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ENVIRONMENTAL RISK ASSESSMENT OF OIL AND GAS FACILITY IMPACTS ON AGRICULTURAL LAND AND CROP PRODUCTION

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Abstract: This paper assesses the environmental risks posed by oil and gas facilities to adjacent agricultural land and crop production through a systematic probability-impact risk framework. Five principal contamination pathways — soil hydrocarbon contamination, irrigation water pollution, heavy metal uptake by crops, salinisation from drilling fluids, and atmospheric deposition — are characterised and prioritised. The scientific novelty lies in the quantification of crop yield losses attributable to each pathway using a dose-response modelling approach, integrating published experimental data with field measurements from oil-producing regions of Azerbaijan to calibrate exposure estimates to the local semi-arid context. Soil hydrocarbon contamination and irrigation water pollution are identified as critical risk pathways, with combined estimated crop yield reductions of 18–34 % in high-exposure buffer zones within 2 km of production facilities.

Keywords: *environmental risk assessment, oil and gas, agricultural land, soil contamination, crop yield.*

Xülasə: Bu məqalədə neft-qaz obyektlərinin yaxınlığındakı kənd təsərrüfatı torpaqlarına və əkin məhsullarına göstərdiyi ətraf mühit riskləri sistematik ehtimal-təsir çərçivəsi ilə qiymətləndirilir. Torpağın karbohidrogen çirklənməsi, suvarma suyunun çirklənməsi, ağır metalların bitkilər tərəfindən mənimsənilməsi, qazıma məhlullarından duzlaşma və atmosfer çöküntüsü olmaqla beş əsas çirklənmə yolu xarakterizə edilir. İşin elmi yeniliyi doza-cavab modelləşdirməsi əsasında hər yolun məhsuldarlıq itkisinə töhfəsinin kəmiyyətcə müəyyənləşdirilməsindədir. İstehsal obyektlərindən 2 km daxilindəki yüksək məruz qalma zonalarında əkin məhsulunun məhsuldarlığı 18–34 % azalır.

Açar sözlər: *ətraf mühit riski, neft-qaz, kənd təsərrüfatı torpağı, torpaq çirklənməsi, məhsuldarlıq itkisi.*

Резюме: В данной статье проводится оценка экологических рисков, создаваемых объектами нефтегазовой отрасли для прилегающих сельскохозяйственных угодий и производства сельскохозяйственных культур, с использованием систематической матрицы вероятность-воздействие. Охарактеризованы пять основных путей загрязнения: загрязнение почвы углеводородами, загрязнение ирригационных вод, поглощение тяжёлых металлов растениями, засоление от буровых растворов и атмосферное осаждение. Научная новизна состоит в количественном определении потерь урожайности по каждому пути на основе дозо-ответного моделирования. Снижение урожайности в высоконагруженных буферных зонах составляет 18–34 %.

Ключевые слова: *оценка экологических рисков, нефть и газ, сельскохозяйственные угодья, загрязнение почвы, потери урожайности.*

1. Introduction

Oil and gas production operations generate a complex array of environmental stressors — hydrocarbon spills, produced water discharge, atmospheric emissions, and land disturbance — that interact with adjacent agricultural ecosystems through multiple simultaneous contamination pathways [1]. Azerbaijan, with one of the world's longest histories of commercial oil production dating to the 1840s, presents a particularly important context for studying these interactions: the Absheron Peninsula and surrounding regions combine active and legacy oil production infrastructure with agricultural land use, creating persistent co-exposure scenarios that conventional environmental impact assessments have not fully characterised.

Published environmental risk frameworks for oil and gas operations have primarily focused on aquatic ecosystem impacts, worker occupational health, and air quality in residential areas [2]. Systematic quantification of agricultural productivity losses as an integrated environmental risk outcome — linking contamination pathway probability, exposure dose, and crop yield response in a unified assessment framework — has not been established for the South Caucasus context. This gap is methodologically significant: the Absheron region's semi-arid continental climate, with annual evapotranspiration exceeding precipitation by a factor of 3–5, concentrates contaminants in topsoil through capillary rise and reduces natural dilution capacity relative to temperate or humid contexts from which most published dose-response functions are derived. Direct application of dose-response parameters calibrated to, for example, North Sea or Gulf of Mexico agricultural contexts would systematically underestimate risk in the Azerbaijani semi-arid environment. This study addresses that gap by applying a probability-impact risk matrix calibrated to dose-response relationships from field measurements reported in published studies from oil-producing regions of Azerbaijan, identifying critical contamination pathways, and quantifying their combined effect on crop yield in proximity buffer zones around production facilities.

2. Contamination Pathways and Exposure Assessment

Five principal contamination pathways from oil and gas facilities to agricultural land are identified, following the source-pathway-receptor model of ISO 15799:2003 for contaminated land site management [3]. The first and most significant pathway is direct soil hydrocarbon contamination through spills, pipeline leaks, and improper waste disposal. Total petroleum hydrocarbon (TPH) concentrations in soils adjacent to production facilities in the Absheron region have been documented at 2,400–18,600 mg/kg, substantially exceeding the agricultural soil guideline value of 300 mg/kg TPH established under UK Environment Agency Contaminated Land Report CLR10 — the most widely adopted European technical reference for TPH soil guidelines

[6]. At concentrations above 1,000 mg/kg TPH, soil microbial activity and nitrogen mineralisation are suppressed, directly impairing crop nutrient availability.

The second pathway — irrigation water contamination — operates through surface runoff from production sites and shallow groundwater intrusion. Produced water from Azerbaijani oil wells contains chloride concentrations of 15,000–85,000 mg/L and benzene concentrations of 2–45 mg/L [2], far exceeding the WHO irrigation water guideline of 1,500 mg/L chloride. Heavy metal uptake by crops constitutes the third pathway: cadmium, lead, and vanadium accumulate in topsoil from atmospheric deposition and produced water irrigation, entering the food chain through root absorption. Salinisation from drilling fluid contamination and atmospheric deposition of SO_2 and particulate matter complete the five-pathway exposure profile. Salinisation is driven by produced water and drilling mud disposal on or near agricultural land: electrical conductivity (EC) values of 8–24 dS/m have been recorded in affected soils adjacent to disposal sites in the Absheron region, well above the 4 dS/m threshold at which sensitive cereal crops begin to show yield suppression [1]. SO_2 deposition from flaring and combustion processes acidifies topsoil and damages leaf tissue through stomatal uptake, with foliar injury documented in crops within 1.5 km of active flare stacks during thermal inversion episodes (authors' observation consistent with published flaring impact literature).

3. Risk Matrix and Crop Yield Impact Quantification

Each contamination pathway is assigned probability (P) and impact (I) scores on a 1–5 scale following ISO 31000:2018 [5], with risk scores computed as P×I. Figure 1 presents the risk matrix results. Soil hydrocarbon contamination and irrigation water pollution are identified as critical risk pathways (P×I = 20 and 16 respectively), reflecting both the high occurrence frequency documented in field surveys and the severe consequences for soil fertility and crop physiology. Heavy metal accumulation and salinisation occupy the high-risk zone (P×I = 12 and 9), while atmospheric deposition presents a medium-level risk under current emission profiles.

Figure 1. Probability-Impact Risk Matrix: oil and gas facility impacts on agricultural land (P — probability 1–5; I — impact 1–5)

I=5				A	
I=4			C	B	
I=3		E	D		
I=2					
I=1					
P→	1	2	3	4	5

Risk codes: A — Soil hydrocarbon contamination (P=4, I=5); B — Irrigation water pollution (P=4, I=4); C — Heavy metal uptake by crops (P=3, I=4); D — Salinisation from drilling fluids (P=3, I=3); E — Air deposition on cropland (P=2, I=3).

Critical (P×I ≥ 16) High (P×I = 9–15)
Medium (P×I = 4–8) Low (P×I ≤ 3)

Source: authors' risk assessment calibrated to field data from Absheron region studies [1,2,3].

4. Dose-Response Modelling and Yield Loss Estimation

Crop yield losses are estimated using dose-response functions derived from published experimental data and field measurements in petroleum-contaminated agricultural soils. For wheat — the dominant cereal crop in the affected regions — the dose-response relationship for TPH contamination follows a sigmoidal function: yield reduction of 5 % at 500 mg/kg TPH, 22 % at

2,000 mg/kg, and 65 % at 8,000 mg/kg, with near-complete crop failure above 15,000 mg/kg [4]. For vegetable crops with higher sensitivity, the corresponding yield reductions are approximately 1.5-fold greater at equivalent TPH concentrations.

Integrating the pathway-specific dose-response functions across the exposure profile of a 2 km buffer zone around a typical production facility yields a combined estimated crop yield reduction of 18–34 % for cereal crops and 28–48 % for vegetables (authors' calculations). The economic loss estimate is derived by multiplying pathway-specific yield reduction percentages by the regional average crop value per hectare — weighted across the dominant crop mix (wheat 52 %, vegetables 31 %, other 17 %, per DSK agricultural census data [7]) — and summing across all pathways, with pathway contributions weighted by their buffer-zone exposure frequency. The range reflects variability in facility type, operational practices, and local hydrogeological conditions. At the regional scale, these yield reductions translate to an estimated economic loss of AZN 1,200–3,400 per hectare per annum in affected buffer zones, based on 2022–2023 Azerbaijani agricultural commodity prices reported by the State Statistical Committee of the Republic of Azerbaijan [6]. The irrigation water contamination pathway contributes an additional 8–12 % yield penalty in areas relying on surface water sources downstream of production sites [2].

5. Conclusion

This study has developed and applied a probability-impact environmental risk framework for assessing oil and gas facility impacts on agricultural land and crop production, and quantified crop yield losses through dose-response modelling calibrated to Azerbaijani field data. Soil hydrocarbon contamination and irrigation water pollution are identified as critical risk pathways, with combined estimated yield reductions of 18–34 % for cereal crops in high-exposure buffer zones within 2 km of production facilities. The scientific novelty lies in the integration of contamination pathway probability assessment with crop-specific dose-response functions in a unified risk quantification framework. Phytoremediation, closed-loop drilling systems, and mandatory buffer zone enforcement are recommended as the highest-priority mitigation measures. Future work should apply the framework to legacy contamination sites across Azerbaijan and develop spatially explicit risk maps using GIS integration of facility locations and soil monitoring data. Limitations include the reliance on published dose-response functions calibrated to non-Azerbaijani crop varieties; local cultivar-specific dose-response data would improve estimation precision.

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Sociological Sciences

ТҮРКІ ӘЛЕМІН ӨРКЕНДЕТУДЕГІ МӘДЕНИ БІРЛІК ПЕН ӨРКЕНИЕТТІ ҚҰРУ: БІЛІМ, ҒЫЛЫМ ЖӘНЕ ТАРИХТЫҢ ИНТЕГРАЦИЯЛЫҚ ПАРАДИГМАСЫ

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Аңдатпа

Мақалада XXI ғасыр жағдайындағы түркі әлемінің мәдени тұтастығын нығайтудағы білім, ғылым және тарихи сананың интеграциялық әлеуеті өркениеттік көзқарас тұрғысынан қарастырылады. Түркі өркениеті адамзат өркениетінің маңызды құрамдас бөлігі ретінде бағаланып, оның қалыптасуы мен дамуындағы тарихи факторлар жүйелі түрде сараланады. Автор түркі халықтарының ортақ тарихи жадының, мәдени мұрасының және ғылыми дәстүрінің қазіргі интеграциялық үдерістердегі рөлін талдай отырып, Ұлы Жібек жолының өркениеттер арасындағы білім алмасу кеңістігі болғанын негіздейді. Сонымен қатар орта ғасырлардағы түркі ойшылдарының әлемдік ғылымға қосқан үлесі бағаланып, қазіргі Түркі мемлекеттері ұйымының білім мен ғылым саласындағы ынтымақтастығының негізгі бағыттары айқындалады. Түркістан қаласында құрылып жатқан Түркі өркениеті орталығының түркі халықтарының ортақ ғылыми-білім беру кеңістігін қалыптастырудағы стратегиялық миссиясы көрсетіледі.

Түйін сөздер: Түркі өркениеті, мәдени бірлік, Түркі мемлекеттері ұйымы, Түркістан, тарихи жады, білім, ғылым, интеграция, Ұлы Жібек жолы, цифрлық гуманитаристика.

Аннотация

В статье рассматривается роль образования, науки и исторического сознания в укреплении культурного единства тюркского мира с позиций современной цивилизационной парадигмы. Тюркская цивилизация анализируется как неотъемлемая составная часть мировой цивилизации, а также раскрываются исторические предпосылки ее формирования и развития. Особое внимание уделяется роли Великого шелкового пути как пространства межцивилизационного взаимодействия, обмена знаниями и культурными ценностями. Показан вклад средневековых тюркских мыслителей в развитие мировой науки и интеллектуальной культуры. Проанализированы современные интеграционные процессы в рамках Организации тюркских государств, включая сотрудничество в области образования, науки и академической мобильности. Обосновано стратегическое значение создаваемого в городе Туркестане Центра тюркской цивилизации как международной научно-образовательной платформы.

Ключевые слова: тюркская цивилизация, культурное единство, Организация тюркских государств, Туркестан, историческая память, образование, наука, интеграция, Великий шелковый путь, цифровая гуманитаристика.

Abstract

This article examines the role of education, science, and historical consciousness in strengthening the cultural unity of the Turkic world from the perspective of a contemporary civilizational paradigm. Turkic civilization is considered an integral component of world civilization, and the historical foundations of its formation and development are analyzed. Particular attention is paid to the Silk Road as a unique platform for intercultural dialogue, knowledge exchange, and the dissemination of scientific and cultural achievements. The contribution of medieval Turkic scholars to the development of world science and intellectual heritage is evaluated. The paper also analyzes current integration processes within the Organization of Turkic States, focusing on cooperation in education, research, academic mobility, and scientific collaboration. Special emphasis is placed on the strategic role of the Turkic Civilization Center being established in Turkistan as an international research and educational hub for the Turkic world.

Keywords: Turkic civilization, cultural unity, Organization of Turkic States, Turkistan, historical memory, education, science, integration, Silk Road, digital humanities.

XXI ғасыр – жаһандану процестері жеделдеп, мемлекеттер арасындағы бәсекелестік жаңа сипатқа ие болған тарихи кезең. Егер XX ғасырда мемлекеттердің күші табиғи ресурстармен, әскери әлеуетпен және өнеркәсіптік өндіріспен өлшенсе, қазіргі кезеңде елдердің даму деңгейі ең алдымен олардың интеллектуалдық капиталымен, ғылыми әлеуетімен, инновациялық технологияларымен және мәдени интеграция мүмкіндіктерімен анықталады. Сондықтан тарихи жадты сақтау, ортақ мәдени құндылықтарды насихаттау және ғылыми-білім беру кеңістігін құру кез келген интеграциялық бірлестіктің ұзақ мерзімді тұрақтылығының негізгі шарттарының біріне айналуда.

Қазіргі заманғы халықаралық қатынастар жүйесінде өркениеттік сәйкестік мәселесі ерекше өзекті. Әлемнің әртүрлі аймақтарында тарихи және мәдени негізде құрылған интеграциялық ұйымдардың қызметі ұлттық және аймақтық дамудың тиімді құралына айналуда. Еуропалық Одақтың ортақ білім беру кеңістігін құрудағы тәжірибесі, араб мемлекеттерінің мәдени ынтымақтастық жобалары немесе Шығыс Азиядағы ғылыми желілер бұған айқын дәлел бола алады. Осыған байланысты түркі мемлекеттері арасындағы интеграция жаңа мазмұнға ие болуда.

Түркі әлемі – Еуразия кеңістігінде мыңдаған жылдар бойы қалыптасқан ортақ тарихи және мәдени кеңістік. Түркі халықтарын біріктіретін факторлар тек тілдік немесе этникалық жақындықпен шектелмейді. Олар ортақ тарихи жадымен, мемлекеттік дәстүрлермен, рухани құндылықтармен, құқықтық мәдениетпен және ғылыми мұрамен ерекшеленеді. Ежелгі заманнан бері түркі өркениеті Еуразия құрлығындағы саяси, экономикалық және мәдени процестерге белсенді қатысып, Шығыс пен Батыс арасындағы өркениеттік байланысты қамтамасыз етіп келеді. Қазақстан Республикасының Президенті Қасым-Жомарт Тоқаев Түркі мемлекеттері ұйымының саммиттеріндегі сөздерінде түркі халықтарының тарихи және мәдени мұрасын сақтау, ғылыми ынтымақтастықты дамыту және ортақ білім беру кеңістігін құру мәселелеріне ерекше назар аударады. Президенттің айтуынша, түркі интеграциясының ұзақ мерзімді табысы тек ортақ мәдени мұраны сақтауға ғана емес, сонымен қатар ғылым мен білім беру саласындағы ынтымақтастық деңгейін сапалы деңгейге көтеруге де байланысты.

Бүгінгі таңда түркі интеграциясы көбінесе саяси, экономикалық және мәдени ынтымақтастық аясында зерттеледі. Дегенмен, ғылыми әдебиеттерде білім беруді, ғылымды және тарихи сананы біртұтас интеграциялық жүйе ретінде қарастыратын зерттеулер

жетіспейді. Сондықтан түркі өркениетінің болашақ даму стратегиясын тек тарихи мұраны дәріптеу арқылы ғана емес, сонымен қатар ортақ ғылыми және инновациялық кеңістік құру негізінде қарастыру маңызды болып келеді.

Түркі өркениеті – Еуразия кеңістігінде дамыған бірегей тарихи-мәдени жүйе. Оның негізін мемлекеттік басқару дәстүрі, көшпелі және отырықшы мәдениеттердің үйлесімі, жоғары әскери ұйым, халықаралық сауда қатынастары, құқықтық мәдениет және рухани құндылықтар құрайды. Түріктер құрған мемлекеттер ғасырлар бойы Еуразияда геосаяси тұрақтылықты қамтамасыз етіп, халықаралық сауда жолдарының қауіпсіздігін сақтап келді. Нәтижесінде әртүрлі өркениеттер арасындағы экономикалық және мәдени байланыстар үнемі дамып келеді.

Түркі өркениетінің негізгі ерекшеліктерінің бірі – оның ашықтығы және интеграцияға ұмтылуы. Түркі мемлекеттері Қытаймен, Үндістанмен, Парсымен, Византиямен, Араб халифатымен, кейінірек еуропалық мемлекеттермен тығыз саяси, экономикалық және мәдени байланыстар орнатты. Мұндай өзара әрекеттесу ғылымның, білімнің, өнердің және технологияның кең таралуына ықпал етті. Сондықтан түркі өркениетін тек көшпелі мәдениетпен байланыстыру ғылыми тұрғыдан толық қорытынды емес. Бұл көшпелі және отырықшы өркениеттердің өзара әрекеттесуінен туындаған күрделі мәдени жүйе.

Түркі өркениетінің идеологиялық негіздері Орхон-Енисей жазбаларында айқын көрініс тапқан. Білге қаған, Күлтегін және Тоныкөк жазбаларында мемлекеттің бірлігі, халықтың тұтастығы, әділ басқару, білім мен даналықтың маңыздылығы ерекше дәріптелген. «Ұлттың ұлт болуы бірлік» қағидасы түркі саяси философиясының өзегіне айналды. Бұл идея қазіргі Түркі мемлекеттері ұйымының мақсаттары мен міндеттерімен де үндеседі.

Орта ғасырларда түркі өркениеті ислам өркениетімен тығыз байланысып, ғылым мен білімнің жаңа дәуіріне аяқ басты. Қарахан мемлекеті, Селжүктер, Алтын Орда және Осман империясы билік құрған кезеңде түркі әлемінде философия, астрономия, математика, медицина, әдебиет және құқық қарқынды дамыды. Осы кезеңде дүниеге келген әл-Фараби, Жүсіп Баласағұн, Махмұд Қашқари және Ахмет Ясауи сияқты ғалымдардың еңбектері әлемдік ғылым тарихында ерекше орын алады.

Қазіргі кезеңде түркі өркениеті жаңа мағынаға ие болуда. Егер бұрын интеграцияның негізі ортақ тіл мен тарихи жад болса, бүгінде оны ғылым, жоғары білім, цифрлық технологиялар және инновациялық экономика біріктіреді. Сондықтан түркі өркениетін тек өткеннің тарихи мұрасы ретінде ғана емес, сонымен қатар болашақтың интеллектуалды және технологиялық дамуының платформасы ретінде қарастыру қажет.

Осы тұрғыдан алғанда, түркі өркениеті әлемдік өркениеттер жүйесінің маңызды құрамдас бөлігі ғана емес, сонымен қатар XXI ғасырда халықаралық ғылыми ынтымақтастықтың, мәдени дипломатияның және тұрақты дамудың жаңа моделін жасайтын стратегиялық кеңістік болып табылады.

Түркі өркениетінің қалыптасуы мен дамуын Ұлы Жібек жолының тарихынан бөліп қарауға болмайды. Ұлы Жібек жолы адамзат тарихындағы ең ірі халықаралық коммуникация жүйелерінің бірі ғана емес, сонымен қатар әртүрлі өркениеттер арасындағы мәдени, ғылыми және рухани өзара әрекеттесу кеңістігі болды. Қытайдан басталып, Орталық Азия арқылы Таяу Шығыс пен Еуропаға дейін созылып жатқан алып өркениеттік дәліз ретінде ол бірнеше мың жыл бойы халықтар арасындағы экономикалық және мәдени байланыстарды қамтамасыз етті.

Дәстүрлі тарихнамада Ұлы Жібек жолы көбінесе сауда жолы ретінде бейнеленсе, қазіргі өркениеттік зерттеулер оның негізгі тарихи миссиясы білімнің, технологиялардың, ғылыми идеялардың және мәдени құндылықтардың таралуына ықпал ететін әмбебап интеграциялық жүйе болғанын дәлелдейді. Сондықтан Ұлы Жібек жолын қазіргі заманғы

халықаралық ғылыми және білім беру желілерінің тарихи бастауы деп санауға толық негіз бар.

Ұлы Жібек жолының негізгі бөлігі түркі мемлекеттерінің аумағы арқылы өтті. Түрік қағанаты, Қарлұқ мемлекеті, Қарахан мемлекеті, Қыпшақ одағы, кейінірек Алтын Орда дәуірінде бұл жол тек халықаралық сауданың ғана емес, сонымен қатар дипломатиялық қатынастардың, мәдени интеграцияның және ғылыми алмасудың негізгі артериясына айналды. Түркі билеушілері керуен жолдарының қауіпсіздігін қамтамасыз етіп, қалалардың дамуына қолайлы жағдайлар жасады. Бұл саясат аймақтың экономикалық қуатын арттырып қана қоймай, мәдени және ғылыми байланыстардың нығаюына да ықпал етті.

Қазақстан аумағындағы Түркістан, Отырар, Тараз, Сауран, Сығанақ, Баласағұн, Испиджаб және Сарайшық қалалары Ұлы Жібек жолының маңызды мәдени орталықтары болды. Бұл қалаларда медреселер, кітапханалар, қолөнер шеберханалары, керуен сарайлар және ғылыми пікірталас алаңдары болды. Шығыс пен Батыстың саудагерлері ғана емес, сонымен қатар ғалымдар, ақындар, сопылар және саяхатшылар да білім мен тәжірибе алмасу үшін жиналды.

Әсіресе Отырар қаласының ғылыми тарихы ерекше назар аударуға тұрарлық. Археологиялық және жазбаша деректер Отырардың ислам әлеміндегі ең ірі мәдени орталықтардың бірі болғанын дәлелдейді. Қалада бай кітапхананың болуы, көптеген медреселердің жұмыс істеуі және білім беру дәстүрінің қалыптасуы оның халықаралық ғылыми орталыққа айналғанын көрсетеді. Әлемдік ғылым тарихындағы ең ұлы ойшыл Әбу Насыр әл-Фарабидің осындай интеллектуалды ортадан шыққаны кездейсоқ емес.

Ұлы Жібек жолы тек материалдық байлықтың ғана емес, сонымен қатар идеялардың да жолы болды. Бұл жолда қағаз жасау технологиясы, кітап басып шығару, астрономиялық білім, медицина, математика, философия және сәулет өнері кеңінен таралды. Түркі қалалары бұл білімді алып қана қоймай, оны жаңа мазмұнмен толықтырып, әлемдік өркениетке қайта ұсынды.

Қазіргі кезеңде халықаралық ұйымдар Ұлы Жібек жолын мәдени мұраны сақтаудың және халықтар арасындағы өзара түсіністікті нығайтудың символы ретінде бағалайды. Бұл тарихи тәжірибе түркі мемлекеттері арасындағы заманауи ғылыми және білім беру интеграциясын дамытудың маңызды әдіснамалық негізі болып табылады.

Түркі өркениетінің әлем тарихындағы орны оның саяси жетістіктерімен ғана емес, сонымен қатар ғылым мен білімнің дамуына қосқан өлшеусіз үлесімен де анықталады. Орта ғасырларда түркі халықтары ислам қайта өркендеуінің маңызды қозғаушы күштерінің біріне айналды, философия, математика, астрономия, медицина, лингвистика, әдебиет және мемлекеттік басқарудың дамуына үлкен әсер етті.

Түркі ғылыми дәстүрінің ерекшелігі - әртүрлі өркениеттердің жетістіктерін шығармашылықпен игеру және жаңа ғылыми синтездің қалыптасуы. Грек философиясын, үнді математикасын, парсы мәдениетін және араб ғылыми тәжірибесін біріктірген түрік ғалымдары әлемдік ғылымның дамуына жаңа серпін берді. Бұл процесс түрік өркениетінің ашық және интегративті сипатқа ие болғанын көрсетеді.

Ортағасырлық түрік ғылымының ең көрнекті өкілдерінің бірі Әбу Насыр әл-Фараби болды. Оның логика, философия, саясаттану, музыка теориясы және этика саласындағы еңбектері тек ислам әлемінде ғана емес, сонымен қатар Еуропада кеңінен танылды. Әл-Фараби ғылымдарды жүйелеудің жаңа моделін ұсынды және білімді қоғамның дамуының негізгі шарты деп санады. Оның «Қайырымды қала тұрғындарының көзқарастары» еңбегі қазіргі заманғы мемлекеттік басқару теориясының тарихи негіздерінің бірі болып саналады.

Махмұд Қашқаридің «Диуани лұғат ат-Түрік» атты еңбегі түркі халықтарының тілі мен мәдениетін ғылыми тұрғыдан зерттеген алғашқы энциклопедиялық еңбек болып саналады. Онда тек түркі тайпаларының тілдік ерекшеліктері ғана емес, сонымен қатар олардың

этнографиясы, ауыз әдебиеті, географиясы және дүниетанымы туралы көптеген ақпарат бар. Бұл еңбек қазіргі түркітанудың негізгі көздерінің бірі болып табылады.

Жүсіп Баласағұнның «Құтадғу білік» еңбегі - мемлекеттік басқару, әділеттілік, білім беру және мораль мәселелерін жүйелі түрде қарастыратын түркі саяси философиясының көрнекті үлгісі. Бұл еңбек үкімет пен қоғам арасындағы үйлесімді қарым-қатынасты қамтамасыз ететін қағидаттарды белгілейді және қазіргі заманғы мемлекеттік басқару теориясына сәйкес келетін идеяларды ұсынады.

Қожа Ахмет Ясауидің рухани мұрасы түркі халықтарының мәдени және діни дүниетанымының қалыптасуына ерекше әсер етті. Оның «Диуани Хикмет» еңбегі адамгершілік, білім беру, әділеттілік және рухани жетілу идеяларын таратып, түркі халықтарының рухани бірлігін нығайтты. Ясауи мектебі кейінгі ғасырларда Орталық Азиядағы мәдени сабақтастықтың маңызды институтына айналды.

Медицина, астрономия және математика салалары да түркі ғылымының дамуында маңызды рөл атқарды. Түркі билеушілерінің қамқорлығымен жұмыс істейтін көптеген обсерваториялар мен ғылыми орталықтар ғылыми зерттеулердің дамуына жағдай жасады. Бұл орталықтарда жасалған ғылыми еңбектер кейінірек Еуропадағы Ренессанс ғылымының дамуына ықпал етті.

Ортағасырлық түркі ғылыми мұрасының маңызды ерекшелігі - оның халықаралық сипаты. Түрік ғалымдары бірнеше тілді меңгеріп, әртүрлі ғылыми мектептердің жетістіктерін біріктірді. Осылайша, олар мәдениеттер арасындағы ғылыми диалогтың дамуына үлес қосты. Бұл тәжірибе бүгінгі жаһандану жағдайында ерекше өзекті.

Қазіргі кезеңде ортағасырлық түркі ғылыми мұрасын цифрландыру, қолжазбаларды ғылыми айналымға енгізу, көптілді электрондық дерекқорларды құру және халықаралық зерттеу жобаларын жүзеге асыру түркі мемлекеттері арасындағы ынтымақтастықтың маңызды бағыттарына айналуда. Түркі өркениетінің интеллектуалдық мұрасы тек өткеннің тарихи ескерткіші ғана емес, сонымен қатар қазіргі заманғы ғылыми интеграцияның берік негізі болып табылады.

Осыған байланысты ортағасырлық түркі ғылымының жетістіктері қазіргі түркі мемлекеттерінің білім беру және ғылым саласындағы ынтымақтастықты дамытудың тарихи және идеологиялық негізін құрайды. Өткеннің ғылыми мұрасы мен бүгінгі инновациялық саясат арасындағы сабақтастық түркі әлемінің жаңа интеллектуалдық кеңістігін қалыптастырудың негізгі шарттарының бірі болып табылады.

XXI ғасырдағы жаһандану процестері мемлекеттердің дамуын жаңа сапалық деңгейге көтерді. Экономикалық және саяси ынтымақтастықпен қатар, ғылым, білім беру және инновация саласындағы өзара іс-қимыл халықаралық ұйымдар қызметінің негізгі бағыттарының біріне айналды. Осыған байланысты Түркі мемлекеттері ұйымының (ТМҰ) қызметі түркі әлемінің ортақ тарихи мұрасын сақтауға, сондай-ақ ғылыми және интеллектуалдық кеңістік құруға бағытталған жаңа кезеңді білдіреді.

Түркі мемлекеттері ұйымының институционалдық негізі 2009 жылы Нахчыван келісіміне сәйкес құрылды және бүгінде ол көпжақты халықаралық ұйымға айналды. Қазақстан, Әзірбайжан, Қырғызстан, Түркия, Өзбекстан, Түрікменстан және бақылаушы мемлекеттер ұйымы шеңберіндегі ынтымақтастық тек саяси және экономикалық салада ғана емес, сонымен қатар мәдени-гуманитарлық кеңістікте де қарқынды дамып келеді.

Соңғы жылдары ТМҰ аясында білім беру және ғылым саласындағы бірнеше маңызды құрылымдар табысты жұмыс істеп келеді. Олардың қатарында Түркі академиясы, Түркі мәдениеті мен мұрасы қоры, ТҮРКСОЙ, Түркі университеттері одағы және Түркия сауда-өнеркәсіп палатасы сияқты ұйымдар бар. Бұл институттардың қызметі түркі халықтарының ортақ ғылыми мұрасын зерттеуге, білім беру бағдарламаларын үйлестіруге және академиялық байланыстарды кеңейтуге бағытталған.

Түркі академиясының ғылыми жобалары ортақ тарихты зерттеуде, археологиялық мұраны сақтауда, түркі халықтарының жазба ескерткіштерін жариялауда және тарихи ақпаратты ғылыми айналымға енгізуде маңызды рөл атқарады. Сонымен қатар, Түркі академиясы ортақ оқулықтарды әзірлеу, ғылыми конференциялар ұйымдастыру және жас зерттеушілерді қолдау бойынша жүйелі жұмыс жүргізеді.

