46,65	57,72	72,44	89,70	105,43
Lysine	g	0,564	0,966	1,876	2,457	3,084	4,056	4,993	5,842
Methionine	g	0,294	0,562	1,080	1,458	1,821	2,331	2,899	3,405
Crude fiber	g	0,960	3,105	4,740	7,396	9,090	10,695	13,095	15,585
Calcium (Ca)	g	0,747	0,867	1,800	2,473	3,489	5,112	6,975	8,146
Phosphorus (P)	g	0,396	0,729	1,354	1,803	2,425	3,198	3,9697	4,617
Sodium (Na)	g	0,142	0,192	0,469	0,553	0,775	1,116	1,360	1,579

As shown in Table 1, the amounts and composition of feed provided per bird per day to turkeys belonging to different crosses in the experimental groups from 1 to 8 weeks of age are presented. According to the data in the table, in addition to the main feed ingredients, 1.5 g of boiled chicken egg and 4.5 g of cottage cheese were provided to one-week-old turkey poults. As the poults increased in age, both the amount and types of grain-based feed ingredients included in the diet were gradually modified. In particular, skim milk was introduced into the diet starting at two months of age. Oat groats were provided up to five weeks of age, while wheat grain was introduced beginning at four weeks of age. The provision of oat groats was discontinued after the poults reached five weeks of age.

From 1 to 8 weeks of age, each turkey poult in the experimental groups consumed a total of 3,848.6 g of corn grain, 2,105.6 g of wheat grain, 399.0 g of oat groats, 955.5 g of sunflower meal, 1,260.0 g of feed yeast, 1,396.5 g of fish meal, 378.0 g of meat and bone meal, 10.5 g of egg, 31.5 g of cottage cheese, 4,326 g of skim milk, 203.18 g of cottonseed oil, 4,977.0 g of green fodder, and 121.8 g of premix. The total nutrient content of the feed consumed was equivalent to 35,112.6 g of feed units, 146,677.3 kJ of metabolizable energy, 12,308.1 g of dry matter, 3,091.7 g of crude protein, 166.9 g of lysine, 95.95 g of methionine, 452.7 g of crude fiber, 207.3 g of calcium, 129.4 g of phosphorus, and 43.3 g of sodium. During the study period, the feeding conditions of turkey poults belonging to different crosses from 9 to 17 weeks of age were investigated (Table 2).

Table 2

Feeding ration of turkeys aged 9-17 weeks in the experimental groups (per bird per day, 2022–2024)

Feed Ingredients and Nutrients	Unit of measurement	Age, weeks								
		9	10	11	12	13	14	15	16	17
Corn grain	g	181,5	202,5	225,0	247,5	264,0	285,0	307,5	330,0	337,5
Wheat grain	g	120,0	147,0	166,5	150,0	157,5	165,0	175,5	192,0	195,0
Barley grain	g	-	-	-	30,0	30,0	33,0	34,5	36,0	36,0
Sunflower meal	g	30,0	30,0	30,0	31,5	33,0	49,5	52,5	54,0	55,5
Feed yeast	g	30,0	30,0	37,5	40,5	42,0	37,5	42,0	46,5	48,0
Fish meal	g	30,0	30,0	25,5	27,0	25,5	18,0	16,5	15,0	15,0
Meat and bone meal	g	12,0	12,0	12,0	13,5	15,0	15,0	13,5	12,0	12,0
Skim milk	g	150,0	150,0	150,0	165,0	165,0	165,0	165,0	165,0	165,0
Cottonseed oil	g	7,50	7,35	7,65	8,55	8,40	8,40	8,55	8,40	9,45
Green fodder	g	195,0	210,0	225,0	225,0	225,0	225,0	225,0	225,0	225,0
Premix	g	4,50	5,25	6,0	6,0	6,45	6,75	7,50	7,50	7,50
Diet composition:										
Feed units	g	1394,7	1548,9	1693,8	1829,5	1914,6	2017,5	2137,5	2269,2	2318,5

Metabolizable energy	Kdj	5829,0	6474,0	7080,0	7648,5	8004,0	8434,5	8935,5	9486,0	9693,0
Dry matter	g	480,6	533,85	583,8	630,45	660,0	695,55	736,95	781,8	799,35
Crude protein	g	95,74	101,89	108,04	115,23	118,89	122,59	128,07	133,68	136,08
Lysine	g	4,695	4,944	5,040	5,427	5,527	5,361	5,539	5,713	5,810
Methionine	g	2,959	3,127	3,219	3,460	3,546	3,666	3,802	3,936	4,003
Crude fiber	g	18,36	20,26	22,05	24,40	25,59	28,84	30,55	32,25	32,83
Calcium *(Ca)*	g	7,633	8,290	8,457	9,025	9,387	9,294	9,696	9,526	11,253
Phosphorus *(P)*	g	3,717	3,871	3,928	4,254	4,377	4,263	4,326	4,393	4,461
Sodium (Na)	g	1,086	1,101	1,032	1,116	1,117	0,973	0,937	0,901	0,907

As presented in Table 2, the daily feed allowance and nutritional composition of the diets provided to turkeys representing different crosses in the experimental groups during the 9–17-week growth period are described. The data show that barley grain was not included in the diets of turkeys during the 9–11-week age period. Beginning at 12 weeks of age, barley grain was incorporated into the ration as one of the major feed ingredients and remained an important component of the diet throughout the subsequent growth period.

During the experimental period, the total feed consumption per turkey from 9 to 17 weeks of age consisted of 16,663.5 g of maize grain, 10,279.5 g of wheat grain, 1,396.5 g of barley, 2,562.0 g of sunflower meal, 2,478.0 g of feed yeast, 1,417.5 g of fish meal, 819.0 g of meat-and-bone meal, 10,080.0 g of skimmed milk, 519.75 g of cottonseed oil, 13,860.0 g of green forage, and 402.15 g of premix. The nutrients supplied through the consumed feed comprised 119,869.4 g of feed units, 501,091.5 kJ of metabolizable energy, 30,128.7 g of dry matter, 7,421.5 g of crude protein, 336.4 g of lysine, 222.026 g of methionine, 1,645.9 g of crude fiber, 577.93 g of calcium, 263.13 g of phosphorus, and 64.19 g of sodium. The calculated feed consumption of turkeys from 1 to 17 weeks of age during the study period is presented in Table 3.

During the study period, turkeys in both experimental groups were reared under identical feeding conditions from 1 to 17 weeks of age. According to the analysis of the data presented in Table 3.1.3 and the experimental results, grain-based feeds, protein sources, and supplementary feed ingredients constituted the major components of the diets provided to the turkeys from 1 to 17 weeks of age. Among the grain components, maize grain served as the primary source of dietary energy. Its consumption amounted to 3,848.6 g during the 1–8-week period and 16,663.5 g during the 9–17-week period, giving a total consumption of 20,512.1 g per turkey. This relatively high proportion indicates the predominant role of maize grain in the overall dietary composition. Wheat grain also represented a substantial proportion of the diet, with a total consumption of 12,385.1 g per turkey. The majority of the wheat grain (10,279.5 g) was consumed during the subsequent growth period, from 9 to 17 weeks of age.

A clear difference was observed in the use of oat groats and barley grain across the different growth periods. Oat groats were used exclusively during the initial growth period (1–8 weeks of age), at a total amount of 399.0 g per turkey, whereas barley grain was predominantly incorporated into the diet during

the 9–17-week period, with a total consumption of 1,396.5 g. This difference may be associated with age-related changes in digestive capacity and the nutritional requirements of turkeys during different stages of growth.

Table 3

Total feed consumption by turkeys in the experimental groups from 1 to 17 weeks of age

Feed ingredients	Feed consumption by age period, g		Total per turkey, g	Total consumption for 100 turkeys, kg
	At 1–8 weeks of age	At 9–17 weeks of age		
Corn grain	3848,6	16663,5	20512,1	2051,21
Wheat grain	2105,6	10279,5	12385,1	1238,51
Oat groats	399,0	-	399,0	39,]
Barley grain	-	1396,5	1396,5	139,65
Sunflower meal	955,5	2562,0	3517,5	351,75
Feed yeast	1260,0	2478,0	3738,0	373,8
Fish meal	1396,5	1417,5	2814,0	281,4
Meat and bone meal	378,0	819,0	1197,0	119,7
Boiled egg	10,5	-	10,5	1,05
Cottage cheese	31,5	-	31,5	3,15
Skimmed milk	4326,0	10080	14406,0	1440,6
Cottonseed oil	203,175	519,75	722,925	72,3
Green fodder	4977,0	13860,0	18837,0	1883,7
Premix	121,8	402,15	523,95	52,4
Diet composition:				
Feed units	35112,6	119869,4	154982,0	15498,2
Feed units consumed per 1 kg of live weight gain			5,17	
Metabolizable energy, Kj	146677,3	501091,5	647768,8	64776,]
Dry matter	12308,1	30128,7	42436,8	4243,7
Crude protein	3091,7	7421,5	10513,2	1051,3
Lysine	166,9	336,4	503,3	50,3
Methionine	97,0	222,026	319,0	31,]
Crude fiber	452,7	1645,9	2098,6	209,]
Calcium (Ca)	207,3	577,9	785,2	78,5
Phosphorus (P)	129,4	263,1	392,5	39,3
Sodium (Na)	43,3	64,2	107,5	10,7

Among the protein sources, sunflower meal (3,517.5 g), feed yeast (3,738.0 g), and fish meal (2,814.0 g) showed relatively high values. In particular, the consistent use of feed yeast during both periods indicates its high biological value. Although meat and bone meal was used in a relatively smaller amount (1,197.0 g), it played an important role in supplementing the diet with minerals. Among the animal-based feed supplements, boiled egg (10.5 g) and cottage cheese (31.5 g) were used only during the initial period and served to support the rapid growth of the young organism. In addition, skimmed milk (14,406.0 g) was provided in a large amount, indicating its importance as a source of protein and minerals.

As a source of fat, cottonseed oil was used in a total amount of 722.925 g, contributing to an increase in the energy density of the diet. Green fodder accounted for the largest quantity, at 18,837.0 g, and played an important role in supplying vitamins and biologically active substances. Premixes (523.95 g) ensured that the diet was balanced in terms of micronutrients and vitamins. Analysis of the overall nutritional

indicators of the diet showed that, during the 1–17-week period, 154,982.0 g of feed units were consumed per turkey, which was sufficient to support intensive growth. The amount of metabolizable energy was 647,768.8 kJ, reflecting the sharp increase in energy requirements as the young birds grew.

The dry matter (42,436.8 g) and crude protein (10,513.2 g) values indicate the high nutritional value of the diet. In particular, a large proportion of the protein was provided during the 9–17-week period (7,421.5 g), supporting the intensive development of muscle tissue. Among the amino acids, the amounts of lysine (503.3 g) and methionine (319.0 g) were at optimal levels, providing adequate conditions for protein synthesis. The increase in crude fiber (2098.6 g) corresponded with the development of the digestive system during the subsequent period. Among the minerals, calcium (785.2 g) and phosphorus (392.5 g) played an important role in the development of the skeletal system, while sodium (107.5 g) was involved in regulating water and electrolyte balance in the body.

Overall, the diets used in the experimental groups were formulated using a differentiated approach according to the age periods of the birds. The balanced distribution of feed components and nutrients contributed to the intensive growth and development of the turkeys. These results confirm that the scientifically based formulation of diets is an important factor in improving the efficiency of livestock and poultry production.

Table 4

Feed consumption rate of turkeys in the experimental groups at 1–17 weeks of age, %

Age, weeks	Feed consumption rate, %	
	Main diet feeds — grain mixtures + green forage	Skimmed milk (whey/skim milk)
1	85,0	-
2	96,7	97,5
3	98,2	98,1
4	98,2	98,1
5	98,2	98,3
6	98,3	98,3
7	98,3	98,5
8	98,3	98,3
9	98,4	98,4
10	98,4	98,4
11	98,4	98,5
12	98,4	98,4
13	98,6	98,4
14	98,6	98,5
15	98,6	98,5
16	98,6	98,5
17	98,6	98,5

As shown by the data presented in Table 4, no significant differences between the experimental groups were observed in the consumption of all types of feeds provided to the turkeys. The consumption rate of grain mixtures and green forage included in the diet by 1-week-old turkeys in the experimental groups was 85.0%, increasing to 96.7% at 2 weeks of age, 98.2–98.3% at 4–8 weeks of age, 98.4% at 9–12 weeks of age, and 98.6% at 13–17 weeks of age. In addition, skimmed milk was introduced into the basal

diet of the turkeys in the experimental groups starting from 2 weeks of age. The turkeys consumed the skimmed milk readily. The consumption rate was initially 97.5%, after which it increased and remained within the range of 98.3–98.5%.

Conclusion

It was established that, from 1 to 17 weeks of age, the turkeys in all experimental groups consumed a total of 15,498.2 kg of feed units, 64,776.9 kJ of metabolizable energy, 4,243.7 kg of dry matter, 1,051.3 kg of crude protein, 50.3 kg of lysine, 31.9 kg of methionine, 209.9 kg of crude fiber, 78.5 kg of calcium, 39.3 kg of phosphorus, and 10.7 kg of sodium. These findings demonstrate the feasibility of organizing industrial-scale turkey production under feeding conditions with the same nutritional composition.

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From Sustainability Claims to Assessable Responsibility: An Evidence-Alignment Analysis of Vertical Farming Organisations

Aziz Abilzade Shahin

Abstract. *Vertical farming is often associated with local food and efficient resource use, but neither characteristic establishes corporate social responsibility (CSR). This article develops a claim–practice–outcome evidence-alignment framework through a secondary, document-based synthesis of a 2026 doctoral thesis drawing on nine interviews and five site observations undertaken in Hungary in 2023–2024. The article does not present new fieldwork or independent recoding of interview transcripts. It selects eight attributed interview extracts and five case-specific observation summaries using explicit inclusion rules, and compares them across operational embeddedness, stakeholder inclusion and outcome verification. The comparison identifies three distinct evidence gaps: observed technical practice without comparable impact measurement; commercially targeted local production without demonstrated wider affordability; and stated social or ethical commitments without independent beneficiary perspectives. The contribution is an auditable diagnostic for evaluating CSR-related claims, not a ranking of firms or a measured assessment of their sustainability performance. The findings remain limited to the documentary evidence reviewed.*

Keywords: *vertical farming, corporate social responsibility, qualitative secondary analysis, evidence alignment, stakeholder inclusion, operational practice*

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Dayanıqlılıq iddialarından qiymətləndirilə bilən məsuliyyətə: vertikal əkinçilik təşkilatlarında sübutların uyğunluğunun təhlili

Əziz Əbilzadə Şahin

Xülasə. *Vertikal əkinçiliyin yerli qida istehsalı və resurslardan səmərəli istifadə ilə əlaqələndirilməsi həmin fəaliyyətin korporativ sosial məsuliyyət (KSM) nəticələrini avtomatik təsdiqləmir. Məqalədə 2026-cı il doktorluq dissertasiyasında təqdim edilmiş, Macarıstanda 2023–2024-cü illərdə toplanmış doqquz müsahibə və beş müəssisə müşahidəsi əsasında ikinci dərəcəli sənəd təhlili aparılır. Yeni müsahibələr keçirilməmiş, ilkin transkriptlər müstəqil şəkildə yenidən analiz edilmişdir. Səkkiz iştirakçı sitatı və beş müşahidə təsviri əvvəlcədən müəyyənləşdirilmiş seçmə meyarları ilə araşdırılmış, məlumatlar təşkilati*

fəaliyyət, maraqlı tərəflərin iştirakı və nəticələrin yoxlanması istiqamətlərində müqayisə edilmişdir. Məqalənin dissertasiyadan fərqlənən analitik töhfəsi iddia, müşahidə olunan praktika və təsdiqlənmiş nəticə arasında uyğunluğu qiymətləndirən çərçivənin hazırlanmasıdır. Təhlil texniki əməliyyatların müşahidəsi ilə ekoloji nəticələrin ölçülməsi, yerli istehsal ilə sosial əlçatanlıq, eləcə də KSM niyyətləri ilə maraqlı tərəflərin birbaşa qiymətləndirməsi arasında üç əsas sübut boşluğunu üzə çıxarır. İstehsal sistemlərinin müxtəlifliyi eyni texnoloji anlayış altında fəaliyyət göstərən təşkilatların sosial və ekoloji təsirlərinin fərqli üsullarla qiymətləndirilməsini zəruri edir. Təşkilat nümayəndələrinin bəyanatları müstəqil maliyyə sənədləri, resurs ölçmələri və benefisiarların ifadələri ilə təsdiqlənmədiyindən, nəticələr müəssisələrin reytinqi və ya dayanıqlılığın ölçülmüş göstəriciləri kimi deyil, mövcud sübutların sərhədlərini göstərən analitik şərhlər kimi təqdim olunur.

Açar sözlər: *vertikal əkinçilik, korporativ sosial məsuliyyət, ikinci dərəcəli keyfiyyət təhlili, sübutların uyğunluğu, maraqlı tərəflər*

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Introduction

Corporate social responsibility (CSR) in agri-food concerns how firms organise production, allocate risks and respond to affected groups. Environmental technologies can make a production process more controllable without establishing who benefits, who bears the costs or whether its aggregate impacts improve. CSR assessment therefore requires more than an account of technical capabilities or charitable intent (Hartmann, 2011). Vertical farming (VF) is an instructive setting because its organisational forms are heterogeneous. Stacked hydroponic research facilities, rotating towers, equipment providers, experimental space-agriculture units and small urban microgreen producers operate with different purposes, resource demands and markets. Treating these arrangements as one technological category risks transferring a claimed benefit from one configuration to another without evidence (Beacham et al., 2019). The variation also reflects the context-sensitive character of agri-food CSR discussed by Luhmann and Theuvsen (2016).

CSR theory distinguishes instrumental, integrative and ethical rationales, but an organisation may pursue revenue, environmental goals and social commitments simultaneously. Mixed motives alone neither validate responsible performance nor prove misleading communication. A stronger question is how a stated intention is connected to identifiable organisational practice and to an outcome that can be examined independently (Garriga & Melé, 2004). The doctoral thesis on which this article draws produced five themes spanning global challenges, VF configurations, adoption constraints, CSR and future collaboration. The present article does not re-present those themes as new empirical discoveries. It asks a narrower, article-specific question: when organisational representatives link VF to CSR, how far can the link be followed from a reported claim, through an observed operational process, to evidence concerning environmental or stakeholder outcomes? Its original contribution is a cross-case diagnostic of evidence alignment, including the circumstances in which available material does not support an impact claim. This is an analytic synthesis of documented findings, not a second independent field study (Abilzade, 2026).