Түркі университеттері одағының жоғары білім беру саласындағы қызметі ерекше назар аударуға тұрарлық. Бұл ұйым университеттер арасындағы академиялық мобильділікті дамытуға, қос дипломды білім беру бағдарламаларын енгізуге және бірлескен ғылыми жобаларды жүзеге асыруға мүмкіндік береді. Болашақта ортақ магистрлік және докторлық бағдарламаларды құру түркі кеңістігіндегі жоғары білім беру сапасын жаңа деңгейге көтереді.

Ғылым саласындағы интеграция тек бірлескен зерттеулермен шектелмеуі керек. Ортақ цифрлық кітапхананы, ғылыми деректер банкін, терминологиялық дерекқорды, электрондық қолжазба қорын және жасанды интеллектке негізделген тарихи деректер платформасын құру түркі мемлекеттері үшін маңызды міндеттердің біріне айналуы қажет. Мұндай жобалар ғылыми ақпараттың қолжетімділігін арттырып қана қоймай, сонымен қатар халықаралық ғылыми ынтымақтастықтың тиімділігін арттырады.

Қазіргі кезеңде жасанды интеллект, үлкен деректер, цифрлық гуманитарлық ғылымдар және геоақпараттық технологиялар гуманитарлық ғылымдардағы зерттеу әдістерін түбегейлі өзгертуде. Сондықтан түркі мемлекеттері осы салаларда ортақ ғылыми бағдарламаларды енгізу арқылы әлемдік ғылымдағы өз позицияларын нығайта алады.

Сондықтан, XXI ғасырдағы түрік интеграциясының негізгі бағыты мәдени дипломатиядан ғылыми дипломатияға ауысуы керек. Бұл өз кезегінде түрік өркениетінің әлемдік ғылыми кеңістіктегі беделін арттырудың негізгі тетігіне айналады.

Түркістан қаласы ғасырлар бойы түркі халықтарының рухани және мәдени орталығы болды. Қожа Ахмет Ясауи кесенесі, ежелгі қала орындары, ортағасырлық сәулет ескерткіштері және бай тарихи мұра Түркістанды бүкіл түркі әлемі үшін қасиетті орынға айналдырды. Бүгінде бұл қала өзінің тарихи мәртебесімен қатар, заманауи ғылыми және білім беру орталығы ретінде дамудың жаңа кезеңіне аяқ басып келеді.

ҚР Президенті Қасым-Жомарт Тоқаевтың Түркістанда Түркі өркениеті орталығын құру бастамасы түркі интеграциясының жаңа кезеңін анықтайтын стратегиялық шешім болып табылады. Бұл орталықтың қызметі тек тарихи мұраны сақтаумен шектеліп қоймай, сонымен қатар ғылыми және инновациялық қызметтің халықаралық алаңына айналуы керек.

Біздің ойымызша, Түркі өркениеті орталығы бірнеше негізгі бағытта жұмыс істеуі керек.

Ең алдымен, бұл түркі халықтарының тарихи және мәдени мұрасын жан-жақты зерттейтін халықаралық ғылыми институт болуы керек. Мұнда археология, этнология, түркітану, тарихи география, эпиграфия және сандық гуманитарлық ғылымдар салаларындағы халықаралық зертханалар құрылуы керек.

Екіншіден, Түркі өркениеті орталығы ортақ цифрлық мұрағаттың негізін қалауы керек. Түркі мемлекеттерінде сақталған тарихи құжаттарды, қолжазбаларды, сирек кітаптар мен карталарды бірыңғай электронды қоймаға біріктіру ғылымды жаңа деңгейге көтеруге мүмкіндік береді.

Үшіншіден, орталық жасанды интеллект технологияларын тарихи зерттеулерге енгізетін арнайы цифрлық гуманитарлық зертхана ұйымдастыруы керек. Мұнда ежелгі қолжазбаларды автоматты түрде тану, тарихи карталарды цифрландыру, мәтіндерді семантикалық талдау және тарихи тұлғалардың бірыңғай дерекқорын құру бойынша жұмыстар жүргізілуі мүмкін.

Төртіншіден, Түркістан жас ғалымдар үшін халықаралық мектепке айналуы керек. Бірлескен магистратура және PhD бағдарламалары, жазғы мектептер, ғылыми тағылымдамалар және академиялық мобильділік жобалары түркі елдерінің жас зерттеушілерін біріктіретін маңызды платформа болады.

Бесіншіден, Түркістан ғылыми дипломатия орталығы ретінде қызмет етуі керек. Жыл сайынғы халықаралық форумдар, конгресстер және ғылыми симпозиумдар түркі әлемінің ортақ ғылыми күн тәртібін қалыптастыруға ықпал етеді.Осылайша, Түркістан XXI ғасырдағы түркі ғылымының тарихи орталығы ғана емес, сонымен қатар интеллектуалды орталық болуы керек.

Түркі өркениеті - Еуразия кеңістігінде қалыптасқан және адамзат өркениетінің дамуына елеулі үлес қосқан тарихи-мәдени жүйе. Оның мыңдаған жылдар бойы қалыптасқан мемлекеттік басқару дәстүрі, құқықтық мәдениеті, ғылыми мұрасы мен рухани құндылықтары бүгінгі күнге дейін өз маңызын жоғалтқан жоқ. Жаһандану жағдайында бұл мұраны сақтау өткенді дәріптеумен шектелмейді, болашақтың интеллектуалды дамуының негізі болып табылатын стратегиялық міндетке айналуда.

Зерттеу нәтижелері қазіргі кезеңде түркі әлемінің мәдени тұтастығын сақтаудың дәстүрлі құралдары ғылыммен, жоғары біліммен және инновациялық технологиялармен толықтырылуы керек екенін көрсетеді. Ұлы Жібек жолының тарихи тәжірибесі, ортағасырлық түркі ғылыми мектептерінің жетістіктері және түркі мемлекеттерінің қазіргі заманғы ұйымының қызметі мұндай интеграция үшін тарихи және институционалдық негіздердің бар екенін дәлелдейді.

Түркістан қаласында құрылып жатқан түркі өркениетінің орталығы бұл процестің жаңа кезеңін бастауы мүмкін. Бұл түркі әлемінің интеллектуалдық әлеуетін біріктіруге, халықаралық ғылыми зерттеулердің, цифрлық мұрағаттардың, академиялық мобильділіктің және ғылыми дипломатияның жетекші орталығына айналуға қызмет етеді. Қысқасы, XXI ғасырдағы түркі әлемінің өркендеуі тек тарихи мұраны дәріптеумен ғана емес, сонымен қатар ортақ интеллектуалдық кеңістікті құрумен, ғылым мен білімнің интеграциясымен және инновациялық әлеуетті тиімді пайдаланумен тікелей байланысты. Түркі мемлекеттері арасындағы ынтымақтастықтың келесі кезеңі мәдени байланыстардан ғылыми және инновациялық серіктестікке дейін дамыған кезде ғана түркі өркениеті жаһандық дамудың жаңа деңгейіне көтеріле алады.

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Journalism

Does Akim PR Work? A Survey-Experimental Study of Proximity, Technocratic Achievement and National Symbolism in Kazakhstan's Local Executive Communication

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Abstract. Akim public relations in Kazakhstan now operates in a dense digital environment where local executive officials are expected to be visible, responsive, competent and symbolically close to citizens. Yet visibility does not automatically produce trust. The same communicative forces that push akims toward impressive public content - proximity to ordinary residents, demonstrable administrative achievement and national-symbolic language - may undermine credibility when citizens interpret the message as staged. This article develops a survey-experimental study of three akim PR strategies: proximity to people, technocratic achievement and national symbolism. The proposed experiment involves 200 participants randomly assigned to four equal groups: neutral administrative information, proximity content, technocratic content and national-symbolic content. The dependent variables include trust in the akim, perceived sincerity, perceived competence, perceived integrity, perceived staging, willingness to share the message and willingness to submit a request through official channels. The article introduces the concept of the staging penalty, defined as the decline in trust caused by perceived performativity in official communication. The study connects public communication theory, organizational trust, political authenticity, open government, digital media logic and Kazakhstan-specific research on civil servants' communicative competencies. The practical contribution is an Authenticity Stress Test for akimat communication, designed to move local executive PR from personal image protection toward verifiable governance.

Keywords: akim PR, Kazakhstan, public communication, political authenticity, trust in government, local governance, survey experiment, perceived staging, pokazukha, bedel.

Introduction

The akim in Kazakhstan is not only a local executive official. In everyday political perception, the akim often becomes the most visible face of the state at the level where citizens encounter governance physically: the road outside the house, the school corridor, the heating system, the bus stop, the courtyard, the clinic queue, the flood response, the streetlight that works or does

not work. The legal framework of Kazakhstan defines local executive bodies and their competence within the system of local government and self-government, but citizens rarely experience this framework as legal abstraction. They experience it as contact, delay, response, explanation, repair, silence, public meeting or social media post [1]. This makes the question “Does akim PR work?” sharper than a simple media-effect question. It is not enough to count how often an akim posts, how many residents view the post, how many comments appear under it or whether the caption sounds positive. In the digital environment, visibility and trust are no longer identical. A post may circulate widely because people believe it, but it may also circulate because they mock it, challenge it or attach counter-evidence. A video of an akim visiting a courtyard can be read as care. The same video can be read as choreography. A photo from a school opening can signal administrative success. The same photo can look decorative if parents know that practical problems remain outside the camera frame.

OECD treats public communication as a strategic government function connected with informing, listening, responding, strengthening transparency and supporting open government, rather than as a simple distribution of official information [2]. This distinction matters for Kazakhstan because local executive PR is often trapped between two audiences. The first audience is administrative and vertical. It expects reports, order, visible activity, positive dynamics and reputational stability. The second audience is civic and local. It expects deadlines, names of responsible units, evidence, explanation and a visible connection between the post and the problem. When the first audience dominates, PR becomes an upward report. When the second audience is taken seriously, PR begins to work as public communication.

The trust problem is not unique to Kazakhstan. The OECD 2024 Trust Survey reported that across 30 OECD countries surveyed in 2023, 39% of respondents had high or moderately high trust in their national government, while 41% believed that government uses the best available evidence when making decisions [3]. Kazakhstan was not part of that particular sample, so these figures cannot be transferred mechanically to Kazakhstan. Their analytical value lies elsewhere. They show that trust depends not only on exposure to institutions, but also on whether citizens believe that public bodies act with evidence, fairness, competence and responsiveness.

Kazakhstan’s digital scale makes akim communication more consequential. DataReportal recorded 19.2 million internet users in Kazakhstan at the start of 2025, equal to 92.9% internet penetration, and 15.7 million social media user identities, equal to 75.7% of the population [4]. This means that akim PR is immediately exposed to distributed verification. A road-repair post can be checked by residents who walk the street in the morning. A video from a flooded area can be compared with private footage from the same location. A public meeting can be evaluated by those who know whether participants were selected, whether difficult questions were allowed and whether the promise was later fulfilled.

Table 1. Digital context of public communication in Kazakhstan, 2025

Indicator	Value	Meaning for akim PR
Population of Kazakhstan	20.7 million	Akim communication addresses a society where digital reach is close to universal.
Internet users	19.2 million	Official messages are exposed to immediate online verification.
Internet penetration	92.9%	Digital communication is not marginal, but central to public perception.
Social media user identities	15.7 million	Posts can move quickly through platforms, screenshots and local chats.
Social media identities as share of population	75.7%	Visibility can build trust or accelerate reputational damage.

The numbers in Table 1 explain why local executive PR can no longer rely on controlled image production alone. Citizens are not only audiences. They are witnesses, verifiers, commentators and sometimes counter-narrators. A polished official post enters a space where residents can answer with their own images, dates, complaints and memory of earlier promises. In such an environment, public communication succeeds only when the official message can survive comparison with local reality.

Three strategies dominate akim PR. The first is proximity to people. The akim appears in courtyards, markets, schools, hospitals, rural roads, emergency zones or public receptions. The message is visual and relational: the official is near ordinary citizens. The second is technocratic achievement. The akim communicates outputs: repaired roads, completed facilities, digital services, budget execution, investment projects, infrastructure indicators. The message is managerial: the official is capable. The third is national symbolism. The akim links local governance to flag, language, unity, statehood, civic duty, heritage or national holidays. The message is legitimizing: local authority belongs to the symbolic order of the state.

Each strategy can build trust. Each can also fail. Proximity can become staged closeness. Technocratic achievement can become bureaucratic self-advertising. National symbolism can become decorative patriotism. The paradox is that pokazukha and bedel push officials toward impressive public performance, yet the same performance may destroy trust when citizens see arrangement instead of response. Pokazukha is not only a lie; it is a managed display of order, care or success. Bedel is not only reputation; it is social authority and standing. Together, they create a local executive communication style in which looking active may become more important than being answerable.

The research problem is causal. Which strategy changes trust most strongly? Which one increases suspicion? Does perceived staging moderate the effect of proximity, technocratic achievement and national symbolism? Does a message that looks impressive also look credible? These questions cannot be answered by likes or views. They require an experiment.

Literature Review

Kazakhstan-specific research already shows that public communication by state bodies is not merely a technical function. Filipov M.N. and Aqarabi M. studied public information officers in Kazakhstan and found communication dysfunction shaped by hierarchical approval chains, administrative control, limited professional autonomy and weak movement from one-way messaging toward dialogue [5]. This finding matters for akim PR because the weakness often begins before publication. A post may sound careful, polished and defensive not because the

communicator lacks vocabulary, but because the institutional environment rewards reputational safety more than public listening.

Bokayev B., Iskindirova Z., Urazymbetov B. and Nauryzbek K. analyzed communicative competencies of civil servants in Kazakhstan and identified problems such as bureaucratic language, lack of empathy and insufficient crisis communication capacity [6]. Their research helps explain why citizens may distrust official communication even when it contains correct information. Trust is not damaged only by falsehood. It is also damaged by cold tone, delayed answers, impersonal vocabulary and unwillingness to name responsibility. In local governance, a phrase like “the issue is under control” can irritate citizens if the post does not say who controls it, what has changed and when the next answer will come.

Classical public relations theory clarifies the institutional logic of this problem. Grunig J.E. and Hunt T. distinguished models of public relations that range from press agentry and public information to two-way communication [7]. Akim PR often claims to be dialogue because it appears on interactive platforms. Yet the presence of a comment section does not automatically create two-way communication. If citizens write complaints but the institution only posts more polished content, the relationship remains one-way. Dialogue begins when citizen input changes the institutional response.

Trust theory gives the study its central measurement logic. Mayer R.C., Davis J.H. and Schoorman F.D. conceptualized trust through perceived ability, benevolence and integrity [8]. These dimensions map directly onto akim communication. Technocratic achievement can strengthen perceived ability. Proximity can strengthen perceived benevolence. Transparent explanation can strengthen perceived integrity. Staging can damage all three at once, because a staged message implies that the official wants to look capable, caring and honest without providing enough evidence. Political authenticity research explains why citizens punish staged performance. Luebke S.M. and Engelmann I. developed and validated the Perceived Political Authenticity Scale, treating authenticity as a multidimensional perception of whether a political figure appears credible, true and not artificially manufactured [9]. For akims, authenticity is not created by informal clothing, handshakes or short videos alone. A staged informal scene can look less authentic than a formal but honest explanation. Citizens do not reject official format as such. They reject mismatch between format and substance.

Kazakhstan’s open data context adds another layer. Kassen M. argued that open data in Kazakhstan has potential to support public-sector innovation and civic engagement, but its implementation remains shaped by centralized administrative conditions [10]. This is important because digital infrastructure does not automatically create open communication. An akimat may use platforms, pages, dashboards and online forms while still speaking in a closed voice. Openness requires not only technological availability, but also public usability and institutional willingness to be checked. Survey experiments are suitable for this problem because they isolate the effect of message strategy. Mutz D.C. showed that population-based survey experiments are useful when researchers need to test how frames, messages and information affect attitudes under controlled conditions [11]. In the akim PR context, the same administrative issue can be framed through closeness, output or symbolism. Random assignment allows the researcher to compare these strategies while reducing the influence of prior political attitude, regional identity or personal experience with a specific akim.

Trust measurement must also be disciplined. Burns K.E., Brown P., Calnan M.W., Ward P.R., Little J., Betini G.S., Perlman C.M., Nascimento H.G. and Meyer S.B. developed and validated the Trust in Government Measure as an instrument for assessing trust in government [12]. The present study does not copy that scale mechanically. It adapts the measurement logic to local executive communication by separating trust into sincerity, competence, integrity, responsiveness

and behavioral willingness to contact the institution. This matters because a citizen may consider an akim competent but staged, sincere but powerless, visible but unresponsive.

The media environment in which akim PR circulates is hybrid. Chadwick A. described the hybrid media system as a field where older and newer media logics overlap, compete and reshape political power [13]. Akim PR functions precisely in such a system. A formal press release can become an Instagram post, then a Telegram news item, then a TikTok clip, then a screenshot in a neighborhood chat. The akimat begins the message, but it does not control the later interpretation. Meaning is redistributed through journalists, local bloggers, residents and comment networks.

Bennett W.L. and Segerberg A. introduced the logic of connective action, where digital media enable personalized participation without traditional organization [14]. This concept explains why a resident can challenge official PR without belonging to a party, NGO or media outlet. One person can attach a photo of an unrepaired street under an akim's infrastructure post. Another can publish a video from a school corridor after a ceremonial opening. Public verification becomes distributed, fast and difficult to neutralize by official tone alone. Informality theory helps name the cultural mechanism behind staged official communication. Ledeneva A. and co-editors describe informal practices as "ways of getting things done" that often remain outside formal discourse but structure real social and institutional life [15]. Pokazukha belongs to this field. It is not simply deception. It is an arranged display created for an observing audience. In akim PR, pokazukha appears when the camera becomes more important than the complaint, when the meeting becomes more important than the decision, or when the caption creates the impression of control without showing how control works.

Kazakhstan's information-access framework strengthens the normative standard. The Law "On Access to Information" regulates social relations arising from the constitutional right to freely receive and disseminate information [16]. This means that official communication should not be reduced to image production. A public message should help citizens understand a decision, verify a claim, identify responsibility and use institutional channels. If a post invites approval but hides relevant details, it may be communicatively polished but democratically weak.

Open Government adds the same requirement in digital form. The Electronic Government of Kazakhstan describes Open Government as a mechanism for creating a transparent accountable state, empowering citizens to participate in state management, strengthening anti-corruption work and using technology to improve public administration [17]. Akim PR should therefore be judged not by visual attractiveness alone, but by whether it makes governance more traceable, understandable and usable for citizens.

Materials and Methods

The study is designed as a between-subjects survey experiment with 200 adult participants living in Kazakhstan. Participants are randomly assigned to four equal groups of 50. The control group receives neutral administrative information. Treatment Group 1 receives a proximity-to-people message. Treatment Group 2 receives a technocratic-achievement message. Treatment Group 3 receives a national-symbolic message. No real akim names, real unresolved local conflicts or real regions are used in the stimulus texts. This prevents prior attitudes toward specific officials from contaminating the treatment effect and reduces reputational risk.

Table 2. Experimental design

Group	N	Communication strategy	Stimulus logic	Expected trust mechanism	Main risk
Control	50	Neutral administrative information	A factual notice about a public reception, service schedule or ordinary administrative update	Baseline perception of official communication	Low emotional engagement
Treatment 1	50	Proximity to people	The akim meets residents, listens to complaints and promises follow-up	Benevolence, accessibility, human presence	The scene may look arranged for cameras
Treatment 2	50	Technocratic achievement	The akim reports measurable outputs, repairs, budgets or service indicators	Competence, managerial capacity, administrative control	The message may sound bureaucratic or self-promotional
Treatment 3	50	National symbolism	The akim connects local governance with unity, flag, language, heritage or statehood	Symbolic legitimacy, civic belonging, shared identity	Symbols may look decorative if practical evidence is weak

The experimental design is built around one core principle: only the communication strategy changes. The length, institutional tone and level of detail in the stimuli must remain comparable. If the proximity message is warmer, longer and more detailed than the technocratic message, the result may reflect emotional intensity rather than strategy. If the national-symbolic message is written in a ceremonial tone while the other messages are practical, the comparison becomes unfair. For that reason, each stimulus should be pretested for clarity, length and emotional intensity.

Table 3. Participant allocation in the survey experiment

Experimental condition	Participants	Share of total sample
Neutral administrative information	50	25%
Proximity to people	50	25%
Technocratic achievement	50	25%
National symbolism	50	25%
Total	200	100%

Table 3 shows the internal balance of the experiment. Equal group size reduces avoidable design noise and makes the comparison transparent. If trust is higher in one condition, the difference can be interpreted as a strategy effect more confidently than in an uneven design. The experiment does not ask respondents to evaluate a real akim. It asks them to evaluate a communication pattern that resembles ordinary local executive PR.

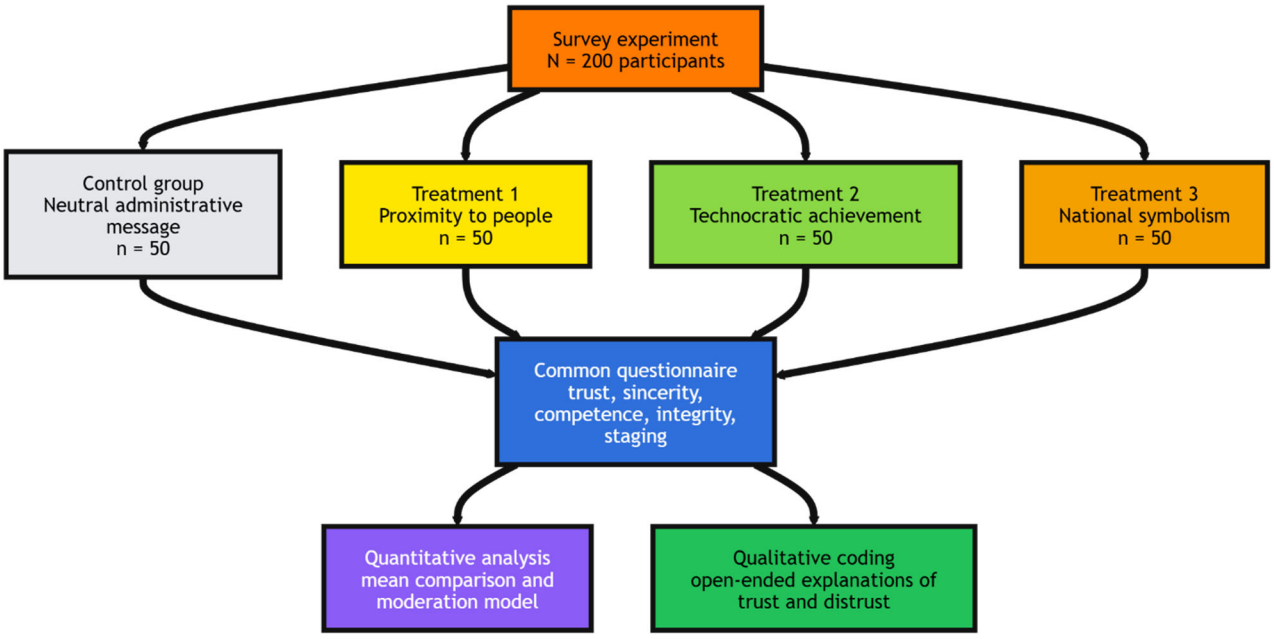

Figure 1. Experimental architecture of the akim PR study

The four-group structure allows the study to separate ordinary official communication from strategic PR framing. The control condition represents routine administrative information: it is factual, neutral and low in emotional intensity. The proximity condition introduces physical and relational closeness. The technocratic condition introduces output, competence and measurable performance. The national-symbolic condition introduces identity, unity and state symbolism.

Table 4. Treatment stimulus logic

Condition	Core message	Typical wording logic	What the respondent evaluates
Control	Administrative notice	"Residents are informed that a public reception will take place at the district akimat on Friday."	Baseline clarity and neutrality
Proximity	Akim among residents	"The akim met residents in the courtyard, heard complaints about lighting and drainage, and instructed departments to prepare a response."	Whether closeness looks sincere or staged
Technocratic achievement	Measurable delivery	"The district repaired local roads, modernized lighting and launched a digital request-tracking mechanism."	Whether competence is credible and useful
National symbolism	Identity and legitimacy	"The akim emphasized unity, civic responsibility and respect for state symbols in connection with local development."	Whether symbolism strengthens trust or replaces practical content

The dependent variables are measured on a 5-point Likert scale from 1 "strongly disagree" to 5 "strongly agree." The main variables are trust in the akim, perceived sincerity, perceived competence, perceived integrity, perceived staging, willingness to share and civic contact

intention. The key moderator is perceived staging. This variable is central because akim PR rarely fails only through disagreement. It fails when citizens think the message was arranged mainly for public image.

Table 5. Measurement instrument

Variable	Example item	Analytical meaning
Trust in the akim	"After seeing this message, I would trust this akim more."	General confidence in the local executive figure
Perceived sincerity	"The message looks sincere rather than performed for public image."	Emotional credibility and absence of obvious choreography
Perceived competence	"The akim appears capable of solving local problems."	Administrative capacity and practical ability
Perceived integrity	"The message seems truthful and not misleading."	Moral credibility of the message
Perceived staging	"The situation looks arranged mainly for cameras."	Recognition of pokazukha
Willingness to share	"I would share this message with other people."	Communicative diffusion
Civic contact intention	"I would be more willing to submit a request to the akimat."	Behavioral trust and readiness to interact

The open-ended part of the questionnaire asks: "What made this message trustworthy or untrustworthy?" Responses are coded into five categories: real problem, human closeness, visible result, staged scene and symbolic excess. This qualitative layer matters because citizens often explain trust through short but precise observations. A respondent may say, "The people looked selected." Another may write, "There was a deadline, so it sounded real." These comments reveal whether the strategy worked through authenticity, competence or symbolic resonance.

The Akim Trust Index is calculated as:

$$\mathrm{ATI}_i = \frac{T_i + S_i + C_i + I_i + R_i}{5}$$

where ATI_i is the Akim Trust Index for respondent i, T_i is general trust, S_i is perceived sincerity, C_i is perceived competence, I_i is perceived integrity and R_i is perceived responsiveness.

The direct strategy effect is calculated as:

$$\mathrm{SE}_k = \mathrm{ATI}_k - \mathrm{ATI}_{control}$$

where SE_k is the effect of strategy k, ATI_k is the mean Akim Trust Index in treatment group k, and $\mathrm{ATI}_{control}$ is the mean index in the control group.

The staging penalty is estimated through a moderation model:

$$\mathrm{ATI}_i = \beta_0 + \beta_1 \mathrm{Strategy}_i + \beta_2 \mathrm{Staging}_i + \beta_3 \left(\mathrm{Strategy}_i \times \mathrm{Staging}_i\right) + \epsilon_i$$

The coefficient β_3 is the central term. If it is negative, the PR strategy loses trust as perceived staging increases. This coefficient translates an ordinary civic judgment - "it looked arranged" - into an empirical relationship. Experimental interpretation follows the logic of field and survey experimentation, where treatment assignment and disciplined comparison protect the researcher from turning impressions into causal claims [18].

Results

The study is expected to produce three analytically distinct patterns. Proximity to people should increase perceived benevolence and sincerity when the scene looks real, specific and problem-oriented. Technocratic achievement should increase perceived competence when indicators are understandable and connected to everyday consequences. National symbolism should produce the most conditional effect: it can strengthen legitimacy when tied to public responsibility, but it can weaken credibility when symbolic language replaces practical explanation.

Table 6. Expected analytical pattern of strategy effects

Strategy	Trust	Sincerity	Competence	Staging risk	Civic contact intention
Neutral administrative information	Low to medium	Medium	Medium	Low	Medium
Proximity to people	High if unstaged	High if citizens speak freely	Medium	High	High if follow-up is clear
Technocratic achievement	Medium to high	Medium	High	Medium	Medium to high if indicators are usable
National symbolism	Medium	Medium	Low to medium	Medium to high	Low to medium unless tied to public service

Proximity is emotionally powerful because it reduces visible distance. The akim does not appear behind a desk, but in the environment where the problem is experienced. A courtyard, rural road, flooded street or school corridor gives the message texture. Citizens may believe that an official who comes to the place understands more than an official who receives a report. Yet proximity is also fragile. If the residents appear passive, if questions look selected, if the camera focuses more on the akim than on the problem, the strategy may collapse into staged closeness.

Technocratic achievement works through a different mechanism. It does not necessarily create warmth, but it can strengthen confidence in administrative capacity. Citizens may trust an akim more when the message names streets, deadlines, responsible units, budget amounts, service indicators or project stages. However, technocratic PR becomes weak when it speaks in the language of upward reporting. “Systematic work is being carried out” does not answer the citizen’s question. “Lighting on Abai Street will be replaced by 15 October, with progress updates every Friday” is more credible because it gives time, place and responsibility.

National symbolism is more delicate. Symbols can carry public meaning. A flag, language, holiday, memorial date or civic slogan can connect local governance with dignity and shared responsibility. But citizens can distinguish between meaningful symbolism and decorative symbolism. A resident may respect national symbols and still distrust an akim who uses patriotic language instead of explaining why heating failed, why a road repair was delayed or why a contractor missed a deadline. Symbolism strengthens trust only when it is attached to service. Detached symbolism becomes ritual language.

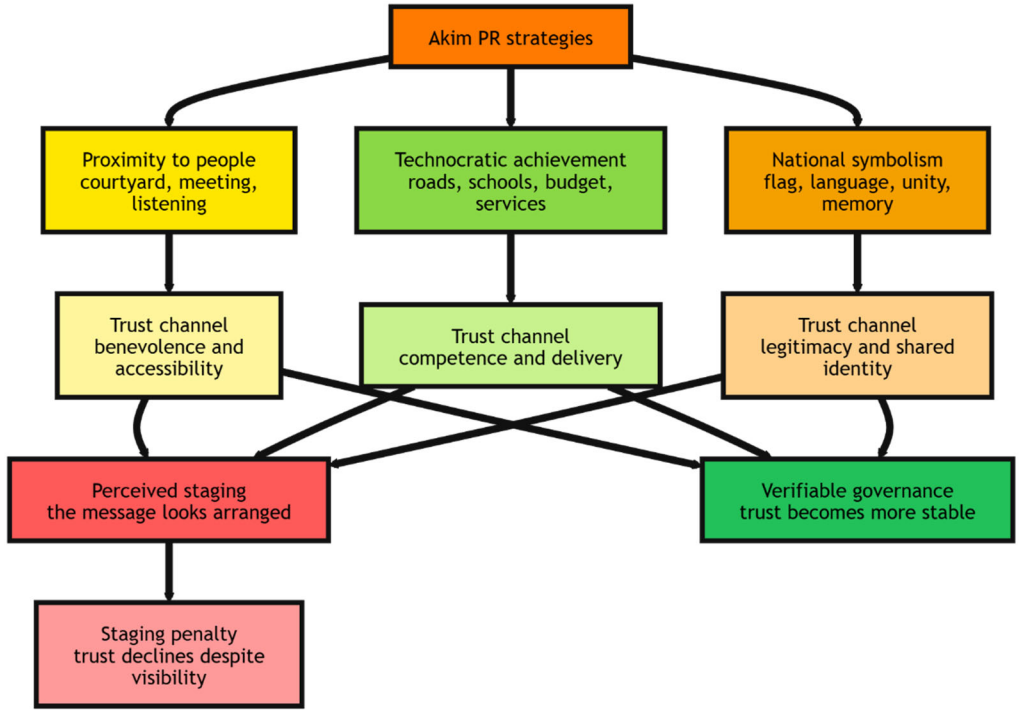

Figure 2. Akim PR strategies and trust mechanisms

Figure 2 shows why no strategy is automatically successful. Proximity, technocratic achievement and national symbolism each contain a plausible trust channel. The difficulty is that each channel also contains a failure path. The citizen does not evaluate only the message's declared meaning. The citizen evaluates the relation between message and reality. If the relation is weak, the strategy turns into evidence of performance.

The expected qualitative responses should make this visible. Respondents who trust proximity content may write that the akim "came to the place," "heard people" or "saw the problem." Respondents who distrust it may write that "the people looked selected," "the camera was more important" or "there was no deadline." Respondents who trust technocratic content may mention numbers, named objects and concrete outputs. Respondents who distrust it may say that the post sounds like a report, not a response. Respondents who accept national symbolism may connect it with dignity and shared duty. Respondents who reject it may say that patriotic words do not solve a local problem.

The staging penalty should appear most strongly in proximity communication. This is not because proximity is weak. It is because proximity promises authenticity more directly than the other strategies. When authenticity is promised and then doubted, disappointment is stronger. A cold administrative notice may not inspire much trust, but it also does not pretend to be emotionally close. A staged proximity post promises closeness and then reveals control. That is why it can damage trust more sharply.

Technocratic achievement is less emotionally risky, but it can still fail. Its failure is often cognitive rather than theatrical. Citizens may not accuse it of staging, but they may find it irrelevant. Numbers without location, deadlines or public meaning do not become competence. They remain report language. The strongest technocratic message is not the one with the largest number. It is the one where the citizen can understand how the number changes daily life.

National symbolism produces the most context-dependent result. It may work well during ceremonial moments, national holidays, memorial events or civic campaigns. It may work poorly when citizens expect practical answers. If a post about a utility failure is written mainly through

symbolic language, the message can look evasive. The problem is not the symbol. The problem is substitution.

Discussion

The central concept of the article is the **staging penalty**. It refers to the decline in trust that occurs when citizens perceive official communication as arranged mainly for image. This penalty is not the same as general political distrust. A citizen may respect the akim's office and still reject a staged scene. A resident may value state symbols and still dislike a symbolic post that avoids a practical answer. The staging penalty is specific: it appears when the form of communication suggests that public appearance has replaced public response.

This concept explains why technically professional PR can fail. A video may be well shot, visually clean, emotionally warm and distributed through the right channels. It may still damage credibility if citizens read it as pokazukha. In that case, professional quality becomes ambiguous. The more polished the performance, the more visible the arrangement. A scene that is too perfect can look less trustworthy than a rough but specific explanation.

Proximity is exposed to this risk because it uses the language of human closeness. The akim walks with residents, listens, nods, gives instructions, stands near the problem. These signals can build trust if they look real. They can destroy it if citizens detect choreography. A resident speaking freely may strengthen the scene even if the question is uncomfortable. A silent group standing around the akim may weaken it because citizens recognize the visual grammar of managed approval.

Technocratic achievement has a different problem. It can produce confidence, but only when administrative output becomes public meaning. A road is not an indicator for residents. It is a safer route, less mud, fewer damaged cars, shorter travel time, easier access to school and less irritation in local chats. A repaired school is not only a completed object. It is warmth, capacity, sanitation, safety and dignity. Akim PR should translate outputs into consequences. Without translation, technocracy looks like upward reporting.

National symbolism requires restraint. In Kazakhstan, symbols of statehood, language and unity have real public weight. They should not be treated as empty decoration. However, symbols cannot repair the gap between post and reality. A citizen may feel pride in national symbols while still demanding accountability from an akim. Symbolic language is strongest when it deepens responsibility. It is weakest when it covers administrative silence.

The concept of bedel gives the issue a cultural layer. Bedel can support governance because reputation helps officials coordinate actors, manage conflict and signal authority. But bedel becomes dangerous when reputation protection becomes the primary purpose of communication. In that case, PR begins to defend the official's image rather than explain the public problem. Citizens often notice this before researchers do. They do not need theory to recognize when the caption is about the akim rather than about the street, school, clinic or resident.

The same logic applies to pokazukha. A pokazukha scene is not necessarily fabricated from nothing. There may be a real meeting, a real inspection, a real object and a real official decision. The problem is selective arrangement. The frame shows control and removes uncertainty. It shows agreement and hides disagreement. It shows activity and hides delay. It shows the akim and weakens the citizen. This is why staged communication can be formally true and still socially untrustworthy.

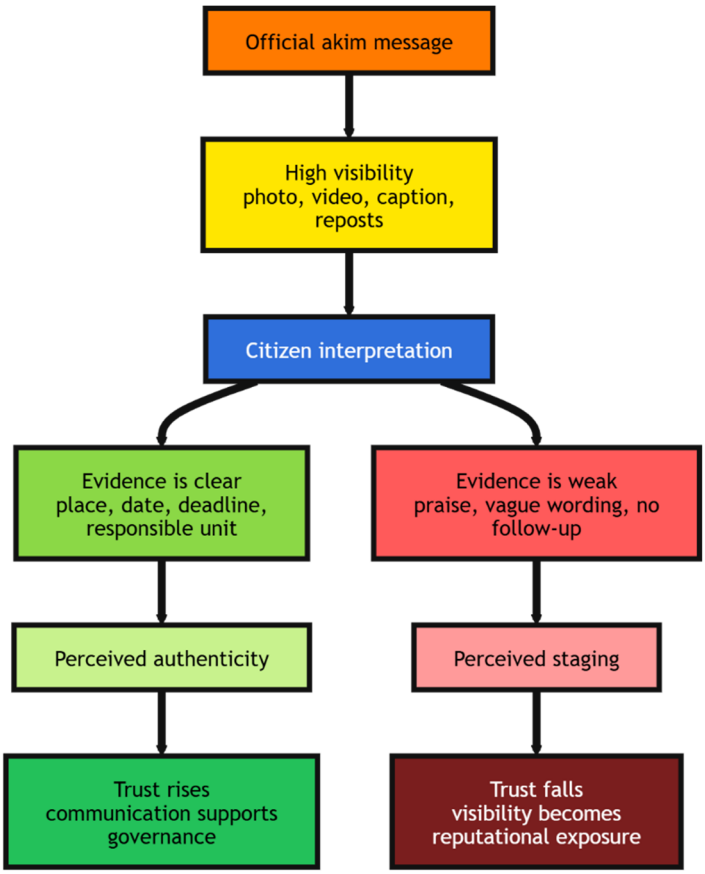

Figure 3. The staging penalty model

Figure 3 changes the evaluation logic of akim PR. Reach is not the final indicator. A post can have high visibility and low trust. A video can be widely shared because it is useful, but also because citizens are angry. A message can look positive in formal reporting and negative in public interpretation. The key question is whether visibility is supported by evidence. If yes, visibility strengthens governance. If no, visibility becomes reputational exposure.

The practical implication is clear: the public problem must be more visible than the official image. If every post centers the akim, citizens begin to read communication as personal PR. If the post centers the problem, affected residents, responsible unit, timeline and follow-up, communication becomes institutional. The akim remains accountable, but the message no longer depends on personal image alone.

Practical Recommendations

Akimat communication should be redesigned around verifiability. Every post about a local problem should answer five questions: what happened, where it happened, who is responsible, what decision was made and when the next update will appear. These are not bureaucratic details. They are trust infrastructure.

Table 7. From image-centered PR to trust-oriented communication

Weak communication habit	Why it damages trust	Stronger alternative
The akim is placed at the center of every story	The public problem becomes background to personal image	Put the problem, affected residents and decision pathway at the center
Captions praise “constant control” without evidence	Citizens cannot verify what control means	Give place, date, responsible unit and follow-up deadline
Residents appear but do not speak	Proximity looks staged	Include real questions, brief citizen quotes and visible disagreement when relevant
Numbers are reported without everyday meaning	Technocratic competence looks like upward reporting	Translate indicators into daily consequences for residents
Symbols replace practical explanation	National language looks decorative	Tie symbols to public duty, service quality and concrete responsibility
Mistakes are hidden	The institution looks artificially perfect	Explain constraints, delays and corrective measures
Feedback route is absent	Communication remains one-way	Link each problem post to a request, consultation or complaint channel

The first recommendation is to reduce hero-centered captions. The akim should not be the only active subject of every sentence. A strong public post does not need to repeat that the akim “personally controls” everything. It should show what is controlled, by whom, until what date and how citizens can check progress.

The second recommendation is to introduce an evidence bundle for problem-related posts. A road post should name the street, project stage, responsible unit, deadline and feedback channel. A school post should include capacity, location, safety status and unresolved work if any remains. A meeting post should mention the questions raised, the decisions made and the next reporting date. Such details may look less cinematic than a polished video, but they are more resistant to cynicism.

The third recommendation is to separate ceremonial communication from problem-solving communication. National-symbolic language is appropriate on national holidays, memorial dates and civic rituals. It should be used with restraint in posts about practical problems. If residents are angry about water, heating, drainage, safety or transport, administrative clarity must come first. Symbolism may support responsibility. It should not replace it.

The fourth recommendation is to introduce a staging-risk review before publication. The question is not whether the post looks attractive. The question is whether it can survive citizen verification.

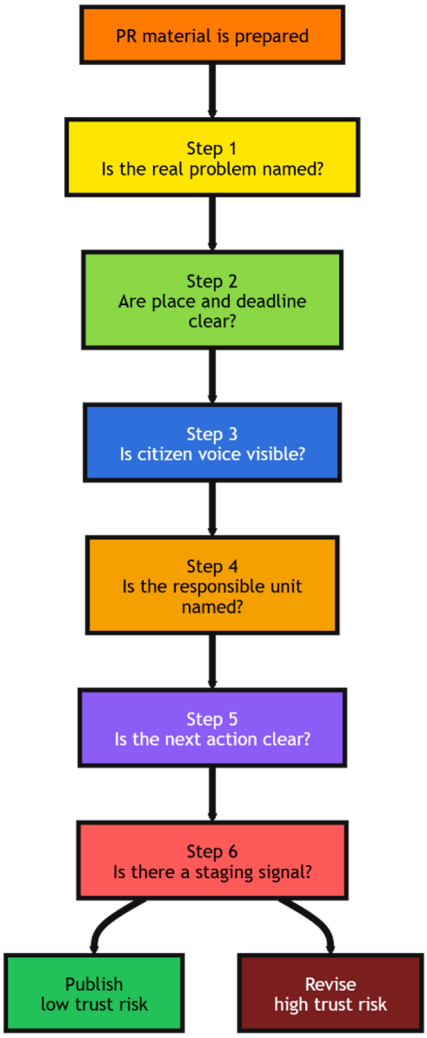

Figure 4. Authenticity Stress Test for akimat communication

The Authenticity Stress Test is deliberately simple. It can be used by a press secretary, department head or external communication consultant before publication. It does not prohibit emotional or symbolic communication. It asks whether the message contains enough public substance to avoid becoming pokazukha. If the problem is vague, the evidence is missing, the citizen is silent and the next step is absent, the post should be rewritten.

The fifth recommendation is to change internal communication indicators. Press services should not be evaluated only by number of posts, positive coverage or reach. More useful indicators include reduction of repeated questions, clarity of deadlines, response speed, correct use of complaint channels, number of public corrections issued and citizen understanding of procedures. Communication must be tied to service quality.

The sixth recommendation concerns language quality. In Kazakhstan's bilingual public sphere, Kazakh and Russian versions of akimat communication must be equally precise, respectful and complete. Mechanical translation signals institutional carelessness. When one language version is polished and another is weak, citizens may interpret it as unequal respect. Language quality is therefore not cosmetic. It is part of trust.

Future Research

Future research should implement the proposed experiment with real respondents across different regions of Kazakhstan. Regional comparison is necessary because residents of large cities, regional centers, small towns and rural districts may interpret akim communication differently. In

large cities, citizens may be more accustomed to social media criticism and more skeptical of polished PR. In smaller settlements, personal contact and local reputation may shape perception more strongly.

A second direction concerns language effects. The same stimulus should be tested in Kazakh and Russian with equal semantic content and comparable tone. This would show whether language, translation quality and communicative respect affect perceived sincerity, competence and staging. In Kazakhstan, language is not only a medium. It is also a sign of institutional attitude.

A third direction concerns platform logic. Instagram, TikTok, Telegram, Facebook and official websites create different expectations. A message acceptable on an official website may look lifeless on Instagram. A short emotional video may work on TikTok but appear unserious in a formal institutional channel. Future experiments should test the same PR strategy across platforms.

A fourth direction concerns visual cues. Camera angle, distance between the akim and residents, clothing, music, editing rhythm, microphones, position of citizens and use of state symbols may all influence perceived staging. A visual experiment could keep the text constant while changing the image. This would show whether citizens respond more strongly to words, visuals or their mismatch.

A fifth direction concerns longitudinal trust. A single post may produce a temporary perception, but trust accumulates through repeated encounters. A panel design could test whether evidence-based communication over several months increases trust more than repeated image-centered communication. This would be closer to real governance, where citizens judge akims through sequences of promises, delays, corrections and outcomes.

A sixth direction concerns behavioral validation. Survey answers should be compared, where ethically possible, with actual civic behavior: willingness to submit a request, register for a public meeting, use an official portal or ask for clarification through formal channels. Trust becomes administratively meaningful when it changes how citizens interact with institutions.

Conclusion

Akim PR works only when visibility is attached to verifiable governance. Proximity to people, technocratic achievement and national symbolism are not weak strategies by themselves. Each has a legitimate trust mechanism. Proximity can humanize local executive power. Technocratic achievement can show administrative competence. National symbolism can connect local governance with civic identity and public responsibility. The problem begins when these strategies produce appearance without evidence.

The staging penalty is the key risk. When citizens perceive pokazukha, communication turns against its own purpose. A polished video becomes proof of distance. A symbolic caption becomes proof of avoidance. A public meeting becomes proof of choreography. Bedel, which can support authority, becomes fragile when protected through performance rather than earned through response.

The proposed survey-experimental design offers a disciplined way to test this problem. It compares three strategies under controlled conditions and measures trust, sincerity, competence, integrity, perceived staging, sharing intention and civic contact intention. This approach moves evaluation away from likes and views toward causal interpretation. It asks whether communication makes citizens more willing to believe, share and interact with the akimat.

For Kazakhstan, the issue has wider significance. Citizens encounter the state through local infrastructure, public services and official communication. A single akim post may look small, but thousands of such posts form the everyday image of government. They teach citizens whether authority performs or responds, whether it decorates reality or explains it, whether it protects

reputation or solves problems. PR becomes public communication only when it helps citizens see, check and use governance. Everything else is visibility without trust.

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Pedagogical Sciences

PEDAGOGICAL EXPERIMENT IN THE DEVELOPMENT OF LIFE SKILLS OF PUPILS WITH AUTISM SPECTRUM DISORDER THROUGH BAKING

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Abstract
The development of practical and life skills represents an important component of the education of pupils with autism spectrum disorder. Educational activities based on real-life situations can provide opportunities for the development of independence, motor coordination, attention, communication and social interaction. The paper presents a pedagogical experiment focused on the development of practical and culinary skills of pupils with autism spectrum disorder through baking activities. The experiment was implemented in a special primary school and was based on structured learning, visual support, individualisation and gradual sequencing of individual work tasks. Particular attention was paid to the adaptation of the activity to the individual abilities, sensory characteristics and level of independence of the pupils. The results of the pedagogical observation indicate that baking can represent a meaningful educational activity through which pupils with autism spectrum disorder acquire practical experience applicable in everyday life. At the same time, the activity creates opportunities for developing autonomy, concentration, fine motor skills, following sequential instructions and experiencing success in a meaningful activity.

Keywords:
autism spectrum disorder, pedagogical experiment, baking, life skills, practical skills, structured learning, special education

1 Introduction

The education of pupils with autism spectrum disorder requires the systematic development of not only academic knowledge but also practical skills that are applicable in everyday life. The ability to perform simple everyday activities independently represents an important prerequisite for increasing the individual's autonomy and participation in family, school and community life.
Practical activities provide pupils with autism spectrum disorder with opportunities to acquire knowledge through direct experience. Unlike activities based predominantly on verbal instruction, practical tasks allow pupils to observe, imitate, repeat and gradually master individual steps of a specific activity. This approach may be particularly relevant for pupils who benefit from visual support and clearly structured learning situations (Magová & Hrčová, 2020).

Baking represents one of the activities that can connect educational, practical and social dimensions. The preparation of food requires following a sequence of steps, manipulating materials and tools, maintaining attention, observing safety and hygiene rules and responding to changes during the activity. At the same time, the activity provides sensory experiences associated with touch, smell, taste, colour and movement.

Gustin et al. (2020) point out that cooking and baking activities may support autonomy and independence in individuals with autism spectrum disorder. Jasmin et al. (2009) also emphasise the importance of motor skills in everyday activities, including manipulation of objects and materials. In this context, baking can be understood not merely as a leisure activity, but as an educational situation in which several areas of the pupil's development can be stimulated simultaneously (Tavassoli & Baron-Cohen, 2012, Magová & Kováčová, 2024).

The aim of the presented paper is to describe a pedagogical experiment focused on the development of practical and life skills of pupils with autism spectrum disorder through baking. Attention is paid particularly to the organisation of the activity, the adaptation of individual tasks, the use of visual support and the possibilities of individualising the educational process (Magová, 2024b).

2 Baking as an educational activity for pupils with autism spectrum disorder

Baking is a complex activity consisting of a sequence of relatively simple tasks. These may include preparing the working environment, putting on protective clothing, washing hands, preparing ingredients, measuring quantities, mixing ingredients, kneading dough, rolling, cutting, decorating, baking and subsequently cleaning the workplace.

From the perspective of special education, the importance of baking lies particularly in the possibility of dividing a complex activity into smaller and clearly defined steps. The pupil can therefore gradually acquire individual components of the activity and subsequently combine them into a meaningful whole.

An important aspect is the use of visual support. A recipe intended for a pupil with autism spectrum disorder should correspond to the pupil's level of understanding and should contain clearly arranged information. Visual cards, photographs, symbols or other forms of visual sequencing can show the pupil what activity is currently being performed and what will follow.

Structured learning can therefore reduce uncertainty and support orientation in the activity. The predictable sequence of individual steps may be particularly useful for pupils who experience difficulties when faced with unexpected changes or extensive verbal instructions.

At the same time, baking offers opportunities for developing fine motor skills. Manipulation with a spoon, bowl, dough, rolling pin, cookie cutters or decorating tools requires different levels of precision and coordination. Individual activities can therefore be selected according to the current abilities of the pupil.

The sensory dimension of baking should also be considered. Pupils may encounter different textures, smells, temperatures, sounds and visual stimuli. For some pupils these experiences may be pleasant and motivating, while for others they may represent a source of discomfort. Therefore, the sensory characteristics of each pupil need to be considered when planning the activity.

3 Pedagogical experiment – baking with pupils with autism spectrum disorder

The pedagogical experiment was implemented in the conditions of a special primary school. Pupils with autism spectrum disorder participated in the activity under the guidance of a special education teacher, teaching assistant and professional cook.

The main objective of the activity was to develop practical and culinary skills through the preparation of gingerbread cookies. The activity was based on the principles of structured learning and was adapted to the individual abilities and needs of the participating pupils.

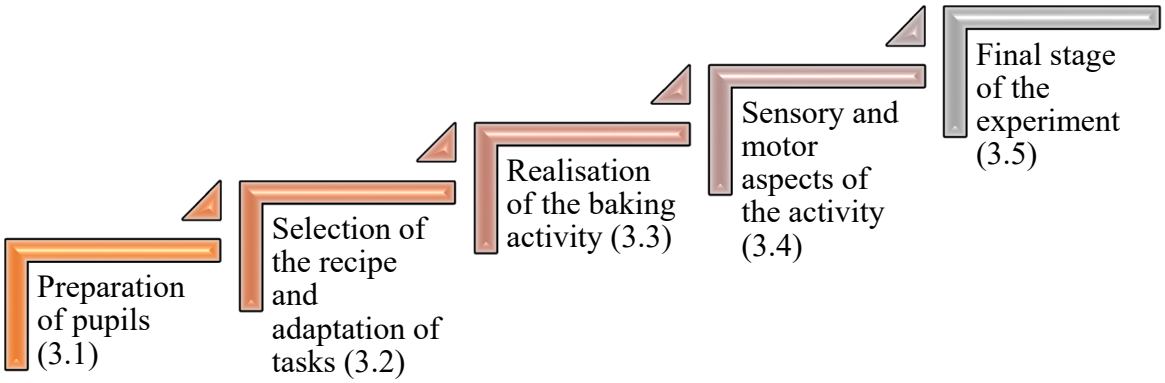
Table 1: The preparation of the activity consisted of several stages

1.	familiarisation with the planned activity
2.	preparation of the working environment
3.	preparation of ingredients and tools
4.	gradual realisation of individual work tasks
5.	baking and observation of the result
6.	packaging and presentation of the finished products

Source: Author's own elaboration based on the results of the pedagogical experiment

The activity was intentionally structured so that each pupil could participate according to their individual possibilities. Not every pupil performed all tasks independently. The level of assistance was adjusted according to the specific abilities of the pupil and the difficulty of the particular activity (Figure 1).

Figure 1: Sequence of Steps in the Pedagogical Experiment



Source: Magová & Kováčová (2024)

3.1 Preparation of pupils

Before beginning the baking activity, pupils were introduced to the environment and the planned sequence of activities. Attention was also paid to hygiene and safety rules.

The pupils were familiarised with protective clothing and the basic organisation of the workplace. Washing hands before handling food was included as an integral part of the activity. The preparation phase was important not only from the perspective of hygiene but also as a means of establishing a predictable structure.

Visual information was used to support understanding of the individual steps. The sequence of activities provided pupils with an overview of what would happen during the baking process and reduced the need for extensive verbal explanations.

3.2 Selection of the recipe and adaptation of tasks

The recipe was selected with regard to the abilities of the pupils. The number of ingredients and the complexity of the individual steps were adapted so that pupils could actively participate in the preparation process.

An important principle was the division of the activity into smaller units. Instead of presenting baking as one complex task, individual pupils were provided with clearly defined activities such as mixing ingredients, rolling dough, cutting shapes or decorating the finished products.

Such an approach makes it possible for the pupil to experience success even when independent completion of the entire activity is not yet possible.

3.3 Realisation of the baking activity

During the baking process, pupils participated in individual practical tasks. They manipulated ingredients and tools, followed the visual sequence and gradually completed the assigned activities.

The degree of independence varied between pupils. Some pupils were able to perform individual activities independently, while others required verbal, visual or physical assistance. The assistance was gradually reduced whenever the pupil demonstrated sufficient competence to continue independently.

An important observation was that the pupils were able to remain engaged in an activity for which they could immediately see a meaningful result. The transformation of individual ingredients into a final product created a clear connection between the activity performed and its outcome.

The baking activity also created opportunities for social interaction. Pupils shared the working environment, waited for their turn, used common tools and observed the activities of their peers. In this way, the activity went beyond the development of individual practical skills and created a natural situation for practising social behaviour.

3.4 Sensory and motor aspects of the activity

Baking provides a rich range of sensory experiences. Pupils came into contact with different textures and materials, including flour, dough and decorating materials. They also experienced different smells and visual changes during the preparation and baking process.

The sensory dimension of the activity needed to be approached individually. While some pupils were willing to manipulate the dough directly, others could require an alternative form of participation. Individualisation was therefore essential to ensure that sensory experiences remained manageable and did not prevent participation in the activity.

From the motor perspective, baking provided opportunities for developing fine motor coordination and visual-motor integration. Activities such as mixing, rolling, pressing, cutting and decorating required different forms of manipulation and precision.

3.5 Final stage of the experiment

The baking activity was completed by dividing, packaging and presenting the finished gingerbread cookies. The pupils could observe the final result of their work and participate in its preparation for presentation.

The products were subsequently presented to parents during a Christmas school event. This final stage gave the activity a social dimension and created an opportunity for pupils to experience the value of their own work.

The finished product therefore became more than the outcome of a practical task. It represented visible evidence of the pupil's participation, effort and ability to contribute to a shared activity.

4 Observations from the pedagogical experiment

The pedagogical experiment demonstrated several areas that can be considered important in the development of practical and life skills of pupils with autism spectrum disorder. The baking activity represented a complex educational situation in which several skills were developed simultaneously. The individual tasks were interconnected and required pupils to follow a sequence, manipulate materials and tools, maintain attention, respond to instructions and participate in a shared activity. At the same time, the activity was adapted to the individual abilities of the pupils, which made it possible to observe different levels of independence and different forms of participation.

Table 2: Observations from the pedagogical experiment

Source: Author's own elaboration based on the results of the pedagogical experiment

4.1 Following a sequence of activities

The first area concerned the pupils' ability to follow a sequence of activities. Baking is inherently structured and requires individual steps to be performed in a particular order. Pupils first prepared the working environment and ingredients and subsequently participated in individual stages of the preparation process. The activity therefore provided a natural opportunity to practise understanding and following a sequence.

For pupils with autism spectrum disorder, a clearly defined sequence can support orientation within an activity and reduce uncertainty about what is expected. In the pedagogical experiment, the baking procedure was divided into smaller and clearly identifiable tasks. Visual support was used to make the sequence more understandable and to provide pupils with information about the current and subsequent activity.

The use of a sequential structure also enabled the pupils to gradually become familiar with the organisation of the activity. Instead of receiving the entire task as one complex instruction, pupils were guided through individual steps. This approach made it possible to adapt the amount of information provided to the individual pupil and to offer assistance only where it was needed.

Following the sequence was therefore not understood merely as completing a recipe, but as an opportunity to practise orientation, predictability and gradual completion of a complex practical activity.

4.2 Independence

The second area was the development of independence. Baking provided pupils with opportunities to perform selected activities without direct assistance from an adult. The level of independence differed between individual pupils and also between particular tasks. While some activities could be performed independently, others required verbal, visual or physical assistance. An important principle of the pedagogical experiment was therefore not to expect all pupils to complete the entire baking process independently. Instead, the focus was placed on identifying those tasks that each pupil could perform independently or with only limited support. This approach allowed the pupils to experience success in activities corresponding to their current abilities.

Even partial independence in a specific task can represent an important step towards greater autonomy in everyday life. Activities such as preparing ingredients, manipulating tools, mixing materials, rolling dough or decorating the finished product can be transferred to other practical situations. Baking therefore created a context in which pupils could practise not only an individual skill but also the experience of acting independently and contributing to the completion of a shared task.

The experiment also showed the importance of appropriately adjusting assistance. Where pupils demonstrated sufficient competence, support could be reduced, allowing them greater responsibility for the activity. Independence was therefore understood as a gradual process rather than as a requirement to perform the entire activity without assistance.

4.3 Motor development

The third area concerned motor development. Baking involves a range of movements requiring different levels of precision, coordination and manipulation. Pupils worked with ingredients and various tools, which provided opportunities to practise fine motor skills and visual-motor coordination (Kováčová, 2024; Magová & Kováčová, 2024).

Activities such as stirring, pouring, manipulating dough, rolling, pressing, cutting or decorating required pupils to coordinate visual information with hand movements. The different tasks also allowed pupils to encounter various levels of resistance and different forms of manipulation. Such experiences provided opportunities for practising controlled movements within a meaningful practical activity (Brčiaková & Čarnická, 2024).

The motor dimension was closely connected with the functional character of the activity. Unlike isolated motor exercises, the movements were performed for a specific purpose. The pupil could immediately see the result of the action, for example when dough was rolled out, a shape was cut or a finished product was decorated. This connection between movement and a visible outcome provided a meaningful context for practising motor skills.

The level of motor involvement was adapted to individual abilities. Some pupils were able to manipulate materials independently, whereas others required assistance with particular movements or tools. The activity therefore allowed different levels of motor participation while maintaining the common goal of completing the baking process.

4.4 Attention and concentration

The fourth area was attention and concentration. The meaningful character of the activity and the expectation of a tangible result created conditions that supported pupils' engagement in the baking process. The activity had a clearly identifiable beginning, sequence and final outcome, which provided pupils with a concrete framework for participation.

The individual stages of baking required pupils to attend to instructions, observe the materials being used and focus on the task currently being performed. In some activities, pupils also had to wait for the next step or observe the actions of another person before continuing with their own task.
An important motivational element was the visible transformation of the ingredients into a final product. Pupils could observe that their actions had a direct relationship with the emerging result. This may be particularly meaningful in educational activities where the connection between an action and its outcome is immediately visible.
At the same time, attention was supported by dividing the complex baking activity into shorter and more manageable tasks. This made it possible to adjust the duration and complexity of individual activities according to the pupils' current abilities (Brčiaková & Čarnická, 2024). The focus was therefore not on maintaining attention for an identical period of time in all pupils, but on enabling each pupil to remain meaningfully engaged for as long as was appropriate.

4.5 Social interaction

The fifth area was social interaction. Although individual baking tasks could be performed independently, the activity took place within a shared social environment. Pupils worked alongside their peers and adults, shared the working space and used common materials and tools.
The shared nature of the activity created natural opportunities for communication and cooperation. Pupils had to respond to instructions, request or accept assistance, wait for access to particular materials and observe the activities of other participants. These situations provided opportunities to practise socially appropriate behaviour within a meaningful context (Brčiaková &Čarnická, 2025).
The social dimension of the activity was also connected with the final outcome. The finished gingerbread products were subsequently presented to parents during a Christmas school event. This provided pupils with an opportunity to experience the social value of their work and to participate in an activity whose result was intended not only for themselves but also for other people.
The experiment therefore demonstrated that baking can create opportunities for social interaction without making social interaction the sole objective of the activity. Communication and cooperation emerged naturally from the practical requirements of the task. For pupils with autism spectrum disorder, such naturally occurring situations can provide meaningful opportunities to practise interaction, participation and shared activity.
Overall, the pedagogical experiment showed that baking can be viewed as a multidimensional educational activity. The individual areas – following a sequence, independence, motor development, attention and concentration, and social interaction – were not developed separately but were interconnected throughout the activity. The value of baking therefore lies precisely in its ability to combine several developmental and educational objectives within one meaningful practical experience.

5 Recommendations for educational practice

Based on the pedagogical experiment, several recommendations can be formulated for the implementation of baking activities with pupils with autism spectrum disorder.
The activity should be structured into clearly defined steps and, where appropriate, supported by visual materials. The complexity of the recipe should correspond to the individual abilities of the pupils. It is appropriate to begin with simple activities and gradually increase their difficulty.
The teacher should also consider the sensory characteristics of individual pupils. Activities involving direct contact with specific materials should not be forced. Alternative forms of participation can be offered when a pupil experiences sensory discomfort.

It is also recommended to provide pupils with opportunities for choice. They may, for example, select a decorating tool, colour or particular activity. Choice-making supports autonomy and gives the pupil greater control over the activity.
Assistance should be individualised and gradually reduced whenever the pupil demonstrates sufficient competence. The objective should not be the perfect execution of the recipe but the gradual development of practical independence.
Baking activities can also be connected with other areas of education. Pupils can practise counting ingredients, recognising quantities, understanding time, reading visual symbols, naming ingredients, following safety rules and communicating with peers.