Methods

Source study, sampling and actor roles

The source is the author's doctoral thesis, completed in July 2026. Its exploratory, abductive study involved nine semi-structured interviews with representatives of nine Hungary-based VF-related organisations in 2023–2024. Seven interviews took place on-site and two online; non-participant, guide-assisted observations were undertaken at five of the nine organisations. Two pilot interviews were retained within the final interview dataset, not added to the reported sample. The original research used Braun and Clarke's reflexive thematic approach (2006, 2019), supported by Delve, moving from 581 initial codes to 54 categories, 37 refined categories and five themes. Those counts describe the doctoral analysis only and are not presented as coding performed for this article (Abilzade, 2026, s. 88–107).

The thesis specifies heterogeneous purposive sampling with iterative expansion. Inclusion required (i) direct involvement in VF production, technology provision, research or education; (ii) explicit or emerging CSR/sustainability relevance; (iii) activities connected with Hungary; and (iv) the ability to describe VF technology, markets or societal and environmental implications. The sampling frame was broadened from an initially envisaged four cases to nine as relevant actors emerged. This design captures different positions in a small field rather than a statistically representative set of producers (Abilzade, 2026, s. 87–92).

Table 1
Source-study participants and their analytical roles

Code / pseudonym	Position / actor function	Interview mode	Site observation
#1 Techlight	CSR and communications expert; electronics manufacturer / VF research	Online	No
#2 Sun	Managing director; VF research and development	On-site	Yes
#3 Light for Greens	CEO; lighting and control technology supplier	Online	No
#4 Tower	CEO; hydroponic tower-system developer/operator	On-site	Yes
#5 CoreGreen	Co-founder; commercial hydroponic herbs/microgreens	On-site	Yes
#6 AstroAgro	Co-founder; space-oriented VF prototype / research	On-site	Yes
#7 Grow	CEO; indoor cultivation equipment / training supplier	On-site	No
#8 Agriculture University	Associate professor; VF research / education	On-site	No
#9 UrbanLeaf	Founder; urban microgreens for hospitality customers	On-site	Yes

Source. Organisational roles and observation coverage transcribed from the doctoral thesis (Abilzade, 2026, s. 88–92, especially the sample overview on s. 92).

The roles in Table 1 are analytically consequential. Statements by suppliers (#1, #3 and #7) concern enabling technology, markets or CSR communication; producers and operators (#4, #5 and #9) can discuss routine cultivation and buyers; research-oriented actors (#2 and #6) describe pilot or experimental capacities; and the university participant (#8) contributes sector expertise rather than firm-level CSR performance. These accounts cannot be pooled as interchangeable evidence of commercial farm results. The observation subset is analysed for practice-level verification; the other four organisations are retained only for interview-based context.

Article-specific documentary selection and synthesis

This article uses the thesis as a bounded documentary corpus. For provenance, its methodology chapter (especially s. 87–117) was consulted; case-level descriptions were inspected in the original results sections on observed sites (s. 136–161), organisational and economic factors (s. 170–189), and CSR (s. 190–222). The thesis's later CSR discussion (s. 263–272) was used to check the original interpretation, not counted as additional independent field evidence. General background literature, third-party anecdotes, hypothetical policy measures and future technology plans were excluded from the evidentiary extract set unless clearly labelled as contextual or prospective. A documentary evidence unit was retained only where the thesis provides a case or interviewee identifier, a traceable page, and information directly relevant to at least one of three comparisons: (a) an environmental or technical practice versus an impact claim; (b) operating viability versus social access; or (c) declared CSR purpose versus stakeholder involvement. To avoid giving the appearance of a new survey or a second thematic analysis, the working set was deliberately limited to five case-specific observational descriptions (O1–O5, one per visited facility) and eight verbatim thesis-published excerpts (Q1–Q8, from six interviewees). Appendix A records each unit, page and use. Selection reflects conceptual relevance and contrasting cases, not frequency or representativeness; an excerpt may inform more than one comparison.

The procedure was: first, separate interview claims (Q units) from documented site configurations (O units); second, compare matched claims with observable equipment and routines wherever a site visit occurred; third, classify the strength of the supporting material by the criteria in Table 2; and fourth, examine whether negative cases or actor-role differences qualify a general claim. Three cross-cutting evidence gaps were then formulated from this matrix. These are new article-level interpretive categories, not additional themes statistically extracted from the original 581 codes. No raw audio, independent transcript recoding, audited accounts, consumer interviews or life-cycle measurements were used in this article.

Operational criteria and inferential boundaries

Table 2
Indicators used to assess the evidential status of CSR claims

Analytic dimension	Positive indicator in available material	What cannot be concluded without further data
Operational embeddedness	Identifiable action already implemented in daily production; corroboration through a case-specific observation or documented practice. Plans and value statements remain reported intentions.	Observed recirculation, lighting or hygiene cannot by itself establish lower life-cycle impact, labour quality or sector-wide performance.

Analytic dimension	Positive indicator in available material	What cannot be concluded without further data
Stakeholder inclusion	Named stakeholder group plus an actual engagement route (e.g., teaching, consultation, access or distribution); label as reported unless the group itself is interviewed or an independent record is available.	A manager's description is not direct testimony from workers, consumers or local residents, nor proof of improved access.
Evidence-based evaluation	Specified indicator, measurement period, comparator/system boundary and traceable record for environmental, financial or social results.	Without records, a claimed saving, profitability or social benefit remains unverified even where the activity itself is visible.

Source. Article-specific operational definitions developed through documentary comparison of Abilzade (2026).

Three evidential labels are used consistently. "Reported" refers to a participant account reproduced in the thesis; "observed" refers to configuration or routines described in its site observations; "outcome verified" is reserved for traceable measurement or direct stakeholder evidence. Because the available corpus does not provide comparable financial accounts, energy or water balances, life-cycle assessments or first-person statements from external beneficiaries, this article does not award a case the final label. This restriction is part of the analytical result rather than a judgment that the firms made no contribution.

Ethics, provenance and access

The parent thesis reports review through university ethics procedures, the use of IBS research ethics documentation, participant information sheets and consent forms, and consent for interviews, recordings and anonymised research reporting. Organisational pseudonyms and interviewee numbers are retained here. The available thesis text does not specify an ethics committee's formal name, approval date or reference number, so these details are not asserted. Whether the initial consent expressly permits quotation in a separate journal article must be checked against the original signed documents before publication (Abilzade, 2026, s. 116–117). The quotations below are reproduced from the thesis text rather than verified anew against original audio or transcripts. Their English wording is therefore treated as thesis-reported text; the original interview language and duration cannot be independently established from the thesis. No public institutional repository URL for the thesis was verified for this revision. The full citation is included below; requests concerning access to the thesis or supporting anonymised material should be addressed to the corresponding author and evaluated under consent, confidentiality and institutional restrictions.

Results

1. Observed operations do not, by themselves, verify environmental impact

Five site descriptions allow a limited comparison between physical production configurations and sustainability-related claims. Sun's facility included recirculating hydroponic supply and automated controls; Tower used rotating hydroponic units and a recirculating nutrient circuit; CoreGreen used stacked production with parallel nutrient delivery; AstroAgro demonstrated an enclosed, sensor-based

experimental prototype; and UrbanLeaf relied on substrate trays and manual, non-recirculating watering. These are differences in actual configurations, not estimates of comparative water, energy or carbon efficiency (Abilzade, 2026, s. 136–161).

Table 3
Cross-case comparison of practice, claim and missing outcome evidence

Observed case	Practice recorded at the site	CSR-relevant interpretation / account	Outcome not verified by source data
Sun (O1; #2)	Automated stacked hydroponics; nutrient and water recirculation; controlled access.	Research-based process control; feasibility depends on context.	Water saved per kg, full energy balance, environmental footprint.
Tower (O2; #4)	Rotating towers; nutrient recirculation; manual harvest.	Modular local cultivation and potential educational use.	Quantified resource savings or external beneficiary impact.
CoreGreen (O3; #5)	Stacked cultivation with parallel nutrient distribution.	Commercial production alongside stated ethical commitments.	Audited profits and independently evidenced stakeholder effects.
AstroAgro (O4; #6)	Programmable enclosed space-agriculture prototype and sensors.	Research transfer and controlled production potential.	Commercial-scale or societal impact of the prototype.
UrbanLeaf (O5; #9)	Shelves and substrate trays; LED lighting; manual, non-recirculating irrigation.	Local microgreens supply for restaurants and catering.	Household affordability, comparable life-cycle results, community impact.

Source. New cross-case comparison constructed from observation descriptions in Abilzade (2026, s. 136–161), combined with attributed interviews on s. 172–199.

The case contrast changes the inference one can draw from a technological label. A visible recirculation loop at Sun or Tower supports the modest statement that a closed-water practice was implemented at those sites. UrbanLeaf is a negative case for the generalisation that all VF installations recirculate irrigation water. None of the five observation summaries supplies a common functional unit, system boundary or comparator that would permit an overall environmental ranking. Thus the first gap is between observable process design and measured environmental consequence. This restriction is consistent with the contextual view of Interviewee #2 (Sun), who stated: “The first is always the feasibility- if vertical farming is suitable for a community or even for a country” (Q1; Abilzade, 2026, s. 172). The quotation is a practitioner’s assessment of feasibility, not empirical proof that one system is preferable in all settings. Environmental life-cycle research reinforces why electricity, materials and

transport must be evaluated together, although the Swedish system assessed by Martin and Molin (2019) cannot serve as a direct quantitative comparator for these Hungarian sites.

2. Business viability and local production do not demonstrate inclusive food access

A second gap arises when production and sales claims are interpreted as social outcomes. Interviewee #3 (Light for Greens) described entry into VF as "a massive initial investment to get into" (Q2; Abilzade, 2026, s. 173). This statement comes from a technology supplier and therefore informs perceived adoption barriers, not the documented accounts of a particular farm. Interviewee #5 (CoreGreen), by contrast, recalled that several advisers had doubted the venture and concluded: "And we are profitable" (Q3; Abilzade, 2026, s. 174). The two accounts are not necessarily inconsistent: one describes sectoral entry costs, while the other reports one firm's position. Neither is an independently audited financial finding. At UrbanLeaf, the participant described a different operational exposure: "If I don't turn the light on for one day, they die. Or if we have a blackout for one day, they die" (Q4, Interviewee #9; Abilzade, 2026, s. 176). This account identifies the potential vulnerability of a production model dependent on timely lighting, but the source provides no measured outage losses or comparison with field agriculture. The site observation documents simple equipment and non-recirculating water use, which complicates any assumption that automation and closed-loop irrigation are inherent features of small VF enterprises. UrbanLeaf's position was also explicitly selective in market terms: "There are people who are not price sensitive. That's our target group" (Q5, Interviewee #9; Abilzade, 2026, s. 185). The university respondent, Interviewee #8, likewise reported that "In Hungary, customers mostly care about the price" (Q6; Abilzade, 2026, s. 199), and characterised the value-oriented segment as small. These are participant perspectives, not a representative consumer survey. Together they explain why a short supply chain and a premium hospitality market can coexist without demonstrating improved affordability for low-income households. The second gap is therefore between local availability and independently evidenced social accessibility.

3. Ethical intention and stakeholder outcomes remain different evidential categories

A third gap concerns the move from organisational purpose to documented beneficiary effects. Interviewee #1 (Techlight) described a shift in CSR discourse: "CSR became a bit wider… companies started to build strategies connected to their sector" (Q7; Abilzade, 2026, s. 191). Interviewee #5 (CoreGreen) offered an ethical counterpoint: "Axioms and values should be things of who you are… not a mask" (Q8; Abilzade, 2026, s. 193). These excerpts demonstrate how actors justify responsibility, but neither alone shows an externally experienced improvement.

The thesis also reports educational initiatives, reduced packaging and community-oriented activities associated with some organisations. Such accounts can identify a stakeholder group and an intended mechanism. However, in this dataset employees, consumers, schools and community beneficiaries were not directly sampled to assess effects, and site visits primarily examined production infrastructure rather than social outcomes. These initiatives are therefore described as participant-reported actions unless directly observed or independently evidenced. An absence of outcome documentation is not evidence of greenwashing, but it prevents an assertion of verified social impact and limits any claim about misleading communication (Abilzade, 2026, s. 190–222; Delmas & Burbano, 2011).

The new comparison brings these three gaps together without ordering companies by "amount of CSR". Instead, each individual claim is examined for the type of support available, the group it concerns and

the evidence still needed. Research prototypes are evaluated as prototypes; suppliers are not treated as commercial producers; and moral or strategic rationales are not confused with observed results.

LEVEL 1 | CLAIM	LEVEL 2 | PRACTICE	LEVEL 3 | OUTCOME
Attributed interview or organisational statement What is promised, valued or described?	Specific routine, infrastructure or transaction What is observable and implemented?	Indicator and affected stakeholder What changed, relative to what comparator?
Evidence label: REPORTED	Evidence label: OBSERVED (where a site visit exists)	Evidence label: VERIFIED only with independent records or stakeholder data

Figure 1

Claim–practice–outcome pathway for evaluating VF-related CSR statements

Source. Conceptual figure developed for this article from the documentary synthesis. Read left to right as an evidence question, not as a maturity score or a firm ranking.

Figure 1 replaces the doctoral thesis's qualitative CSR spectrum. That illustration located firms along strategic, hybrid and normative positions but did not establish a uniform evidence rule for each placement. Moreover, its mixed actor roles and reliance on managers' accounts make ordinal comparisons especially fragile. The present framework therefore evaluates the status of a claim rather than assigning a firm a presumed level of ethical performance. The three gaps identified above are article-specific analytical findings obtained by using that framework on the selected evidence units.

Discussion

The evidence-alignment perspective makes a distinction found in CSR theory operational for the cases reviewed. Wood (1991) separates principles, organisational responsiveness and behavioural outcomes. In the present comparison, participant statements provide insight into principles, observations show selected processes, and verified external outcomes remain largely outside the available dataset. A report of closed-loop irrigation or a values-based mission should consequently be cited as evidence of that process or stated orientation, not of its wider net effect. This perspective also clarifies why strategic and normative interpretations are not a scale of responsibility. Firms may support environmental improvement while pursuing price premiums, revenue or reputational benefits; these motivations can coexist. The analytic test is not whether commercial benefit exists, but whether a specified action is traceable and whether a claimed external benefit can be evaluated. Treating a reported commitment as proof of public benefit would collapse distinctions that stakeholder theory and CSR scholarship retain (Donaldson & Preston, 1995; Aguilera et al., 2007).

Carroll (2016) treats economic, legal, ethical and philanthropic responsibilities as concurrent rather than as stages that permit postponing the social dimensions of performance. The present cases do not refute that framework. They instead show why commercial survival, operational control and external benefit need separate indicators. Shared-value reasoning is plausible where social and business benefits actually coincide, but premium sales alone cannot establish the societal component of the shared value proposition (Porter & Kramer, 2011). The framework highlights a problem of stakeholder voice. A representative can identify employees, customers, schools or communities as important, but a representative's account

does not substitute for these groups' experiences. This matters where premium-priced local production is presented as a contribution to food access. A credible study of such a claim would require evidence about price, distribution, beneficiary characteristics or direct accounts from those affected. These data are absent from the source study, so the article identifies a question requiring investigation rather than claiming a measured equity outcome.

A similar discipline applies to environmental responsibility. Visible water recirculation, local siting and precise climate control are plausible mechanisms for particular benefits, but overall performance depends on electricity, cultivation inputs, materials, transport, production yields and the comparison system. The source observations were not designed as a life-cycle assessment or an energy audit. The article's contribution is to specify this inferential boundary, not to calculate footprints that were never recorded (Martin & Molin, 2019). The documentary nature of the analysis imposes important limits. Case selection was purposive; technology providers, research facilities, producers and an academic respondent had different opportunities to report on daily production and external effects. The eight quotations were selected for analytic contrast rather than exhaustive content coverage. The secondary reading was confined to the completed thesis; no new participant checking or independent transcript analysis occurred. The resulting framework is therefore a transparent interpretive tool that warrants testing with primary stakeholder evidence and standardised outcome measures, not an externally validated CSR index.

Conclusion

A secondary comparison of the Hungarian doctoral material points to three distinguishable evidentiary gaps: observed operating features without comparable environmental outcome data; viable or premium-positioned local production without proof of wider food accessibility; and declared CSR intentions without direct evidence from the stakeholder groups said to benefit. These are not universal characteristics of VF firms, but limitations and tensions visible in the selected material. The article's distinct contribution is a claim–practice–outcome assessment framework with explicit documentary selection, case-level traceability and conservative inference rules. It offers a way to discuss CSR integration without treating technical capability, managerial intention and measured societal effect as interchangeable. The thesis's earlier firm-level CSR spectrum is not reused as a ranking. Where practitioners suggest a role for VF alongside greenhouses, that proposition remains a context-dependent hypothesis for comparative investigation, not a conclusion established by these cases. Further research could combine audited energy and input records, a common unit of product output, real pricing and access data, and interviews with workers, buyers and community beneficiaries. Such evidence would make it possible to test whether observed practices translate into the CSR outcomes currently described mainly in organisational narratives.

Declarations

Data and source access. The re-used source is the author's July 2026 doctoral thesis, fully identified in the reference list. An independently verifiable public repository link has not been established for this manuscript. Participant recordings and original transcripts are not supplied as an open dataset. Any request for source access or anonymised extract documentation should be evaluated by the corresponding author against the original consent conditions and the institution's confidentiality rules.

Ethics. The source study reports institutional ethical review and written participant consent (Abilzade, 2026, s. 116–117). The formal committee name, approval reference and scope of consent for separate journal publication require confirmation from the original institutional ethics file; the manuscript does not invent those particulars.

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RİYAZİYYAT VƏ MEXANİKA ELMLƏRİ

MATHEMATICS AND MECHANICS SCIENCES

Matrislər cəbrinin iqtisadiyönümlü hərbi məsələlərə tətbiqi

Aynur Əliyeva[1*], Nəzirə Bayramova[1]

Xülasə. *Məqalədə matrislər cəbrinin elementlərinin iqtisadiyönümlü hərbi məsələlərə tətbiqinə baxılmışdır. Matrislər haqqında ümumi anlayışlar, matrislər üzərində əməllər məqalədə öz əksini tapmışdır. Daha çox diqqət matrislərin hasilinin kommutativ olmadığının, yəni vuruqların ardıcıllığından asılı olmasına yönəldilmişdir. İstənilən ölçülü iki matrisin hasilinin həmişə mümkün olmadığı, matrisi matrisə vurmaq üçün birinci matrisin sütunlarının (yəni sətir elementlərinin) sayının ikinci matrisin sətirlərinin (yəni sütun elementlərinin) sayına bərabər olması faktı ön plana çəkilmişdir. Matrislərin hasilindən istifadə edərək, məsələlər həll olunmuşdur. Həll prosesində göstərilmişdir ki, ixtiyari ölçülü sütun matrisi ixtiyari ölçülü sətir matrisinə vurmaq olar. Lakin, ixtiyari ölçülü sətir matrisi ixtiyari ölçülü sütun matrisinə vurmaq olmaz.*

Açar sözlər: *matrislər cəbri, sətir matris, sütun matris, üçbucaq matris, skalyar matris, matrisin transponirə edilməsi, simmetrik və çəpsimmetrik matris, matrislərin hasili*

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Application of Matrix Algebra to Economically-Oriented Military Problems

Aynur Aliyeva[1*], and Nazira Bayramova[1]

Abstract. *This article examines the application of elements of matrix algebra to economically-oriented military problems. General concepts regarding matrices and operations on matrices are presented. Particular attention is given to the fact that matrix multiplication is non-commutative—that is, the result depends on the order of the factors. It is highlighted that the product of two matrices of arbitrary dimensions is not always possible; specifically, for matrix multiplication to be defined, the number of columns in the first matrix must equal the number of rows in the second matrix*

Problems have been solved using the concept of matrix multiplication. It is demonstrated that a column matrix of any dimension can be multiplied by a row matrix of any dimension; however, a row matrix of any dimension cannot be multiplied by a column matrix of any dimension.