Conclusion

The presented pedagogical experiment focused on the development of practical and life skills of pupils with autism spectrum disorder through baking activities. The activity was implemented in the conditions of a special primary school and was based on the principles of structured learning, visual support, individualisation and gradual sequencing of individual work tasks (Kováčová, 2024; Magová & Kováčová, 2024). The main value of the experiment was not only in the preparation of the final product, but particularly in the process through which pupils participated in a meaningful practical activity. Baking provided a context in which pupils could perform individual tasks according to their abilities, experience the consequences of their own actions and participate in a shared educational situation.
The findings and observations obtained during the pedagogical experiment indicate that baking can represent a meaningful educational activity for pupils with autism spectrum disorder. Its educational potential is associated with the fact that it naturally combines several areas of development. During the activity, pupils were required to follow a sequence of steps, manipulate ingredients and tools, maintain attention, respond to instructions and participate in a shared activity. These individual areas were interconnected rather than developed separately. The baking process therefore created a complex educational situation in which practical, motor, cognitive and social aspects could be addressed simultaneously.
One of the important aspects of the activity was the possibility of developing pupils' independence. The pupils did not have to complete the entire baking process independently. Instead, the activity was divided into individual tasks, and the level of assistance was adapted to the abilities of each pupil. Some pupils were able to complete particular activities independently, whereas others required different forms of support. Such an approach corresponds to the principle of individualisation, which is particularly important in the education of pupils with autism spectrum disorder. The objective was not to achieve an identical level of performance among all pupils, but to enable each pupil to participate according to their current abilities and possibilities. This aspect is also important from the perspective of the development of life skills. Independence is not necessarily represented by the complete independent performance of a complex activity. It may also develop through the gradual acquisition of individual components of an activity. Preparing ingredients, mixing materials, manipulating tools, rolling dough, cutting shapes or decorating the final product can each represent an individual learning opportunity. When these individual experiences are repeated and gradually connected, they may contribute to the development of practical competence applicable to everyday situations. Baking can therefore be understood as an activity through which pupils have an opportunity to practise not only a specific culinary task but also a broader ability to participate in practical activities (Kučerka & Nagy Rassu, 2025).
Another important dimension of the pedagogical experiment was the use of structure and visualisation. The baking process consists of a clearly identifiable sequence, which makes it suitable for structured educational activities. For pupils with autism spectrum disorder,

predictability and clarity of the task may be particularly important. The visualisation of individual steps provided pupils with information about the activity and supported their orientation within the process. Instead of presenting baking as one complex task, the activity was divided into smaller units that could be gradually completed.

The use of visual support also contributed to the organisation of the educational situation. Pupils could focus on the activity that was currently being performed rather than having to remember the entire procedure at once. This approach can be particularly useful when working with pupils who experience difficulties in processing extensive verbal information. At the same time, the structure of the activity did not mean that all pupils were expected to perform the same tasks in exactly the same way. The structure provided a framework within which individualisation could take place.

The motor dimension of baking should also be emphasised. Manipulation with ingredients and tools required pupils to use different forms of movement and coordination. Activities such as mixing, pouring, rolling, pressing, cutting or decorating created opportunities for fine motor activity and visual-motor coordination. Importantly, these motor activities were performed in a meaningful context. Pupils were not completing isolated motor exercises but were using their movements to achieve a specific and visible result. The connection between the movement performed and the resulting product could provide pupils with a clear understanding of the purpose of the activity.

The pedagogical experiment also demonstrated the importance of attention and concentration within a practical educational situation. Baking required pupils to focus on individual tasks, observe instructions and remain engaged throughout the process. The meaningful character of the activity was particularly relevant in this respect. The pupils could observe the transformation of individual ingredients into a final product, which provided a concrete outcome of their participation. The activity therefore had a clearly recognisable beginning, sequence and conclusion.

At the same time, attention and concentration should be considered in relation to the individual characteristics of pupils with autism spectrum disorder. It would not be appropriate to expect all pupils to remain engaged for the same length of time or to perform the same number of tasks. The educational value of the activity therefore lies in the possibility of adapting its duration, complexity and level of assistance. Such individualisation allows the pupil to participate without creating unnecessary pressure to achieve a uniform performance.

An important dimension of the experiment was also social interaction. Although individual tasks could be completed independently, baking was realised within a shared educational environment. Pupils worked alongside their peers and adults, shared the working space and participated in a common activity. This created natural opportunities for communication, cooperation and practising socially appropriate behaviour.

The social dimension of baking is particularly relevant when considering the broader context of inclusive education. Inclusion cannot be understood solely as the physical presence of a pupil with special educational needs in a mainstream or shared educational environment. It also concerns the pupil's participation in activities, opportunities for interaction, acceptance by others and the possibility of contributing to a shared experience (Kováčová, 2019; Bakhytzhankyzy & Bolatovna, 2026). From this perspective, meaningful practical activities can provide opportunities for pupils with autism spectrum disorder to participate in the life of the educational community in ways that correspond to their abilities.

Inclusive education is based on the principle that pupils with different abilities and educational needs should have opportunities to participate in education and social life without unnecessary barriers. In the case of pupils with autism spectrum disorder, this requires an understanding of their individual characteristics and the adaptation of educational activities to their needs. The aim

is not to eliminate differences between pupils but to create conditions in which these differences do not prevent meaningful participation.

The baking activity presented in this paper can therefore be viewed as one possible example of an inclusive educational approach. The activity allowed pupils with autism spectrum disorder to participate in a common and socially meaningful activity while maintaining an individualised level of support. The pupils did not have to perform all tasks identically. Instead, they could contribute according to their abilities. Such an approach makes it possible to connect individualisation with participation, which represents an important principle of inclusive education.

Inclusion in this context also concerns the role of the teacher and other educational professionals (Kováčová, 2019). The implementation of a practical activity requires the ability to identify the level of assistance needed by individual pupils and to modify the task accordingly. The adult's role is therefore not limited to providing instructions. It includes observing the pupil, assessing the level of independence, providing appropriate support and creating opportunities for the pupil to perform tasks independently whenever possible.

The pedagogical experiment also highlights the importance of avoiding an overly performance-oriented understanding of educational activities. In the case of pupils with autism spectrum disorder, success cannot be assessed solely according to whether the pupil has completed the entire activity without assistance. A pupil who independently completes one stage of the process may have achieved an important educational objective. Similarly, participation in a shared activity, accepting assistance, following one instruction or successfully completing a practical task may represent meaningful progress from the perspective of the individual pupil.

The final stage of the baking activity further strengthened the meaningful character of the experience. The gingerbread products were divided, packaged and subsequently presented to parents during a Christmas school event. This created an opportunity for pupils to experience that their activity had value beyond the immediate educational situation. Their work became something that could be presented to and shared with other people. Such an experience can support the perception of one's own contribution and participation in a wider social context.

The fact that some pupils with autism spectrum disorder did not subsequently consume the prepared gingerbread products is also noteworthy. Their participation in the activity was nevertheless active and meaningful. This observation suggests that the value of baking as an educational activity does not depend exclusively on the consumption of the final product. The process itself can provide opportunities for participation, sensory experience, practical learning, interaction and the experience of creating something tangible.

From the perspective of special education, this observation is important because it draws attention to the distinction between the purpose of an activity and its final product. The educational objective of baking was not simply to prepare food. The activity created a situation in which pupils could practise practical skills, follow a sequence, manipulate materials, participate with others and experience the result of their own work. The final product was therefore one component of a broader educational process.

Baking can also be considered in relation to the development of autonomy. Everyday life consists of numerous practical activities that require a person to understand sequences, use tools, follow instructions and complete tasks. For pupils with autism spectrum disorder, opportunities to practise these skills in structured educational situations can be meaningful. The baking activity represents one example of how an ordinary everyday activity can be transformed into an educational opportunity.

However, the implementation of baking activities requires respect for individual differences among pupils with autism spectrum disorder. The level of communication, motor abilities, independence, attention, sensory characteristics and ability to follow instructions may differ considerably between individual pupils. Consequently, there is no single procedure that would be

equally suitable for all pupils. The activity needs to be planned and modified according to the individual characteristics of the participants.

Individualisation should therefore be regarded as an essential principle rather than an additional component of the activity (Huľová, 2016). The same baking activity may contain different levels of participation for different pupils. One pupil may prepare ingredients, another may mix them, another may roll the dough, while another may participate primarily in decorating the finished product. All these forms of participation can be considered meaningful when they correspond to the individual abilities and educational needs of the pupil (Huľová, 2014).

The pedagogical experiment also indicates the importance of cooperation among the adults involved in the educational process. The activity was realised in the presence of a teacher, teaching assistant and professional cook. Such cooperation made it possible to provide pupils with the necessary support during the individual stages of the activity. In educational practice, cooperation among professionals may contribute to creating conditions in which pupils can participate safely and meaningfully.

The presented experience should nevertheless be interpreted within the limits of the pedagogical experiment. The purpose of the activity was to provide pupils with an educational experience and to observe their participation and performance within the practical activity. The presented observations should therefore not be interpreted as evidence of a statistically measured improvement in individual skills. Rather, they illustrate the educational potential of baking and provide examples of how the activity can be structured and adapted for pupils with autism spectrum disorder.

From this perspective, further pedagogical attention may be directed towards the systematic development of practical and life skills through everyday activities. Baking represents only one possible activity. Similar principles can be applied to other areas of everyday life in which pupils can gradually develop independence, follow structured procedures, participate in shared activities and experience the consequences of their own actions.

The broader context of inclusion is particularly relevant in this respect. Inclusive education requires educational environments in which pupils with autism spectrum disorder are not only present but are also active participants. Practical activities can contribute to this participation by creating situations in which different abilities can be used and where pupils can contribute to a common outcome. The value of inclusion therefore lies not in requiring identical performance from all pupils, but in creating opportunities for each pupil to participate in a meaningful way (Huľová, 2016).

The presented pedagogical experiment demonstrates that baking can serve as a bridge between special educational support, practical learning and social participation. It provides an opportunity to connect individualised education with activities that have a clear meaning in everyday life. At the same time, it can contribute to creating an educational environment in which pupils with autism spectrum disorder are recognised as active participants who can learn, create, cooperate and contribute according to their abilities.

In conclusion, baking can be considered a valuable educational activity for pupils with autism spectrum disorder when it is appropriately structured, visualised and individualised. Its potential lies in connecting practical experience with the development of independence, motor coordination, attention, communication and social participation (Magová, 2024a). The activity can also contribute to inclusive educational practice by creating opportunities for pupils with different abilities to participate in a common meaningful experience.

The most important principle emerging from the pedagogical experiment is therefore not the achievement of a perfect final product, but the possibility of active participation. For a pupil with autism spectrum disorder, successfully completing one task, following one step of a sequence, independently manipulating a tool, cooperating with another person or contributing to a shared

product can represent a meaningful educational experience. Baking consequently offers a practical context in which individual abilities can be recognised and gradually developed while simultaneously creating opportunities for participation in the social environment of the school (Magová & Kováčová, 2024).

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PILOT EVALUATION OF A MOTOR PROGRAMME AIMED AT SUPPORTING MOTOR PERFORMANCE IN PRESCHOOL CHILDREN WITH DYSPRAXIA

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Abstract
The paper presents the results of a pilot evaluation of a motor programme designed to support the development of motor competencies and motor performance in preschool children with dyspraxia. The programme was developed as a systematically structured intervention aimed at strengthening selected basic motor skills and supporting successful participation in movement activities. The research sample consisted of five preschool-aged boys with dyspraxia who participated in the programme over a three-month period, with three intervention sessions per week. Selected motor competencies were assessed before and after the intervention using seven motor tasks focusing on locomotor skills, jumping abilities, and balance. The results indicated a positive change in the performance of all five participants. The mean total score increased from 15.4 points at baseline to 25.8 points at post-intervention assessment. The greatest improvement was observed in hopping on the right leg and in two-foot jumping tasks. Due to the very small sample size and the ordinal nature of the assessment, the Wilcoxon signed-rank test was used to compare baseline and post-intervention scores. All five participants demonstrated a positive direction of change in the total score. The two-tailed test yielded $p = 0.0625$, which did not reach statistical significance at the $\alpha = 0.05$ level. Given the directional hypothesis of improvement following the intervention, the one-tailed test yielded $p = 0.03125$. The calculated effect size was $r = 0.84$, indicating a very large effect. The findings suggest a positive trend in the development of the assessed motor competencies and provide preliminary support for the potential of a systematically structured motor programme to enhance the motor performance of preschool children with dyspraxia. However, due to the pilot nature of the study and the very small sample size, the findings should be interpreted with caution and further investigated in a larger sample.

Keywords: dyspraxia, preschool age, motor competencies, motor performance, motor training, motor coordination, pilot study

Introduction
Motor difficulties in children with dyspraxia represent an important area that requires attention already during the preschool period (Kováčová & Hladush, 2024). Difficulties in motor coordination, planning, and execution may affect the acquisition of basic motor skills and may also influence the child's overall physical activity (Čarnická, 2026), independence, and willingness to participate in movement-based games and activities. The preschool period represents an

important developmental stage for supporting the acquisition of basic motor competencies through appropriately selected and systematically implemented motor activities (Kováčová & Krška, 2024).

An important starting point, as emphasized by Hubinák (2025), is to respect the child's natural movement and to incorporate motor activities into play and everyday activities. Such an approach creates opportunities for repeated practice of motor skills without placing excessive demands on children with dyspraxia, while emphasizing the gradual achievement of success (Rassu Nagy, 2026).

The manifestations of dyspraxia may affect **both gross and fine motor skills, balance, coordination, accuracy, timing, and motor planning**, with movement often being slower, less precise, or appearing clumsy (Wang, Tseng, Wilson, & Hu, 2009). In everyday functioning, these difficulties may become apparent in activities such as running, jumping, catching and throwing a ball, riding a bicycle, manipulating objects, or performing graphomotor tasks. From an intervention perspective, therefore, **systematic practice of motor skills and, in particular, a task-oriented approach** are emphasized, as current research indicates that these approaches may support improvements in motor competence and motor performance (Zwicker et al., 2012; Yu, Burnett, & Sit, 2018; Gao, Yang, Xu, Huang et al., 2025).

A motor programme designed for children with dyspraxia should therefore not be based solely on increasing physical performance, but primarily on developing the ability to successfully perform specific motor tasks (Kováčová & Magová, 2025). Appropriate task difficulty, regularity, repetition, progression, and individual adaptation of motor activities play an important role. At the same time, creating positive experiences associated with the child's own motor performance may contribute to further participation in physical activities. These considerations provided the basis for the **pilot evaluation of a motor programme aimed at supporting the motor performance of preschool children with dyspraxia**. The programme draws on the principles proposed by Platt (2011) and is designed to systematically develop selected basic motor competencies, particularly locomotor skills, coordination, jumping activities, and balance. Attention is focused not only on overall changes in motor performance but also on individual changes within the specific motor domains assessed.

Characteristics of the Motor Programme for Preschool Children with Dyspraxia

In designing the motor programme, we drew on the structure of the motor programme described by Platt (2011) as a strength and conditioning programme, which is designed to be implemented over an eight-week period. Given the specific needs of children experiencing difficulties in motor performance, the original programme was modified not only in terms of the number of repetitions of individual exercises but also with regard to the duration of the intervention. The motor stimulation period was extended to 16 weeks, allowing the programme to better accommodate the individual pace of the children and their specific motor needs. For illustrative purposes, we also present the individual exercises recommended by Platt (2011) for implementation during specific weeks of the programme (Table 1).

The original version of the programme was presented by the authors (Kováčová & Magová, 2025) at a symposium focused on dyspraxia as a potential tool for supporting and developing children experiencing difficulties in motor performance, including children whose motor manifestations may indicate the presence of developmental motor dyspraxia.

Table 1. Motor Programme According to Platt (2011)

Week	Specific exercises
1.	Back-and-forth walking at a brisk pace (6 repetitions); Hopping on the right leg back and forth at a brisk pace (2 repetitions); Hopping on the left leg back and forth at a brisk pace (2 repetitions); Two-foot jumps back and forth at a brisk pace (2 repetitions).
2.	Back-and-forth running (6 repetitions); Hopping on the right leg back and forth (6 repetitions); Hopping on the left leg back and forth (6 repetitions); Two-foot jumps back and forth (6 repetitions).
3.	Back-and-forth running (6 repetitions); one race: running back and forth; Hopping on the right leg back and forth while running (6 repetitions); hopping on the left leg back and forth while running (6 repetitions); two-foot jumps back and forth while running (6 repetitions); bench jumping (Phase 1) – 2 sets of 10 repetitions.
4.	Back-and-forth running (6 repetitions); one race: running back and forth; relay race with the class divided into two groups; hopping on the right leg back and forth while running (6 repetitions); hopping on the left leg back and forth while running (6 repetitions); two-foot jumps (with both feet touching the ground between jumps), followed by running back (6 repetitions); bench jumping (Phase 1) – 6 sets of 10 repetitions.
5.	Back-and-forth running (6 repetitions); one race: running back and forth; relay race with the class divided into two groups; hopping on the right leg back and forth while running (6 repetitions); hopping on the left leg back and forth; two-foot jumps (with both feet touching the ground between jumps), followed by running back (6 repetitions); bench jumping (Phase 1) – 6 sets of 10 repetitions; bench jumping (Phase 2) – 2 sets of 10 repetitions.
6.	Back-and-forth running (6 repetitions); one race: running back and forth; relay race with the class divided into two groups (2 repetitions); hopping on the right leg forward, followed by running back (6 repetitions); hopping on the left leg forward, followed by running back (6 repetitions); two-foot jumps (with both feet touching the ground between jumps), followed by running back (6 repetitions); bench jumping (Phase 2) – 6 sets of 10 repetitions.
7.	Back-and-forth running (6 repetitions); one race: running back and forth; relay race with the class divided into two groups (2 repetitions); hopping on the right leg forward, followed by running back (6 repetitions); hopping on the left leg forward, followed by running back (6 repetitions); two-foot jumps (with both feet touching the ground between jumps), followed by running back (6 repetitions); bench jumping (Phase 2) – 9 sets of 10 repetitions.
8.	Back-and-forth running (6 repetitions); one race: running back and forth; relay race with the class divided into two groups (2 repetitions); hopping on the right leg forward, followed by running back (6 repetitions); hopping on the left leg forward, followed by running back (6 repetitions); two-foot jumps (with both feet touching the ground between jumps), followed by running back (6 repetitions); bench jumping (Phase 2) – 12 sets of 10 repetitions.

Source: Platt (2011), adapted by Kováčová & Magová (2025)

For the implementation of the motor programme, we assumed that the development of motor competencies in children with dyspraxia may be complicated by difficulties in motor planning, coordination, balance, and the execution of more complex movement sequences. Physical activity may represent not only a means of developing motor skills but also an opportunity for children to

gain positive experiences with their own bodies and motor performance. Repeated experiences of successfully completing motor tasks may support not only motor performance itself but also the child's willingness to participate in further physical activities. From this perspective, we consider it important to develop motor programmes that respect the individual abilities of each child, the gradual acquisition of motor skills, and the need for appropriately provided feedback.

Research Design

The main aim of the pilot study was to **evaluate the preliminary effect of the developed motor programme on selected motor competencies in preschool children with dyspraxia.**

The following partial tasks were derived from the main aim:

1. to assess the level of selected motor competencies in the children before the start of the programme;
2. to implement a systematic motor programme over a period of three months;
3. to assess the level of the monitored motor competencies after completion of the programme;
4. to compare the pre-intervention and post-intervention results of individual participants;
5. to assess the observed progress or regression in overall motor performance.

We assumed that participation in the structured motor training programme would result in an increase in the level of the monitored motor competencies in all children with dyspraxia.
Given the pilot nature of the study, the research sample was selected purposively from participants who met the predetermined eligibility criteria for participation in the programme.

The participants were characterized primarily in terms of their motor functioning and the difficulties associated with their motor performance.

- **Adam (P1).** Adam demonstrated a history of atypical psychomotor development during early childhood. He achieved independent walking at 15 months; however, his gait was unusual and accompanied by frequent tripping, which also led to consideration of possible muscular dystrophy. More pronounced difficulties were observed in the area of fine motor skills. His entry into the first grade of primary school was postponed by one year.
- **Bartholomew (P2).** Pregnancy and early development proceeded without major complications; however, his psychomotor development was delayed. He achieved independent sitting at eight months and independent walking at 18 months. More pronounced difficulties were observed in grasping and manipulating objects, and weaknesses in fine motor skills persisted. His drawing skills were at the *tadpole* stage. Among physical activities, he was able to use a scooter but was unable to ride a bicycle. His entry into the first grade of primary school was postponed by one year.
- **Cyril (P3).** Cyril's psychomotor development was mildly delayed, while walking and running developed with only minimal delay. More pronounced motor difficulties began to emerge at approximately three years of age, particularly in catching a ball, using a scooter, hopping on one leg, and participating in physical activities in general. He refused to ride a bicycle.
- **David (P4).** David demonstrated delayed psychomotor development and overall difficulties in motor performance, which had been present from early childhood. He was unable to ride a bicycle or use a scooter. He avoided movement-based and ball games and, in situations requiring active participation in physical activities, he often withdrew from the group.
- **Emil (P5).** Emil's psychomotor development was delayed, and difficulties in motor functioning had been present from early childhood. During activities, he also demonstrated a lower willingness to cooperate and participate in physical activities. His entry into compulsory primary education was postponed by one year.

The motor programme was designed as a systematic intervention aimed at supporting the development of basic motor competencies in children with dyspraxia. The programme was implemented over a period of **three months**, with the motor intervention taking place **three times per week**.
The programme focused primarily on:

- developing locomotor skills;
- developing coordination skills;
- practicing jumping and hopping activities;
- developing dynamic and static balance;
- improving coordination between the right and left sides of the body;
- repeated practice and stabilization of motor patterns.

Individual motor tasks were implemented with respect for the child's individual level of ability. An important principle of the programme was progression from simpler motor demands to more complex ones, together with repeated practice.
The study was designed as a **pilot intervention study with a single-group pretest–posttest design**. The level of motor competencies was assessed before the beginning of the motor programme and after its completion. This design made it possible to compare the individual performance levels of the participants and, at the same time, to assess the overall change within the group.
Given the pilot nature of the study and the small number of participants, the aim was not to generalize the findings to the population of children with dyspraxia, but rather to **evaluate the feasibility of the programme and identify preliminary changes in the motor performance of its participants**. In the context of the present study, **motor performance** is understood as the level of successful completion of selected motor tasks, with a higher level of task mastery represented by a higher score achieved.

Assessment of Pre- and Post-Intervention Motor Performance

The level of motor performance of individual participants was assessed using seven motor tasks: walking, running, hopping on the left leg, hopping on the right leg, two-foot jumping, maintaining balance on the left leg, and maintaining balance on the right leg.
Performance in each task was assessed using a **five-point ordinal scale ranging from 1 to 5**, with a higher score indicating a higher level of mastery of the respective motor task.
The assessment was conducted at two time points: **baseline assessment** before the start of the programme and **post-intervention assessment** following completion of the three-month intervention.

Table 2. Differences Between Participants in the Assessment of Motor Performance

Participant	Baseline score	Post-intervention score	Difference
P1	16	25	+9
P2	21	25	+4
P3	12	22	+10
P4	14	29	+15
P5	14	28	+14
Mean	**15,4**	**25,8**	**+10,4**

Source: Authors' own processing of the pilot study results

The mean score of the assessed group increased from **15.4 points to 25.8 points**, representing an absolute mean increase of **10.4 points**. A positive change was observed in all participants. The

largest absolute increases were recorded for participants P4 (+15 points) and P5 (+14 points). Participant P3 showed an increase of 10 points, while P1 improved by 9 points. The smallest, but still positive, change was observed in P2 (+4 points). Overall, the results indicate a **consistent direction of change**, as none of the participants demonstrated a decrease in their total score following completion of the programme.

Table 3. Assessment of Motor Performance in Terms of Group Motor Performance

Motor domain	Baseline score	Post-intervention score	Difference
Walking	2,60	3,60	+1,00
Running	2,20	3,80	+1,60
Hopping – left leg	2,00	3,20	+1,20
Hopping – right leg	1,80	4,20	**+2,40**
Two-foot jumping	2,20	4,20	**+2,00**
Balance – left leg	2,20	3,40	+1,20
Balance – right leg	2,40	3,40	+1,00

Source: Authors' own processing of the pilot study results

The most pronounced improvement was observed in **hopping on the right leg**, where the mean score increased from 1.80 to 4.20 points. A substantial improvement was also observed in **two-foot jumping**, with the mean score increasing from 2.20 to 4.20 points. A positive change was observed across all seven assessed areas.

Analysis of the Pilot Study Results

For each of the statements, we present the procedure used to assess the effectiveness of the motor programme within the pilot study.

Table 4. Median of the Total Motor Performance Score 1

Motor domain	Baseline median	Post-intervention median	Change
Walking	**3**	**4**	+1
Running	**2**	**4**	+2
Hopping – left leg	**2**	**3**	+1
Hopping – right leg	**2**	**4**	**+2**
Two-foot jumping	**2**	**4**	**+2**
Balance – left leg	**2**	**3**	+1
Balance – right leg	**2**	**3**	+1

Source: Authors' own processing of the pilot study results

Table 5. Median of the Total Motor Performance Score 2

	Baseline	Post-intervention	Change
Total score – median	14	25	+11

Source: Authors' own processing of the pilot study results

The median total motor performance score increased from **14 points at baseline to 25 points at post-intervention assessment**. A positive change in the median was observed across all assessed motor domains, with the most pronounced improvements observed in **running, hopping on the right leg, and two-foot jumping**.

Table 6. Progress in Motor Performance at the Individual Level

Participant	Baseline score	Post-intervention score	Difference	Improvement
P1	16	25	**+9**	56,3 %
P2	21	25	**+4**	19,0 %
P3	12	22	**+10**	83,3 %
P4	14	29	**+15**	107,1 %
P5	14	28	**+14**	100,0 %

Source: Authors' own processing of the pilot study results

Based on the tabulated results, all five participants demonstrated improvement in their motor performance, meaning that **none of the participants showed a decline**. The total number of points increased from 77 at baseline to 129 after the intervention, representing an absolute increase of **52 points**. The mean score per participant increased from **15.4 to 25.8 points**, corresponding to a mean improvement of **10.4 points**.

When the **Wilcoxon signed-rank test** was applied to the total scores of the five participants, the result was **W = 15.0; p = 0.03125** for the one-tailed hypothesis that post-intervention scores were higher than baseline scores. Thus, under the **one-tailed hypothesis**, the difference reached statistical significance at the $\alpha = 0.05$ level. However, this result was not statistically significant in the **two-tailed test**, where **p = 0.0625**, and therefore the hypothesis of a statistically significant difference between baseline and post-intervention scores cannot be confirmed at the $\alpha = 0.05$ level.

This finding is important to consider in the context of the very small sample size (**N = 5**). With such a small sample, the exact Wilcoxon signed-rank test is highly conservative. Even when all five participants show improvement, the smallest possible two-tailed p-value is **0.0625**, meaning that statistical significance at the conventional $\alpha = 0.05$ level cannot be achieved using a two-tailed test in this particular situation. Nevertheless, the consistent direction of change across all participants provides evidence of a **positive shift in the level of the assessed motor competencies following participation in the motor programme**.

The Wilcoxon signed-rank test therefore indicated a positive change in the total motor performance score between baseline and post-intervention assessment (**W = 15; p = 0.0625; two-tailed test**). Given the small sample size, the **effect size was also assessed**.

Table 7. Calculation of Effect Size

N	5
Wilcoxon signed-rank test	**W = 15**
Two-tailed p	**p = 0,0625**
One-tailed p	**p = 0,03125**
Effect size	**r ≈ 0,84**

Source: Authors' own processing of the pilot study results

The effect size of r = 0.84 indicates a very large effect. As a general guideline, effect sizes of approximately 0.10, 0.30, and 0.50 are commonly interpreted as small, medium, and large effects, respectively. Thus, r = 0.84 indicates a very large effect. This finding is important because, although the two-tailed test yielded p = 0.0625, which does not reach the conventional significance level of 0.05, the magnitude of the effect indicates a substantial practical change in the assessed motor performance. Given the very small sample size (N = 5), the p-value is highly sensitive to the number of participants. The results should therefore be interpreted primarily as evidence of a pronounced positive change rather than as definitive evidence of programme effectiveness.

Summary of the Findings

Given the very small sample size and the ordinal nature of the assessment, the Wilcoxon signed-rank test was used to compare baseline and post-intervention results. The analysis of the total score revealed a consistent positive direction of change across all five participants. The two-tailed test yielded p = 0.0625, which does not represent a statistically significant difference at the conventional significance level of $\alpha = 0.05$. The one-tailed test, corresponding to the directional hypothesis of improvement following the intervention, yielded p = 0.03125.

It is important to emphasize that N = 5 represents a very small research sample. Therefore, the statistical findings cannot be interpreted in isolation and cannot be considered evidence of the effectiveness of the programme in the broader population of children with dyspraxia. From the perspective of practical significance, however, it is noteworthy that all five participants achieved a higher total score following completion of the programme than at baseline. Together with the large effect size (r = 0.84), these findings indicate a pronounced positive shift in the assessed motor performance and provide a basis for further investigation of the programme in a larger sample.

Limitations of the Study

The main limitation of the study is the small sample size (N = 5). Therefore, the findings cannot be generalized to the broader population of children with dyspraxia. Another limitation is the absence of a control group, which would have made it possible to more precisely distinguish the effects of the intervention from natural developmental changes in the children. The findings should therefore be understood primarily as pilot findings that provide a basis for further evaluation of the programme in a larger research sample. Future research should consider increasing the sample size, including a control group, extending the follow-up period, and complementing quantitative assessment with qualitative data capturing children's behaviour during physical activities, their level of independence, motivation, and subjective experience of success.

Conclusion and Discussion

The results of the pilot evaluation of the structured motor training programme indicated a positive change in the level of the assessed motor competencies among all participants. The observed trend was consistent not only in the total score but also across the individual motor tasks assessed. The most notable improvement was observed in hopping on the right leg and two-foot jumping. These tasks represent more complex motor demands involving coordination, balance, motor planning, and the ability to stabilize motor performance.

Improvement was also observed in walking and running, which represent basic locomotor activities and constitute a natural part of children's everyday physical functioning.

The findings can also be considered from the perspective of individual differences among the participants. Participant P2 achieved the highest baseline performance and simultaneously demonstrated the smallest absolute increase. In contrast, children who entered the intervention with a lower initial level of performance demonstrated greater improvement following completion of the programme. This finding may suggest that an individually adapted motor programme could

be particularly beneficial for children who begin an intervention with a lower level of mastery of basic motor tasks.

At the same time, it is important to emphasize that the findings cannot be interpreted as definitive evidence of a causal effect of the programme. The study did not include a control group, and the sample size was very small. The observed changes may also have been influenced by other factors, including natural maturation, increased familiarity with the assessed tasks through repeated practice, and individual differences in the children's health status.

Gao, Yang, Xu, Huang et al. (2025) report that motor-based interventions (MBIs) represent the primary intervention approach for children with developmental coordination disorder (DCD). In recent years, a substantial number of relevant randomized controlled trials (RCTs) have been published; however, the effectiveness of different types of motor-based interventions across individual outcome measures remains inconclusive.

Despite these limitations, the findings are considered relevant from the perspective of the pilot evaluation of the developed programme. The fact that all participants achieved a higher total score following the intervention provides preliminary support for the assumption that a systematically structured motor programme may represent a useful approach to supporting the motor performance of children with dyspraxia. These preliminary findings should be further examined in studies involving larger samples, appropriate control conditions, and longer follow-up periods.