Keywords: *matrix algebra, row matrix, column matrix, triangular matrix, scalar matrix, matrix transposition, symmetric and skew-symmetric matrices, product of matrices*

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1. Giriş

Matris anlayışı və ona əsaslanan ali riyaziyyatın bölməsi –matrislər cəbri- bu ildən H.Əliyev adına Hərbi institutda fəaliyyət göstərən menecment ixtisasında təhsialanlar üçün olduqca böyük əhəmiyyətə malikdir.Matrislər bütün elm sahələrində,o cümlədən iqtisadiyyatda geniş istifadə olunur. Bu onunla izah olunur ki,iqtisadi obyekt və proseslərin riyazi modellərinin əhəmiyyətli bir hissəsi kifayət qədər sadə və ən əsası-kompakt matris formasında yazılır.Matrislərdən isifadə edərkən bütün işarələr çox kompakt,əyani və mahiyyəti saxlayan olur.Beləki,matrislərin köməyi ilə bəzi iqtisadi asılılıqları göstərmək olur. (Alməmmədov et al., 2015a; Krass & Chuprynov, 2005).

2. Material və metodlar

Misal üçün iqtisadiyyatın müxtəlif sahələrində,resursların paylanması üçün aşagıdakı cədvəl tərtib olunub.

Resurslar	İqtisadi sahələr	
	Sənaye	Kənd təsərrüfatı
Elektroenergetika	4,7	3,9
Əmək resursları	3,2	2,4
Su ehtiyatları	5,2	4,9

Bu cədvəli matrislərin köməyi ilə daha kompakt şəkildə ifadə etmək olar: (Griguletskii & Yashchenko, 2004; Kremer, 2010).

$$A=\begin{pmatrix} 4,7 & 3,9 \\ 3,2 & 2,4 \\ 5,2 & 4,9 \end{pmatrix}$$

Bu yazılışda matrisin $a_{11}=4,7$ elementi sənayedə istifadə olunan elektroenergetikann miqdarnı, $a_{32}=4,9$ elementi isə kənd təsərrüfatında nə qədər su ehtiyatlarından istifadə olunduğunu göstərir. Yaxud da,istehsal prosesində hər bir rübdə,ildə müxtəlif növ məhsulların göstəricilərini və ya müxtəlif növ məhsulların istehsalına sərf olunan xammal növlərini matris şəklində yazmaq daha

əlverişlidir.Məsələn,respublikamızda m sayda tikiş müəssisəsi, istehsal olunan məhsulları,müxtəlif hərbi geyimləri:

gündəlik ,səhra və parad geyim formasını hərbi hissələrə çatdırmaq üçün n sayda hərbi anbar fəaliyyət göstərir.Birinci tikiş fabrikinin birinci anbara göndərdiyi məhsulun həcmini a_{11} -lə, ikinci anbara göndərdiyi məhsulun həcmini a_{12} -lə və s. n –ci anbara göndərdiyi məhsulun həcmini a_{1n} lə işarə edək.Eyni qayda ilə ikinci tikiş fabrikinin birinci anbara göndərdiyi məhsulun həcmini a_{21} - lə, ikinci anbara göndərdiyi məhsulun həcmini a_{22} -lə və s. n –ci anbara göndərdiyi məhsulun həcmini a_{2n} -lə işarə edək.Bu prosesi m-ci tikiş fabrikinə kimi təkrarlasaq, m-ci tikiş fabrikinin n-ci anbara göndərdiyi məhsulun həcmini a_{mn} -lə işarə etsək və bunları cədvəl şəklində yazsaq,

$$\begin{pmatrix} a_{11}\ a_{12}...a_{1n} \\ a_{21}\ a_{22}...a_{2n} \\ ..... \\ a_{m1}\ a_{m2}...a_{mn} \end{pmatrix}$$

$m \times n$ ölçülü matris alarıq.Bəzən matrisi qısa olaraq, $\left(a_{ij}\right)$ $\left(i=\overline{1,m};\ j=\overline{1,n}\right)$ və ya $\left\|a_{ij}\right\|$ $\left(i=\overline{1,m};\ j=\overline{1,n}\right)$ kimi də yazırlar. Matrisləri, adətən, latın əlifbasının böyük hərfləri $A, B, C, X, Y, ...$ ilə işarə edirlər. Matrisi təşkil edən ədədlərə onun elementləri deyilir. a_{ij} yazılışı matrisin i-ci sətri ilə, j-cu sütununun kəsişməsində duran elementi göstərir. $m = n$ olduqda alınan matris n -tərtibli kvadrat matris adlanır. Bir elementdən ibarət olan matrisə birtərtibli matris deyilir. Birtərtibli matrisi onu təşkil edən yeganə ədədlə eyniləşdirirlər: $(a_{11}) = a_{11}$ .Yalnız bir sətri olan matrisə sətir matris, yalnız bir sütunu olan matrisə sütun matris deyilir, məsələn, (Orucov, 2014; Strang, 2023).

$$A = (8 \quad 4 \quad 3 \quad 1)\ ,\ B = \begin{pmatrix} 0 \\ 2 \\ 5 \end{pmatrix}.$$

n -tərtibli kvadrat matrisin $a_{11}, a_{22}, ..., a_{nn}$ elementləri çoxluğu həmin matrisin baş diaqonalı, $a_{1n}, a_{2(n-1)}, ..., a_{n1}$ elementləri çoxluğu isə yan (çəp, kənar) diaqonalı adlanır. Baş diaqonaldan aşağıda (yuxarıda) yerləşən bütün elementləri sıfra bərabər olan matris yuxarı (aşağı) üçbucaq matris adlanır:

$$\begin{pmatrix} a_{11} & 0 & ... & 0 \\ a_{21} & a_{22} & ... & 0 \\ ... & ... & ... & ... \\ a_{n1} & a_{n2} & ... & a_{nn} \end{pmatrix} \quad \text{və ya} \quad \begin{pmatrix} a_{11} & a_{12} & ... & a_{1n} \\ 0 & a_{22} & ... & a_{2n} \\ ... & ... & ... & ... \\ 0 & 0 & ... & a_{nn} \end{pmatrix}.$$

Ancaq baş diaqonalının elementləri sıfırdan fərqli olan kvadrat matrisə diaqonal matris, baş diaqonal elementləri eyni bir ədəd olan diaqonal matrisə isə skalyar matris deyilir. Baş diaqonal elementləri vahidə bərabər olan skalyar matris vahid matris adlanir və E_n (və ya I_n) hərfi ilə işarə edilir. Bütün elementləri sıfra bərabər olan kvadrat matrisə sıfır matris deyilir və O ilə işarə olunur. (Əhmədov, 2015; Shipachev, 2005).

$\begin{pmatrix} a_{11} & 0 & \dots & 0 \\ 0 & a_{22} & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & a_{nn} \end{pmatrix}$ -diaqonal matris, $\begin{pmatrix} a & 0 & \dots & 0 \\ 0 & a & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & a \end{pmatrix}$ -skalyar matris,

$\begin{pmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 1 \end{pmatrix}$ -vahid matris, $\begin{pmatrix} 0 & 0 & \dots & 0 \\ 0 & 0 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 0 \end{pmatrix}$ -sıfır matris.

A matrisinin bütün sətirləri ilə sütunlarının yerlərinin dəyişdirilməsinə (nömrələrini saxlamaqla) onun çevrilməsi (transponirə edilməsi) deyilir və A^*, A', A^T simvollarından biri ilə işarə edilir. Aydındır ki, $\left(A^T\right)^T = A$ olar. $A = A^T$, yəni $a_{ij} = a_{ji} (i, j = \overline{1,n})$ olduqda A matrisinə simmetrik, $a_{ij} = -a_{ji}$ olduqda isə çəpsimmetrik matris deyilir. Simmetrik matrisdə baş diaqonala nəzərən simmetrik olan elementlər bərabərdirlər. Çəpsimmetrik matrisdə isə baş diaqonalda sıfırlar yerləşir və bu diaqonala nəzərən simmetrik olan elementlər isə işarəcə fərqlənirlər. (Pismennyi, 2018; Veysova, 2013).

Eyni ölçülü və bütün uyğun elementləri bərabər olan matrislərə bərabər matrislər deyilir.Əgər matrisin hər hansı sətrinin elementi sıfırdan fərqli, ondan soldakı elementlərin hamısı sıfra bərabərdirsə, onda bu element həmin sətrin kənar elementi adlanır. Əgər matrisin ikincidən başlayaraq hər bir sətrinin kənar elementi özündən əvvəlki sətrin kənar elementindən sağda yerləşərsə, belə matris pilləvari matris adlanır, məsələn:

$$\begin{pmatrix} 1 & 2 & 4 & 7 \\ 0 & -1 & -1 & -3 \\ 0 & 0 & 0 & 0 \end{pmatrix}.$$

Eyni $(m \times n)$ ölçülü $A = (a_{ij})$ və $B = (b_{ij})$ $(i = \overline{1,m};\ j = \overline{1,n})$ *matrislərinin cəmi* həmin ölçülü və hədləri $c_{ij} = a_{ij} + b_{ij}$ $(i = \overline{1,m};\ j = \overline{1,n})$ kimi təyin olunan $C = (c_{ij})$ $(i = \overline{1,m}; j = \overline{1,n})$ matrisinə deyilir və $C = A + B$ kimi işarə olunur.

Xassələri:

1. $A + O = A$,

2. $A + B = B + A$,

3. $(A+B)+C=A+(B+C)$,

4. $(A+B)^T=A^T+B^T$.

Eyni ölçülü matrisləri çıxmaq üçün onların uyğun elementlərini çıxmaq lazımdır. Aydındır ki, həmişə $A-A=O$.

Verilmiş $A=(a_{ij})$ $(i=\overline{1,m};\ j=\overline{1,n})$ matrisinin həqiqi λ ədədinə hasili, hədləri $b_{ij}=\lambda a_{ij}$ $(i=\overline{1,m};\ j=\overline{1,n})$ kimi təyin olunan $B=(b_{ij})$ $(i=\overline{1,m};\ j=\overline{1,n})$ matrisinə deyilir və $B=\lambda A$ (və ya $B=A\lambda$) ilə işarə olunur. Deməli matrisi ədədə vurmaq üçün onun bütün elementlərini həmin ədədə vurmaq lazımdır.

Xassələri:

1. $(\lambda\mu)A=\lambda(\mu A)$,

2. $\lambda(A+B)=\lambda A+\lambda B$,

3. $(\lambda+\mu)A=\lambda A+\mu A$,

4. $(\lambda A)^T=\lambda A^T$.

Eyni ölçülü A və B matrislərinin xətti kombinasiyası $\alpha A+\beta B$ şəklində ifadəyə deyilir, burada α və β ixtiyari ədədlərdir. $(m\times n)$ ölçülü $A=(a_{ij})$ $(i=\overline{1,m};\ j=\overline{1,n})$ matrisinin $(n\times p)$ ölçülü $B=(b_{ij})$ $(i=\overline{1,m};\ j=\overline{1,n})$ matrisinə hasili hədləri

$$C_{ij}=\sum_{k=1}^{n}a_{ik}b_{kj}\ \ (i=\overline{1,m};\ j=\overline{1,p})$$

kimi təyin olunan $(m\times p)$ ölçülü $C=(c_{ij})$ $(i=\overline{1,m};\ j=\overline{1,p})$ matrisinə deyilir və $C=AB$ ilə işarə olunur. Tərifdən aydındır ki, A matrisinin B matrisinə vurmaq üçün A-nın sütunlarının sayı B-nin sətirlərinin sayına bərabər olmalıdır.Xüsusi halda hər bir kvadrat A matrisini özü özünə vurmaq olar. Bu halda həmin matrisin kvadratı, kubu və s. alınır: $A\cdot A=A^2, A\cdot A\cdot A=A\cdot A^2=A^3,\ldots$ Qeyd edək ki, matrislərin hasili üçün yerdəyişmə xassəsi doğru deyildir ($AB\neq BA$).

Xassələri:

1. $IA=AI=A$,

2. $OA=AO=O$,

3. $\lambda(AB) = (\lambda A)B = A(\lambda B)$,

4. $(A+B)C = AC + BC$,

5. $C(A+B) = CA + CB$,

6. $A(BC) = (AB)C$,

Onu da vurğulayaq ki, ixtiyari ölçülü sütun matrisi ixtiyari ölçülü sətir matrisə vurmaq olar. Yəni, $A(m\times 1)\cdot B(1\times n) = C(m\times n)$ matrisi alınar.Lakin ,ixtiyari ölçülü sətir matrisi ixtiyari ölçülü sütun matrisə vurmaq olmaz.Bu yalnız $A(1\times n)\cdot B(n\times 1) = C(1\times 1)$ olduqda mümkündür.

3. Nəticələr

Matrislərin hasilinə aid iqtisadiyönümlü hərbi məsələyə baxaq. (Alməmmədov et al., 2015b; Ermakov, 2006).

3.1. Tikiş fabrikində parça sərfi və maya dəyəri

Məsələ 1.Tikiş fabrikinə iki parçadan kursantlar üçün geyim növləri sifarış verilib.Bu parçalardan kursantlar üçün papaq,şərf,şalvar,kitel və köynək tikmək lazımdır.Bu parçaların işlədilməsi norması A matrisi ilə verilir.

Məsələnin həlli: Bir ədəd geyim növü üçün parça sərfi A matrisi ilə,sifarişin həcmi P vektoru ilə, parça növlərinin qiymətləri isə D vektoru ilə verilmişdir.Parça sərfi matrisi $A = \begin{pmatrix} 0,5 & 1 \\ 0,6 & 1 \\ 2 & 1,5 \\ 1.3 & 2 \\ 0,7 & 0 \end{pmatrix}$

Sifariş həcmi $P = (140, 160, 150, 170, 160)$,Parçaların qiyməti $D = \begin{pmatrix} 10 \\ 20 \end{pmatrix}$ ilə işarə olunmuşdur.Ümumi parça sərfi

$$Q = PA$$

Burada P sifarişin həcmini göstərən 1 × 5 ölçülü sətir vektoru, A isə 5 × 2 ölçülü parça sərfi matrisidir. Buna görə Q = PA hasili 1 × 2 ölçülü sətir vektorudur.

Deməli,ümumi parça sərfi,matrislərin hasilindən istifadə edərək hesablanır.Birinci parça üçün

$$140\cdot 0,5 + 160\cdot 0,6 + 150\cdot 2 + 170\cdot 1,3 + 160\cdot 0,7 =$$
$$= 70 + 96 + 300 + 221 + 112 = 799$$

İkinci parça üçün

$$140 \cdot 1 + 160 \cdot 1 + 150 \cdot 1,5 + 170 \cdot 2 + 160 \cdot 0 =$$
$$= 140 + 160 + 225 + 340 = 865$$

$$Q = (799\,865)$$

Əvvəlcə bir geyimin maya dəyərini tapaq.

$$C = A \cdot D$$

$$C = \begin{pmatrix} 0,5 & 1 \\ 0,6 & 1 \\ 2 & 1,5 \\ 1.3 & 2 \\ 0,7 & 0 \end{pmatrix} \cdot \begin{pmatrix} 10 \\ 20 \end{pmatrix} = \begin{pmatrix} 0,5 \cdot 10 + 1 \cdot 20 \\ 0,6 \cdot 10 + 1 \cdot 20 \\ 2 \cdot 10 + 1,5 \cdot 20 \\ 1,3 \cdot 10 + 2 \cdot 20 \\ 0,7 \cdot 10 + 0 \cdot 20 \end{pmatrix} = \begin{pmatrix} 25 \\ 26 \\ 50 \\ 53 \\ 7 \end{pmatrix}$$

Yəni,25 pul vahidi papaq,26 pul vahidi şərf,50 pul vahidi şalvar,53 pul vahidi kitel,7 pul vahidi köynək üçün sərf olunan maya dəyərini hesablamalıyıq.Ümumi məhsul dəyərini tapaq.

$$S = PC = 140 \cdot 25 + 160 \cdot 26 + 150 \cdot 50 + 170 \cdot 53 + 160 \cdot 7 = 25\,290$$

$$S = 140 \cdot 25 + 160 \cdot 26 + 150 \cdot 50 + 170 \cdot 53 + 160 \cdot 7 =$$
$$= 3500 + 4160 + 7500 + 9010 + 1120 = 25290$$

3.2. Hərbi inşaat sifarişinin resurs və xərc hesablamaları

Məsələ 2.Hərbi inşaat briqadası işğaldan azad olunmuş ərazilərdə 5 klub, 7 əsgər yeməkxanası və 12 əsgər yataqxanası tikilməsi sifarişini aldı.Bu tip binaların hər birinə işlədiləcək bəzi xammalların növləri məlumdur: polad, ağac, şüşə, rəng və həmçinin işçi qüvvəsi.Onların sərfi uygun olaraq aşağıdakı cədvəldə verilmişdir:

Binaların tipi	Polad	Ağac	Şüşə	Rəng	İşçi qüvvəsi
Klub	5	20	16	7	17
Yeməkxana	7	18	12	9	21
Yataqxana	6	25	8	5	13

Qəbul edək ki, polad, ağac, şüşə, rəng və həmçinin işçi qüvvəsinin hər vahidinə uyğun olaraq 15,8,5,1,10 pul vahidi qədər xərc tələb olunur(hər pul vahidinin minliklə götürüldüyü nəzərdə tutulur).Tapmalı: a) Sifarişi yerinə yetirmək üçün sərf olunacaq xammalın miqdarını və işçi qüvvəsinin sayını; b) Hər tip binanın başa gəlmə xərcini ; c) bütün binaların başa gəlməsi üçün ümumi xərcin miqdarını.