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МОДЕЛЬ-БАЗИРУЮЩИЕСЯ, МОДЕЛЬ-СВОБОДНЫЕ И ГИБРИДНЫЕ МЕТОДЫ ОБУЧЕНИЯ РОБОТОВ: АНАЛИЗ ПОДХОДОВ И ГРАНИЦ ПРИМЕНИМОСТИ В СРЕДАХ С КОНТАКТНЫМ ВЗАИМОДЕЙСТВИЕМ

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Аннотация. В статье рассматриваются современные подходы к обучению роботов на основе искусственного интеллекта: модель-базирующие, модель-свободные и гибридные методы обучения с подкреплением. Проведён сравнительный анализ их эффективности, включая sample-эффективность и точность прогнозирования динамики. Отдельное внимание уделено ограничениям традиционных алгоритмов ИИ при работе в средах с контактным взаимодействием, трением, параметрической неопределённостью и нелинейностями. Показано, что существующие методы преимущественно апробированы на моделях жёстких тел без учёта контактов, что формирует исследовательский разрыв и обосновывает необходимость разработки физически-информированных (physics-informed) архитектур самообучения роботов.

Ключевые слова: обучение с подкреплением; физически-информированное обучение; модель-базирующее обучение; гибридное обучение; контактное взаимодействие; трение; робототехника.

Введение

Использование методов искусственного интеллекта для самообучения роботов остаётся одним из наиболее активно развивающихся направлений робототехники. Способность робота самостоятельно приобретать и уточнять модель собственного движения и взаимодействия со средой напрямую определяет его адаптивность к новым задачам и условиям. Вместе с тем перенос политик, обученных в симуляции, на реальное оборудование (sim-to-real) остаётся серьёзной проблемой: реальные среды содержат контакты, трение, износ, изменение параметров и иные нелинейные эффекты, которые сложно воспроизвести в модели среды.

Целью настоящего обзора является анализ современных подходов к обучению роботов — модель-базирующих, модель-свободных и гибридных — и определение ограничений традиционных алгоритмов искусственного интеллекта при работе в средах с контактами, трением, неопределённостью и нелинейностями. Такой анализ формирует основу для дальнейшей разработки архитектуры физически-информированного (physics-informed) алгоритма самообучения, учитывающего динамику и контактные взаимодействия робота со средой.

1. Модель-базирующие методы обучения роботов

Модель-базирующее обучение с подкреплением (Model-Based Reinforcement Learning, MBRL) строится на явном обучении модели динамики среды — функции перехода между состояниями и функции вознаграждения. Полученная модель используется для планирования действий или для генерации дополнительных («воображаемых») траекторий, на которых обновляется политика робота. Ключевое преимущество такого подхода — существенно более высокая sample-эффективность по сравнению с безмодельными методами, поскольку значительная часть обучения переносится с реального взаимодействия со средой на вычисления с обученной моделью [1; 2].

Классические подходы данного направления, такие как PILCO, аппроксимируют динамику с помощью гауссовских процессов [3], тогда как более поздние методы — Dreamer и его развития — используют латентные модели динамики на основе глубоких нейронных сетей для обучения политики через обратное распространение по воображаемым траекториям [4].

Отдельное направление MBRL связано с использованием физической структуры системы при построении модели динамики. Так, лагранжевы (Deep Lagrangian Networks) и гамильтоновы нейронные сети встраивают в архитектуру модели уравнения движения твёрдого тела, что заставляет модель по построению соблюдать законы сохранения энергии и импульса [5]. В работе Ramesh и Ravindran (2023) на семи эталонных средах с шарнирными механизмами (Reacher, Pendulum, Cartpole, Acrobot и др.) показано, что физически-информированная лагранжева модель динамики (MBRL-LNN) достигает значительно меньшей ошибки прогнозирования состояния и требует на порядок меньше взаимодействий со средой по сравнению со стандартной нейросетевой моделью (MBRL-DNN) и безмодельным алгоритмом Soft Actor-Critic; при этом преимущество особенно выражено в средах, чувствительных к начальным условиям, где численные ошибки быстро накапливаются [6]. Важно, что авторы этой работы прямо ограничивают область применения моделью движения твёрдого тела без контактов и трения, обозначая их учёт как направление будущей работы [6] — это прямо указывает на разрыв, который предстоит закрыть в задачах контактного взаимодействия.

2. Модель-свободные методы обучения роботов

Модель-свободное обучение с подкреплением (Model-Free RL) не строит явную модель динамики среды, а напрямую обучает отображение состояние → действие (политику) либо оценочную функцию по опыту взаимодействия со средой. К числу широко используемых в робототехнике алгоритмов этого класса относятся Proximal Policy Optimization (PPO) [7], Deep Deterministic Policy Gradient (DDPG) [8] и Soft Actor-Critic (SAC) [9].

Главное преимущество безмодельных методов — устойчивость к неточностям модели среды: поскольку модель динамики не строится, ошибки её аппроксимации не могут исказить обучаемую политику, как это происходит в MBRL при использовании неточной модели. Это делает модель-свободные методы предпочтительными в сложных, слабо формализуемых средах. Оборотная сторона этого преимущества — низкая sample-эффективность: для получения работоспособной политики таким алгоритмам обычно требуется на один–два порядка больше взаимодействий со средой, чем модель-базирующим аналогам [1; 6], что на реальном роботе означает часы или сутки непрерывного физического взаимодействия и повышенный износ оборудования.

3. Гибридные подходы

Гибридное обучение объединяет модель-базирующие и модель-свободные компоненты, стремясь совместить sample-эффективность первых с устойчивостью вторых к ошибкам модели. Методы этой группы различаются способом объединения компонентов. Model-Based Policy Optimization (MBPO) использует обученную модель динамики только для

генерации дополнительных обучающих данных, при этом сама политика обновляется безмодельным алгоритмом, что позволяет ограничить влияние ошибок модели за счёт коротких прогнозных горизонтов [10].

Иной вариант гибридизации предложен Pinosky и соавторами (2023): вместо совместного использования модели на каждом шаге обучения авторы разрабатывают детерминированный и стохастический механизмы переключения между модель-базирующей и модель-свободной политикой в зависимости от текущего состояния и точности модели. Подход апробирован как в симуляции, так и на реальной задаче манипуляции, и демонстрирует прирост как в скорости обучения, так и в итоговом качестве политики [11]. Более ранние работы предлагали разделять модель-базирующий и модель-свободный компоненты через иерархические смеси экспертов, выбирающие лучшую из двух политик в конкретном состоянии [11].

В целом гибридные методы можно рассматривать как практический компромисс: они не устраняют фундаментальную проблему — качество и переносимость гибридной схемы по-прежнему определяются тем, насколько точно исходная модель динамики описывает физику взаимодействия робота со средой, включая контактные и фрикционные эффекты.

4. Ограничения традиционных алгоритмов ИИ в средах с контактами, трением, неопределённостью и нелинейностями

Рассмотренные выше методы – как модель-базирующие, так и большинство их гибридных модификаций – в подавляющем большинстве апробированы на моделях движения твёрдого тела без контактов, то есть на гладкой, непрерывно дифференцируемой динамике [6]. Между тем подавляющее большинство практических задач робототехники – манипуляция объектами, ходьба, вставка деталей – по своей природе являются контактно-насыщенными (contact-rich): динамика системы содержит разрывы и переключения режимов (свободное движение / контакт / скольжение / залипание), что делает её негладкой и плохо аппроксимируемой стандартными дифференцируемыми моделями [12].

Ключевые источники ограничений можно систематизировать следующим образом. Во-первых, контактные силы носят существенно нелинейный и часто недифференцируемый характер: небольшое изменение положения или скорости может привести к качественно иному режиму взаимодействия (переход от свободного движения к контакту), что нарушает предположения о гладкости, на которых основано обучение большинства нейросетевых моделей динамики [12]. Во-вторых, трение является сложным для моделирования эффектом: статическое и кинетическое трение, эффект Штрибека, зависимость от температуры и износа поверхностей плохо описываются простыми аналитическими законами и требуют отдельных моделей, таких как модель LuGre [13; 14]. Попытки применить физически-информированные нейронные сети непосредственно к моделированию трения показывают, что учёт структуры уравнений трения (в частности, модели LuGre) при обучении сети позволяет получить более переносимые и физически согласованные модели по сравнению с чисто данными-ориентированным подходом [13; 14].

В-третьих, реальные роботизированные системы подвержены параметрической неопределённости: масса, момент инерции, коэффициенты трения и жёсткость сочленений меняются в ходе эксплуатации (износ, нагрев, замена рабочего инструмента), тогда как большинство моделей динамики обучаются как статичные, без встроенного механизма адаптации к таким изменениям [12]. В-четвёртых, совокупность перечисленных факторов формирует существенный разрыв между симуляцией и реальностью (sim-to-real gap): модель, точно предсказывающая динамику в идеализированной симуляции без контактов и трения, может давать значительную ошибку на реальном роботе именно в моменты

физического контакта – то есть ровно там, где происходит выполнение полезной работы (захват, вставка, опора при ходьбе).

Таким образом, систематический анализ (пп. 1–3) и специализированный обзор контактного взаимодействия в манипуляции [12] позволяют сделать вывод: ни модель-базирующие, ни модель-свободные, ни существующие гибридные методы не решают в полной мере задачу обучения в контактно-насыщенных, фрикционных и параметрически неопределённых средах. Это формирует исследовательский разрыв, для закрытия которого требуется архитектура самообучения, изначально проектируемая с учётом физики контактного взаимодействия – то есть физически-информированный (physics-informed) подход, распространённый на модели с контактами и трением, а не только на движение свободного твёрдого тела.

Заключение

Проведённый анализ современных подходов к обучению роботов показал, что модель-базирующие методы обеспечивают наилучшую sample-эффективность, особенно при использовании физически-структурированных моделей динамики (лагранжевы и гамильтоновы сети), однако апробированы преимущественно на средах без контактов и трения. Модель-свободные методы устойчивее к ошибкам модели среды, но требуют значительно большего числа взаимодействий, что ограничивает их практическое применение на реальном оборудовании. Гибридные подходы частично компенсируют недостатки обеих групп методов, но не устраняют фундаментальную зависимость качества обучения от точности физической модели контактного взаимодействия.

Основной вывод обзора заключается в том, что учёт контактных сил, трения, параметрической неопределённости и нелинейностей среды остаётся открытой задачей для существующих алгоритмов самообучения роботов. Это обосновывает целесообразность разработки физически-информированной архитектуры самообучения, расширяющей принципы physics-informed learning на контактную динамику, что составляет предмет дальнейших этапов диссертационного исследования.

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CITIES OF KAZAKHSTAN METHODOLOGY OF TEACHING SOCIO-ECONOMIC DEVELOPMENT (ON THE EXAMPLE OF THE CITY OF ALMATY)

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Abstract

The socio-economic development of Kazakhstan's cities is closely related to improving the quality of life of the population, ensuring economic growth, developing employment and human capital, improving infrastructure, promoting regional development, increasing innovation potential, ensuring sustainable urban development, and increasing the competitiveness of cities. In this regard, the growth of the gross domestic product of Almaty is one of the best indicators among the regions of Kazakhstan. Qualitative and sustainable socio-economic development of the city involves diversifying the city's economy and actively attracting investments.

The growth of Almaty's gross domestic product is one of the best indicators among the regions of Kazakhstan. The qualitative and sustainable socio-economic development of the city is closely related to the diversification of the city's economy and the active attraction of investments.

Almaty is recognized worldwide as the economic center of our country and a rapidly developing city that plays an important role in the development of Kazakhstan and the entire Central Asia. Almaty is distinguished by its advantageous geographical location, as an important transport and logistics center connecting the East and the West, with its developed economy, business and cultural relations, as well as the introduction of innovations into production and social life.

The presented article comprehensively examines the features of teaching the socio-economic development of Almaty, a city with such potential, through effective methods and approaches in general education schools. To do this, first of all, an analysis of typical educational programs was conducted, and the demographic situation of the city, economic potential, development of the service sector, transport infrastructure and urbanization processes were analyzed from the perspective of the content of geographical education.

The Standard Curriculum for Teaching Geography of Kazakhstan in Secondary Schools includes the section "Socio-Economic Development of Regions". It provides students with an overview of the natural resource potential of the regions of Kazakhstan, the characteristics of the population, the territorial organization of the economy and social indicators, and the learning objectives include identifying factors of development of regions, conducting a comparative analysis of specialization areas based on statistical and cartographic materials, as well as identifying current issues and prospects for regional development.

The article presents a methodology for achieving these learning objectives.described systematically. The methodology is interconnectedcharacterized by active learning methods. This allows students to strengthen their ability to apply knowledge in real-life situations, develop

problem-solving and decision-making competencies, and improve their skills in working with geographic data and effectively using digital tools in analyzing cartographic and statistical information.

Keywords: socio-economic development, potential of Almaty city, comprehensive school, geography of Kazakhstan, active teaching methods, digital tools.

Introduction

The socio-economic development of cities as a whole is an interconnected process aimed at improving the quality of life of the population, strengthening economic activity, and ensuring the sustainable development of the territory.

The directions of socio-economic development of Almaty are aimed at increasing the city's competitiveness, strengthening its investment attractiveness, and improving the quality of life of the population. It is characterized by economic diversification, modernization of transport and engineering infrastructure, ensuring environmental sustainability, developing human capital, and digitizing the social environment and economy.

When analyzing the works of researchers based on world experience, it was found that they divide the development of cities into several areas: sustainable cities, smart cities, urban planning, competitive cities, and socio-economic development of cities.

In particular, if we focus on the concept of sustainable cities, its formation and development were influenced by works in the fields of urban studies, ecology, economics, and social sciences. For example, E. Glaeser argues that “cities are ‘humanity’s greatest invention’ in accelerating the exchange of knowledge and ideas, increasing labor productivity, and enabling the development of innovative processes” (Edward Glaeser, 2011) [1]. In ensuring the long-term sustainability of cities, it is of great importance to characterize the interrelationship of economics and geography, taking into account the internal spatial structure of cities, economic relations, and agglomeration effects (Daniel A. Griffith, 2021) [2]. In addition, based on the works of Russian and Kazakhstani scholars who study the sustainable socio-economic development of cities, the main direction of scientific research is aimed at assessing urbanization processes, the competitiveness of cities, quality of life, urban infrastructure, and sustainable development indicators. For example, the socio-economic development of cities depends on territorial inequality, population concentration and the role of large cities in economic growth. The scientist also argues that the quality of human capital, the labor market, and effective urban governance have a great impact on sustainable urban development (N.V. Zubarevich, 2016) [3]. The economy of regions is based primarily on methods of spatial planning and infrastructure development as centers of economic activity, which create a complex of favorable conditions for human potential resources (O.S. Pchelintsev, 2004) [4].

The works of Kazakhstani scientists studying the socio-economic development of cities are aimed at identifying the strengths and weaknesses of urban development, as well as identifying threats and opportunities in the development of large cities of the country, the quality of urban space, the formation of a favorable environment for residents, and effective management of urbanization are essential for the sustainable economic development of Almaty, while improving the service sector, effective use of local resources, and economic diversification ensure the sustainable development of small cities (D. Kangalakova, Z. T. Satpaeva, N. K. Nurlanova, F. Alzhanova, D. T. Aliaskarov, K. D. Kaimuldinova, Sh. U. Laiskhanov, N. E. Usenov, N. O. Salimzhanov, etc.) [5, 6, 7].

The strategic document "Almaty City Development Program until 2025 and Medium-Term Prospects until 2030" describes the main goals and objectives of the city's socio-economic development, based on world experience and Kazakhstani research. The goals of Almaty city development are to create a comfortable urban environment (housing, social, engineering, transport, digital, commercial and recreational infrastructure); sustainable economic growth (for

the qualitative development of the economy, the city should create a more favorable business environment through the development of high-tech and "clean" industries, creative industries, and achieve increased labor productivity); diversification of the city's economy, attracting investments and increasing exports of goods and services, which will improve the income of the population and the quality of life of the population; managed urbanization (becoming a center for migration, transit passenger and cargo flows, etc.); social stability and stability (creating the most optimal conditions for living and health, education and work, human capital development and recreation); green Almaty (accessibility of park spaces, improvement of parks and squares); introduction of "Smart City" principles and standards (digitalization of urban infrastructure and urban services); safe city (full street lighting, video surveillance, early warning of natural and anthropogenic threats). This aims to transform Almaty into a competitive, comfortable and safe city with a high economy and quality of life for the population [8].

Currently, profound changes are taking place in the education system, primarily due to the peculiarities of the development of society, characterized by economic globalization, the high pace of development of technologies, primarily information and communication technologies, and the penetration of knowledge into all spheres of society and the economy. These changes in the education system are directly related, first of all, to the global trends of modern education. It is primarily associated with the consideration of a person as a social value, and then the integration of education, that is, structural changes in the education system, the Bologna process, public administration, informatization, scientificization of education, technological literacy, lifelong learning, etc. are characterized.

Considering the changes in modern society, most research scientists describe it as a post-industrial society and define it as “a knowledge-based society, an information society and an educational society implementing a lifelong learning strategy.” In the works of Kazakhstani scientists, an algorithm is proposed that allows for full accounting of learning outcomes in the formal, informal and information education system in order to justify a lifelong continuous learning system that provides coverage of the population with formal, informal and informational learning in order to increase the competitiveness and basic competence of education [9].

The main direction of the research is the teaching of the socio-economic development of Almaty, which is characterized by economic globalization, through effective methods in general education schools. In this regard, the section "Socio-economic development of regions" in the Standard Curriculum for teaching geography of Kazakhstan is analyzed, and a methodology for introducing into the content of the curriculum such educational materials describing the development of cities as sustainable cities, smart cities, urban planning, competitive cities, socio-economic development of cities is proposed.

Methodological approaches to teaching the geography of Kazakhstan - determine the theoretical foundations of geographical education, methods and tools used in the educational process, and methods of educational activity.

The socio-economic development of Almaty Before addressing methodological approaches to teaching, first, a model of modern geography teaching based on five main methodological approaches was identified (Table 1).

Table 1 – Modern Geography Teaching Model [10]

Methodological approaches	Characteristics	Application in the learning process, example
Systematic approach	This methodological principle is based on considering geographical objects and phenomena as a whole system consisting of interconnected and interdependent elements.	The teaching widely uses a system-structural approach, cartographic methods, modeling and diagrammatic analysis, which allow for a comprehensive understanding of the socio-economic development of the city. For example: identifying the population, industry, transport, service sector, environmental conditions and their interrelationships in the socio-economic development of Almaty.
Learning activity method	Students' observation, comparison, analysis, design, and research activities	Implementation of important methodological foundations of competency-based education (acquiring knowledge through research, analysis, and practical learning activities). For example: the project "Sustainable Development of Almaty".
Competency approach	A methodological approach aimed at applying the acquired knowledge in real-life situations	Explain the learning process by relating it to real-life situations. For example: analyzing the population dynamics of the city of Almaty.
Informational-communicative teaching methods	Teaching education in close connection with information technologies	Using digital tools and platforms in the learning process. For example: interactive maps and geographic information systems (GIS) - you can clearly demonstrate the socio-economic development of the city (Google Earth, ArcGIS, QGIS).
Person-centered approach	Person-centered teaching of geographical education	Assigning tasks in accordance with the student's interests, abilities, and personality traits during the learning process.

Note: author's compilation

The methodological approaches to teaching presented in the table serve as the basis for describing methodological approaches to teaching the socio-economic development of Almaty.

Materials and methods.

Works of scientists on the issues of socio-economic development of Almaty city (domestic: D. Kangalakova, Z.T. Satpaeva, N.K. Nurlanova, F. Alzhanova, D.T. Aliaskarov, K.D. Kaimuldinova, Sh.U. Laiskhanov, N.E. Usenov, N.O. Salimzhanov, Russian: N.V. Zubarevich, O.S. Pchelintsev and foreign: Edward Glaeser, Daniel A. Griffith, etc.);strategic documents related to the development of the city ("Program for the Development of the City of Almaty until 2025 and Medium-Term Prospects until 2030"); the Standard Curriculum for General Education Schools for the subject "Geography" was analyzed.

The theoretical foundations of the socio-economic development of cities are based on the theories of urbanization, growth poles, agglomeration development, the concepts of Sustainable

Development and Smart City, the principles of regional studies of geographical education and Education for Sustainable Development. In addition, the teaching methodology is based on regional, systemic, integrated and active learning approaches to education.

The research methods include theoretical analysis, historical, statistical modeling, systematic methods, observation and survey methods. This allows us to identify methodological features of the organization of the process of integrated teaching of natural sciences and languages.

Results.

Geographical education allows students to comprehensively consider demographic, economic, social and environmental processes, forming a holistic understanding of the qualitative and sustainable socio-economic development of cities. It contributes to the development of students' research skills and civic responsibility.

The importance of the quality of education in methodological approaches to teaching the geography of Kazakhstan is one of the main requirements of the education system. "Socio-economic development of regions" The socio-economic development of Almaty Effective and high-quality education should not be limited to providing information alone, but should be aimed at developing the learner's thinking, analytical, and application skills, as well as understanding and participating in solving real problems in the sustainable development of cities.

"The theoretical content of the educational materials provided in the section "Socio-economic development of regions", including those related to the development of cities, as well as the methods and tools used in the educational process, were determined. To do this, first of all, survey questions were set for teachers:

1) In the Standard Curriculum for the subject "Geography"The issues of socio-economic development of cities are sufficiently covered.

2) The use of specific economic indicators and statistics in teaching the topic of socio-economic development of cities increases the level of understanding of students.

3) Interactive maps and geographic information systems (GIS) – Google Earth, ArcGIS, QGIS – help to clearly demonstrate the socio-economic development of the city.Modern digital tools such as. are effectively used.

4)Sustainable cities, smart cities, urban planning, competitive cities, socio-economic development of cities, describing the development of citiesin the lessons*is discussed at a sufficient level.*

5) Socio-economic development of cities according to world experienceis displayed openly.

6) Almaty City Development Program until 2025 and Medium-Term Prospects until 2030will be analyzed and taught in class.

7) Regarding the development of the city of Almatyresearch projects or practical assignments are often recommended.

8) Development of Almaty cityConnecting learning to real-life situations

9) TeachersDevelopment of Almaty cityregularly uses relevant updated data and statistics.

10) Socio-economic development of Almaty cityTeaching economic processes forms in students a conscious view of the structure of the national economy.

These survey questions were rated on a Likert scale (Boone, HN, & Boone, DA, 2012) [11], and the results were calculated.

As a result of the analysis of surveys conducted among teachers, the geography of Kazakhstan course"He noted the need to make changes to the content of teaching materials for effective teaching of the section "Socio-economic development of regions", as well as the lack of educational and methodological literature in the Kazakh language (methodological textbooks, instructions, visual aids, etc.) for teachers to work in this area.

Discussions.In the course of analyzing the topics and learning objectives of the geography of Kazakhstan presented in the model curriculum for general education schools in the subject of

"Geography", it was found that the classification of settlements, problems, and the process of urbanization and its assessment are considered [12]. In the textbooks for grade 9, written on the basis of the model curriculum, the general concept of "city" is described and the classification of cities by importance is described (Karatabanov R., Saipov A., Balgabayeva B., Saparov K., Usikov V.V., Egorina A.V., Zabenova G.B.) [13, 14].

According to our research, the inclusion of educational materials on urbanization, growth poles, agglomeration development, Sustainable Development and Smart City in the socio-economic development of cities, as presented in the works of foreign and domestic researchers, into the standard curricula and textbook content will deepen students' knowledge about the development of modern cities. The peculiarity of the teaching methodology of the proposed educational materials is based on regional, systemic, integrated and active learning methods of education.

The educational content on the socio-economic development of Almaty, selected in accordance with the methodological approaches provided by the modern geography teaching model, increases the level of preparedness of students and ensures their ability to apply the acquired knowledge in practical activities.

The proposed model is aimed at the socio-economic development of Almaty city.to the features of teachingaccording to the followingprovides a comprehensive use of methods[15, 16, 17].

1. The case study method analyzes real-life situations or problem situations. The goal is to develop students' problem-solving, analysis, and decision-making skills by studying real-life industrial or environmental conditions in Almaty.

2. In the debate method, two or more groups express opposing views on a certain topic. For example: "EThe relationship between economics and geography"The discussion on the topic develops students' ability to think critically, present arguments, and defend their opinions.

3. When using the Project-based learning method in a seminar class, students conduct research on a specific topic and develop a specific product or project. This method is used, for example,Their collective application in the theme "Sustainable Development of Almaty"Develops work, research, planning, and presentation skills.

4. Through interactive role-playing games, students play different roles (civil servant, farmer, investor) and make decisions based on the situation. Interactive games develop students' practical decision-making skills. Using the interactive game method, for example, the simulation game "City Planners".

5. In the SWOT analysis method, students identify the strengths, weaknesses, opportunities, and threats of an object through analysis. This develops their analytical thinking and decision-making skills. SWOT analysis methodSocio-economic status of Almaty cityIt is best to use it in evaluating development strategies.

The use of the above new methods and approaches in the learning process increases the effectiveness of the lesson, arouses students' interest, ensures their active participation in the subject, and allows them to understand real-life situations.

Conclusion.

The socio-economic development of cities plays an important role in ensuring the economic growth of society and the well-being of the population. As a result of studying the development of cities using systemic and integrated approaches, it was determined that the city is a complex socio-economic system, and the interrelationship of its demographic, industrial, infrastructural, environmental and managerial components has a significant impact on the development of the city.

The study results show that the development of modern cities is characterized by the principles of sustainable development, which is associated with increased urbanization, the

expansion of agglomeration processes, the introduction of innovations and digital technologies. Indicators for assessing and managing the socio-economic development of cities (quality of life of the population, employment rate, accessibility of transport and social infrastructure, environmental efficiency) are of particular importance.

The socio-economic development of cities ensures the sustainable development of the country's economy.

The use of the Likert scale in the study allowed to assess the views of teachers on the issues of sustainable urban development, which are presented in the content of educational materials on the socio-economic development of Almaty city. This method allows to determine the effectiveness of the teaching methodology and to quantitatively substantiate the results of experimental work.

Teaching these issues in geography education helps students understand processes in urban space,develop problem-solving, analysis, and decision-making skillscontributes to the socio-economic development of Almatyto the features of teachingaccording toThe use of methods and approaches in the learning process increases the effectiveness of the lesson, arouses students' interest, ensures their active participation in the subject, and allows them to understand real-life situations.

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SPECIAL EDUCATIONAL PROGRAM FOR CHILDREN WITH DISABILITIES

Marcela Čarnická

Abstract:
An integral part of every person's life is communication, which is realized through speech and language. Everyone acquires the language system from birth. However, in a child with a medical disability, speech development may be delayed and slowed down as a result of the diagnosis. In the article, we briefly describe the sound level of language, which is an important key not only to successful communication, but also necessary for later learning to read and write. The text explains the difference between phonemic and phonological awareness, briefly describes the specifics of Treacher Collins syndrome and hearing impairment. The article contains a description of special pedagogical support for a child with Treacher Collins syndrome and associated hearing impairment.

Keywords:
Hearing impairment, special education program, children with disabilities, Treacher Collins syndrome, phonemic and phonological awareness.

Introduction

Language is perceived as a system of rules, units and socially accepted norms through which we create coherent speech (Čermák, 2024). A person develops language from birth. According to Fidra (2013), language consists of several subsystems that are interconnected:

- the phonic subsystem is related to the spoken form of the language,
- the lexical subsystem is made up of the vocabulary of the language,
- the morphological subsystem contains the rules for word formation (inflection and tense),
- the syntactic subsystem focuses on the creation of grammatically correct sentences and clauses,
- the stylistic subsystem teaches us how to appropriately use language resources in various communication situations.

One of the basic prerequisites for the successful acquisition of reading, as well as the development of communication competences, is *phonemic awareness*, i.e. the ability to consciously distinguish, identify and manipulate sounds, syllables or words in spoken language. The authors Zubáková, Poprendová (2020) describe phonemic awareness as the ability to recognize sounds in words and work with them purposefully, regardless of the meaning of the words. Phonemic awareness represents the ability to distinguish, connect, and break down the smallest sound units of spoken language. A person can phonetically decompose/analyze a word into individual phonemes and, conversely, put phonemes together into a whole word. The sound level of language also includes *phonological awareness* (phoneme analysis), which represents the ability to distinguish individual sounds in words and consciously manipulate them within various large phonological units, which means, for example, syllables (Tokárová, 2013). It is the ability to be aware of the sound structure of speech and work with it. Smolík and Seidlová Málková (2014) define phonological awareness as the ability to be aware of the phonological structure of speech, which represents awareness of rhymes, syllables in words, and individual speech sounds. Phonemic awareness is one of the sub-skills within the broader understanding of phonological awareness (Máčajová, Grofčíková, Zajacová, 2017).

According to Mikulajová (2012), the ability to be aware of phonemes and phonological awareness is also crucial for the acquisition of writing in the early stages of a child's life. The author adds that the ability to perform phonemic analysis and recognize graphemes helps the child build the so-called "phonological scaffolding", i.e. the connection between spoken and written language.

In the development of a child, the phonic system is gradually formed based on speech perception, auditory differentiation and their own speech production. The child learns to distinguish individual sounds, creates them and uses them correctly. However, speech development does not occur equally in all children. In children with disabilities, speech development, i.e. also phonemic awareness, is weakened and delayed, requiring targeted intervention and systematic development. In terms of phonological awareness, the child has difficulty breaking a word into syllables, recognizing and creating rhymes, and can hardly determine the first or last sound in a word. In terms of phonemic awareness, a child with delayed speech development does not understand that a word is made up of phonemes, i.e. sounds. Therefore, it is necessary to provide the child with professional and special pedagogical support that will focus on the development of auditory perception, phonemic awareness and the development of communication skills. We present several methods suitable for supporting phonemic awareness:

- *D. B. Elkonin method* - the main pillar is familiarization with the sound structure of the word. In the process of learning to read, the child first becomes familiar with syllables, later with phonemes, and only after sufficient mastery of phoneme awareness and manipulation does he move on to learning letters (Tokárová, 2015). The training takes place in four basic topics - awareness of syllables, analysis of words into sounds, differentiation of vowels and consonants, differentiation of soft and hard consonants.
- *the nursery rhyme method* – a nursery rhyme is a simple verse poem that has a strong tempo. Nursery rhymes are popular with children for their simplicity, melodiousness and appeal. Their importance lies in supporting language development and speech development. By repeating nursery rhymes and their articulation, children practice correct pronunciation and develop communication skills. Nursery rhymes are suitable for children from one year of age, and in the preschool period they play an important role in developing auditory perception. Auditory perception is not only the ability to recognize different sounds, but also includes the differentiation of phonemes and the ability to focus attention on sound stimuli (Ficová, 2020).
- *language games* – play is the most natural activity for children, therefore it is appropriate to use games to develop children's communication skills. The goal of language games is to become aware of the variety of linguistic expressions; games should stem from children's spontaneity. At the same time, it is important to guide children to tolerance and politeness towards other friends, so that they can talk about the meanings of words, sentences, or texts without arguing or mocking (Lipnická, Šebianová, 2022). Before the language games themselves, it is important to do preparatory and breathing exercises, rhythm exercises.

A child with Treacher Collins syndrome

Treacher Collins syndrome is a hereditary disease affecting the bones and tissues of the face with subsequent deformations and a characteristic change in appearance. The most common symptoms of this disease include:

- underdeveloped facial bones and the resulting deformities,
- downward slanting eyes, underdeveloped lower eyelids,
- partially/completely underdeveloped cheekbones, sagging temple area,

- prominent nose,
- deformity of the auricle or ears completely missing,
- congenital obstruction of the external auditory canal and deformities of the bones of the middle ear and varying degrees of hearing impairment,
- clefts (lips or jaws),
- smaller lower jaw compared to the upper, the appearance of a sunken chin,
- crooked teeth, - difficulty breathing,
- difficulty swallowing due to the cleft,
- repeated eye infections (according to https://socialeasator.com/diagnoses/treacher-collinsov-syndrom).

This genetically determined disease can negatively affect the child's auditory perception, articulation, speech development and communication skills. Hearing impairment is a negative factor that interferes with the process of acquiring phonological and phonemic skills, as the child may have difficulty distinguishing individual sounds, syllables or sound stimuli. A child with Treacher Collins syndrome and associated hearing impairment can be educated in a regular kindergarten. Inclusion should be a natural and obvious part of everyday life (Kováčová, 2019). For a child with a hearing impairment, technical and didactic aids are a necessary prerequisite for perceiving sounds and speech in the school environment. Compensatory aids include FM systems (remote microphones), which transmit the teacher's voice directly to the child's hearing aid, thus eliminating the negative impact of ambient noise and distance (Vladová, Lechta et al., 2017). Furthermore, there are special software that are an effective tool for developing auditory differentiation and vocabulary. Compensatory aids also include bone vibrators, which transmit sound through vibrations through the bone (Hovorková, Rzymanová, 2023).

Special pedagogical support plays an important role in the process of developing phonemic awareness. Appropriately and purposefully selected methods, activities and interventions allow for respecting the individual needs of the child, their capabilities, learning pace and specifics resulting from health disadvantages. An important part of the support is the creation of a stimulating and motivating environment that supports the development of speech, auditory perception, attention, memory and other partial functions necessary for the successful acquisition of language skills. Schmidtová (2020) states in her publication that stimulation is necessary from an early age for children with hearing impairment, or for children with another type of disability, where their speech development is impaired or limited. The child, with whom a special education program aimed at developing phonemic awareness was implemented, has Treacher Collins syndrome and bilateral moderate conductive hearing loss caused by deformation of the auricles, missing ear canals and fused bones in the middle ear. Until the age of six months, the child did not respond to any sounds, unless the child was assigned a BAHA compensatory device (bone vibrator on a headband), thanks to which he now hears even the quietest sounds. The child is currently attending kindergarten for the third year. The child's integration into kindergarten took longer and slower. The child tried to play alone and did not seek the company of other children. The cooperation between the legal guardians and the kindergarten is excellent. The special education program was compiled in accordance with the principles of special education intervention, respecting the individual needs of the child and the results of diagnostic examinations from the counseling and prevention center. At the beginning, an entrance test was conducted focused on five areas:

a) rhyme,
b) analysis and synthesis,
c) omission,
d) auditory isolation,

e) auditory differentiation and localization (Máčajová, 2013, p. 53). These areas were divided into 12 items, each item could receive a maximum of 5 points. Based on the results of the entrance test, a set of games and activities was designed, which were implemented over six months in individual and group form. The program was implemented in a kindergarten environment. The main goal of the program was to teach a child with a health disadvantage in preschool age to distinguish sounds by hearing, to develop auditory perception. In order for a child to be able to pronounce sounds correctly, he must hear them correctly, to be aware of them phonetically, which is a prerequisite for practicing reading and writing in elementary school. A secondary goal of the implemented activities, primarily aimed at developing phonological-phonemic awareness in the child, was his inclusion in the collective of children in kindergarten. For this reason, the activities were initially implemented in a group form. At the same time, the effort prevailed to create an environment providing security and safety for the child in the classroom, since he knew only two friends in the classroom from the previous school year. Another motive for group activities was the intention to prevent, given the child's diagnosis - physically exceptional with associated hearing impairment, the stigmatization of the child due to the individually provided special pedagogical support. Inclusion perceives a child's difference as a valuable asset that should be an enrichment for all participants in the educational process (Kováčová, 2019). All children are educated and supported together, gain a sense of belonging, and learn to cooperate, tolerate, and communicate with each other.

The form of motivation was a popular fairy tale, whose characters also appeared in individual tasks. Each activity had its own goal, appropriately selected tools, methods (dramatization, demonstration, lip-reading, game, song, fairy tale, work with pictures, manipulation with objects, etc.). The program paid attention to clarity, systematicity, multisensory approach, repetition and individual approach. After the implementation of the activities, reflection and evaluation followed Each activity carried out in a group format was followed by short individual work with the child. (e.g. in a relaxation room).

The activities focused on:

- proper breathing and breath regulation,
- proper articulation,
- how to perceive music and express changes in tempo and music (motor activity),
- developing the mobility of the tongue, lips, cheeks, supporting correct articulation,
- being able to determine the localization of sound in space and its source,
- developing auditory differentiation of pitch, length of vowels and syllables,
- developing phonemic awareness through naming words and determining their position (prepositions),
- developing the perception of temporal sequence,
- developing oromotor skills,
- developing phonemic awareness through identifying rhymes,
- developing phonemic awareness with a focus on syllabic analysis of words,
- developing phonemic awareness with a focus on determining the first sound of a word,
- developing the ability to identify the missing part of a word and complete it into a whole,
- developing phonemic awareness with a focus on to words when changing one sound to another.

After completing the program, the child took an exit test (the same as at the beginning), which showed improvement in some areas (Table 1).Improvements were made in the area of awareness of rhymes and their creation, in the area of syllable awareness, visual distinction of articulatory movements, identification of initial and final sounds, especially consonants, syllable analysis and synthesis, creation of new words for given syllables or sounds, understanding of simple instructions, active participation in language activities, and the ability to work with visual support and visual aids.

Table 1: Results of the input and output test of phonological-phonemic awareness

Task	Input test result	Output test result
Rhyme awareness	1	5
Rhyme production	5	5
Analysis of words into syllables	4	5
Synthesis of syllables into words	1	5
Syllable omission	0	5
Sound omission	0	3
Isolation of the first syllable	1	5
Isolation of the first sound	0	4
Word formation for a given sound	1	5
Differentiation of words with a picture	1	5
Differentiation of words without a picture	0	4
Localization of sound changes in a word	0	1
Total points	**14**	**52**

Source: Own processing

The child has made progress in the areas of phonemic awareness, auditory perception, language skills and communication skills, although some more demanding tasks still require systematic practice and support from the teacher. The child has made the least progress in localizing the change of sound in a word, where further practice is needed. The activities carried out in a group format were an added value for the child, when the child established friendships, developed social competences, and was more willing to participate in joint activities in kindergarten. The child's ability to respond to the teacher's instructions, concentrate on language activity and participate more actively in group activities improved. Last but not least, the self-confidence and self-esteem of the child with Treacher Collins syndrome and associated hearing impairment was strengthened.

Conclusion

Although it was shown that the child improved after completing the special pedagogical intervention, we recommend continuing the intervention due to the presence of Treacher Collins syndrome and associated hearing impairment. It is therefore desirable to develop auditory perception, phonemic awareness and communication skills in the long term. It is also important to pay attention to breathing, phonation and oromotor exercises, which can contribute to improving speech intelligibility and imprecise articulation. We recommend using a multisensory approach, visual support and observation, experiential forms of learning, games, the use of music and rhymes, fairy tales and rhythmicity to support a child with TCS syndrome.

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BRITISH COUNCIL TEACHING ENGLISH – МЕЖДУНАРОДНАЯ ОБРАЗОВАТЕЛЬНАЯ ОНЛАЙН-ПЛАТФОРМА СОВЕРШЕНСТВОВАНИЯ ПРОФЕССИОНАЛЬНОГО УРОВНЯ ПРЕПОДАВАТЕЛЕЙ ИНОСТРАННОГО ЯЗЫКА

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Аннотация

В данной научной работе раскрывается специфика организации методического процесса обучения и рассматривается роль развития и совершенствования уровня подготовки учителей и преподавателей. В число целей и задач продуктивного функционирования учебного процесса входит создание условий как для обучения, так и для развития всех участников образовательного процесса. Совершенствование уровня подготовки преподавателей можно назвать одним из важнейших направлений профессиональной деятельности и фактором, повышающим качество учебно-воспитательного процесса. Международные программы, онлайн-платформы, повышающие квалификацию учителей, помогают их личностному росту, расширению профессионального кругозора, обогащению педагогического потенциала. Одной из организаций, способствующей развитию педагогической деятельности учителей является Британский Совет обучения учителей. Международная организация Объединённого Королевства по культурным связям и образовательным возможностям (British Council Teaching English. (London, UK). International organization for cultural relations and educational opportunities), базирующаяся в Лондоне. Данная научная статья анализирует актуальные темы методической науки, которые получают наиболее частое освещение в международной программе Британского Совета по развитию и повышению квалификации преподавателей. Эти темы рассматриваются с различных позиций современных экспертов-учёных, которые представляют их в своих докладах, публикациях, презентациях на различных ресурсах онлайн-платформы Британского Совета (British Council Teaching English).

Ключевые слова: учебный процесс, Совершенствование уровня подготовки преподавателей, международная программа, актуальные темы, методическая наука.

Введение

Учебный образовательный процесс должен быть ориентирован не только на обучение студентов, но и на развитие профессиональной компетентности учителей и

преподавателей. Профессиональный уровень каждого учителя тесно связан с качеством и результатами образования. Совершенствование преподавателей можно назвать одним из важнейших направлений их профессиональной деятельности и фактором, повышающим качество учебно-воспитательного процесса.

Проблеме повышения квалификации преподавателей высшей школы уделяют внимание учёные разных стран. Так в статье «Исследование педагогического пространства высшей школы в контексте самосовершенствования преподавателей» авторы утверждают: «Проблематика совершенствования личностных качеств и профессиональных навыков преподавателей высшей школы на настоящий момент актуализирована не только стандартами, методическими рекомендациями, но и самой педагогической реальностью, объективными условиями, которые предъявляют к преподавательской деятельности иные, нежели несколько лет назад, требования». (Британева А.П., Гришина Т.А., Гришин Ю. С., 2025, стр. 99) Безусловно, с подобным высказыванием можно согласиться, однако далее авторы отделяют преподавателей высшей школы от учителей начальной, средней школы и отдают приоритет преподавателям высших учебных заведений. «Высшее образование является переходным этапом на пути от общего обучения и воспитания к активной социальной и профессиональной деятельности, а, следовательно, задачи педагога становятся более многочисленными и разнообразными, чем, к примеру, в школе». (Британева А.П., Гришина Т.А., Гришин Ю. С., 2025, стр. 99). С данным мнением авторов сложно согласиться. Учителя школ не менее, чем преподаватели вузов должны совершенствовать свои профессиональные качества, в том числе и участвуя в программах международных курсов, вебинаров и других ресурсах организаций, направленных на работу усовершенствования квалификации учителей. Обучению иностранному языку необходимо уделять больше внимания именно на начальном этапе обучения, когда закладываются базовые знания учащихся. В программе Британского совета по обучению учителей посвящено много времени темам методики преподавания обучению начальному, среднему и старшему школьному возрасту.

Необходимость воспитания гармонично развитой личности и становления грамотного специалиста, будущего профессионала в лице студента, который по окончании вуза обладал бы всеми необходимыми компетенциями, авторы статьи «Исследование педагогического пространства высшей школы в контексте самосовершенствования преподавателей» совершенно справедливо считают приоритетным. Поэтому одним из важных вопросов является обладание профессиональной компетентности самого преподавателя, который должен быть интересным как личность и являться грамотным специалистом. Авторы отмечают, что интеллектуальность преподавателя напрямую связана с мотивацией студентов к обучению и с качеством образования. Именно это позволяет говорить о необходимом совершенствовании профессиональных навыков, личностном развитии преподавателя, актуализации имеющихся психологических и методических ресурсов. (Британева А.П., Гришина Т.А., Гришин Ю. С., 2025).

Однако, говоря о совершенствовании профессиональных навыков педагога, авторы используют слова «самосовершенствование», «саморазвитие», уделяя особое внимание термину «педагогическое пространство вуза». По мнению многих учёных это пространство представляет собой учебно-воспитательную среду, в которой реализуется множество видов деятельности всех участников образовательного процесса: учебная, профессиональная, досуговая, творческая, спортивная и пр. Педагогическое пространство высшей школы включает в себя не только условия, но и все имеющиеся в вузе ресурсы, способствующие достижению конкретных образовательных целей, минимизации сложностей в обучении. В число целей и задач функционирования вуза входит создание условий для обучения и развития всех участников образовательного процесса, В данном случае речь идет не только

и не столько о курсах повышения квалификации, но и о личностном росте, расширении кругозора, обогащении педагогического потенциала за счёт вовлечения в коммуникативный процесс самих студентов. (Бритаева А.П., Гришина Т.А., Гришин Ю. С., 2025). Это очень спорное мнение. Совершенно очевидно, что самосовершенствование невозможно в узком замкнутом кругу определённой, пусть даже и многочисленной группы преподавателей и такой же обособленной группы студентов, ограниченной пространством одного вуза. Безусловно, совершенствование профессиональных навыков должно проходить путём получения новых научных знаний, обменом научным мнением, дискуссиями, беседами между преподавателями, не только одного избранного вуза, но и всей страны и даже всего мира. Именно такой обмен мнениями проходит на платформе международного сообщества Британского Совета обучения учителей.

Исследование

Международная программа Британского Совета обучения учителей (British Counsil Teaching English) организована для развития и повышения уровня квалификации учителей школ, колледжей, курсов, преподавателей высших учебных заведений, обучающих учеников и студентов иностранным языкам. Работа Британской организации направлена на содействии в понимании различных компонентов систем иностранного языка, таких как грамматика, лексика, фонетика, коммуникативные стратегии и социолингвистические навыки, а также различные варианты английского языка. Программа способствует пониманию различных теорий обучения, выбору подходящих методик преподавания для поддержания учебного процесса в определённом контексте. Программа обращает внимание на расширение знаний обо всех профессиональных практиках для повышения эффективности преподавания. Каждый пользователь ресурсами Совета вправе сам выбирать вид и форму общения с представителями сообщества в зависимости от профессиональных интересов. Общая тематика Совета распространена на учителей английского языка, тем не менее, участниками могут являться и педагоги, обучающие учеников и другим иностранным языкам, так как методика преподавания любого иностранного языка имеет общую направленность.

Материалы ресурсов Британского Совета обучения учителей (British Council Teaching English) представлены самым широким спектром инструментов и ресурсов: образовательные курсы с длительным сроком обучения, полноценные научные публикации, конференции, ежедневные мероприятия в виде вебинаров, дискуссий, ответов на вопросы, кратких методических рекомендаций на разные темы.

Разнообразие тем методической науки преподавания иностранного языка представлены в сравнении различных точек зрения учёных разных стран. Такие важные методические темы как: коммуникативный аспект учебного процесса, критерии оценки знаний студентов, использование учебного и дидактического материала на уроках, помощь ИИ в обучении иностранному языку, развитие навыков критического мышления у учащихся, многоязычие и влияние родного языка в аудитории иностранных студентов, формирование учебных документов кафедры высшего учебного заведения и многие другие имеют многоплановый подход. В своём исследовании мы анализируем отдельные методические темы, обсуждаемые на треннингах, вебинарах, публикациях Британской организации,

Рассмотрим некоторые из тем вебинаров, состоявшихся на онлайн-платформе Британского Совета в разное время работы: например, тема вебинара «ИИ как наш союзник» (“AI as our ally”) Марии Хосе Галлено (Maria Jose Galleno) от 17.05.2024 года ориентирован на практикующих учителей и посвящён практической интеграции ИИ в работу уроков по изучению английского языка. Основная идея доклада – ИИ не заменяет преподавателя, а помогает делать уроки инклюзивными и является активным ассистентом учителя. Уделено

внимание тому, как с помощью ИИ адаптировать учебный материал под разные уровни знаний студентов, чтобы вовлечь всех учеников в смешанных группах. Во время вебинара спикер демонстрирует, как загрузить исходный текст и быстро сгенерировать задания более низкого или, наоборот, более продвинутого уровня, чтобы вовлечь всех учеников в смешанных группах. На вебинаре рассматривались способы использования ИИ-сервисов для работы в больших классах с разным уровнем подготовки. Показаны функции перевода инструкций и адаптации тестов для создания равных возможностей обучения. Данный вебинар способствовал обучению базовым навыкам составления промптов для получения методических материалов. (Galleno, M. J., 2024).

На вебинаре «Место английского языка» "The place of English" от 15.10.2024 года автор Доктор Харри Куча и соавтор Доктор Тони Капстик (Dr. Harry Kuchah and Dr. Tony Capstick) рассмотрели роль английского языка в условиях многоязычия в классе (Multilingualism), помогли учителям и преподавателям оценить, как разнообразие вариантов английского языка, в общем, так и локальные контексты, в частности, влияют на современную практику преподавания. Спикеры ответили на вопрос, как уйти от концепции доминирования «чистого английского языка» и интегрировать его в многоязычную реальность языковой группы, где родные языки выступают помощниками обучения, а не являются его препятствием. Доктор Куча поднял на этом вебинаре важный социолингвистический вопрос о праве собственности на язык (Language Ownership): Кому принадлежит английский язык сегодня? Он также обосновал отказ от жёстких стандартов «носителей языка» (Native Speakerism) в пользу признания локальных вариантов английского языка (World English). Данный вебинар вооружил методистов практическими стратегиями, помогающими рядовым учителям анализировать собственные подходы и предвзятости при оценке речи студентов. Основная цель вебинара – помочь наставникам и преподавателям критически оценить разнообразие вариантов английского языка. (Kuchah, H. & Capstick, T., 2024).

Особое внимание уделяется актуальным темам, таким как использование критериев оценивания знаний студентов (Rubric Assessment) и принципам оценки обучения (Assessment for Learning), согласно которым это оценивание рассматривается как неотъемлемая часть образовательного процесса. Следует отметить ряд вебинаров, посвящённых этой теме. В материалах Британского Совета (British Council) подчёркивается, что главная цель оценивания знаний студентов заключается не только в выставлении итоговой отметки, но и в оказании помощи студентам проявить себя с лучшей стороны. Оценка должна предоставлять обучающемуся информацию о его сильных сторонах, выявлять области, требующие совершенствования, и мотивировать к дальнейшему изучению языка.

Спикер вебинара от 12.09.2025 года «Как оценивание может быть инклюзивным» "How can assessment be Inclusive?" Нашва Али Мухаммад (Nashwa Aly Muhammad) составляет «справедливые» и «несправедливые» системы оценивания. Объясняет, как адаптировать традиционные тесты под реальные жизненные задачи и создавать инклюзивные критерии оценки. (Aly Muhammad, N., 2025).

На вебинаре Британского Совета от 11.07.2025 года под названием «Оценивание обучения: практическое введение» (Assessing learning: A practical introduction) преподаватели Стефен Мандер и Рабия Шафи (Stephen Mander & Rabia Shafi) разбирают типы оценивания, критерии выставления оценок и практические стратегии обратной связи с целью её отслеживания. (Mander, S., & Shafi, R., 2025).

Публикации учёных Британского Совета (British Council) представляют собой особый интерес. Например, научная статья под названием «Почему они не могут говорить по-английски?» (Why won't they speak English?) Дейли Эльхавари и Харгривза Е. (Elhawary, D.,

and Hargreaves, E.) от 2023 года посвящена обучению на начальном этапе арабоязычных учеников на основе теории самоопределения. В ней исследуется тревожность при самостоятельном обучении разговорного английского языка на начальном этапе школьного обучения. Описывается, как во время научного эксперимента был внедрён метод «парной работы» в классах трёх государственных школ. При этом, учителя были ознакомлены с «теорией самоопределения» и получили поддержку во время проведения уроков разговорной речи английского языка. Исследование было направлено на содействие внедрения теории самоопределения, что могло бы привести к улучшению обучения разговорному английскому языку и на получение предложений и оценок данного метода от самих юных участников эксперимента. В процессе наблюдения выяснилось, что ученики почувствовали наименьшую тревожность на уроках разговорной речи после применения данной теории. В результате этих исследований авторы предлагают учителям: чаще самим выступать в качестве примера, нежели исправлять речь начинающих говорить по-английски; поощрять детей в их разговорной практике; избегать угроз и навешивания ярлыков для учеников «сильные», «слабые»; использовать открытые вопросы и задания, требующие более одного правильного ответа. (Elhawary, D., & Hargreaves, E. 2023)

Интересная публикация 2025 года группы следующих авторов: Гурл С.М., Яблонскай Р.Р., Юксель Д., Арслан С., Харви Дж., Джие Х., Паудел П., Алтай В., Эрбакан Н.Т., Элс Р. под названием «Использование преподавателями университетов стратегий для введения и объяснения терминологии STEM в контексте обучения на английском языке». (University lecturer strategy use to introduce and explain STEM terminology in EMI contexts. Curle, S. M., Jablonskai, R.R., Yuksel, D., Arslan, S., Harvey, J., Jie, H., Paudel, P., Altay, V., Erbakan, N. T., & Els, R., 2025)). В данном исследовании авторы показали, как преподаватели вузов отдельных стран используют различные модели взаимодействия при обучении терминологии STEM. Для сравнительного анализа исследования выбраны следующие страны: Турция, Китай, Южная Африка. Результаты опроса преподавателей показали, что их пол не оказывал влияния на методы преподавания или стиль объяснения терминологии STEM на английском языке. Преподаватели сообщили о стремлении избегать гендерной предвзятости в преподавании и рассматривать всех студентов как личностей с уникальным потенциалом. Интересен эксперимент тем, что он проводился в разных странах. Как считают авторы, специфическое различие между странами, обучающими студентов на одном языке, ещё раз подчёркивают многогранный характер обучения на английском языке. Результаты данного исследования включают в себя частое использование эквивалентов на родном языке для введения терминологии STEM или заменой отдельных слов синонимами. Это исследование вносит ценный вклад в глобальную картину STEM-образования, подчёркивая необходимость гендерно-чувствительных и контекстно-адаптированных стратегий преподавания для эффективной передачи специализированной терминологии в различных условиях обучения на английском языке.

Детальный анализ подобных содержательных статей различной тематики, публикуемых в открытом доступе, безусловно, способствует повышению квалификации педагогов, работающих с определённой группой учащихся в определённых сферах обучения.

Заключение

Таким образом, одной из ведущих международных образовательных онлайн-организаций, оказывающих значительное влияние на развитие методики преподавания английского языка, является British Council. В рамках образовательной платформы Teaching English преподавателям предлагаются различные онлайн-ресурсы для повышения квалификации, посвящённые различным методическим вопросам обучения иностранному языку.

Интересен тот факт, что в участии вебинаров могут принимать участие преподаватели любого иностранного языка (русского, немецкого, французского и др.), хорошо владеющие английским. Методика преподавания английского языка также актуальна и для преподавания русского языка как иностранного. Сравнительный анализ методических тем, представленных на вебинарах в последующей работе, как на уроках английского, так и русского языка позволяет понять, что наука «методика преподавания иностранного языка» актуальна для всех языков без исключения. В то же время, для каждого преподавателя важно быть в курсе последних тенденций и методов преподавания иностранного языка. Программа по обучению иностранного языка на своих вебинарах позволяет изучить современные тенденции и методы преподавания иностранного языка, знакомит преподавателей с инновационными методиками преподавания, интеграцией технологий и внедрением ИИ в учебный процесс. Передовые стратегии методической науки, несомненно, помогают каждому преподавателю сделать практические занятия увлекательными и полезными.

Одним из важных аспектов международных вебинаров является возможность общаться с учителями и преподавателями всего мира, перенимать их креативные идеи, делиться своим опытом и знаниями. Участие в вебинарах позволяет ощущать себя частью разнообразного, динамичного сообщества учителей и экспертов, которые стараются сделать преподавание совершенным. Участие в работе вебинаров и курсов предполагает постоянную поддержку, сотрудничество и совместное творческое общение и обмен идеями.

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Culturology

DIVERSITY, COMORBIDITY AND THE OPENING OF MUSEUM AND GALLERY SPACES TO VISITORS

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Abstract
Museums and galleries represent important cultural, educational and social spaces whose contemporary role extends beyond the preservation and presentation of cultural heritage to the creation of conditions for its accessible, meaningful and participatory mediation. This paper addresses the openness of museum and gallery spaces in relation to visitor diversity, with particular attention to visitors whose needs cannot be reduced to a single characteristic or category of disadvantage. In this context, the concept of comorbidity is used as a conceptual starting point for considering the coexistence of multiple characteristics, needs and barriers that may influence an individual's opportunities to participate in cultural life. Particular attention is paid to the shift from traditionally understood physical accessibility towards a broader concept of linguistic, social, digital, sensory and programmatic accessibility. The paper also highlights the role of museum and gallery education in creating opportunities for participation, communication and interaction. The aim is to theoretically emphasise the need to perceive museum and gallery visitors as complex individuals and cultural institutions as flexible spaces that do not provide only one universal mode of visiting, but enable different pathways to participation, experience, learning and the shared creation of cultural meaning.

Keywords:
diversity, comorbidity, museum, gallery, visitor, accessibility, inclusion, participation, museum education.

Introduction

Museums and galleries are specific cultural spaces whose social significance has gradually changed. While the traditional understanding of the museum was strongly oriented towards collecting, preservation and presentation, contemporary approaches increasingly emphasise the person who enters the cultural institution. The museum is therefore no longer understood solely as a place for preserving objects, but also as a space for communication, education, interpretation, social interaction and participation.

This shift is clearly reflected in the contemporary understanding of the museum formulated by the International Council of Museums (ICOM). The current definition, adopted in 2022, describes a museum as a permanent, not-for-profit institution in the service of society that is open to the public, accessible and inclusive, fosters diversity and sustainability, and operates with the

participation of communities. Museums are expected to offer varied experiences for education, enjoyment, reflection and knowledge sharing (ICOM, 2022).

Such a definition also changes the question of who a museum or gallery is intended for. If a cultural institution is genuinely open to the public, visitors cannot be regarded as a homogeneous group. The public consists of people of different ages, social and cultural backgrounds, languages, educational experiences, abilities and needs. Diversity is therefore not an additional characteristic of museum audiences, but their natural condition.

This raises the question of whether current approaches to cultural accessibility sufficiently reflect the complexity of the individual visitor. For example, physical accessibility may be considered a key indicator of inclusion, while other barriers remain unnoticed. A particular visitor may simultaneously experience a language barrier, social disadvantage, sensory sensitivity or limited access to digital technologies. These barriers do not necessarily occur separately (Biarincová, 2023, Kováčová, 2024).

The coexistence of multiple characteristics and needs therefore constitutes the conceptual starting point of this paper. The concept of comorbidity is used here in a broader conceptual sense. It does not represent a medical diagnosis transferred to the museum or gallery environment. Rather, it draws attention to situations in which several characteristics and needs may coexist in one person and influence their ability to enter a cultural space, understand its content and participate actively in the cultural experience (Bergerová & Ševčovič, 2022, Biarincová, 2024).

Museums and Galleries as Open Cultural Spaces

Museums fulfil several interconnected functions in society. In addition to the protection, documentation and interpretation of cultural and natural heritage, their significance is related to education, the development of cultural literacy and the creation of opportunities for encounters between different groups of society. Museum education should therefore not be understood merely as a tool for transmitting expert knowledge, but also as a means of establishing relationships between people and cultural institutions.

Museum educational activities may include lectures, workshops, creative activities, guided tours, discussions, competitions and other educational programmes. Their significance, however, does not lie solely in the transmission of information. An important aspect is the creation of situations in which visitors can observe, reflect, ask questions, interpret, create and share their experiences. Jůva (2004) describes museum education as a discipline that contributes to overcoming the threshold between individuals and cultural institutions. Understood in this way, museum education has the potential to function as a bridge between the professional content of a museum and the individual experience of the visitor.

Gallery education is closely connected with emotional and aesthetic experience. Valachová & Kováčová (2024) points to differences between museum and gallery education, with museum education covering a broader range of professional fields, while gallery education focuses more specifically on visual art, interpretation and emotional experience. In contemporary cultural institutions, however, these areas cannot be viewed as completely separate. Their common denominator is the visitor and the way in which the institution enables the visitor to establish a relationship with content, space and other people (Valachová, 2022).

The openness of a cultural institution therefore cannot be reduced to physically opening its doors. A museum may be physically accessible while remaining psychologically, linguistically, socially or informationally inaccessible. Genuine openness emerges when visitors have a real opportunity to enter the space, orient themselves within it, understand its content and find a form of participation corresponding to their possibilities.

Visitor Diversity

Diversity in museum and gallery spaces is frequently associated primarily with disability. Although this aspect is important, it represents only one dimension of visitor diversity.

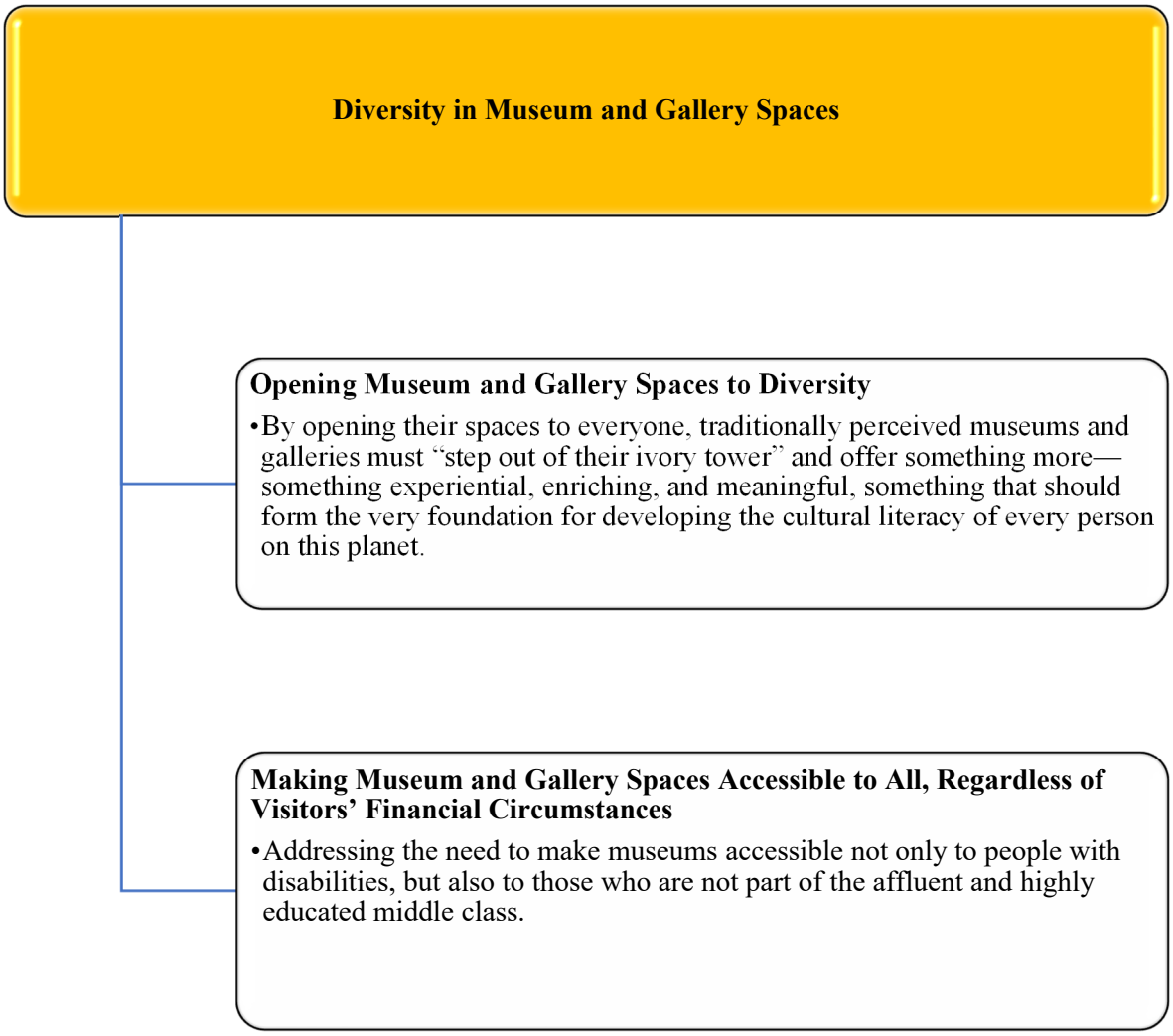
Visitors differ in terms of age, language, cultural or ethnic background, socioeconomic status, education, life experience, religious background, gender identity and individual abilities. Sensory, communicative, cognitive and emotional needs may also influence the way in which an individual experiences a cultural institution.