Məsələnin həlli:

Verilənləri matris formasında ifadə edək.Sifariş vektoru S ilə işarə edək. S sətir matrisi tikiləcək binaların(klub, yeməkxana , yataqxana) sayıdır:

$$S = (5 \;\; 7 \;\; 12)$$

Sərf matrisini A ilə işarə edək.A nın sətirləri bina tiplərini, sütunları ımaterialları (polad, ağac, şüşə, rəng, işçi qüvvəsinin sayı) ifadə edir :

$$A = \begin{pmatrix} 5 & 20 & 16 & 7 & 17 \\ 7 & 18 & 12 & 9 & 21 \\ 6 & 25 & 8 & 5 & 13 \end{pmatrix}$$

Qiymət matrisi Q sütun matrisidır.Bu hər materialın və işçi qüvvəsinin vahid dəyərini ifadə edir:

$$Q = \begin{pmatrix} 15 \\ 8 \\ 5 \\ 1 \\ 10 \end{pmatrix}$$

a) Sifarişi yerinə yetirmək üçün sərf olunacaq xammalın miqdarını və işçi qüvvəsinin sayını tapaq.Hər materialın ümumi sərfi binaların sayının hər materialın bir binaya sərfiyyatlarının hasilləri cəmidir.Yəni , sətir matrisinin matrisə vurulmasıdır: $S \cdot A$ matrisinin ölçüsünü müəyyən edək.Matrislərin hasilinin ölçüsünün tapılması qaydasına görə

$$(1 \times 3) \cdot (3 \times 5) = (1 \times 5)$$

şəklində alınar. $S \cdot A$ matrisinin elementlərini tapaq.

Material	Hesablama	Nəticə
Polad	5·5 + 7·7 + 12·6 = 25 + 49 + 72	146
Ağac	5·20 + 7·18 + 12·25 = 100 + 126 + 300	526
Şüşə	5·16 + 7·12 + 12·8 = 80 + 84 + 96	260
Rəng	5·7 + 7·9 + 12·5 = 35 + 63 + 60	158
İşçi qüvvəsi	5·17 + 7·21 + 12·13 = 85 + 147 + 156	388

Əldə etdiklərimizi matris şəklində yazaq.

$$S \cdot A = (146 \;\; 526 \;\; 260 \;\; 158 \;\; 388)$$

alınar.Yəni sifarişin yerinə yetirilməsi üçün 146 vahid polad, 526 vahid ağac, 260 vahid şüşə, 158 vahid rəng və 388 vahid işçi qüvvəsi sərf olunacaq.

b) Hər tip binanın başa gəlmə xərcini hesablayaq. Bir binaya sərf olunan xərc hər materialın miqdarı ilə bu materialın qiymətinə hasilinin sərfiyyatlarının hasilləricəmidir.Yəni matrisin sütun matrisə vurulmasıdır. $A \cdot Q$ matrisinin ölçüsünü müəyyən edək Matrislərin hasilinin ölçüsünün tapılması qaydasına görə

$$(3\times 5)\cdot(5\times 1) = (3\times 1)$$

şəklində alınar. $A \cdot Q$ matrisinin elementlərini tapaq.

Binaların tipi	Hesablama	Xərc (min pul vahidi)
Klub	5·15 + 20·8 + 16·5 + 7·1 + 17·10 = 75 + 160 + 80 + 7 + 170	492
Yeməkxana	7·15 + 18·8 + 12·5 + 9·1 + 21·10 = 105 + 144 + 60 + 9 + 210	528
Yataqxana	6·15 + 25·8 + 8·5 + 5·1 + 13·10 = 90 + 200 + 40 + 5 + 130	465

Əldə etdiklərimizi matris şəklində yazaq.

$$A \cdot Q = \begin{pmatrix} 492 \\ 528 \\ 465 \end{pmatrix}$$

Şərtə görə pul vahidləri minliklədir: klub 492 min, yeməkxana 528 min, yataqxana 465 min pul vahidinə başa gəlir.

c) Bütün sifarişin ümumi xərcini iki yolla tapa bilərik:

1-ci yol :

b bəndində aldığımız nəticəni sifariş sayına vurmaqla tapılır. $S \cdot (A \cdot Q)$:

$$5\cdot 492 + 7\cdot 528 + 12\cdot 465 = 2460 + 3696 + 5580 = 11\ 736$$

2-ci yol :

a bəndində aldığımız nəticəni qiymətlərə vururuq, $(S \cdot A) \cdot Q$:

$$146\cdot 15 + 526\cdot 8 + 260\cdot 5 + 158\cdot 1 + 388\cdot 10 = 2190 + 4208 + 1300 + 158 + 3880 = 11\ 736$$

Beləliklə, bütün sifarişin ümumi xərcini 11 736 min pul vahidi tapdıq.

4. Müzakirə

Təklif:Aiınmış nəticələrə əsasən tövsiyə olunur ki,istehsal prosesində yüksək maya dəyərinə malik məhsullar üzrə parça sərfi normaları optimallaşdırılsın və istehsal xərclərinin azaldılması istiqamətində tədbirlər görülsün.Eyni zamanda daha az maya dəyərinə malik məhsulların istehsalının artırılması fabrikin ümumi iqtisadi səmərəliliyinin yüksəldiməsinə şərait yarada bilər.

Qeyd etmək lazımdır ki,məsələnin matrislərin hasilinə istinad edərək həlli istehsal prosesinin iqtisadi təhlilini sadələşdirir və resursların planlaşdırılmasında operativ qərarların qəbul edilməsinə imkan verir.

5. Nəticə

Birinci məsələdə aparılmış hesablamalar əsasında müəyyən edilmişdir ki,verilmiş sifarişin yerinə yetirilməsi üçün birinci növ parçanın ümumi sərfi 799 vahid,ikinci növ parçanın ümumi sərfi 865 vahid təşkil edir.bi isə göstərir ki,ikinci növ parça daha intensiv istifadə l olunur və onun tədarükü xüsusi diqqət tələb edir.Hər bir hazır məhsulun vahidinə düşən maya dəyərinin təhlili nəticəsində məlim olmuşdur ki,ən yüksək xərc kitelin istehsalına (53 pul vahidi),ən aşağı xərc isə köynəyin istehsalına (7 pul vahidi)düşür.Bütün sifariş üzrə hazır məhsulların ümumi dəyəri 25290 pul vahidi olmuşdur.

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TEXNİKA ELMLƏRİ

TECHNICAL SCIENCES

Attention-Guided Sparse Aggregation and Hetero Geneity-Aware Optimization for Federated Wireless Traffic Prediction

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Abstract. *In cellular networks, wireless traffic forecasting is essential for proactive communication system adaptation. Wireless traffic prediction at the edge using Federated Learning (FL) has garnered a lot of attention due to its improved privacy protection and exemption from raw data transmission. However, existing FL-based traffic prediction methods still require substantial gradient exchange between local customers and a central server, and it remains unclear how to model the spatial dependencies among local customers within the FL architecture. To address this, we propose an FL framework, built on a Distributed Autonomous Network (DAN) architecture for 6G wireless communication, that proceeds through four stages, local modelling, gradient clipping and compression, path-level accumulation, and global optimization, to minimize communication load while maintaining forecasting accuracy. At each customer, an L2-norm gradient clipping step is followed by Top-K sparsification and 1-bit quantization to substantially shrink the size of the uploaded gradients. To offset the information lost through this compression, a Path Attention Aggregation Module learns customer-specific attention weights from each customer's upload trajectory, combining gradient-stability indicators with local performance measures, so that consistent, high-quality updates are weighted more heavily during aggregation; three customized aggregation strategies, all-correlated, δ-threshold, and k-relevant, further use gradient correlation to capture the spatial interdependence among customers. A Heterogeneity-Aware Adaptive Optimizer, built on Adam, additionally tunes each customer's learning rate, momentum, and weight-decay settings to its own traffic characteristics and enforces cross-round consistency, mitigating the effects of non-IID data across customers.*

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Experiments on two real-world wireless traffic databases show that the proposed approach outperforms modern algorithmic techniques and can increase communication efficacy by up to two orders of magnitude, without compromising forecasting precision.

Keywords: *cellular networks, traffic forecasting, autonomous network, compression, quantization, heterogeneity*

Federativ simsiz trafik proqnozlaşdırılması üçün diqqət mexanizminə əsaslanan seyrək aqreqasiya və heterogenliyi nəzərə alan optimallaşdırma

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Xülasə. *Mobil rabitə şəbəkələrində simsiz trafikin proqnozlaşdırılması rabitə sisteminin qabaqlayıcı şəkildə uyğunlaşdırılması üçün vacibdir. Federativ öyrənmədən (FL) istifadə etməklə şəbəkənin kənarında simsiz trafikin proqnozlaşdırılması məxfiliyin daha yaxşı qorunması və ilkin məlumatların ötürülməsinə ehtiyacın aradan qaldırılması sayəsində böyük diqqət cəlb etmişdir. Bununla belə, mövcud FL əsaslı trafik proqnozlaşdırma metodları yerli müştərilərlə mərkəzi server arasında hələ də əhəmiyyətli həcmdə qradiyent mübadiləsi tələb edir və FL arxitekturası daxilində yerli müştərilər arasındakı məkan asılılıqlarının necə modelləşdirilməsi tam aydın deyil. Bu problemi həll etmək üçün 6G simsiz rabitəsi üzrə paylanmış avtonom şəbəkə (DAN) arxitekturasına əsaslanan FL çərçivəsi təklif edirik. Bu çərçivə proqnozlaşdırma dəqiqliyini qorumaqla rabitə yükünü minimuma endirmək məqsədilə dörd mərhələni əhatə edir: yerli modelləşdirmə, qradiyentlərin məhdudlaşdırılması və sıxılması, trayektoriya səviyyəsində toplanma və qlobal optimallaşdırma. Hər bir müştəridə L_2 normasına əsaslanan qradiyent məhdudlaşdırılmasından sonra yüklənən qradiyentlərin həcmini əhəmiyyətli dərəcədə azaltmaq üçün Top-K seyrəkləşdirməsi və 1 bitlik kvantlaşdırma tətbiq edilir. Sıxılma nəticəsində yaranan məlumat itkisini kompensasiya etmək üçün trayektoriya üzrə diqqətə əsaslanan aqreqasiya modulu hər bir müştərinin yükləmə trayektoriyasından həmin müştəriyə xas diqqət çəkilərini öyrənir. Modul qradiyent sabitliyi göstəricilərini yerli performans göstəriciləri ilə birləşdirərək ardıcıl və yüksək keyfiyyətli yeniləmələrə aqreqasiya zamanı daha böyük çəki verir; bütün korrelyasiyalı yeniləmələri, δ həddini və k uyğun yeniləməni əsas götürən üç fərdiləşdirilmiş aqreqasiya strategiyası isə müştərilər arasındakı məkan qarşılıqlı asılılığını nəzərə almaq üçün qradiyent korrelyasiyasından istifadə edir. Adam alqoritminə əsaslanan, heterogenliyi nəzərə alan adaptiv optimallaşdırıcı əlavə olaraq hər bir müştərinin öyrənmə sürətini, momentumunu və çəkilərin zəiflədilməsi parametrlərini onun trafik xüsusiyyətlərinə uyğunlaşdırır və təlim raundları arasında ardıcıllığı təmin edərək müştərilər üzrə müstəqil və eyni paylanmış olmayan məlumatların (non-IID) təsirini azaldır. Real simsiz trafikə aid iki verilənlər bazası üzərində aparılan eksperimentlər göstərir ki, təklif olunan yanaşma müasir alqoritmik üsulları üstələyir və proqnozlaşdırma dəqiqliyini qorumaqla rabitə səmərəliliyini 100 dəfəyədək artıra bilir.*

Açar sözlər: *mobil rabitə şəbəkələri, trafikin proqnozlaşdırılması, avtonom şəbəkə, sıxılma, kvantlaşdırma, heterogenlik*

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1. Introduction

One of the crucial features that present fifth-generation (5G) networks lack is edge intelligence, enabled by AI methods (such as ML and DL). As a result, both academic and commercial research communities have concluded that edge intelligence will be crucial to the development of sixth-generation (6G) communication networks (Al-Quraan et al., 2023). Shifting a portion of the information storage and computation of services from the central cloud to peripheral nodes that are both physically and cognitively close to the end customers can significantly reduce end-to-end latency and improve computing efficiency and communication effectiveness (Letaief et al., 2019). Since many intelligent network functions, like self-organisation and self-optimisation, rely significantly on edge computing to be realised, wireless traffic modelling at a distance is crucial for anticipated traffic situations. Even though a lot of research has been done on wireless traffic forecasting, nearly all of it falls under the category of centralized system training, which necessitates sending raw data from edge nodes (local customers) to the central cloud (Niknam et al., 2020). Because these edge nodes are geographically dispersed, sending raw data not only uses up bandwidth but also raises privacy concerns in the event that bad actors target them (Yuan et al., 2024). System training and forecasting may now be done at the edge because of the development of distributed ML, especially federated learning (FL). In the FL paradigm, a central cloud orchestrates the cooperative training of a global system by several edge nodes. Instead of sending raw data to the cloud, a single edge node only needs to transmit the most recent system or the gradient data to the centralized database (Habib et al., 2024).

Applying FL to wireless traffic presents numerous problems, despite its promising benefits in system forecasting. First, the wireless system incurs nontrivial transmission expenses due to the frequent transmission of gradients or attributes between nodes on the edge and the centralized server, particularly when the system is big, even though there is no transfer of raw traffic data involved in the system training (Xu et al., 2019). Second, due to user mobility, edge nodes exhibit distinct traffic patterns and intricate spatiotemporal connections. Traditional FL algorithms are not effective because they don't distinguish between the distinct contributions that each edge node makes to the eventual global system; instead, they just average the inclinations of those nodes. More precisely, the geographic locations and traffic patterns of three edge nodes are chosen from our Milan database (C. Zhang et al., 2019; C. Zhang et al., 2018; L. Zhang et al., 2022). Forecasting performance is enhanced by averaging the systems of two edge nodes with comparable traffic patterns. However, system aggregation might not be beneficial and might potentially worsen performance if their patterns are different (Zhao et al., 2020). This propose a unique federated learning is a standard technique based on association and gradient reduction to address the two issues mentioned above in wireless traffic

forecasting. In particular, we reduce the cost of sending messages between the server in the centre and customers in the area by including gradient sparsification in wireless traffic forecasting. Researchers also suggest employing error feedback and gradient tracking approaches to counteract the unfavorable impacts of gradient compression due to the lossy nature of sparsification. Additionally, in order to capture different geographical dependencies of local customers, we suggest three customized system aggregation procedures that are generated from the gradient correlation matrix. This is the first study to describe such a distributed architecture and its related techniques, to the best of the researchers' knowledge, for wireless traffic forecasting that incorporates spatiotemporal properties. The experimental findings show that the proposed technique with asymmetrical compression and association performs better than the state-of-the-art and can increase the effectiveness of communication by up to two orders of magnitude higher without compromising forecasting accuracy.

The remainder of this paper is organized as follows. Section 2 reviews existing studies on wireless traffic prediction, deep-learning-based forecasting, and federated learning approaches. Section 3 presents the proposed system model and methodology. Section 4 describes the experimental setup and evaluates the proposed framework. Finally, Section 5 concludes the paper by summarizing the major findings and contributions.

2. Related works

Wireless connectivity traffic forecasting plays a critical role in enhancing the cognitive capabilities of upcoming communication relationships, including intelligent network administration and efficiency has received a lot of attention lately (Y. Li et al., 2020). Previous research on wireless traffic forecasting has mostly concentrated on conventional statistical systems like entropy, α-stable, and ARIMA and its variants. However, these systems' inability to accurately depict wireless traffic is limited by the nonlinear characteristics of wireless traffic (Kunang et al., 2021). The advancement of wireless traffic forecasting has been significantly accelerated by the quick development of AI methods, particularly ML and DL. In recent years, a number of ML- and DL-based methods have emerged. To address wireless traffic forecasting issues, techniques based on graph neural networks, deep belief networks, long-short term relationships, and Bayesian processes have been examined (Sherubha & Mohanasundaram, 2019a; Sherubha & Mohanasundaram, 2019b; Sherubha et al., 2020). Additionally, the encoder-decoder architecture can capture spatiotemporal interdependence in wireless traffic forecasting. The researchers in (Wang et al., 2019) recommended employing convolutional neural networks, for instance can simultaneously encapsulate both temporal and spatial reliance for wireless traffic predictions at the city or network level. Additionally, they took into account several temporal connections, including periodicity and closeness. A three-dimensional convolutional network was used in (R. Li et al., 2017) to improve spatial-temporal learning over wireless communications. Additionally, cross-domain information, such as points of significance, has been shown to be beneficial in enhancing forecasting accuracy in (Shen et al., 2021). To lower system complexity and enhance representation learning, attention methods are later incorporated into wireless traffic forecasting.

The aforementioned studies primarily concentrate on centralized wireless traffic forecasting, which uses a lot of throughput since a strong node needs to receive raw wireless traffic information for development. To address this issue and train a forecasting system at the edge, FL-based approaches are beginning to appear. For the purpose of predicting traffic flow, as in (Tran et al., 2019) recommended a federated gated recurrent neural network. Additionally, the researchers in (T. Li et al., 2020) created FedDA, a dual-attention method that informs the method of learning with both past global expertise and local improvements in order to address the data heterogeneity problem that FL faces. FedDA achieves state-of-the-art performance and was

specifically intended for wireless traffic forecasting (Gao et al., 2024). Although our work takes into account using the FL paradigm to train a cell phone traffic estimation platform, it is different from all of the aforementioned efforts in two significant ways. To reduce the cost of sending messages between the server in the center and customers in the area, we first use gradient compression for wireless traffic forecasting. Second, in order to capture the geographical relationships among different local customers, we create customized gradient aggregation schemes based on gradient correlation (L. Li et al., 2023; Lin et al., 2020). Table 1 shows the comparison of existing approaches.