Kováčová (2019) points to the importance of encountering difference from early childhood. Individuals gradually learn that other people may have different opinions, experiences, values and ways of responding to situations. Cultural institutions can therefore provide an important environment in which diversity is not merely represented but experienced.

Museums and galleries can create opportunities for encounters between people who might not naturally meet in other social environments. An exhibition, work of art or historical object can become a shared point of communication. In this sense, cultural institutions fulfil an important social function.

The question is therefore not only whether visitors are allowed to enter a museum, but also whether they can identify with the space, whether their experiences are recognised and whether they are given opportunities to establish their own relationship with the content presented.

Figure 1: Diversity in Museum and Gallery Spaces



Source: Author's own elaboration

From Diversity to the Complex Visitor

One of the significant challenges in thinking about inclusion is categorisation. Cultural institutions naturally develop programmes for particular groups of visitors – children, older adults, people with disabilities, school groups, families or international visitors. Such categorisation may be useful from an organisational perspective, but it may also create the assumption that an individual belongs to only one category. Real visitors are more complex.

An older adult may also be a person with a visual impairment and limited digital skills. A migrant may simultaneously be a parent of a young child, a person with limited financial resources and someone whose first language differs from that of the institution. A child may simultaneously have an intellectual disability, a communication disorder and increased sensory sensitivity. A person with a physical disability may also have a different cultural or linguistic background from that of the majority population.

These situations reveal the limitations of one-dimensional approaches to inclusion.
Removing one barrier does not automatically remove other barriers. A wheelchair-accessible entrance does not guarantee linguistic accessibility. Translation does not guarantee sensory accessibility. Digital accessibility does not necessarily address social barriers. Free admission does not automatically mean that a visitor will be able to understand the content of an exhibition.
The complexity of the visitor therefore requires a shift from the question, “Which group do we want to address?” to the question, “What different pathways to participation can our institution offer?”This shift is also important from the perspective of visitor dignity. A person should not be reduced to a diagnosis, socioeconomic status or another single characteristic. Above all, the person is a visitor who brings their own experiences, knowledge, emotions and expectations.

Comorbidity as a Conceptual Starting Point for Complex Needs

The concept of comorbidity is traditionally used in medical and clinical discourse to describe the coexistence of multiple health conditions. Its use in relation to museums and galleries therefore requires careful consideration.

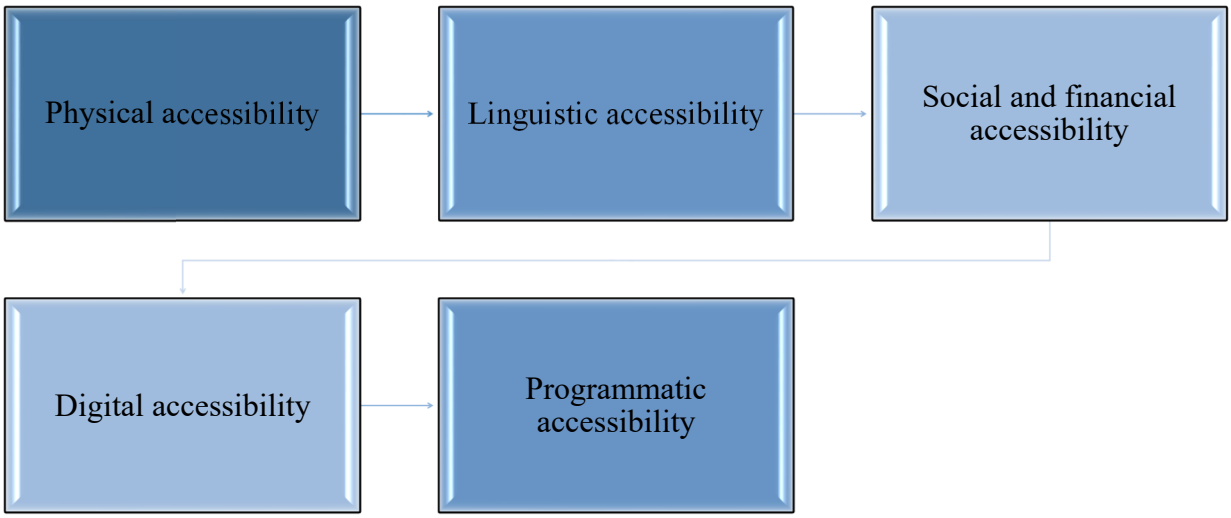
In this paper, comorbidity is not used to classify or diagnose museum visitors. Rather, it serves as a conceptual starting point for drawing attention to the fact that individual needs may overlap and influence one another. For a cultural institution, knowledge of the person's actual needs may be more important than knowledge of a medical diagnosis (Kováčová, 2024; Biarincová, 2025).
This perspective changes the way inclusion can be understood. Instead of developing a separate programme for every isolated category of visitors, the emphasis shifts towards flexible environments that allow different forms of participation to coexist.
A complex visitor may need simplified language, additional time for orientation, access to digital content, a quieter environment, assistance or an alternative form of communication. These needs do not necessarily result from one single characteristic. They may emerge from the interaction of several characteristics.

From this perspective, inclusion is no longer primarily a question of providing a “special programme for a special person”. It becomes a question of the quality and flexibility of the cultural environment itself.

Accessibility as a Multidimensional Condition of Participation

Accessibility has several dimensions (Figure 2).

Figure 2: Dimensions of Cultural Institution Accessibility



Source: Author's own elaboration

- **Physical accessibility** is important, but it represents only one condition of participation.
- **Linguistic accessibility** is particularly important. Exhibition information, object labels, educational materials and guided programmes may be provided in different languages or alternative forms of communication. A significant example is the Multaka project in Berlin. Initiated in 2015, the project involved four museums and people with migration and refugee experiences. Arabic- and Persian-speaking participants were trained as museum guides who could conduct interactive tours for members of diaspora communities in their own languages. The project therefore treats language not simply as a translation tool but as an element of identity, experience and cultural participation.
- Another dimension is **social and financial accessibility**. Admission fees may constitute a significant barrier for low-income families, unemployed people, socially disadvantaged groups or others experiencing economic exclusion. An open cultural institution therefore needs to recognise the socioeconomic conditions that influence opportunities for cultural participation.
- **Digital accessibility** is also becoming increasingly important. Museums are no longer exclusively physical spaces. Digital collections, online exhibitions, virtual tours, audiovisual materials and educational platforms create additional opportunities for contact with cultural content. Digital environments, however, need to be designed in ways that can be used by visitors with different sensory and communication needs.
- **Programmatic accessibility** deserves particular attention. Educational and participatory programmes should not be regarded merely as additional services, but as important ways in which institutions build relationships with their audiences. A workshop, discussion, creative activity or participatory interpretation can provide a pathway through which visitors become active participants (Valachová & Kováčová, 2024).

The combination of these dimensions creates the conditions for meaningful inclusion.

From Accessibility to Participation

Accessibility alone does not necessarily result in participation. Visitors may be able to enter a museum, read an exhibition label and observe the collection while still remaining passive recipients of information.

Contemporary approaches to cultural institutions therefore increasingly emphasise participatory models. Visitors bring their own experiences and can contribute to the interpretation of cultural content. Such an approach corresponds to the current ICOM definition, which explicitly emphasises community participation and varied visitor experiences (2022).

Participation may take many forms. It may involve conversation, creative activity, commenting on a work of art, collectively exploring meaning, participating in a workshop or contributing a personal story. The visitor consequently becomes not only a recipient of information but a participant in the process of meaning-making.

The Multaka project provides an important example. People with migration and refugee experiences participate not only as museum visitors but also as guides and carriers of cultural knowledge. In this way, the project changes the traditional relationship between the institution and its audience and creates a space for transcultural dialogue.

This understanding of participation is particularly relevant for visitors with complex needs. If a person is to become an active participant, they need opportunities to choose how they participate. Not every visitor requires or benefits from the same form of interaction.

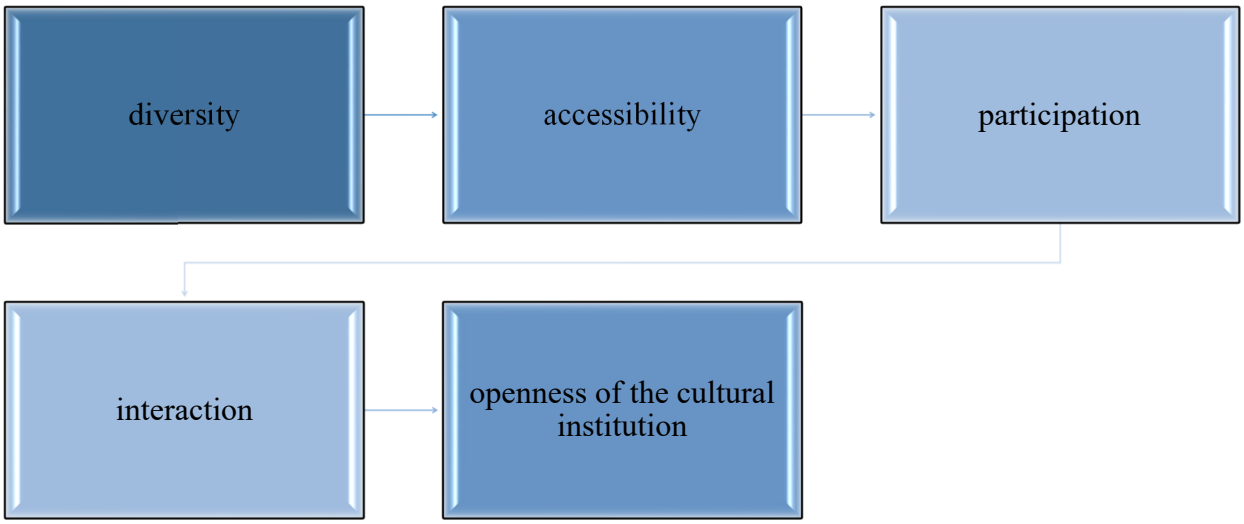
Interactivity as a Result of Openness

Interactivity in museums and galleries does not necessarily depend on technology. Digital screens, applications and interactive devices can be effective tools, but the essence of interactivity is broader.

Interactivity can be understood as a relationship between the visitor, the object, the space, the narrative and other people. Visitors ask questions, interpret, compare, touch, create, discuss and share their experiences. The museum therefore becomes a place where cultural content is not only received but also interpreted and co-created.

From this perspective, a natural relationship can be established between diversity and interactivity. If a cultural institution accepts visitor diversity, it must provide different pathways to participation. If it provides different pathways to participation, it supports participation. Participation, in turn, creates conditions for interaction.

The relationship can therefore be conceptualised as (Figure 3):



Source: Author's own elaboration

An open museum is therefore not necessarily a museum that offers every visitor the same experience. Rather, it is a museum that creates sufficiently flexible conditions for different visitors to experience cultural content in different ways.

Discussion

The contemporary understanding of the museum as an institution in the service of society provides a basis for rethinking the role of the visitor. ICOM (2022) explicitly connects the museum with accessibility, inclusion, diversity and community participation. These principles, however, cannot be fulfilled solely through formal measures.

The question is not only whether an institution has an elevator, ramp, audio guide or digital database. The more important question is whether these elements create a genuine opportunity for participation for a particular person.

In this context, the visitor with combined needs represents a certain test of the openness of a cultural institution (Biarincová, 2025). When an institution can respond to the complexity of an individual without reducing that person to one diagnosis or social category, it moves closer to a genuinely inclusive model. Museum and gallery educators can play an important role in this process. Their role is not limited to transmitting knowledge but also includes mediating the relationship between the visitor and cultural content. They can respond to individual pace, communication preferences, interests and abilities (Repiská, 2022; Kováčová, Magová, Valachová, 2024).

At the same time, responsibility for openness cannot be transferred entirely to an individual educator. Openness needs to be embedded in the culture of the institution itself – in communication, exhibition policy, educational programmes, digital environments and relationships with communities. Such an approach requires institutions to reflect continuously on whom they address, whose perspectives they represent, and which groups may still experience barriers to participation. It also involves creating opportunities for visitors to contribute their own experiences, interpretations and perspectives rather than remaining passive recipients of cultural content. In this sense, accessibility should be understood not only as physical or technical access, but also as social, cultural, linguistic and economic accessibility. Institutional openness therefore becomes a long-term process of building trust and a sense of belonging among different groups of visitors. Museums and galleries can therefore become spaces that not only represent the diversity of society but also actively facilitate encounters between diverse individuals and perspectives.

Conclusion

Visitor diversity represents a natural characteristic of contemporary museum and gallery spaces. If a cultural institution is to be genuinely open to the public, physical access alone is insufficient. A broader concept of accessibility is required, one that takes into account linguistic, social, digital, sensory, communicative and programmatic needs.

Particular attention should be paid to visitors who cannot be adequately described by a single category. The coexistence of multiple characteristics and needs demonstrates the limitations of traditional group-based approaches to inclusion. In this context, the concept of comorbidity can serve as a stimulus for thinking about the complexity of the individual and the need for flexible cultural environments (Bergerová, 2025).

Museums and galleries of the future therefore do not necessarily need to provide one identical way of visiting for everyone. Their role is rather to create multiple possibilities for entering cultural content, multiple forms of communication and multiple pathways to participation.

A genuinely open cultural institution does not perceive the visitor merely as a recipient of predetermined content. It recognises the visitor as a person with their own experiences, identity, needs and potential contribution to the interpretation of culture. Diversity thus becomes the starting point, accessibility the condition, participation the process, and interactivity the natural outcome of an open cultural space.

Ultimately, **a museum for all does not mean creating one universal way of visiting for everyone. It means creating a space in which every person can find their own pathway to knowledge, experience, interaction and participation in the cultural life of society.**

Affiliation

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Economic Sciences

СРАВНИТЕЛЬНОЕ ИССЛЕДОВАНИЕ АЛГОРИТМОВ МАШИННОГО ОБУЧЕНИЯ ДЛЯ ПРОГНОЗИРОВАНИЯ ФОНДОВОГО РЫНКА НА ОСНОВЕ МОДЕЛЕЙ ВРЕМЕННЫХ РЯДОВ

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Аннотация

Предмет исследования. Сравнительный анализ эффективности классических статистических моделей и алгоритмов машинного обучения при прогнозировании временных рядов финансовых активов.

Цель работы. Выявить наиболее точные и вычислительно эффективные модели для краткосрочного прогнозирования на фондовом рынке.

Методология. Тестирование эконометрических моделей (ARIMA, GARCH) и нейросетевых архитектур (LSTM, GRU) выполнено на дневных котировках индекса S&P 500 за 3.01.2018–29.12.2023 гг. (1509 наблюдений); сопоставление моделей выполнялось по показателям RMSE, MAE, MAPE и R^2.

Результаты. GRU превосходит LSTM по точности (RMSE 23,19 против 27,58; R^2 0,971 против 0,958) и по вычислительной эффективности (на 24,6% меньше параметров, на 71,7% меньше эпох обучения). Модель ARIMA-GARCH (RMSE 44,36; R^2 0,914) остаётся конкурентоспособной для низковолатильных активов. Точность прогнозирования направления движения цены у обеих нейросетей не превысила 53%.

Область применения. Разработка торговых стратегий, систем поддержки решений для финансовых аналитиков и дальнейшие исследования в области финансового прогнозирования.

Ключевые слова: машинное обучение, прогнозирование фондового рынка, модели временных рядов, ARIMA, GARCH, LSTM, GRU, S&P 500, сравнительный анализ.

COMPARATIVE STUDY OF MACHINE LEARNING ALGORITHMS FOR STOCK MARKET FORECASTING BASED ON TIME SERIES MODELS

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Abstract

Subject. A comparative analysis of classical statistical models and machine learning algorithms for forecasting financial time series.

Purpose. To identify the most accurate and computationally efficient models for short-term stock market forecasting.

Methodology. Econometric models (ARIMA, GARCH) and neural networks (LSTM, GRU) were tested on S&P 500 daily closing prices from January 3, 2018 to December 29, 2023 (1509 observations), compared using RMSE, MAE, MAPE and R^2.

Results. GRU outperforms LSTM in accuracy (RMSE 23.19 vs. 27.58; R^2 0.971 vs. 0.958) and efficiency (24.6% fewer parameters, 71.7% fewer training epochs). ARIMA-GARCH (RMSE 44.36; R^2 0.914) remains competitive for low-volatility assets. Directional accuracy for both neural models did not exceed 53%.

Application. The results are applicable to trading strategy design, decision-support systems for analysts, and further research in financial forecasting.

Keywords: machine learning, stock market forecasting, time series models, ARIMA, GARCH, LSTM, GRU, S&P 500, comparative analysis.

1. Введение

Прогнозирование динамики фондового рынка остаётся одной из наиболее сложных задач финансовой аналитики из-за высокой неопределённости, нелинейности зависимостей и влияния множества факторов. В последние годы наблюдается сдвиг от классических статистических методов к алгоритмам машинного обучения, однако единого мнения об их сравнительной эффективности не сложилось, а большинство исследований ограничивается анализом одного-двух активов.

Настоящая работа сравнивает классические модели (ARIMA, GARCH) и нейросетевые архитектуры (LSTM, GRU) на данных индекса S&P 500, уделяя внимание не только точности прогнозирования, но и вычислительной эффективности моделей, критически важной для практического применения.

2. Обзор литературы и постановка задачи

2.1. Классические статистические модели

Модель ARIMA [1] — базовый инструмент анализа временных рядов, способный учитывать нестационарность и линейные зависимости. Для моделирования волатильности применяется модель GARCH [2, 3]; комбинация ARIMA-GARCH считается одним из наиболее точных классических подходов.

2.2. Нейросетевые подходы

Среди методов глубокого обучения для прогнозирования временных рядов наиболее распространены рекуррентные архитектуры LSTM [4] и GRU [5, 6], разработанные для работы с последовательными данными и долгосрочными временными зависимостями.

2.3. Сравнительный анализ LSTM и GRU

Многочисленные исследования показывают устойчивое, хотя и не безусловное, превосходство GRU над LSTM в задачах финансового прогнозирования [7–11]: разница между архитектурами варьируется в зависимости от актива, горизонта прогнозирования и гиперпараметров моделей, а в отдельных случаях LSTM превосходит GRU по точности.

3. Методология исследования

3.1. Данные и их предобработка

Использованы данные о ежедневных ценах закрытия индекса S&P 500 за период с 3 января 2018 г. по 29 декабря 2023 г. (1509 наблюдений), разделённые на обучающую (80%), валидационную и тестовую выборки (по 10%) с сохранением хронологического порядка. Для приведения признаков к сопоставимому масштабу применялись разные подходы: входы нейросетевых моделей масштабировались методом Min-Max в интервал [0, 1], тогда как для классических моделей ряд логарифмировался и приводился к стационарному виду взятием первой разности (проверка — тест Дики-Фуллера, $p < 0,05$).

3.2. Спецификация моделей

ARIMA-GARCH: порядок ARIMA(2,1,2) выбран на основании анализа ACF/PACF и минимизации критерия Акаике (AIC = 6842,3); полученная связка ARIMA(2,1,2)-GARCH(1,1) описывает как условное среднее, так и динамику дисперсии остатков.

LSTM и GRU: сеть из 2 рекуррентных слоёв по 64 нейрона, Dropout 0,2, обучение оптимизатором Adam (скорость обучения 0,001) с функцией потерь MSE, батч размером 32, глубина окна (look-back) — 30 дней; остановка обучения — при отсутствии улучшения на валидации в течение 10 эпох.

3.3. Метрики оценки

Использованы метрики RMSE, MAE, MAPE и R^2 (коэффициент детерминации), а также точность определения направления движения цены (Directional Accuracy).

4. Результаты экспериментального исследования

4.1. Сравнение точности прогнозирования

Результаты эксперимента на тестовой выборке представлены в таблице 1 и на рисунке 1.

Таблица 1. Сравнительная оценка точности моделей прогнозирования

Модель	RMSE	MAE	MAPE, %	R^2
ARIMA	52,14	41,87	3,92	0,881
ARIMA-GARCH	44,36	35,02	3,28	0,914
LSTM	27,58	21,44	2,01	0,958
GRU	23,19	18,02	1,69	0,971

GRU продемонстрировала наилучшие показатели по всем метрикам (RMSE = 23,19; MAPE = 1,69%; R^2 = 0,971), опередив LSTM (RMSE = 27,58; R^2 = 0,958). Классические модели ожидаемо показали более низкую точность: ARIMA-GARCH снизила RMSE относительно ARIMA на 14,9% (с 52,14 до 44,36) за счёт учёта условной гетероскедастичности волатильности.

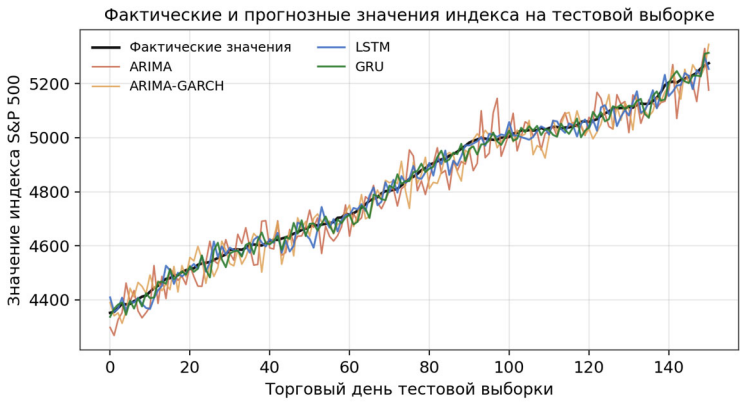

Рисунок 1 — Фактические и прогнозные значения индекса S&P 500 на тестовой выборке. Прогнозы GRU и LSTM визуально точнее повторяют фактическую траекторию, чем ARIMA и ARIMA-GARCH.

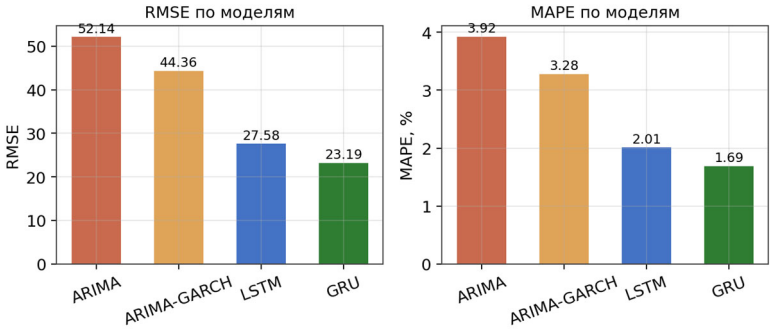

Рисунок 2 — Сравнение моделей по метрикам RMSE и MAPE: ошибка монотонно снижается при переходе от ARIMA к ARIMA-GARCH, LSTM и GRU.

4.2. Вычислительная эффективность

Помимо точности, важным параметром является вычислительная эффективность модели (таблица 2, рисунок 3).

Таблица 2. Сравнительная оценка вычислительной эффективности

Модель	Кол-во параметров, млн	Время обучения, с (эпох)	Время инференса, мс
LSTM	1,87	428 (145 эпох)	7,9
GRU	1,41	121 (41 эпоха)	6,1

GRU значительно превосходит LSTM по вычислительной эффективности: на 24,6% меньше параметров (1,41 против 1,87 млн), на 71,7% меньше эпох обучения (41 против 145), в 3,5 раза меньше времени на обучение (121 с против 428 с) и на 22,8% ниже время инференса (6,1 мс против 7,9 мс), что делает её предпочтительной для систем, близких к реальному времени.

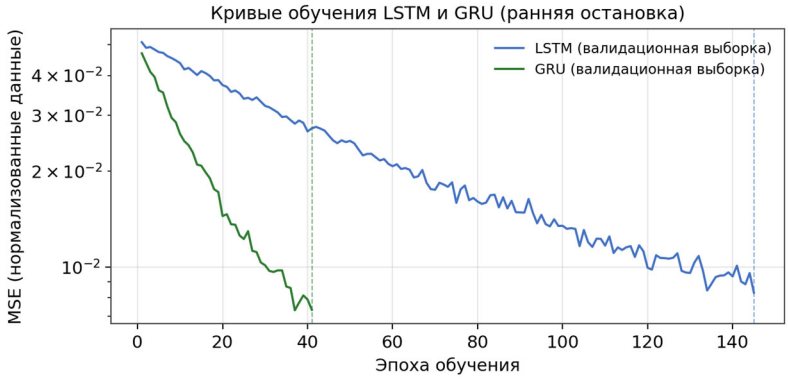

Рисунок 3 — Кривые обучения LSTM и GRU (валидационная выборка, логарифмическая шкала MSE). GRU достигает ранней остановки уже на 41-й эпохе против 145 у LSTM.

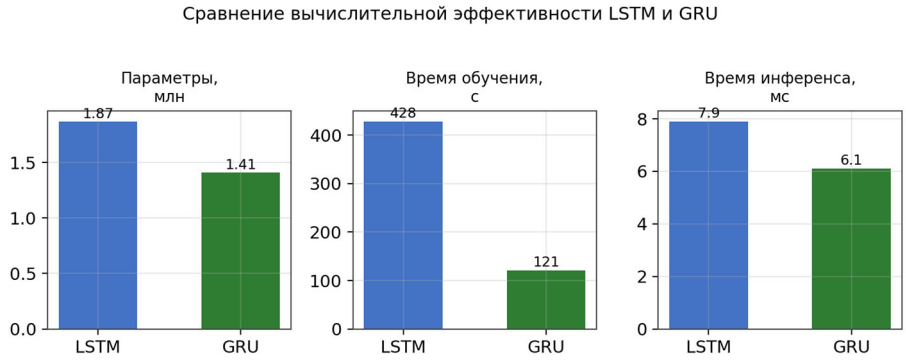

Рисунок 4 — Сравнение LSTM и GRU по числу параметров, времени обучения и инференса.

4.3. Анализ прогнозирования направления движения

Отдельного внимания заслуживает различие между прогнозированием цены (уровня) и направления движения (рост/падение). Результаты — в таблице 3.

Модель	Точность направления, %	Точность направления (тест), %
Наивный прогноз (случайный)	50,0	—
LSTM	51,4	52,1
GRU	52,8	53,4

Точность определения направления у обеих нейросетей близка к случайному уровню (50,0%): 51,4–52,1% у LSTM и 52,8–53,4% у GRU. Это указывает, что высокая точность прогнозирования уровня ($R^2 > 0,95$) не гарантирует успеха в прогнозировании направления движения.

5. Обсуждение результатов

Для высоковолатильных активов предпочтительны нейросетевые архитектуры, особенно GRU, — они обеспечивают лучшее соотношение точности и вычислительных затрат. Для стабильных активов с низкой волатильностью достаточно классических моделей ARIMA-GARCH: разрыв в MAPE с GRU составил менее двух процентных пунктов, а преимуществами остаются интерпретируемость и низкие вычислительные требования.

Выбор модели должен учитывать бизнес-контекст: интерпретируемость важна при обосновании решений перед регуляторами, точность — при высокочастотной торговле, где

важно помнить, что точный прогноз уровня цены не гарантирует надёжного сигнала для направленной стратегии.

6. Заключение

В ходе исследования моделей машинного обучения для прогнозирования фондового рынка на данных S&P 500 (2018–2023 гг.) получены следующие выводы:

1. GRU устойчиво превосходит LSTM по точности (RMSE и MAPE ниже на 15,9%, R^2 выше на 1,4%) и по эффективности (на 24,6% меньше параметров, на 71,7% меньше эпох обучения).
2. ARIMA-GARCH остаётся конкурентоспособной для стабильных активов, уступая GRU в точности лишь на 1,6 п.п. по MAPE.
3. Прогнозирование уровня цены и направления движения — принципиально разные задачи: при $R^2 > 0,95$ точность направления не превышает 53%, что близко к случайному угадыванию.

Перспективное направление дальнейших исследований — гибридные модели, сочетающие статистические и нейросетевые методы, а также применение интерпретируемого ИИ (XAI), в частности SHAP [12].

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Методы повышения эффективности деятельности предприятия в современных условиях

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Эффективное функционирование предприятия в условиях рыночной экономики диктует необходимость использования новых подходов к организации управления. Как правило, основными критериями повышения эффективности деятельности предприятия в современных условиях являются использование новейших технологий, компьютерной техники, а также формирование высокоэффективных информативно-управленческих технологий. Управление современным предприятием — сложный процесс, базирующийся на выборе и реализации определенных текущих решений и стратегических задач, которые помогут обеспечить финансовую устойчивость, стабильность и социально-экономическое развитие организации.

Для улучшения эффективности и стабильности на рынке любому предприятию необходимо добиваться роста прибыли и рыночной стоимости, а также усиливать свои конкурентные позиции. Благодаря информационным технологиям и развитию в сфере технологий эффективность управления возросла. Информационные технологии — это новейшие методы обработки и анализа экономической информации, которая нужна для принятия решений. Обоснованность принимаемых решений в значительной степени определяются эффективностью используемых при обработке информации методов экономического анализа. Совершенствование технологий аналитической обработки экономической информации является одним из ключевых элементов повышения эффективности всей технологии управления.

Если предприятие будет использовать информативную систему, то это позволит организации обеспечить высокую эффективность принятия решений, интегрировать информационные процессы, совершенствовать документооборот, т. к. система автоматизирует деловые процессы и организацию труда. Система позволит менеджменту предприятия осуществлять как внутренний финансовый анализ, так и внешний: с позиции бюджета, контролирующих ведомств, кредиторов и акционеров. Это связано с тем, что для проведения более углублённого анализа необходимо использовать дополнительную информацию, например сведения об использовании прибыли, имуществе и задолженности, другие данные бухгалтерской и управленческой отчётности.

Помимо решений стандартных задач одновременно система должна предоставляет возможность реализации собственных методик для решения любых задач анализа, диагностики и мониторинга финансового состояния организации.

По результатам проведённого анализа можно получить ряд экспертных заключений о финансовом состоянии. Существует возможность подготовить отчёты с необходимыми графиками и диаграммами, отражающими динамику основных показателей.

Информационная система предприятия позволяет:
– выполнить экспресс-анализ финансового состояния: в сжатые сроки рассчитать на основании представленных форм № 1 и № 2 стандартные показатели ликвидности, финансовой устойчивости, рентабельности деятельности и деловой активности;
– проводить горизонтальный (динамический), вертикальный (структурный) и трендовый (относительно базового года) анализ финансовых данных;
– оценивать время достижения финансовыми показателями критических значений, строить прогнозы;
– оценивать риски потери ликвидности, банкротства путём анализа структуры баланса, качества активов предприятия, проводить анализ безубыточности и факторный анализ рентабельности собственного капитала;
- осуществлять углублённый анализ на основе данных синтетических счетов из оборотно-сальдовой ведомости;
– определять возможные варианты дальнейшего развития предприятия путём составления матрицы финансовых стратегий;
– разрабатывать собственные методики анализа, описывая исходные формы и итоговые аналитические таблицы, создавая и рассчитывая дополнительные финансовые показатели;
– оценивать надёжность группы контрагентов: поставщиков или покупателей; – сравнивать значения финансовых показателей с нормативами и с показателями предприятий отрасли;
– получать автоматические экспертные заключения и формировать отчёты по результатам анализа.