Table 1
Existing approach comparison

Ref.	Main Technique	Key Strength	Major Limitation / Research Gap
(Xu et al., 2019)	Scalable Gaussian Process	Provides a probabilistic framework for wireless traffic prediction	Scalability and modeling complexity can increase with large-scale, highly nonlinear traffic patterns
(C. Zhang et al., 2018)	Densely Connected CNN	Effectively captures spatial characteristics of citywide cellular traffic	Centralized learning requires collection of traffic data and introduces communication/privacy concerns
(C. Zhang et al., 2019)	Deep Transfer Learning	Exploits cross-domain information to improve cellular traffic prediction	Depends on centralized data processing and does not directly address federated communication overhead
(Zhao et al., 2020)	Spatial-Temporal Attention CNN	Jointly models spatial and temporal dependencies through attention and convolution	Primarily designed for centralized prediction rather than privacy-preserving distributed learning
(Wang et al., 2019)	Spatio-temporal Cellular Traffic Prediction	Models temporal and spatial relationships in metropolitan cellular traffic	Centralized architecture requires aggregation of raw traffic information
(R. Li et al., 2017)	Application-level Traffic Learning and Prediction	Learns application-level cellular traffic characteristics	Does not address privacy preservation or federated communication efficiency
(Shen et al., 2021)	Time-wise Attention CNN	Attention mechanism improves temporal feature representation	Does not explicitly solve non-IID client heterogeneity or FL communication cost
(L. Zhang et al., 2022)	Federated Meta-Learning	Enables edge-based wireless traffic prediction while reducing raw-data sharing	Frequent model/gradient communication can still impose substantial transmission overhead
(Tran et al., 2019)	Federated Learning over Wireless Networks	Provides an optimization framework for distributed FL over wireless networks	General FL framework rather than a traffic-specific spatial-correlation mechanism

Ref.	Main Technique	Key Strength	Major Limitation / Research Gap
(T. Li et al., 2020)	Federated Optimization for Heterogeneous Networks	Uses a proximal objective to improve training under non-IID data	Does not explicitly model spatial relationships among wireless traffic clients
(Gao et al., 2024)	FL with multi-time-scale information	Incorporates multiple temporal scales into federated traffic forecasting	Communication and client-dependency modeling remain challenges
(L. Li et al., 2023)	Gradient similarity-based FL	Exploits similarity among client gradients during aggregation	Does not jointly provide aggressive gradient compression and adaptive path-level attention
(Lin et al., 2020)	Gradient Sparsification / Compression	Significantly reduces communication bandwidth during distributed training	Lossy compression can discard useful gradient information and is not specifically designed for wireless traffic forecasting

3. System Model

In the context of distributed autonomous networks (DAN), a recommended sixth-generation (6G) cellular communication network framework, we conduct an investigation of wireless traffic forecasting. We abstract a rudimentary system model for wireless traffic forecasting after introducing the idea of DAN (Lu et al., 2019). To satisfy the many requirements of upcoming 6G networks, the DAN architecture is designed to enable plug-and-play, flexible deployment, and on-demand network customization through distributed and autonomous features. To accomplish underground, ground, satellite, and marine communications, DAN has numerous dispersed cloud units placed in various locations. Each cloud unit contains processing and networking features, namely a smart interface engine and baseband unit (BBU) pool (Nie et al., 2017), they are intelligent enough to assist the network data analytics function by gathering and analyzing data. Here, M satellite cloud units at the perimeter and one centralised cloud server in the mobile centralized network make up our wireless traffic forecasting system model (Ji et al., 2019). The number of BSs supported by each cloud unit varies based on coverage demands. Every BS's mobile traffic data is tracked, gathered, and stored in the local database in real-time. Employing these databases, the cloud perform load-aware traffic management and network control while training a forecasting system w in a federated manner to forecast future traffic quantity. For example, when the anticipated traffic flow is low, to save energy, some BBUs can be placed in an idle mode. A wireless traffic database $D_m = \{x_i^m, y_i^m\}_{i=1}^n, where\ x_i^m = [v_i^m, v_{i+1}^m, \ldots, v_{i+p-1}^m]\ and\ y_i^m = v_{i+p}^m$, is stored by each of the M cloud unit in the communication system. In particular, when creating training and test data samples, p is the chosen sliding window size and v_i^m represents the amount of wireless traffic during cloud unit $m's$ scheduled time slot $'i'$. To get the forecasting system w, leveraging FL or more specifically, cross-silo FL. This work can express our objective function as follows:

$$\arg\min_{w \epsilon R^d} \{f(w) = \frac{1}{M} \sum_{m=1}^{M} f_m(w)\} \quad (1)$$

Whereby, d is the system characteristic's dimensionality and $f_m(\cdot)$ is customer $m's$ local objective function. $f_m(\cdot)$ typically has the form of $(x_i^m, y_i^m; w)$, where $(\cdot)$ assesses the difference between the ground truth value and the forecasts. In the conventional FL paradigm, there are two basic phases to solve (1): global aggregation on the server side and local updates on the customer. In particular, the local customer m calculates the gradient information $g_t^m = \nabla f_m(w_t)$ at the t^{th} communication cycle and sends it along to the server. The server updates the global model in the second step employing the gradients it receives from local customers. FedAvg, the traditional weight update of FL algorithms can be expressed as:

$$\arg\min_{w \epsilon R^d} \{f(w) = \frac{1}{M} \sum_{m=1}^{M} f_m(w)\} \quad (2)$$

Where, M_t is a collection of local customers during transmission round t, and η is the server's standard rate of learning. Additionally, a set's cardinality is represented by $|.|$.

3.1. Recommended system

Four consecutive stages comprise the general architecture of the recommended FQL architecture, as depicted in Fig 1: local modelling, global optimization, path-level accumulation, and gradient processing. First, each financial institution's local strategy modelling networks receive locally generated market data that has been evaluated, as well as macroeconomic variables independently. Local strategy characteristics are generated at each customer employing a uniform forecasting backbone, such as a Transformer or LSTM version (Han et al., 2024). Customers do not send the full set of system characteristics after multiple rounds of local training. Rather, the Gradient Clipping method and Compression Module, which finds and quantizes the top$-K$ gradients to drastically lower transmission volume, are used to choose the most meaningful gradients. The compacted gradients are attached along with path-related information about them, such as indications like past gradient volatility and local strategy performance, before being sent to the central server. In order to improve the legitimacy and efficacy of the global update, the on the server-side Path Attention Aggregating Module uses unbalanced grouping along with attention score calculations to dynamically evaluate each customer's uploading channel, removing unstable or ineffective contributions. The next development cycle is subsequently started by broadcasting the final global system to every customer. Additionally, throughout local instruction, each client employs a Heterogeneity-Aware Optimizer to manage structural and stochastic variability across commodities. To ensure that the update procedure complies with region-specific financial behaviors, this module adaptively modifies optimizer settings based on local market dynamics. The module ensures that the FQL architecture concurrently operates within all rounds of neighborhood training and creates a locked evaluation loop with the global aggregates stage to ensure high-quality communication, privacy security, and outstanding strategy flexibility across universities (Jeleel-Ojuade, 2024).

3.2. Path Attention Aggregation Module

Vectors are used or sequences of image patches are commonly used as input in traditional self-attention methods. To create context-sensitive representations, the main goal is to calculate the pairwise interaction intensity among elements. These methods, which concentrate on intra-sample connections, are extensively used in computer vision and NPL. On the other hand, inter-customer path-level importance modelling is the focus of this article presents the Path Attention Aggregation Mechanism. It specifically seeks to dynamically assess how the release of this update trajectory of each consumer is based on its previous training performance and the communicated characteristic sequences contribute to the training of the global system (Chatzigiannis et al., 2023). This method is a federated-level focus mechanism that focuses on each customer's prior training

effectiveness; this revised trajectory is released. As a result, it is very different from traditional approaches that focus on input interpretation and normalization objectives, and modelling complexity. A simple three-layer completely interconnected neural network is used to build the Path Concentration component. An attribute vector for the uploading path of each consumer serves as the network's input. It consists of two main types of data: (1) advanced gradient sustainability indicators, which document how consistently local changes have occurred over the course of previous rounds. Among these is the mean interpersonal cosine equivalent between contemporary slopes, calculated as $\sigma_i = std\ (|\left|\nabla\theta_i^{(t-j)}\right||)$, for $j = 1, \ldots, k$ which measures the directional stability of local communications; and the subject of study is strategy measures that demonstrate the monetary quality of a consumer's local ecosystem. These consist of the average validation return $r_i = 1/T \sum_{t=1}^{T} R_i^{(t)}$ and the Pearson correlation coefficient ($Corr_i = corr(\hat{\hat{R}}_i, \hat{R}_{global})$ between the global system's recommendations over a held-out set and the customer's expected returns. To create customer-specific weights for aggregation, the interest system is fed these concatenated characteristics. Three layers make up the network structure: a layer for entering data, a layer that is concealed with 64 units activated by ReLU, and a layer called output that creates the interest weight αi for each path, standardized using the Softmax algorithm with dimensions [$batch_size$,8]. This is the definition of the mathematical flow:

$$h_i^{(1)} = ReLU\ (W_1 x_i + b_1); W_1 \epsilon R^{8*64} \tag{3}$$

$$h_i^{(2)} = W_2 h_i^{(1)} + b_2;\ \ W_2 \in R^{64*1} \tag{4}$$

$$\propto_i = \frac{\exp(h_i^2)}{\sum_j \exp(h_j^2)} \tag{5}$$

In this case, the vector of path attributes for customer I is denoted by xi, and the appropriate attention weight employed in gradient aggregation is represented by αi. A normalized total of the customer grades based on their attentiveness ratings is used to calculate the global constant update:

$$\theta^{t+1} = \sum_{i=1}^{N} \alpha_i . \nabla\theta_i^{(t)} \tag{6}$$

This module works in tandem with the Heterogeneity-Aware Optimizer (Kang et al., 2024). The latter enhances the attention mechanism's ability to discriminate while assessing customer inputs by improving the consistency and accuracy of local elevation variations. Consequently, during aggregation, low-quality pathways are efficiently suppressed. This creates a positive feedback loop at the system level: the path attention module improves the global aggregation process, while the heterogeneity-aware optimization increases the quality of local training. In the end, this cooperative dynamic improves the FQL architecture's resilience and strategic performance. This integrated mechanism is represented by the structure diagram's aggregate branch.

3.3. Gradient Clipping and Compression

The recommended Gradient Clipping and Compression Module is intended to improve training robustness and convergence stability while addressing communication bottlenecks brought on by inconsistent network resources across borders in federated schooling. Following local training, each customer initially completes gradient standardization and trimming using $L2$-norm, as illustrated in Figure 3. The gradients are then sent to the main location for worldwide aggregation after quantized compression and sparse selection. This module functions as a gradient-path reduction component in accordance with the component diagram's gateway and

rescaler architecture, rather than adhering to the structure of traditional deep networks. Let $\nabla\theta i_i \in R^d$ be an inclination vector at customer i. The following is how $L2$-norm clipping is used to stop a typical gradient explosion or instability:

$$\widetilde{\nabla}\theta_i = \frac{\nabla\theta_i}{\max(1, \frac{|\nabla\theta_i|_2}{C})} \tag{7}$$

Where, C is a predefined clipping threshold that is either dynamically changed or often set to $C = 1.0$ according to the customer's past volatility. By ensuring that $\left|\widetilde{\nabla}\theta_i\right|_2 \leq C$, this process keeps any one customer from having an unreasonable effect on the global system. After the trimming, the device performs Top-K sparse picking. The sparse operator of selection $\mathcal{T}(\cdot)$, which keeps the $K\%$ items with the definition of the most significant absolute integer that sets all other values to zero, is as follows. Let K represent the upload ratio.

$$\widetilde{\nabla}\theta_i^{(K)} = T_k(\widetilde{\nabla}\theta_i) \tag{8}$$

Here, 1-bit quantization procedure is provided to further minimize transmission overhead. This enables the server to reconstitute the compressed gradient by transmitting the average magnitude of the non-zero items while retaining only their sign. The following is the definition of the quantized representation:

$$q_i = sign\left(\widetilde{\nabla}\theta_i^K\right).\tilde{m}_i;\ \ \tilde{m}_i = \frac{1}{K}\sum_{j\in supp\ (\widetilde{\nabla}\theta_i^K)} |\widetilde{\nabla}\theta_{i,j}^K| \tag{9}$$

To achieve high compression speeds, the final upload is made up of the mean, the mean amplitude m and the sparse index set $supp(\cdot)$. The global gradient is rebuilt at the server in question using linear translation. This method is consistent with the diagram's router-rescaler architecture, in which rescalers carry out normalization and de-quantization while routers feed gradients into compression paths depending on Top-K significance. While the effectiveness of communication is significantly increased by $1-$bit compression, it intrinsically loses detailed information regarding gradient magnitudes, which could result in biased updates or impede convergence in real-world scenarios. To mitigate this, the condensed values are balanced by a score for attention taken from the Path Attention Module presented by the FQL framework, based on each customer's past performance and stability rather than being aggregated uniformly. By ensuring that more dependable and consistent updates have a bigger impact during accumulation, this approach successfully offsets the loss of sharpness caused by aggressive digitization. Quality-weighted aggregation and sparsity-aware compression work together to develop a "high-quality, high-weight" minimization approach that preserves robustness and fulfilment. The global aggregate can be stated analytically as follows:

$$\theta^{(t+1)} = \sum_{i=1}^{N} \alpha_i . q_i \tag{10}$$

Where, q_i is the condensed gradient, and α_i is the path module's concentration weight. In theory, this combined approach builds a compressed potential space adjusted minimum-bias estimation with the subsequent maximum error requirement:

$$E[|\theta^{(t+1)} - \theta^* \begin{bmatrix}2\\2\end{bmatrix} \leq O\left(\frac{1}{KN}\sum_{i=1}^{N} \propto_i^2 . |\nabla\theta_i - \theta^*|_2^2\right) \quad (11)$$

This shows that in addition to lowering communication costs, the compressed module maintains convergence durability and robustness across heterogeneity market data distributions when combined with path-aware weighted.

3.4. Optimizer

There are significant structural variations between commercial at the national and regional levels in federated quantitative strategy modelling. These variables include variances in trading systems, commodity liquidity, fluctuation trends, and patterns influenced by legislation. These result in customer data that is identically dispersed (non-IID) and very non-independent. Local over-fitting or failure to converge may occur when a uniform optimization method is applied across such contexts. A Heterogeneity-Aware Adaptive Optimizer is presented as a solution to this problem. While preserving convergence and consistency during global aggregation, through local instruction, this component changes dynamically optimization variables to match the unique market features of every consumer. The recommended method integrates a programmable controller network and expands on the Adam optimizer. The controller provides the optimizer's speed of learning ηi, tempo parameter β_i, and weight decomposition factor λ_i for this particular round depending on common measures of monetary volatility, including skewness of return patterns of distribution, volume fluctuation values, and historical variability. Considering an input width of $[batch_size,4]$, LeakyReLU-controlled invisible layer of width 32, and an outcome layer of length 3 that corresponds to the three adjustable hyper-characteristics, the controller network is made up of two completely connected layers. The following is how the resulting results are directly integrated into the standard Adam upgrade rules:

$$m_t = \beta_i m_{t+1} + (1-\beta_i)\nabla\theta_t; \; v_t = \lambda_i v_{t+1} + (1-\lambda_i)(\nabla\theta_t)^2 \quad (12)$$

$$\theta_{t+1} = \theta_t - \eta_i . \frac{m_t}{\sqrt{v_t} + \varepsilon} \quad (13)$$

As a result, each customer's characteristics $\eta_i, \beta_i, and\ \lambda_i$ are adaptively computed allowing each to adhere to a locally tailored upgrade trajectory based on its unique market features. Customers can avoid poor convergence or divergence caused by structural mismatches by employing this design. The server calculates a cross-round consistency factor c_i based on each customer's path variation during the preceding three rounds in order to guarantee consistency inside the federated system. Before aggregation, learning rates are modified employing this feedback in accordance with the following:

$$\eta_i^{new} = \eta_i^{old} . (1 - \gamma . \mathrm{c_i}) \quad (14)$$

Where, the scaling coefficient is γ. Greater divergence from the global strategy is indicated by a larger c_i, which calls for a lower learning rate. This approach is especially useful when combined with the Path Sensitivity Module: the adaptive optimizer lessens the impact of a customer's notable deviation caused by structural heterogeneity, preventing negative impacts on the global system. Consequently, the FQL architecture improves the durability and scalability of cross-market strategies for trading by the concurrent use of path concentration and heterogeneity-aware methods of optimization to increase stability and velocity of convergence in heterogeneous settings.

4. Numerical results

Researchers conduct tests on two real-world wireless traffic databases. First, we provide a brief description and analysis of the two databases. Next, we give a thorough description of the evaluation measures, characteristic values, and associated baselines. Finally, we compare our recommended algorithm's forecasting ability with the most advanced systems. Researchers conduct investigations on two real-world wireless communications datasets in this part. We first discuss and assess the two collections briefly. Next, we give a thorough description of evaluation measures, characteristic settings, and the associated baselines. Finally, we compare our suggested technique's forecasting effectiveness with that of cutting-edge systems.

4.1. Baseline algorithms

Algorithms for Baselines and Assessment Measures: The following cutting-edge algorithms are compared with our approach.

FedAvg: Federated learning from decentralized data is pioneered by this work. After performing local SGD several times, the customers communicate the gradients or updated characteristics to the server, which aggregates them to produce the final system.

FedProx is one example. By including a proximal term in the objective function of local customers, it was recommended to stabilize FedAvg's training on non-IID data. Federal Att. Instead of employing a simple average, the server uses a weighted aggregation with weights derived from the Euclidean distance between the local system and the global system.

FedDA. This approach is an example of a federated optimization procedure based on dual attention. The Euclidean distances between local systems, the worldwide system, and the quasi-global system are taken into account by the server when updating the worldwide system.

FedCOMGATE. This is the most advanced FL algorithm that uses gradient compression methods. When gradient compression is introduced, it offers theoretical guarantees regarding the convergence of FL. FedCOMGATE is not intended for wireless traffic forecasting, but rather for general ML challenges. In the subsequent experiments, we employ three commonly used metrics like Root Mean Square Error (RMSE), Mean Absolute Error (MAE), and R-squared (R2) score to objectively assess the effectiveness of several wireless traffic forecasting systems. The discrepancy between forecasts and ground reality is indicated by RMSE and MAE. Better forecasting outcomes are shown by smaller values. Based on the percentage of total variation in forecasts that the system can account for, the R-squared score gives an indication of how well the system replicates forecasts. The better the forecasting outcomes, the higher the values. Furthermore, we compare the quantity of communicated gradients (ΔC) between various algorithms' central servers and local customers.

4.2. Experimental setup

The following characteristics are used to achieve the experiment results. First, we create training and test databases employing a sliding window method. In particular, the system is trained employing data from the first seven weeks, and forecasting performance is evaluated employing all remaining data. The window dimension p is set to 6, and we anticipate the traffic amount of the following time slot using one-hour web browsing as feature information. To standardize all data specimens subtract the mean from each cloud and divide the result by the standard deviation to speed up training. For edge customers, a relatively light forecasting system is desirable due to the need to reduce the additional computation and computer training overhead related to communication in traditional wireless networks. Consequently, a three-layer MLP

architecture with 128, 128, and 1 hidden neurons is created. We adhere to the guidelines in earlier studies when it comes to setting the hyper characteristic values involved in FL. In particular, we train our system with 200 rounds of communication employing stochastic gradient descent (SGD) as the optimizer. Employing a multi-step learning rate scheduler with checkpoints of 100 and 150, we begin with 0.1 and decay it by 10 for the learning rate of local updates. The server's learning rate, η, is set to 1.0. We update the neighborhood system employing five steps of SGD with a batch size of twenty and a compression ratio of 0.01 before transmitting the gradients to the server for aggregating. Unless otherwise noted, we use $k = 4\ and\ \delta = 0.5$ in our k-relevant and δ-threshold methods. It should be noted that all forecasting systems including our system and all baseline systems use precisely the same network design and characteristic settings to enable fair performance assessments. This work use the PyTorch library to implement all algorithms, and we execute the script on a CentOS workstation.

4.3. Overall performance analysis

The observed forecasting capabilities of several algorithms. FedProx has a characteristic μ that balances the proximal term's importance. In a similar vein, FedDA maintains a characteristic ϕ to regulate the number of enhanced data samples that are sent to the server to train quasi-global systems. This table makes it clear that our recommended method outperforms all of the baselines in terms of forecasting accuracy. More precisely, on the Milan database, several algorithms perform quite similarly, while on the Trentino database, they differ significantly. Employing the Milan database as an example, the highest-quality prediction result was obtained using our technique paired with the k-relevant consolidation approach of 0.0788 for the MAE metric. FedDA transfers everything of the server-side enhanced data specimens ($\phi = 100$) and obtains the second-best MAE score, 0.0790. This suggests that our approach achieves around the same level of effectiveness as the best benchmark technique. Our highest result for the R^2 score on the Milan database is 0.9501, which is similar to FedDA's second-best result of 0.9493. In the meanwhile, our approach significantly outperforms baselines on the Trentino database. For example, under the k-relevant aggregation method, our algorithm's best MAE result is 0.3621. This demonstrates that the best foundation MAE result, which has the value 0.3849 produced using the proposed technique, has been improved by at least 5.9%. Similarly, our methodology raises the R^2 score from the proposed method's 0.9273 to the all-correlated aggregation strategy's 0.9499 as in Fig 4. More specifically, FedProx only need to communicate gradient values of each cloud to the computer, Att and FedAvg have the identical interactions; no more correspondence is required. Even though FedDA outperforms all baselines in terms of forecasting performance, transferring a portion of the enhanced data specimens to the host to train a quasi-global algorithm necessitates a little more transmission. Compared to FedDA, our method is more communication-efficient because it just needs to communicate the associated gradient coefficients and the condensed value. Furthermore, compared to the traditional model, a networked decompression technique that additionally necessitates the movement of controlling variables for slope updating, our algorithm has a reduced communication complexity as in Fig 5. Despite having the lowest communication complexity of all baselines, the models forecasting performance is still worse than ours because our method is able in order to record the irregular spatial connections of various SCUs thanks to tailored aggregation strategies. As a result, our recommended algorithm outperforms the proposed model in terms of forecasting performance.

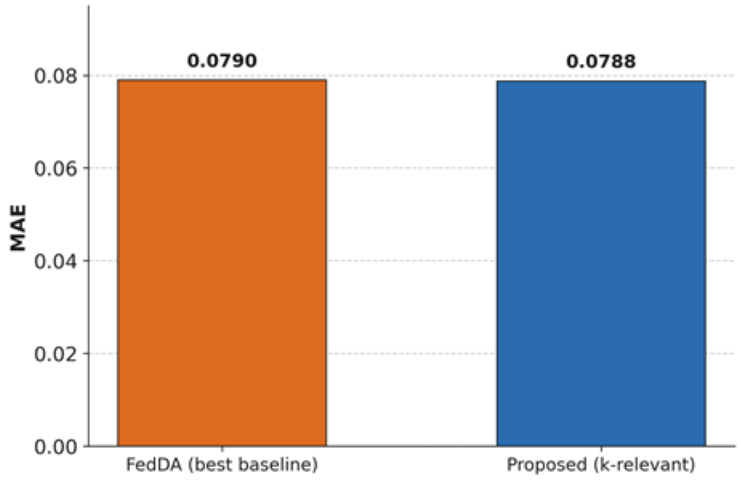


Figure 2
MAE prediction with dataset **1**

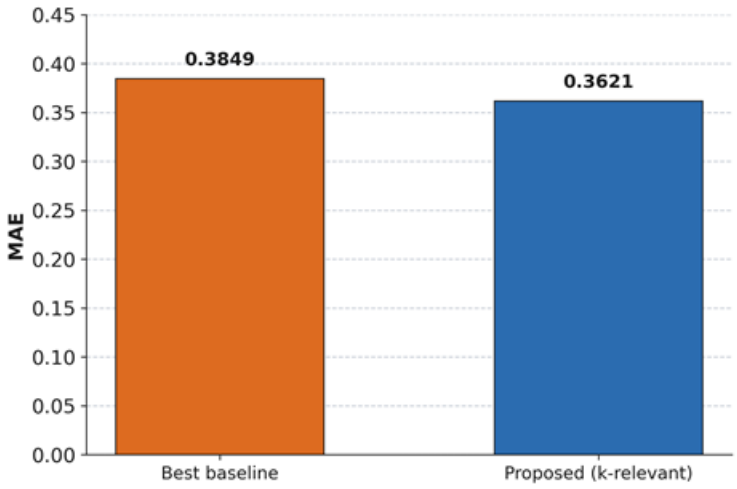


Figure 3
MAE prediction with dataset 2

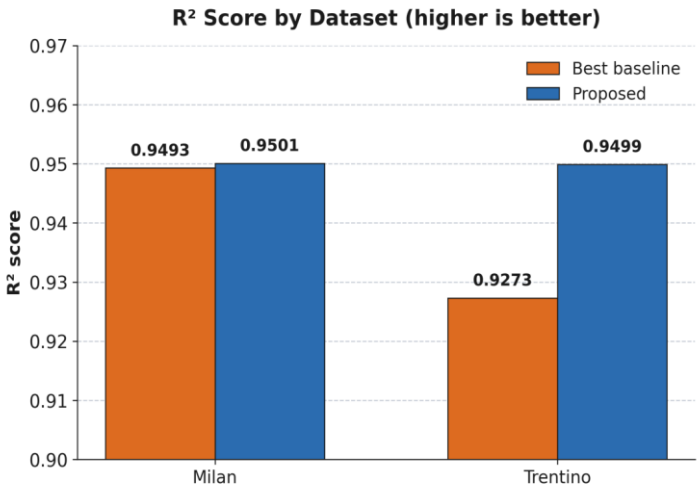


Figure 4
R^2 score based on given dataset

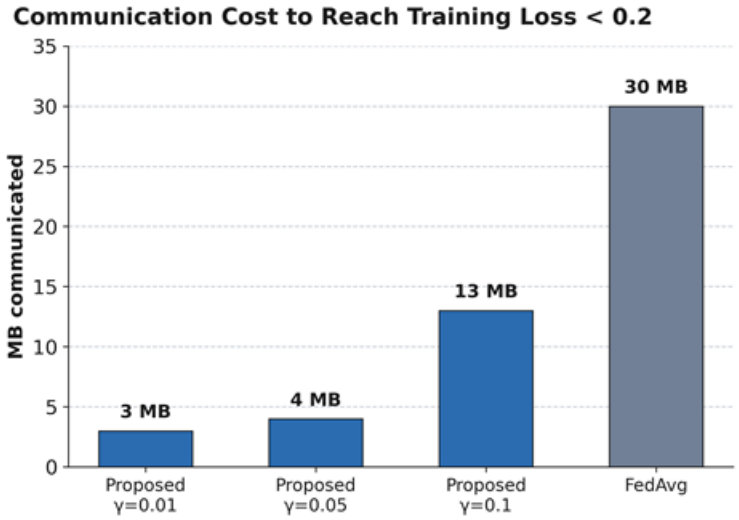


Figure 5
Communication cost

4.4. Efficiency analysis

The following section examines our algorithm's convergence and communication effectiveness in terms of transmitted gradient size as well as training loss, correspondingly. We just compare our algorithm with FedAvg. They present standardized communication inefficiencies at varying compression ratios ($\gamma \in \{0.01, 0.05, 0.1\}$) since the compression ratio has the greatest impact on our algorithm's performance. The model show that during the early stages of system training (less than 50 cycles), our method produces a greater loss than FedAvg. This is because FedAvg does not use gradient compression; therefore, all of the gradient data is sent to the server for federated optimization, which leads to a smaller training loss and faster convergence. But as instruction goes on, our approach gets closer to FedAvg and then surpasses it because our customized aggregation mechanism captures the spatial correlations of various SCUs in addition to

sending all gradient information to the server. Our method may save a significant amount of bandwidth during system training under specific training loss limitations employing the Trentino database as an illustration. To achieve a loss of less than 0.2, our method requires roughly $3\,MB\ (\gamma = 0.01), 4\,MB\ (\gamma = 0.05), and\ 13\,MB\ (\gamma = 0.1)$ communications. However, FedAvg needs more than 30 MB of bandwidth to achieve the same performance. The Milan database exhibits a similar phenomenon; the specific causes are not included here.

4.5. Predicting analysis

Our recommended algorithm's advantages in terms of both communication complexity and forecasting performance. Two SCUs are chosen from each database without sacrificing generality. Meanwhile, the two chosen cloud unit for the Trentino database are situated in Bocenago and Andalo, respectively. These cloud units are chosen at random considering their geographic locations or commonalities. It also includes the overall prediction-inaccuracy Cumulative Distribution Functions (CDFs) for different cloud units. For the sake of clarity, we solely compare our algorithm with FedAvg and FedDA. Additionally, the k-relevant aggregation strategy is used to collect all findings related to the recommended method. All three methods function remarkably well for the two cloud units since there is good agreement between the physical values of truth and the forecasts during throughout peak and off-peak hours are shown. The percentiles of errors in forecasting that are fewer than 100 are 66%, 70%, and 72% for FedAvg, FedDA, and our system, respectively. For the two chosen cloud unit that our method correctly forecasts the traffic levels, particularly for the peak traffic values. Because FedAvg cannot handle the issue of data heterogeneity, its result is unsatisfactory. The data dispersion and partial resolution of the data heterogeneity issues, the FedDA algorithm outperforms FedAvg in predicting traffic during peak hours. However, FedDA is still not as good as our method since it could not capture the unique spatial correlations between various cloud unit which are crucial for predicting spatial temporal wireless traffic.

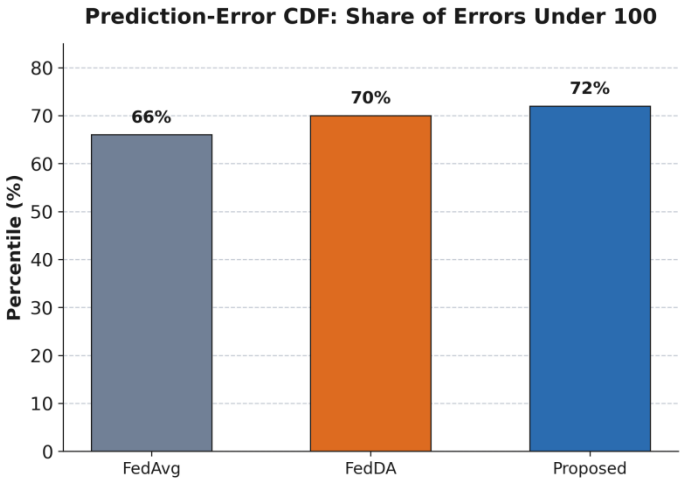


Figure 6
Prediction-error

4.6. Sensitivity analysis

Our approach's final forecasting success will depend on a number of factors, most notably the input feature size and the typical compression ratio. To make it easier to comprehend these characteristics, we only present

the RMSE results for the Trento database in Fig 2 and Fig 3. MAE and R^2 score exhibit RMSE values on both sets of databases showed remarkably comparable patterns.

1) Compression Ratio: Considering it shows how quickly the system gathers all of the local clients' gradient data, the compression ratio has the biggest impact on forecasting performance. Various compression ratios and present the outcomes of our three customized aggregation algorithms. This graph demonstrates how the RMSE effectiveness quickly increases when the server receives an increasing amount of gradient data from the local client as the compression ratio increases, for instance, from 0.01 to 0.1. Whenever the server gets sufficient gradient information, it can learn the forecasting system effectively. However, since the forecasting system's capacity for generalization does not increase, maintaining an increase in the compression ratio does not always result in more performance increases. In experiments, a compression ratio of 0.1 yields comparatively decent results as in Fig 6.

2) Aggregated Customers k and Threshold δ: The work display the outcomes of various $k\ and\ \delta$ selections when the compression ratio is set to 0.1. Both statistics show that performance deteriorates when too many customers participate in system aggregation. For instance, the RMSE findings are worse when $k = 6\ or\ \delta = 0.4\ compared\ to\ k = 3\ and\ \delta = 0.7$, respectively. On the other hand, since very little information is used for system personalization, too few customers are chosen, and system effectiveness is not enhanced by aggregated ($k = 1\ or\ \delta = 0.8$). Consequently, there is a trade-off between customer involvement and profitability.

3) Input Feature Size: Our team of algorithms' forecasts are also influenced by the size of the input feature; the outcomes are shown. This image makes it clear that input durations for continuous training that are either inadequate or too lengthy is inappropriate. The relationships between the input and the goal may not be accurately reflected if the input duration is too short. On the other hand, an input length that is excessively long may introduce significant noise, making the system difficult to learn. Using traffic for an hour ($n = 6$) as input to forecast the traffic for the following time slot, the forecasting performance is comparatively better.

4) Number of Local Updates τ and Local Batch Size: The RMSE results for regional batch size and the quantity of local repetitions τ are displayed. A trade-off between computation and communication is managed by these two factors. There are fewer communications between local customers and the server when there are more calculations at the local customers due to a large τ or batch size. However, if each customer goes too far in the direction of its own gradient update, an excessive amount of local processing could slow down convergence or stop the model from converging at all. This could lead to the distribution of a subpar aggregated system for training at nearby customers on the following grounds. For instance, our system's forecasting performance deteriorates when raising τ from 6 to 8 or batch size from 20 to 40. It is evident from the aforementioned considerations that choosing characteristics for the recommended FL architecture and the pertinent algorithms always involves trade-offs. Grid search methods can be used to find the ideal values of the aforementioned characteristics in practical tests and implementations.

5. Conclusion

In this study, we investigated wireless traffic forecasting at the edge for future 6G communication infrastructures and proposed an FL framework, built on a Distributed Autonomous Network architecture that combines gradient compression with attention-based, correlation-aware aggregation to reduce communication cost without sacrificing forecasting accuracy. At the client side, the framework applies L2-norm gradient clipping followed by Top-K sparsification and 1-bit quantization to substantially shrink the gradients transmitted to the central server. To offset the resulting loss of information, a Path Attention

Aggregation Module assigns each customer's upload an attention weight derived from its gradient-stability and performance history, so that dependable, consistent updates dominate the global aggregation; this is complemented by a Heterogeneity-Aware Adaptive Optimizer that adapts each customer's learning rate, momentum, and weight-decay settings to its local traffic characteristics and enforces cross-round consistency across customers. Additionally, we developed three customized aggregation techniques, all-correlated, δ-threshold, and k-relevant, to capture the spatial dependencies of various customers, employing gradient correlation to depict the links between dispersed local customers' traffic patterns. This work tested our recommended algorithm on two real-world databases, and the outcomes showed that it outperformed the most advanced methods for wireless traffic forecasting in terms of both accuracy and communication.

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Neft-qaz məhsullarının hərəkətində logistika amilləri

Türkan Qurbanova[1], Ayan Hümbətli[1*]

Xülasə. *Müasir dövrdə qlobal enerji bazarlarında baş verən struktur dəyişiklikləri, enerji resurslarına tələbatın dinamik xarakter alması və beynəlxalq təchizat zəncirlərində qarşılıqlı asılılığın güclənməsi neft-qaz sənayesində logistika proseslərinin səmərəli idarə olunmasını strateji zərurətə çevirmişdir. Neft və qaz məhsullarının hasilat məntəqələrindən emal, saxlanma və son istehlak istiqamətlərinə hərəkəti mürəkkəb texnoloji, iqtisadi və təşkilati proseslərin qarşılıqlı əlaqəsi əsasında həyata keçirilir. Bu baxımdan nəqliyyat infrastrukturunun inkişaf səviyyəsi, saxlanma sistemlərinin texniki imkanları, daşınma marşrutlarının optimallaşdırılması, enerji sərfiyyatı, əməliyyat xərcləri və logistika risklərinin idarə edilməsi məhsul hərəkətinin fasiləsizliyini və iqtisadi səmərəliliyini müəyyənləşdirən əsas amillər kimi çıxış edir. Məqalənin əsas məqsədi neft-qaz məhsullarının hərəkətinə təsir göstərən logistika amillərini sistemli şəkildə araşdırmaq, onların saxlanma və nəqliyyat proseslərinin texniki-iqtisadi göstəriciləri ilə qarşılıqlı əlaqəsini nəzəri-metodoloji baxımdan qiymətləndirmək və logistika fəaliyyətinin optimallaşdırılması istiqamətlərini müəyyənləşdirməkdir. Tədqiqatın metodoloji əsasını sistemli yanaşma, müqayisəli təhlil, elmi-nəzəri ümumiləşdirmə və logistika göstəricilərinin çoxmeyarlı qiymətləndirilməsi prinsipləri təşkil edir. Araşdırma çərçivəsində daşınma məsafəsi, nəqliyyat vasitələrinin buraxılış qabiliyyəti, saxlama müddəti, məhsul itkiləri, infrastruktur etibarlılığı, enerji tutumluluğu və əməliyyat xərcləri kimi göstəricilərin logistika sisteminin ümumi fəaliyyətinə təsiri nəzərdən keçirilir. Məqalədə innovativ yanaşma kimi rəqəmsal əkiz texnologiyalarının (Digital Twin), əşyaların internetinin (IoT), süni intellekt əsaslı proqnozlaşdırma modellərinin və real vaxt rejimində monitorinq sistemlərinin neft-qaz logistikasına inteqrasiyası imkanları araşdırılır. Bu texnologiyaların tətbiqi əsasında nəqliyyat axınlarının koordinasiyasının təkmilləşdirilməsi, potensial texniki nasazlıqların qabaqcadan müəyyənləşdirilməsi, məhsul itkilərinin minimuma endirilməsi və logistika qərarlarının məlumatlara əsaslanan şəkildə qəbul edilməsi istiqamətləri əsaslandırılır. Eyni zamanda, iqtisadi səmərəlilik, texnoloji etibarlılıq, əməliyyat təhlükəsizliyi və ekoloji dayanıqlılıq göstəricilərinin vahid qiymətləndirmə sistemində birləşdirilməsi neft-qaz məhsullarının hərəkətinin kompleks idarə olunması üçün perspektivli metodoloji yanaşma kimi irəli sürülür. Neft-qaz məhsullarının hərəkətində logistika amillərinin kompleks nəzərə alınması, saxlanma və nəqliyyat proseslərinin inteqrasiyalı idarə edilməsi, həmçinin innovativ rəqəmsal texnologiyaların tətbiqi logistika xərclərinin optimallaşdırılması, əməliyyat etibarlılığının yüksəldilməsi və enerji təchizatı zəncirinin dayanıqlılığının gücləndirilməsi baxımından mühüm əhəmiyyət daşıyır.*

Açar sözlər: *neft-qaz logistikası, məhsul hərəkəti, nəqliyyat infrastrukturu, saxlanma prosesləri, logistika amilləri, təchizat zənciri, logistika səmərəliliyi, rəqəmsal əkiz, optimallaşdırma*

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Logıstıcs Factors in the Movement of Oil and Gas Products

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Abstract. *In the contemporary global economy, structural changes in energy markets, the dynamic nature of demand for energy resources, and increasing interdependence within international supply chains have made the efficient management of logistics processes in the oil and gas industry a strategic necessity. The movement of oil and gas products from production sites to processing facilities, storage terminals, and final consumption destinations involves complex technological, economic, and organizational processes. In this context, the development of transportation infrastructure, the technical capabilities of storage systems, transportation route optimization, energy consumption, operating costs, and logistics risk management are among the key factors determining the continuity of product flows and their economic efficiency. The primary objective of this article is to systematically investigate the logistics factors influencing the movement of oil and gas products, assess their relationships with the technical and economic performance indicators of storage and transportation processes from a theoretical and methodological perspective, and identify opportunities for optimizing logistics operations. The methodological framework of the research is based on a systems approach, comparative analysis, theoretical synthesis, and the principles of multicriteria assessment of logistics performance indicators. The study examines the influence of transportation distance, transport infrastructure throughput capacity, storage duration, product losses, infrastructure reliability, energy intensity, and operating costs on the overall performance of the logistics system. As an innovative approach, the article explores opportunities for integrating Digital Twin technologies, the Internet of Things (IoT), artificial intelligence-based predictive models, and real-time monitoring systems into oil and gas logistics. The potential application of these technologies is examined in relation to improving the coordination of transportation flows, anticipating technical failures, minimizing product losses, and supporting data-driven logistics decision-making. Furthermore, the integration of economic efficiency, technological reliability, operational safety, and environmental sustainability indicators into a unified evaluation framework is proposed as a promising methodological approach to the comprehensive management of oil and gas product movements. The comprehensive consideration of logistics factors affecting the movement of oil and gas products, integrated management of storage and transportation processes, and implementation of innovative digital technologies are of considerable importance for optimizing logistics costs, improving operational reliability, and strengthening the resilience of energy supply chains.*

Keywords: *oil and gas logistics, product movement, transportation infrastructure, storage processes, logistics factors, supply chain, logistics efficiency, digital twin, optimization*

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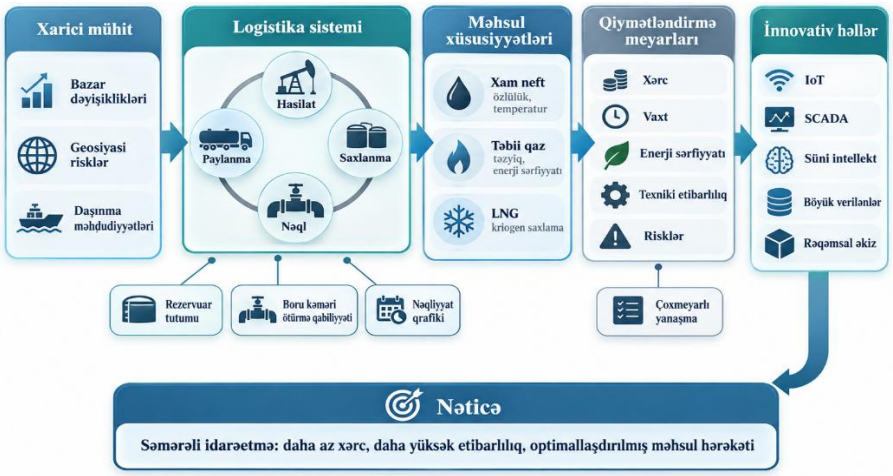
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1. Giriş

Müasir dünya iqtisadiyyatında enerji resurslarının strateji əhəmiyyətinin artması, beynəlxalq enerji bazarlarında struktur dəyişiklikləri və təchizat zəncirlərinin mürəkkəbləşməsi neft-qaz məhsullarının

hərəkətində logistika proseslərinin səmərəli idarə olunmasını zəruri edir. Neft və qaz məhsullarının hasilat məntəqələrindən emal müəssisələrinə, saxlama terminallarına və istehlak bazarlarına çatdırılması nəqliyyat infrastrukturu, texnoloji imkanlar və iqtisadi resursların qarşılıqlı əlaqəsi əsasında həyata keçirilir. Beynəlxalq nəqliyyat marşrutlarında yaranan məhdudiyyətlər, daşınma tariflərinin dəyişkənliyi və geosiyasi risklər logistika sistemlərinin dayanıqlılığına bilavasitə təsir göstərir. UNCTAD-ın araşdırmalarında qlobal nəqliyyat zəncirlərində baş verən pozuntuların daşınma xərclərinə və təchizatın etibarlılığına təsiri xüsusi vurğulanır (United Nations Conference on Trade and Development [UNCTAD], 2024). Neft-qaz logistikasının əsas xüsusiyyəti məhsul axınlarının hasilat, saxlanma, nəql və paylanma mərhələləri üzrə əlaqələndirilmiş idarə olunmasıdır. Bu proseslərdə rezervuarların tutumu, boru kəmərlərinin ötürmə qabiliyyəti, nəqliyyat vasitələrinin yüklənməsi və əməliyyatların icra müddəti logistika səmərəliliyini müəyyənləşdirən mühüm göstəricilər hesab olunur. Ayrı-ayrı mərhələlər arasında texnoloji və təşkilati uyğunsuzluqların yaranması məhsul itkilərinin artmasına, əlavə əməliyyat xərclərinə və təchizatın fasiləsizliyinin pozulmasına səbəb ola bilər. Elmi tədqiqatlarda neft məhsullarının təchizat zəncirinin planlaşdırılmasında inteqrasiya olunmuş optimallaşdırma modellərinin tətbiqi məhsul axınlarının əlaqələndirilməsi baxımından mühüm yanaşma kimi qiymətləndirilir (Lima et al., 2021).

Neft və qaz məhsullarının fiziki-kimyəvi xüsusiyyətləri onların nəqli və saxlanması proseslərində fərqli logistika tələbləri yaradır. Xam neftin daşınmasında özlülük, temperatur və hidravlik müqavimət, təbii qazın nəqlində isə təzyiq rejimi, kompressor stansiyalarının fəaliyyəti və enerji sərfiyyatı əsas texnoloji amillər kimi çıxış edir. Mayeləşdirilmiş təbii qazın logistikasında kriogen saxlanma və xüsusi nəqliyyat infrastrukturu əlavə əməliyyat məhdudiyyətləri formalaşdırır. Bu baxımdan logistika proseslərinin optimallaşdırılması məhsulun texniki xüsusiyyətləri, infrastrukturun imkanları və nəqliyyat qrafiklərinin qarşılıqlı uyğunluğu əsasında həyata keçirilməlidir (Oliveira et al., 2016).



Şəkil 1

Neft-qaz məhsullarının hərəkətində logistika

Mənbə. Müəllif tərəfindən elmi-nəzəri yanaşmaların sistemləşdirilməsi və ümumiləşdirilməsi əsasında hazırlanmışdır.

Şəkil 1-də neft-qaz məhsullarının hərəkətinə təsir göstərən əsas logistika amilləri və onların qarşılıqlı əlaqəsi konseptual şəkildə təqdim edilmişdir. Modeldə bazar dəyişiklikləri, geosiyasi risklər və daşınma məhdudiyyətləri xarici təsir amilləri kimi müəyyənləşdirilmiş, hasilat, saxlanma, nəql və paylanma mərhələləri vahid logistika sistemi çərçivəsində əlaqələndirilmişdir. Məhsulların fiziki-kimyəvi xüsusiyyətlərinin nəzərə alınması ilə xərc, vaxt, enerji sərfiyyatı, texniki etibarlılıq və risklərin

çoxmeyarlı qiymətləndirilməsi əsaslandırılmışdır. Eyni zamanda, IoT, SCADA, süni intellekt və rəqəmsal əkiz texnologiyalarının tətbiqi logistika proseslərinin optimallaşdırılması, əməliyyat xərclərinin azaldılması və təchizatın etibarlılığının yüksəldilməsi üçün perspektivli istiqamətlər kimi göstərilmişdir.

Logistika fəaliyyətinin qiymətləndirilməsində yalnız daşınma xərclərinin minimumlaşdırılması kifayət etmir. Məhsulun çatdırılma müddəti, saxlanma tutumundan istifadə səviyyəsi, enerji sərfiyyatı, texniki etibarlılıq və əməliyyat riskləri də ümumi səmərəliliyə təsir göstərir. Bu göstəricilərin fərqli ölçü vahidlərinə malik olması onların vahid qiymətləndirmə sistemində birləşdirilməsini aktuallaşdırır. ISO 55000:2024 standartında aktivlərin həyat dövrü üzrə idarə olunması və təşkilati dəyərin artırılması prinsipləri müəyyən edilmişdir (International Organization for Standardization [ISO], 2024). Boru kəmərlərinin texniki bütövlüyünün risk əsaslı idarə edilməsi isə təhlükəsizlik və təchizatın fasiləsizliyi baxımından xüsusi əhəmiyyət daşıyır (American Petroleum Institute [API], 2019). Beləliklə, iqtisadi, texnoloji və təhlükəsizlik göstəricilərinin çoxmeyarlı qiymətləndirilməsi logistika qərarlarının elmi əsaslandırılması üçün mühüm metodoloji istiqamətdir.

Rəqəmsal transformasiya neft-qaz logistikasında innovativ idarəetmə mexanizmlərinin tətbiqinə yeni imkanlar yaradır. Əşyaların interneti (IoT), süni intellekt, SCADA sistemləri, böyük verilənlərin analitikası və rəqəmsal əkiz (Digital Twin) texnologiyaları məhsul axınlarının real vaxt rejimində monitorinqini, avadanlıqların texniki vəziyyətinin proqnozlaşdırılmasını və nəqliyyat əməliyyatlarının optimallaşdırılmasını dəstəkləyə bilər. Beynəlxalq Enerji Agentliyinin tədqiqatlarında rəqəmsal texnologiyaların enerji sektorunda əməliyyat səmərəliliyinin və texniki təhlükəsizliyin yüksəldilməsi baxımından potensialı göstərilmişdir (International Energy Agency [IEA], 2017). Rəqəmsal əkiz modellərinin tətbiqi isə boru kəmərlərinin istismar vəziyyətinin qiymətləndirilməsi, potensial nasazlıqların aşkarlanması və alternativ əməliyyat ssenarilərinin modelləşdirilməsi üçün perspektivli yanaşma hesab olunur (Azimi et al., 2026).

2. Məqsəd

Tədqiqatın əsas məqsədi neft-qaz məhsullarının hərəkətinə təsir göstərən logistika amillərini sistemli şəkildə müəyyənləşdirmək, onların saxlanma, nəql və paylanma proseslərinin texniki-iqtisadi göstəriciləri ilə qarşılıqlı əlaqəsini qiymətləndirmək və logistika sisteminin səmərəliliyinin yüksəldilməsi üçün innovativ idarəetmə yanaşmalarını əsaslandırmaqdan ibarətdir. Bu məqsədlə nəqliyyat infrastrukturunun ötürmə qabiliyyəti, rezervuarların tutumundan istifadə səviyyəsi, daşınma müddəti, əməliyyat xərcləri, enerji sərfiyyatı, məhsul itkiləri və texnoloji risklər logistika fəaliyyətinin əsas qiymətləndirmə meyarları kimi nəzərdən keçirilir.

Tədqiqat çərçivəsində neft və qaz məhsullarının fiziki-kimyəvi xüsusiyyətlərinin nəqliyyat və saxlanma texnologiyalarının seçiminə təsirinin araşdırılması, logistika mərhələləri arasında funksional asılılıqların müəyyənləşdirilməsi və resurs axınlarının optimallaşdırılması imkanlarının qiymətləndirilməsi qarşıya qoyulur. Eyni zamanda, iqtisadi səmərəlilik, texniki etibarlılıq, əməliyyat təhlükəsizliyi və ekoloji dayanıqlılıq göstəricilərinin qarşılıqlı əlaqəsi əsasında çoxmeyarlı qiymətləndirmə yanaşmasının formalaşdırılması nəzərdə tutulur. Bu yanaşma müxtəlif ölçü vahidlərinə malik logistika göstəricilərinin normallaşdırılması və müqayisəli təhlili vasitəsilə alternativ idarəetmə qərarlarının əsaslandırılmasına istiqamətlənmişdir.

Cədvəl 1
Neft-qaz logistikasında əsas qiymətləndirmə meyarları

Qiymətləndirmə meyarı	Əsas göstərici	Tədqiqat istiqaməti
İqtisadi səmərəlilik	Logistika xərcləri	Xərclərin azaldılması
Nəqliyyat səmərəliliyi	Daşınma müddəti	Vaxtın optimallaşdırılması
Saxlanma səmərəliliyi	Rezervuarların doluluğu	Tutumdan səmərəli istifadə
Enerji səmərəliliyi	Enerji sərfiyyatı	Enerji itkilərinin azaldılması
Texniki etibarlılıq	Nasazlıq və dayanma halları	Risklərin minimumlaşdırılması
Ekoloji dayanıqlılıq	Məhsul itkisi və emissiyalar	Ekoloji təsirin azaldılması
Rəqəmsal idarəetmə	Monitorinq və proqnozlaşdırma	Qərarların optimallaşdırılması

Mənbə. Müəllif tərəfindən tədqiqatın məqsədlərinə uyğun olaraq hazırlanmışdır.

Cədvəl 1-də neft-qaz məhsullarının hərəkətində logistika səmərəliliyini müəyyənləşdirən əsas iqtisadi, texnoloji və ekoloji meyarlar sistemləşdirilmişdir. Təqdim olunan göstəricilər daşınma və saxlanma xərclərinin optimallaşdırılması, enerji itkilərinin azaldılması, texniki etibarlılığın yüksəldilməsi və rəqəmsal idarəetmə imkanlarının qiymətləndirilməsinə yönəlmişdir. Bu meyarların kompleks təhlili logistika proseslərinin çoxmeyarlı qiymətləndirilməsi və səmərəli idarəetmə qərarlarının əsaslandırılması üçün metodoloji baza formalaşdırır.

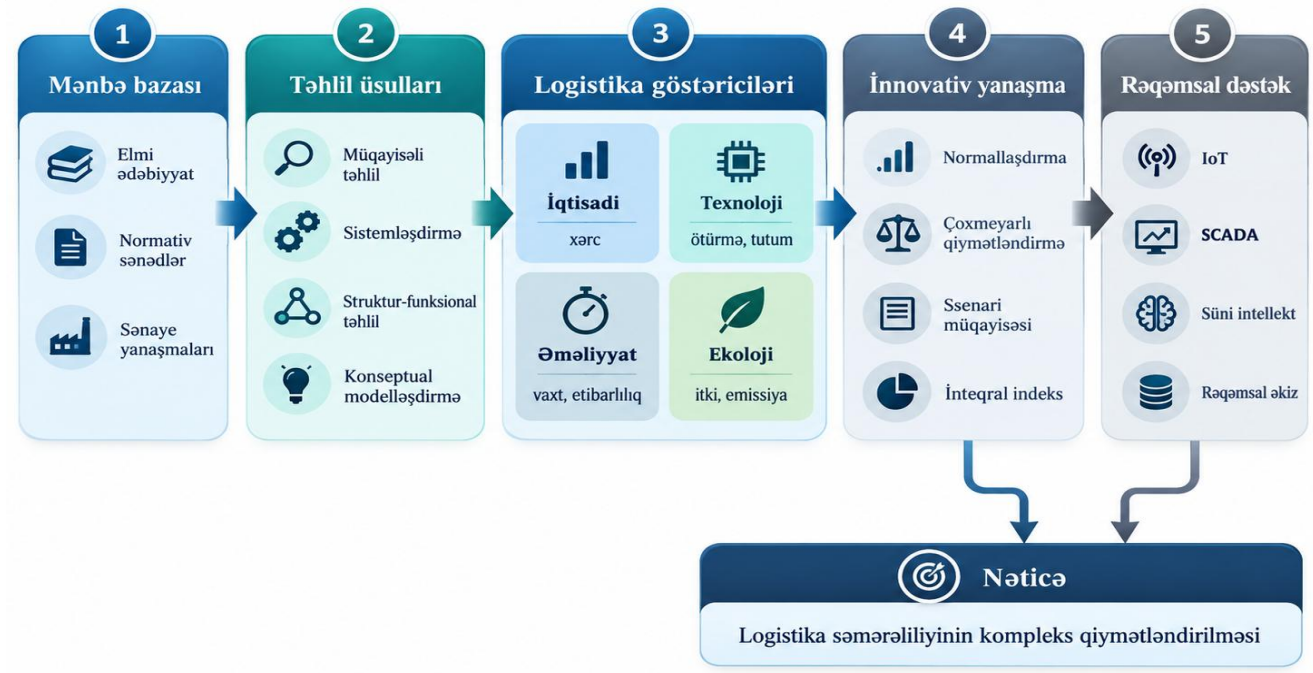
Araşdırmanın innovativ məqsədlərindən biri əşyaların interneti (IoT), SCADA sistemləri, süni intellekt və rəqəmsal əkiz texnologiyalarının neft-qaz logistikasına inteqrasiya imkanlarını müəyyənləşdirməkdir. Bu texnologiyaların tətbiqi perspektivləri məhsul axınlarının real vaxt rejimində monitorinqi, texniki nasazlıqların proqnozlaşdırılması, nəqliyyat marşrutlarının optimallaşdırılması və əməliyyat risklərinin qabaqlayıcı idarə edilməsi baxımından qiymətləndirilir.

Tədqiqatın nəzərdə tutulan elmi nəticəsi neft-qaz məhsullarının hərəkətində logistika amillərini iqtisadi, texnoloji və ekoloji meyarlar əsasında əlaqələndirən konseptual qiymətləndirmə modelinin formalaşdırılmasıdır. Təklif olunan model saxlanma və nəqliyyat proseslərinin koordinasiyasının təkmilləşdirilməsi, logistika xərclərinin optimallaşdırılması və enerji təchizatı zəncirinin dayanıqlılığının gücləndirilməsi istiqamətində idarəetmə qərarlarının elmi əsaslandırılmasına xidmət edə bilər.

3. Metodlar

Tədqiqat neft-qaz məhsullarının hərəkətində logistika amillərinin saxlanma, nəql və paylanma proseslərinin səmərəliliyinə təsirini müəyyənləşdirmək məqsədilə sistemli və çoxmeyarlı qiymətləndirmə yanaşmaları əsasında formalaşdırılmışdır. Araşdırmanın metodoloji əsasını elmi ədəbiyyatın müqayisəli təhlili, sistemləşdirmə, struktur-funksional təhlil, konseptual modelləşdirmə və ümumiləşdirmə metodları təşkil edir. Tədqiqat çərçivəsində neft-qaz təchizat zəncirinin əsas mərhələləri arasında texnoloji və iqtisadi əlaqələr araşdırılmış, məhsul axınlarının idarə edilməsinə təsir göstərən amillər müəyyənləşdirilmişdir. Logistika proseslərinin inteqrasiya olunmuş planlaşdırılması və optimallaşdırılması üzrə elmi yanaşmalar metodoloji əsas kimi nəzərə alınmışdır (Lima et al., 2021; Oliveira et al., 2016). Araşdırmada logistika səmərəliliyinin qiymətləndirilməsi üçün göstəricilər iqtisadi, texnoloji, əməliyyat və ekoloji istiqamətlər üzrə qruplaşdırılmışdır. İqtisadi göstəricilərə daşınma və saxlanma xərcləri, texnoloji göstəricilərə rezervuarların tutumundan istifadə və boru kəmərlərinin ötürmə qabiliyyəti, əməliyyat göstəricilərinə çatdırılma müddəti və infrastrukturun etibarlılığı, ekoloji göstəricilərə isə enerji sərfiyyatı, məhsul itkiləri və emissiyalar aid edilmişdir. Bu göstəricilərin qarşılıqlı

əlaqələrinin müəyyənləşdirilməsi üçün struktur-funksional təhlil yanaşmasından istifadə olunmuş, texniki etibarlılıq və risklərin idarə edilməsi üzrə beynəlxalq metodoloji prinsiplər nəzərə alınmışdır (API, 2019; ISO, 2024).



Şəkil 2

Tədqiqatın metodoloji yanaşması

Mənbə. Müəllif tərəfindən elmi-nəzəri yanaşmaların müqayisəli təhlili və ümumiləşdirilməsi əsasında hazırlanmışdır.

Şəkil 2-də neft-qaz məhsullarının hərəkətində logistika səmərəliliyinin qiymətləndirilməsi üçün təklif olunan metodoloji yanaşma əks etdirilmişdir. Model elmi mənbələrin təhlili, iqtisadi, texnoloji, əməliyyat və ekoloji göstəricilərin sistemləşdirilməsi, normallaşdırılması və çoxmeyarlı qiymətləndirilməsi mərhələlərini əhatə edir. Eyni zamanda, IoT, SCADA, süni intellekt və rəqəmsal əkiz texnologiyalarının tətbiqi imkanları nəzərə alınmaqla logistika proseslərinin kompleks qiymətləndirilməsi üçün konseptual əsas formalaşdırılır. Tədqiqatın innovativ metodoloji istiqaməti müxtəlif ölçü vahidlərinə malik logistika göstəricilərinin normallaşdırılması və vahid inteqral qiymətləndirmə modelində birləşdirilməsi imkanlarının əsaslandırılmasından ibarətdir. Təklif olunan yanaşmada hər bir göstəricinin normallaşdırılmış qiyməti və əhəmiyyət əmsalı nəzərə alınmaqla logistika səmərəliliyinin ümumiləşdirilmiş indeksinin formalaşdırılması nəzərdə tutulur. Bu məqsədlə çoxmeyarlı qərar qəbuletmə üsullarından, xüsusilə çəkili qiymətləndirmə və alternativ ssenarilərin müqayisəsi metodlarından istifadə imkanları araşdırılır. Göstəricilərin seçilməsi zamanı onların ölçülə bilməsi, məlumat əlçatanlığı, iqtisadi əhəmiyyəti və logistika nəticələrinə təsir potensialı əsas meyarlar kimi qəbul edilir. Rəqəmsal idarəetmə imkanlarının qiymətləndirilməsi üçün IoT, SCADA, süni intellekt və rəqəmsal əkiz texnologiyalarının funksional xüsusiyyətləri müqayisəli şəkildə nəzərdən keçirilmişdir. Bu texnologiyaların məhsul axınlarının monitorinqi, texniki nasazlıqların proqnozlaşdırılması, nəqliyyat qrafiklərinin koordinasiyası və əməliyyat risklərinin azaldılması istiqamətində tətbiq potensialı təhlil edilmişdir. Rəqəmsallaşmanın enerji sektoruna təsiri və boru kəmərlərinin rəqəmsal modelləşdirilməsi üzrə elmi yanaşmalar nəzəri əsas kimi istifadə edilmişdir (Azimi et al., 2026; IEA, 2017).

Tədqiqat nəzəri-konseptual xarakter daşıdığından müəssisə səviyyəsində ilkin statistik məlumatların toplanması və eksperimental qiymətləndirmə həyata keçirilməmişdir. Təklif olunan metodoloji yanaşmanın gələcək empirik tətbiqi real logistika göstəriciləri əsasında normallaşdırma, əhəmiyyət əmsallarının müəyyənləşdirilməsi və alternativ idarəetmə ssenarilərinin müqayisəsini nəzərdə tutur. Bu yanaşma neft-qaz məhsullarının hərəkətində logistika səmərəliliyinin kompleks qiymətləndirilməsi və optimallaşdırma qərarlarının elmi əsaslandırılması üçün metodoloji baza kimi təklif edilir.

4. Təhlil və müzakirə

Neft-qaz məhsullarının hərəkətində logistika səmərəliliyinin təhlili göstərir ki, nəqliyyat, saxlanma və paylanma əməliyyatlarının nəticəliliyi ayrı-ayrı texniki göstəricilərdən daha çox onların qarşılıqlı koordinasiya səviyyəsindən asılıdır. Məhsul axınlarının qeyri-bərabər paylanması, infrastrukturun buraxılış qabiliyyətində yaranan məhdudiyyətlər və əməliyyat qrafikləri arasındakı uyğunsuzluqlar təchizat zəncirində əlavə xərclərin formalaşmasına şərait yaradır. Lima, Relvas və Barbosa-Póvoanın tədqiqatında neft məhsullarının təchizat zəncirinin qeyri-müəyyənlik şəraitində planlaşdırılması üçün optimallaşdırma yanaşması təklif edilmişdir. Bu yanaşma logistika xərcləri və məhsula tələbat kimi dəyişənlərin planlaşdırma qərarlarında birlikdə nəzərə alınmasının əhəmiyyətini göstərir (Lima et al., 2021).

Cədvəl 2

Neft-qaz məhsullarının hərəkətində logistika amillərinin müqayisəli qiymətləndirilməsi

Logistika amili	Əsas göstərici	Potensial təsir	Optimallaşdırma istiqaməti
Nəqliyyat	Daşınma müddəti	Vaxt və xərc dəyişməsi	Marşrut optimallaşdırılması
Saxlanma	Rezervuar tutumu	Ehtiyat və saxlama xərcləri	Tutumun balanslaşdırılması
Enerji	Enerji sərfiyyatı	Əməliyyat xərclərinin artması	Enerji monitorinqi
Texniki vəziyyət	Avadanlığın etibarlılığı	Dayanma və nasazlıq riskləri	Proqnozlaşdırıcı texniki xidmət
Ekoloji təsir	İtki və emissiyalar	Resurs itkisi və ekoloji risklər	Sızmaların monitorinqi
Rəqəmsal idarəetmə	Məlumatların operativliyi	Qərarların gecikməsi	IoT və rəqəmsal əkiz
Təchizat dayanıqlılığı	Fasiləsizlik səviyyəsi	Təchizat pozuntuları	Ssenari əsaslı planlaşdırma

Mənbə. Müəllif tərəfindən elmi-nəzəri yanaşmaların müqayisəli təhlili əsasında hazırlanmışdır (API, 2019; Azimi et al., 2026; IEA, 2017, 2025; ISO, 2024; Lima et al., 2021; Oliveira et al., 2016).

Cədvəl 2-də təqdim olunan müqayisəli təhlil logistika amillərinin iqtisadi və texnoloji nəticələrə təsirinin müxtəlif istiqamətlərdə formalaşdığını göstərir. Nəqliyyat və saxlanma göstəriciləri məhsul axınlarının təşkili ilə, enerji sərfiyyatı və texniki etibarlılıq əməliyyat resurslarından istifadə ilə, ekoloji və rəqəmsal göstəricilər isə logistika sisteminin dayanıqlı idarə olunması ilə əlaqələndirilmişdir. Bu amillərin qarşılıqlı təsiri onların vahid qiymətləndirmə mexanizmində birləşdirilməsini metodoloji baxımdan əsaslandırır. Logistika proseslərinin qarşılıqlı asılılığının qiymətləndirilməsi zamanı saxlanma infrastrukturu ilə nəqliyyat sisteminin əlaqəsi xüsusi əhəmiyyət daşıyır. Rezervuarların məhdud tutumu məhsulun qəbul və ötürülmə intensivliyinə təsir göstərdiyi halda, boru kəmərlərinin qeyri-bərabər yüklənməsi nəqliyyat qrafiklərinin pozulmasına səbəb ola bilər. Oliveira və həmmüəlliflərinin

araşdırmasında neft terminalları ilə emal müəssisələri arasında məhsul axınlarının planlaşdırılmasında gəmi gəlişləri, mövcud rezervuar tutumu və boru kəmərlərinin iş qrafiki vahid optimallaşdırma çərçivəsində nəzərdən keçirilmişdir (Oliveira et al., 2016). Bu baxımdan saxlanma və nəqliyyat resurslarının əlaqələndirilmiş idarə edilməsi məhsul hərəkətinin fasiləsizliyi üçün əsas təşkilati-texnoloji şərtlərdən biridir. Logistika amillərinin iqtisadi nəticələrə təsiri xərc, vaxt, enerji sərfiyyatı və texniki etibarlılıq göstəriciləri arasında yaranan qarşılıqlı asılılıqlarla xarakterizə olunur. Məsələn, daşınma müddətinin azaldılması məqsədilə nəqliyyat intensivliyinin artırılması əlavə enerji sərfiyyatı və avadanlıqların istismar yüklənməsi ilə müşayiət oluna bilər. Digər tərəfdən, rezervuar ehtiyatlarının yüksək səviyyədə saxlanılması təchizatın fasiləsizliyini dəstəkləsə də, saxlama xərclərini və kapitalın ehtiyatlarda bağlanmasını artıra bilər. Logistika qərarlarının yalnız bir göstərici əsasında qiymətləndirilməsi ümumi iqtisadi səmərəliliyin düzgün müəyyənləşdirilməsini məhdudlaşdırır.

Tədqiqat çərçivəsində innovativ yanaşma kimi logistika göstəricilərinin normallaşdırılması və çəkili qiymətləndirmə əsasında inteqral səmərəlilik indeksinin formalaşdırılması təklif edilir. Bu yanaşmada xərc, vaxt və məhsul itkisi kimi minimumlaşdırılması məqsədəuyğun olan göstəricilərlə infrastruktur etibarlılığı və təchizat fasiləsizliyi kimi maksimumlaşdırılması nəzərdə tutulan göstəricilər fərqli normallaşdırma qaydaları ilə müqayisə edilə bilən qiymətlərə çevrilməlidir. Daha sonra göstəricilərin əhəmiyyət dərəcələrinə uyğun çəkilərin müəyyənləşdirilməsi alternativ logistika qərarlarının ümumiləşdirilmiş qiymətləndirilməsinə imkan verə bilər. ISO 55000:2024 standartında aktivlərin idarə edilməsinin təşkilati məqsədlərlə əlaqələndirilməsi və nəticəyönümlü yanaşma prinsipləri bu qiymətləndirmə modelinin metodoloji əsaslandırılmasında nəzərə alınmışdır (ISO, 2024). Çoxmeyarlı qiymətləndirmənin mühüm aspektlərindən biri texniki risklərlə iqtisadi nəticələr arasında optimal tarazlığın müəyyənləşdirilməsidir. Boru kəmərləri və saxlama infrastrukturlarında texniki etibarlılığın azalması məhsul itkilərinə, planlaşdırılmamış dayanmalara və əlavə bərpa xərclərinə səbəb ola bilər. API RP 1160 standartında təhlükəli mayelərin nəqlində risklərin qiymətləndirilməsi, texniki bütövlüyün qorunması və qabaqlayıcı tədbirlərin planlaşdırılması sistemli idarəetmənin əsas komponentləri kimi təqdim edilir (API, 2019). Bu prinsiplərin logistika göstəriciləri ilə əlaqələndirilməsi risklərin yalnız təhlükəsizlik baxımından deyil, həmçinin iqtisadi itkilərin qarşısının alınması baxımından qiymətləndirilməsinə imkan yaradır.

İnnovativ texnologiyaların müqayisəli təhlilində rəqəmsal monitorinq sistemlərinin məlumatların operativliyi və qərarların dəqiqliyi baxımından potensial üstünlükləri müəyyən edilir. IoT sensorları və SCADA infrastrukturu vasitəsilə əldə edilən əməliyyat məlumatlarının süni intellekt alqoritmləri ilə təhlili nasos və kompressor stansiyalarında texniki kənarlaşmaların müəyyənləşdirilməsini, enerji sərfiyyatının izlənilməsini və məhsul axınlarının proqnozlaşdırılmasını dəstəkləyə bilər. Beynəlxalq Enerji Agentliyinin araşdırmalarında rəqəmsallaşmanın enerji sistemlərində məhsuldarlığın, təhlükəsizliyin və əməliyyat səmərəliliyinin artırılması potensialı qeyd edilmişdir (IEA, 2017). Rəqəmsal əkiz texnologiyasının tətbiqi isə fiziki logistika obyektlərinin virtual modelləri əsasında alternativ idarəetmə ssenarilərinin təhlilinə şərait yaradır. Azimi və həmmüəlliflərinin tədqiqatında boru kəmərləri üçün rəqəmsal əkiz modellərinin texniki vəziyyətin monitorinqi, sızmaların aşkarlanması və proqnozlaşdırıcı texniki xidmət istiqamətlərində tətbiq imkanları araşdırılmışdır (Azimi et al., 2026). Bununla belə, rəqəmsal texnologiyaların iqtisadi səmərəliliyi məlumat keyfiyyəti, ilkin investisiya xərcləri, modellərin dəqiqliyi və kibertəhlükəsizlik tələbləri nəzərə alınmadan qiymətləndirilə bilməz.

Nəticə

1. Aparılmış nəzəri-konseptual təhlil əsasında müəyyən edilmişdir ki, neft-qaz məhsullarının hərəkətində logistika səmərəliliyi nəqliyyat, saxlanma və paylanma proseslərinin qarşılıqlı

koordinasiyasından, infrastrukturun texniki imkanlarından və əməliyyat risklərinin idarə olunmasından asılıdır.

2. Tədqiqat çərçivəsində iqtisadi, texnoloji, əməliyyat və ekoloji göstəricilərin çoxmeyarlı qiymətləndirilməsi logistika qərarlarının əsaslandırılması üçün perspektivli metodoloji yanaşma kimi müəyyənləşdirilmişdir.
3. IoT, SCADA, süni intellekt və rəqəmsal əkiz texnologiyalarının logistika sistemlərinə inteqrasiyası məhsul axınlarının monitorinqi, texniki nasazlıqların proqnozlaşdırılması və resurslardan istifadənin optimallaşdırılması baxımından mühüm potensiala malikdir.
4. Təklif olunan konseptual yanaşma logistika xərclərinin azaldılması, əməliyyat etibarlılığının yüksəldilməsi və enerji təchizatı zəncirinin dayanıqlılığının gücləndirilməsi istiqamətində gələcək empirik tədqiqatlar üçün metodoloji əsas formalaşdırır.

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İÇİNDƏKİLƏR

CONTENTS

HUMANİTAR VƏ İCTİMAİ ELMLƏR

HUMANITIES AND SOCIAL SCIENCES

Mariam Koberidze, Tinatin Mshvidobadze
Child's Language Development 7
Nadjat Mous
World Literature: Concept, Evolution, Criteria, and Critical Perspectives 17
Flora Karimova, Asif Abdullayev,
Gunel Guliyeva, Aftandil Mammadli
Dynamic effects of tourism CO_2 emission intensity and economic growth under the framework of SDG 13 ... 26
Azizkhon Rasulov
Informatization as a Driver of Social Acceleration: A Conceptual Analysis with Reference to Uzbekistan 32
Sihem Ouaddane
Algorithmic Financial Governance and Diagnostic Transparency: A Comparative Study of the Pharmaceutical Sector Using DuPont Analysis and Python (2020–2024) 41
Sevinj Alakbarova
Protection of Civilians During Armed Conflicts: Fundamental Principles of International Humanitarian Law and Challenges of Implementation 60
Lalə Qocayeva
İnsan və süni intellekt əməkdaşlığı şəraitində riyazi təfəkkürün inkişaf etdirilməsi 68
Liu Yousha
Framing the Lachin Corridor Crisis: Selective Discursive Convergence in Azerbaijani, Chinese, and Institutional Communication 77
Nazmiye Hazar
Toponymic Analysis of Public School Names in the Turkish Republic of Northern Cyprus: A Study Based on the Pre-1974 Settlement Structure 90
Zahra Abbas, Asma Khelil, Djamila Menidjel
Impact of E-Government Indicators on Tax Revenues in Algeria: Econometric Study for the Period 2003–2025 114
Drifa Ghezali
Effectiveness of the robo-advisor in managing and enhancing investment portfolio returns: analytical and evaluative study of the "Tamra Capital" platform 131
Layadi Nour El-Houda
Decomposing Aggregate Energy Intensity and Analyzing Sectoral Trends in Algeria (1990–2020) 147
Kamran Shirinzade
Chinese Projects in Central Asia 160
Olimxodjayev Fayyozxo'ja
Information as a Strategic Resource in Contemporary Society a Socio Philosophical Model of Responsible Value Creation 174

İsmayıl Qəribli
Ümumi mülkiyyət anlayışının və növlərinin normativ ifadəsi: Azərbaycan hüququ və müxtəlif hüquq sistemlərinin müqayisəli təhlili 183

TƏBİƏT ELMLƏRİ

NATURAL SCIENCES

Ağasəmid İsayev, Sevinc Sadiqova, İradə Nağıyeva, İradə Zərbəliyeva
İçməli suyun təmizlənməsində nanotexnologiyalarin rolu (İcmal) 198
Mehri Khalilova, Zeynab Huseynova, Saadat Aliyeva, Mehriban Hasanava, Nargiz Eminbayli, Elza Mustafayeva
Growth and Exterior Characteristics of F_2-Generation Hybrid Female Buffaloes 204
Shoira Aminova
The Effect of Vilofoss Mineral Feed Additive on Productive and Wool Quality Characteristics in Fattening Hissar Lambs 211
Sarvar Po'latov, M. Abdurayimova, Sevinchoy Mustafoyeva
Growth, Development and Biological Characteristics of Medicinal Marshmallow (*Althaea officinalis* L.) and Quality Indicators of Raw Materials 217
Yo.Sh.Karimova
Feeding Of "Big-6" And "Bronze-708" Turkeys 224
Aziz Abilzade Shahin
From Sustainability Claims to Assessable Responsibility: An Evidence-Alignment Analysis of Vertical Farming Organisations 233

RİYAZİYYAT VƏ MEXANİKA ELMLƏRİ

MATHEMATICS AND MECHANICS SCIENCES

Aynur Əliyeva, Nəzirə Bayramova
Matrislər cəbrinin iqtisadiyönümlü hərbi məsələlərə tətbiqi 243

TEXNİKA ELMLƏRİ

TECHNICAL SCIENCES

Rajakani Velumani, N.Babu, K.Madhan, and P.Maithili
Attention-Guided Sparse Aggregation and Hetero Geneity-Aware Optimization for Federated Wireless Traffic Prediction 253
Türkan Qurbanova, Ayan Hümbətli
Neft-qaz məhsullarının hərəkətində logistika amilləri 272

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