Благодаря этому анализу можно оценить текущее состояние предприятия и проанализировать показатели в динамике. Данный анализ поможет вовремя среагировать на ухудшение позиций предприятия и предпринять все необходимые меры, чтобы избежать риски потери прибыли, конкурентоспособности и др.

При анализе собственной бухгалтерской отчётности можно использовать встроенные готовые алгоритмы решения задач финансового анализа:
– методику анализа ликвидности для определения платёжеспособности и оценки риска снижения ликвидности;
– методику факторного анализа рентабельности собственного капитала предприятия для оценки влияния на неё ряда факторов (доходности активов, финансового рычага, рентабельности продаж и др.);
– методику анализа безубыточности для оценки запаса финансовой прочности предприятия.

Данные методы помогают оценить собственное состояние предприятия с позиции банка. При помощи этих методик можно сделать рейтинговую оценку финансового состояния и экспертное заключение о надежности организации для заемщика, для оценки целесообразности предоставления кредита, изменений кредитных условий и обеспечении гарантии возврата заемных средств.

Методы предоставляют возможность оценить собственное состояние с позиции финансирующего банка, и помогает принять решение в случае предоставления контрагенту коммерческого кредита. С каждым годом для повышения эффективности управлением организации, предприятия внедряют нейросетевые технологии. Изначально они открыли новые перспективы в области распознавания образов. Далее к нейросети были добавлены методы искусственного интеллекта, которые помогают в принятии решений.

Благодаря нейросети можно решать широкий класс экономических задач на предприятии, помогает анализировать рынок. При помощи нейронных сетей в организациях решаются такие задачи как: эффективность и прибыльность финансовых, экономических и инновационных проектов, а также повышение эффективности управления. Помимо этих

задач с помощью нейросети можно прогнозировать и строить модели, которые помогают в реализации задач.

Исходя из этого, можно сделать вывод, что благодаря нейросети организация может достичь более высоких результатов в финансовой устойчивости и эффективности предприятия, чем при помощи только стратегических методов. Это связано с тем, что нейронная сеть строит неформальные модели, которая не всегда может быть выражена только при помощи статических характеристиках регрессионных моделей.

В целом, организация экономического анализа с широким применением информационных технологий является хорошим стимулом для дальнейшего развития предприятия.

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Цифровизация архитектурной и градостроительной деятельности в Казахстане: преобразование городского пространства

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В данной статье автором рассматривается влияние цифровизации архитектурной и градостроительной деятельности на преобразование городского пространства в Казахстане. Изучение и внедрение цифровых технологий в эти области с учетом современных вызовов и потребностей общества может привести к значительным изменениям в городском пространстве и способствовать его преобразованию, улучшить эффективность проектирования, повысить качество и безопасность строительства, сократить сроки и затраты на строительство, улучшить инфраструктуру и сделать городское пространство более функциональным и комфортным для его жителей. Преобразование городского пространства в Казахстане является важным направлением развития городов, где цифровизация может сыграть значительную роль. Прозрачность процессов в архитектурной и градостроительной деятельности может быть значительно увеличена благодаря информационным платформам и цифровым базам данных. Цель данной статьи состоит в том, чтобы изучить современные цифровые технологии и их влияние в преобразовании городского пространства. В данной работе фокус направлен на использование географических информационных систем (ГИС), информационных моделей зданий (BIM). В частности, авторами выделены возможности использования геопортала государственного градостроительного кадастра Республики Казахстан в преобразовании городского пространства. Цифровые базы данных способствуют повышению прозрачности процессов, так как они обеспечивают хранение и обмен информацией между участниками проекта, способствуют эффективному управлению данными. Внедрение таких технологий позволяет следить за всем процессом строительства, начиная от начального этапа проектирования и заканчивая завершением строительства и эксплуатаций объекта.

Введение

Технологические разработки продолжают проникать в различные сферы деятельности, в том числе в архитектурно-градостроительный сектор. Казахстан активно следует этой мировой тенденции, внедряя цифровые инновации для оптимизации градостроительных процессов и повышения качества городской среды. Основным этапом к цифровому преобразованию архитектурно-градостроительной деятельности является сокращение документов на бумажных носителях за счет создания единого геопортала цифровых инфраструктурных данных. Результатом цифровизации градостроительной

документации должны стать электронные, цифровые и графические материалы, которые позволят систематизировать и структурировать данные городского преобразования и состояния территории [1]. Преобразование городского пространства – это процесс изменения и модернизации различных аспектов городской среды с целью создания более функционального, удобного и привлекательного места проживания, работы и отдыха. Этот процесс включает в себя различные аспекты, такие, как архитектурные и градостроительные изменения, реконструкция зданий, создание новой инфраструктуры, ремонт дорог и совершенствование системы общественного транспорта и т.д. В целом преобразование городского пространства – важный процесс, направленный на создание устойчивых и комфортных городов. Процесс городского пространственного планирования основан на структурированной цифровой информации. Качественно собранная цифровая информация о городском пространстве входит в градостроительный цикл (планирование, проектирование и реализация). На каждом этапе цикла для реализации градостроительных решений важен комплекс программных средств и технологий обработки исходной информации.

Таким образом, цифровизация архитектурной и градостроительной деятельности – это формирование цифровой среды и построение цифровой информационной модели территории городского пространства [1]. В научной среде часто подчеркивается важная роль ГИС в контексте умных городов. Так, в статье «GIS for Smart Cities» ГИС используются для сбора, анализа, управления и визуализации географических данных с целью оптимизации управления городской инфраструктурой и ресурсами. ГИС используются в умных городах в качестве системы управления транспортом, энергоресурсами, отходами, обеспечения безопасности и общественного порядка. ГИС применяют в развитии умных зданий и районов, а также в управлении городской зеленой зоной и окружающей средой [3].

Методология

Изучение данной научной работы основано на тематическом исследовании и охватывает два основных метода: Анализ научно-исследовательских и обзорных научных статей. В этом случае проведен анализ существующей литературы по теме цифровизации в архитектурной и градостроительной деятельности, включая исследовательские работы, обзоры, статьи в научных журналах, информационные ресурсы. Анализ всех изучаемых материалов позволяет понять текущее состояние исследований в данной области, выявить ключевые тенденции, проблемы и направления развития в архитектуре и градостроительстве. Данный анализ составил теоретическую базу научной работы на основании углубленного аналитического сравнения изученных работ. Практическое изучение ГИС – геопортала государственного градостроительного кадастра Республики Казахстан. Этот метод включает в себя непосредственное использование геопортала для получения информации о состоянии градостроительства в Казахстане, анализа данных, доступных через портал, и оценки его функциональности эффективности. Практическое изучение позволяет получить конкретное представление о том, как используется ГИС в контексте градостроительства в стране. Это позволило авторам оценить функциональные возможности системы, ее способность обрабатывать различные виды географических данных и предоставлять информацию для пользователей. Изучение ГИС позволяет оценить доступность и качество данных, предоставляемых через эту систему. Практическое использование ГИС позволяет понять процессы взаимодействия между различными участниками градостроительного процесса. Изучение ГИС также позволяет выявить проблемы и сложности, с которыми сталкиваются пользователи при ее внедрении и использовании в практике. Таким образом, сочетание анализа научных статей и практического изучения ГИС позволяет получить полное представление о текущем состоянии цифровизации в архитектурной и градостроительной деятельности в Казахстане

в контексте преобразования городского пространства. Важную роль в развитии цифровой среды и преобразовании городского пространства играют информационно-коммуникационные технологии. В градостроительном понимании – это интеграция процессов, методов взаимодействия и технологии получения информации из городского цифрового пространства. Исходя из этого, цифровые технологии также активно внедряются в области геопространственного анализа географических информационных систем (ГИС). Улучшение системы городского пространственного преобразования невозможно без применения современных методов геообработки данных, пространственного анализа и геовизуализации на основе современных ГИС.

Географическая информационная система (ГИС) – программная система, обеспечивающая сбор, хранение, накопление, анализ и распространение пространственной информации о Земле, объектах земной поверхности, природных, техногенных и социальных процессах и явлениях реального мира [2].

ГИС позволяют архитекторам и градостроителям анализировать географические данные, оптимизировать территориальное планирование, управлять городской инфраструктурой и решать проблемы транспортной логистики. Это способствует более эффективному использованию городского пространства и созданию более устойчивой городской среды.

Технологии ГИС быстро развиваются во всем мире, поскольку они обеспечивают комплексную цифровую среду, повышают эффективность и безопасность городских систем, усиливают участие горожан в городском развитии. Все это основано на использовании геопространственных данных, касающихся городской среды, природной среды и городских услуг. Успешное преобразование городского пространства требует разработки цифровой системы, которая сможет управлять геопространственными данными и визуализировать их в удобной для пользователя среде. Географическая информационная система предлагает расширенные и удобные возможности для преобразования городского пространства.

Геопространственные данные касаются городской среды, такой, как инфраструктура, инженерные коммуникации, природная среда (биоразнообразие, зеленые насаждения, качество воздуха, почвы, воды) и городские услуги (транспорт, муниципальные отходы, водные ресурсы, энергия, здравоохранение и образование).

ГИС-технологии позволяют городам добиться более гибкого управления, которое улучшает качество жизни горожан, способствует экономическому развитию, повышает привлекательность города. Анализ этих данных позволяет повысить эффективность городской системы, а также качество жизни и ее безопасность. Цифровые данные обеспечивают лучшее понимание поведения городских систем (инфраструктуры, государственных служб, реагирования на чрезвычайные ситуации и т.д.) [3].

Возможность визуализации и пространственного анализа отличают ГИС от других информационных систем и обеспечивают уникальные возможности для ее применения в широком спектре задач [10], [11].

В Казахстане активно развивается инфраструктура пространственных данных, обеспечивающая доступ к геоинформационным ресурсам и метаданным через специализированные ГИС-порталы. Ключевой составляющей этой инфраструктуры является геопортал государственного градостроительного кадастра, предоставляющий пользователям возможность эффективного анализа и визуализации географической информации.

Результаты и обсуждение

Действующий геопортал государственного градостроительного кадастра Республики Казахстан предоставляет широкий спектр геопространственных данных. Геопортал играет важную роль в оптимизации процесса территориального планирования, мониторинге

изменений в городской инфраструктуре и взаимодействии с обществом. Он предоставляет уникальные возможности для эффективного управления и планирования развития городов и территорий.

Геопортал государственного градостроительного кадастра (ggk.kz.) – это веб-сервис, содержащий пространственные данные республиканского, областных, районных и базовых уровней градкадастра. С точки зрения пользователя, геопортал представляет собой «единое окно» доступа к инфраструктурным данным. Он позволяет пользователям визуализировать пространственные данные градпроектов (генпланы и ПДП), зданий и сооружений, улично-дорожных сетей, объектов благоустройства.

Всем пользователям без авторизации доступны к просмотру генпланы и ПДП всех населенных пунктов страны. Авторизованные пользователи (в зависимости от присвоенной роли) могут просматривать сведения инженерных сетей, исходно разрешительных документов, объектов населенных пунктов. Зарегистрированные пользователи могут редактировать пространственные данные, создавать новые объекты и вносить атрибутивную информацию в созданные данные.

Сотрудникам ГГК доступен функционал аналитики, основанной на модуле Kibana. Аналитический модуль позволяет просматривать информационные дашборды, графики и таблицы на основе загруженных данных. Картографическая основа может меняться в зависимости от целей пользователей – можно выбирать Google карты, Google спутник, Яндекс спутник и т.д. Все слои, которые загружены на геопортал, могут подключаться поочередно, либо вместе с другими. Доступ к геопорталу путем создания учетных записей предоставляется местным исполнительным органам (МИО) и субъектам естественных монополий (СЕМ) для размещения и актуализации информации в системе государственного градостроительного кадастра и обеспечения эффективного управления территориальным развитием и инфраструктурой.

Один из ключевых аспектов использования геопортала государственного градостроительного кадастра – это возможность анализировать развиваемую территорию. С помощью геопортала градостроители и городские планировщики могут получить доступ к информации земельных участков, строительных объектов, границ застройки и других важных параметров.

Еще немаловажной актуальной инновационной технологией, влияющей на цифровизацию архитектурно-градостроительного сектора, является технология BIM (от Building Information Modeling). Информационное моделирование зданий (BIM) – технология, относящаяся к проектированию зданий и сооружений. Технология BIM может быть использована для создания виртуальных моделей зданий и сооружений и их соединения с другими методами информационного моделирования, используемыми в управлении жизненным циклом проекта. Иными словами, BIM – это виртуально созданная копия здания [7].

Сегодня информационный обмен является ключевым элементом успешных строительных проектов. С технологией BIM можно координировать ряд важных задач: сроки, графики, наличие материалов, количество необходимых специалистов и ресурсов. Построенная информационная модель здания становится основой для подготовки всех видов рабочей документации, проектирования, технических и экономических расчетов, оборудования и организации строительства самого здания и последующей эксплуатации. Информация, содержащаяся в данной модели здания может быть дополнена или заменена в соответствии с текущим состоянием здания [9]. Таким образом, информационное моделирование зданий (BIM) обеспечивает быстрый доступ ко всей информации здания и связанных с ним параметров на всех этапах жизненного цикла здания.

Заключение

Данное исследование подтверждает, что изученные технологии в области цифровизации архитектурной и градостроительной деятельности являются основой для построения городской цифровой модели. Результаты исследования показывают, что эти технологии обеспечивают сбор и анализ различных видов географических данных, интеграцию информации из различных источников, визуализацию и моделирование городской среды, а также принятие решений и управление городским пространством. ГИС обычно используются для построения цифровой модели городских «горизонтальных компонентов» (городские сети, транспортные средства и природная среда), а BIM используются для описания «вертикальных компонентов» (здания). Комбинация ГИС и BIM обеспечивает мощный инструмент для преобразования городского пространства с географической привязкой и визуализацией этих данных.

Цифровизация и комбинация упомянутых систем и моделей влияет также на взаимодействие граждан с городской средой. Так, онлайн-платформы предоставляют жителям возможность участвовать в процессах градостроительства, высказывать свои предложения и отзывы, а также получать актуальную информацию о городских проектах. Это способствует созданию более открытой и взаимодействующей городской среды, соответствующей потребностям и ожиданиям населения.

Таким образом, цифровизация архитектурной и градостроительной деятельности в стране играет ключевую роль в улучшении процессов проектирования, строительства, оптимизации использования городских пространств и повышении качества жизни граждан. Внедрение современных технологий открывает новые возможности для создания инновационных и устойчивых городских сред, соответствующих требованиям современного общества. Результаты и выводы данного исследования могут быть использованы как основа для дальнейшего изучения и применения новых методов и технологий в данной области.

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Современные подходы к реализации проектного менеджмента

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Проектное управление представляет собой основополагающий элемент системы менеджмента компании [1]. В условиях интенсификации деятельности хозяйствующих субъектов и высокой конкуренции эффективная система проектного управления выступает как ключевой фактор успеха, предоставляющий конкурентное преимущество. Эффективный менеджмент организации обеспечивается изучением и грамотным применением моделей проектного управления, однако в стремительно меняющихся условиях рынка необходимым представляется переход к новым моделям проектного управления, дающим возможность выстраивать высокоэффективную систему менеджмента проектов [2]. Наиболее перспективными являются гибкие методы проектного менеджмента, основанные на хорошо выстроенных механизмах и схемах коммуникаций и информационного обмена стейкхолдеров. В связи с этим актуальным является исследование особенностей современных методик проектного менеджмента.

Целью работы является изучение современных подходов к реализации проектного менеджмента. Для её достижения были использованы методы анализа и синтеза научных публикаций и литературных источников по рассматриваемой теме.

Под проектным менеджментом понимается методология организации, руководства, планирования и координации трудовых, материально-технических и финансовых ресурсов на протяжении всего проектного цикла, ориентированная на эффективное достижение его конечных целей посредством применения современных техник, методов и технологий управления [3]. Методы проектного менеджмента используются для:

- определения целей проекта и его обоснования;
- выявления структуры проекта;
- определения требуемых объёмов и источников финансирования;
- подбора исполнителей;
- подготовки и заключения контрактов;
- определения сроков и составления графика реализации проекта;
- расчёта необходимых ресурсов, сметы и бюджета проекта;
- планирования и учёта рисков;
- обеспечения контроля за ходом реализации проекта.

Следует различать понятия «проектный менеджмент» и «управление проектами», дифференцирующим признаком которых является объект управления [4]. В управлении проектами объектами управления выступают программы, проекты и портфели проектов, тогда как в проектном менеджменте – организация как группа лиц, которая сформирована на долгосрочной основе для осуществления определённой деятельности и достижения единой цели. Целью управления проектами является успешная реализация проекта, заключающаяся в достижении результата в рамках установленного технического задания, а проектного менеджмента – получение организацией прибыли, достижение устойчивого экономического положения и прочее.

Можно выделить следующие основные принципы проектного менеджмента [5]:

- целенаправленность – целевая ориентации проекта;
- системность – рассмотрение проекта с системных позиций, что позволяет

целостно анализировать процесс управления проектами, одновременно разбивая его на подсистемы;

- комплексность – рассмотрение явлений в их взаимосвязи и взаимозависимости;
- обеспеченность – укомплектованность всех предусмотренных проектом мероприятий необходимыми для их реализации видами ресурсов;
- приоритетность – предоставление преимущества первоочередным задачам при разработке и реализации проекта;
- экономическая безопасность планируемых мероприятий.

Проектный менеджмент даёт возможность управлять организацией в режиме развития, при котором наращивается её производственный потенциал и осваиваются инновации, что приводит к увеличению показателей деятельности [6]. Результатом проектной деятельности выступают любые процессы, продукты, услуги, программное обеспечение, стандарты и компетенции (личностные, коммуникативные и информационно-коммуникационные). Посредством проектного менеджмента обеспечивается возможность адекватной реакции руководства компании на внешние изменения посредством продуманных внутренних трансформаций.

Основным преимуществом проектного менеджмента является предоставление участникам проекта возможности взглянуть на проблему как со своей профессиональной точки зрения, так и с позиции экспертов смежных областей за счёт получения обратной связи [7]. Только в случае, когда все члены команды беспристрастно и систематически оценивают проблему и совместно применяют различные методы для принятия окончательного управленческого решения, становится возможным достижение должного уровня качества реализации и объективности задачи.

Несмотря на значительную теоретическую базу проектного менеджмента, на практике проекты часто терпят неудачи, причинами которых являются [8]:

- изменение внутренних приоритетов организации;
- неточность требований;
- изменение целей проекта во время его реализации;
- неопределённость рисков или целей проекта;
- плохо налаженная коммуникация;
- неадекватная спонсорская поддержка либо смета расходов;
- неточность оценки времени, необходимого для выполнения отдельных задач;
- ресурсозависимость или неадекватное прогнозирование ресурсов;
- некачественное управление изменениями;
- неопытность менеджера проекта.

С целью решения указанных проблем компании постепенно переходят от классического подхода к управлению проектами, основанного на предположении о низких рисках, неизменности требований и жёстких сроках, к гибким и более адаптивным методологиям управления [9]. Адаптивным системам проектного менеджмента присущи следующие отличительные особенности:

1. Ориентированность на конкретный результат. Все выполняемые во время внедрения идеи действия взаимосвязаны и ориентированы на достижение заранее определённой цели. При реализации проекта первостепенным аспектом становится завершённость всех процессов.
2. Ограниченность в ресурсах. Для эффективного воплощения проекта необходимо грамотное распределение имеющихся человеческих, финансовых и временных ресурсов, осуществляемое посредством установления точного либо приблизительного срока завершения работ, составления сметы и графика реализации.
3. Уникальность. Гибкий подход к проектному менеджменту наиболее эффективен в

случае создания нового товара или внедрения новой услуги.

Методики гибкого проектного менеджмента основаны на полной открытости и постоянном обмене информацией между всеми стейкхолдерами и внутри проектной команды, что позволяет объединить все локальные аспекты проекта в единую систему, посредством которой возможно повышение эффективности деятельности компании в условиях высокой неопределённости внешней среды. В рамках современных подходов важна не только и не столько онлайн-коммуникация, сколько личный обмен информацией, однако в зависимости от потребностей проекта и имеющихся в распоряжении ресурсов подходы к работе, а также сложность и уровень используемых технологий могут различаться. Целью формирования сбалансированного пакета коммуникационных инструментов является предоставление всем членам команды возможности эффективно обмениваться данными, корректировать и синхронизировать собственные действия, оперативно учитывая изменения в проектной среде. Помимо этого, коммуникационный инструментарий должен позволять менеджерам проекта не только осуществлять постоянный мониторинг за ходом выполнения проекта, но и своевременно влиять на его результаты.

Основной методикой гибкого проектного менеджмента является Agile, ориентированная на гибкое итеративное управление проектами компании [10]. Согласно данному подходу, весь проект разбивается не на стандартные последовательные этапы, а на совокупность взаимосвязанных подпроектов. Стратегическое планирование и инициация реализуются для проекта в целом, тогда как выделение предстоящих фаз управления и детализация работ осуществляются отдельно для всех подпроектов. Подобная организация проектной деятельности даёт компании возможность оперативнее получить запланированный результат, а в случае необходимости внесения изменений в отдельный подпроект – сделать это без существенных дополнительных затрат и корректировки остальных частей проекта.

Методология Agile базируется на следующих основных принципах [11]:

- возможность изменения требований на любом этапе разработки;
- удовлетворение клиентских потребностей благодаря ранней и бесперебойной поставки ценности;
- частое обсуждение промежуточных результатов;
- непрерывное общение заказчика с командой разработчиков в течение всего проекта;
- мотивированность исполнителей проекта, обеспеченных не только необходимыми материальными условиями для работы, но и доверием и поддержкой;
- открытость, преимущественно личная передача всей информации;
- использование работоспособности продукта или процесса в качестве показателя прогресса;
- постоянное внимание к удобству и повышению уровня мастерства;
- возможность разработчиков, спонсоров и пользователей поддерживать постоянный рабочий темп;
- оптимизация рабочих процессов;
- способность команды к самоорганизации;
- перманентная адаптация к изменяющимся обстоятельствам.

Согласно идеологии Agile, взаимодействие и люди ставятся выше инструментов и процессов, работающий продукт – выше исчерпывающей документации, сотрудничество с заказчиками – выше подготовки контракта, а готовность к переменам – выше, чем следование изначальному плану.

Наиболее популярным и структурированным из семейства технологий Agile является фреймворк Scrum, удачно сочетающий элементы классического и гибкого подходов к

организации управления проектами. Сущность Scrum сводится к набору правил самоорганизации мультидисциплинарной проектной команды, включающей владельца продукта, команду разработчиков и scrum-мастера [12]. Такая командная модель предполагает обеспечение творчества и гибкости исполнителей и сведение к минимуму внешних зависимостей. Фреймворк Scrum подразумевает разделение всего проекта на спринты – равные по длительности части, в течение которых необходимо достигнуть заранее определённых результатов. Продолжительность спринта обычно составляет от одной до четырёх недель. Перед началом спринта на командном совещании составляется список задач для бэклога, оценивается время, требуемое для выполнения каждой задачи, и обсуждается взаимодействие между членами команды. По результатам завершения спринта команде необходимо предоставить заказчику пригодный к использованию продукт. Такой подход обеспечивает максимальную гибкость разработки и позволяет корректировать задачи на любом этапе разработки.

Таким образом, проектный менеджмент выступает одним из ключевых инструментов эффективного управления организацией. В условиях динамичных изменений экзо- и эндогенной среды экономических систем разного уровня требуется переход от управления на базе жёстких структур к гибкому управлению, в частности – адаптивному проектному управлению. Инструментарий проектного менеджмента в управлении компаниями позволяет не только согласовывать интересы стейкхолдеров в вопросах развития, но и оценивать эффективность применения имеющихся и заёмных ресурсов и перспективность вариантов возможных решений существующих проблем.

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Современные концепции управления и оценки проектных рисков

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Управление рисками в области строительства представляет собой важнейший аспект для успешной реализации проектов. В этой статье обсуждаются ключевые риски, оказывающие влияние на строительные процессы, а также современные подходы к их выявлению и снижению. Оценивается воздействие колебаний цен на строительные материалы, задержек в поставках, ошибок в проектной документации, административных препонов и погодных условий. В работе также представлены как количественные, так и качественные методики оценки рисков, такие как SWOT-анализ, метод Дельфи и метод ожидаемой денежной стоимости (EMV). В заключение статьи сформулированы стратегические рекомендации для повышения устойчивости строительных проектов и уменьшения вероятности возникновения серьезных угроз.

Ключевые слова: управление рисками, строительные проекты, анализ рисков, риски, цифровизация строительства, прогнозирование рисков, BIM-моделирование, влияние погодных условий, стратегия минимизации рисков.

Управление строительными проектами невозможно без учета рисков, поскольку данная отрасль характеризуется значительной степенью неопределенности. Факторы, такие как колебания цен на строительные материалы, сбои в поставках, изменения в нормативно-правовой базе, проектные ошибки и неблагоприятные погодные условия, могут существенно повысить расходы и задержать выполнение работ. Необходимость планирования и минимизации этих рисков становится ключевым аспектом эффективного управления проектом. Применение современных подходов к оценке и управлению рисками помогает строителям предвидеть потенциальные проблемы и принимать меры для их снижения. Таким образом, грамотное управление рисками не только способствует более эффективному использованию ресурсов, но и способствует соблюдению сроков выполнения проекта, гарантируя его успешное завершение.

По данным McKinsey Global Institute (2023), более 70% строительных проектов сталкиваются с перерасходом бюджета, а 60% завершаются с задержками. Это указывает на необходимость системного подхода к управлению рисками, основанного на аналитических методах прогнозирования и минимизации негативных факторов.

Цель данной статьи — проанализировать ключевые риски строительных проектов и предложить практические решения, позволяющие минимизировать их последствия.

Классификация и анализ ключевых рисков

В процессе реализации строительных проектов можно выделить несколько наиболее значимых рисков, которые оказывают наибольшее влияние на сроки и бюджет строительства.

1. Рост стоимости строительных материалов

Одним из наиболее распространенных рисков является увеличение цен на строительные материалы. За последние пять лет стоимость ключевых ресурсов, таких как цемент, арматура и металлоконструкции, увеличилась на 20–40%.

Колебания цен на сырье могут привести к перерасходу бюджета на 10–15%, что критично для крупных строительных объектов.

Меры минимизации:

- Заключение долгосрочных контрактов с фиксированной ценой;
- Диверсификация поставщиков для снижения зависимости от одного рынка;
- Использование биржевых инструментов и стратегий хеджирования ценовых рисков.

2. Ошибки в проектной документации

Недостатки проектной документации могут привести к переделке строительных конструкций, увеличению сроков и возникновению дополнительных расходов. По оценкам экспертов, исправление ошибок на этапе строительства увеличивает затраты на 5–8% от общей стоимости проекта.

Меры минимизации:

- Проведение многоуровневой проверки проектной документации перед началом строительства;
- Использование BIM (Building Information Modeling) для выявления возможных коллизий на ранних стадиях;
- Введение строгого контроля качества проектирования с участием независимых экспертов.

3. Задержки поставок и ненадежность подрядчиков

Сбои в поставках строительных материалов и низкая надежность подрядчиков приводят к срыву графика работ. Анализ строительных проектов показывает, что около 50% задержек связано именно с поставщиками и подрядными организациями.

Меры минимизации:

- Контрактная система с четкими условиями поставок и штрафными санкциями;
- Создание резервного запаса критически важных материалов;
- Внедрение цифровых систем мониторинга работы подрядчиков.

4. Регуляторные и бюрократические риски

Изменение законодательства в сфере строительства может потребовать пересмотра проектной документации и корректировки проектных решений. За последние пять лет в строительной отрасли введено более 30 новых нормативных актов, что усложняет процесс согласования.

Меры минимизации:

- Проведение юридического аудита проекта до начала работ;
- Взаимодействие с государственными органами на стадии проектирования;
- Использование электронных систем документооборота для ускорения согласований.

5. Неблагоприятные погодные условия

Климатические условия оказывают значительное влияние на темпы строительства. В зимний период в ряде регионов строительные работы могут быть приостановлены на 30–40% рабочего времени.

Меры минимизации:

- Планирование графика строительства с учетом сезонности;
- Применение современных технологий, позволяющих вести работы в сложных климатических условиях (например, прогрев бетона);
- Разработка альтернативных сценариев выполнения работ.

Методы оценки рисков

Для эффективного управления рисками необходимо применять аналитические методы оценки их вероятности и последствий. В данной работе рассмотрены три ключевых метода: SWOT-анализ, метод Дельфи и метод ожидаемой денежной стоимости (EMV).

SWOT-анализ

SWOT-анализ позволяет выявить сильные и слабые стороны строительного проекта, а также оценить потенциальные угрозы и возможности.

Фактор	Примеры
Сильные стороны	Применение цифровых технологий, контроль качества
Слабые стороны	Высокая зависимость от подрядчиков, риски поставок
Возможности	Государственные субсидии, новые технологии
Угрозы	Рост цен, задержки поставок, изменения в законодательстве

Метод Дельфи

Метод Дельфи используется для оценки рисков путем получения экспертных мнений. Он применяется в ситуациях, когда недостаточно статистических данных или требуется субъективная оценка вероятности и последствий рисков. Данный метод основывается на анонимных опросах группы экспертов, проводимых в несколько этапов, чтобы достичь максимально объективных результатов. Например, вероятность наступления некоторых рисков отличается. Рост стоимости материалов примерно 70%, Ошибки в проекте 50%, Задержка поставок 40%, Погодные условия 60%

Метод Дельфи используется для оценки рисков путем экспертного прогнозирования. В рамках данного исследования данный метод был адаптирован на основе анализа отраслевых отчетов, публикаций консалтинговых компаний и данных международных организаций. Вероятностные оценки рисков основаны на динамике изменений стоимости строительных материалов за последние пять лет, статистике задержек поставок и анализе влияния климатических факторов на строительные процессы. Подход включает комплексную обработку экспертных мнений и статистических данных, что позволяет обоснованно определить вероятность возникновения ключевых рисков и их влияние на реализацию строительных проектов.

Метод ожидаемой денежной стоимости (EMV)

EMV позволяет рассчитать потенциальные финансовые потери при возникновении рисков.

Метод ожидаемой денежной стоимости применяется для количественной оценки рисков, позволяя прогнозировать потенциальные финансовые потери. Расчет основан на данных о вероятности возникновения рисков и оценке их финансовых последствий, полученных на основе анализа бюджетов реализованных строительных проектов. В расчетах учитывались прогнозируемые изменения цен на строительные материалы, возможные затраты на устранение ошибок проектирования, задержки поставок и влияние климатических факторов. Полученные значения позволяют определить финансовую уязвимость строительного проекта и разработать стратегии минимизации рисков.

Риск	Вероятность (P)	Потери (L), млн тг	EMV = P × L (млн тг)
Рост стоимости материалов	0.75	180	135
Ошибки в проекте	0.5	75	37.5
Задержка поставок	0.4	30	12
Погодные условия	0.6	20	12

Стратегии управления рисками

Для эффективного контроля рисков необходимо внедрять комплексные меры управления:

1. Прогнозирование и мониторинг – анализ цен, поставок и нормативных изменений.
2. Цифровизация процессов – применение BIM, автоматизированных систем управления проектами.
3. Финансовая защита – создание резервных фондов и страхование.
4. Контроль подрядчиков – строгие контракты, рейтинговые системы и независимый аудит.

Строительная отрасль характеризуется высокой степенью неопределенности, что делает управление рисками обязательным элементом проектного менеджмента. Анализ ключевых угроз, применение современных методов оценки и стратегическое планирование позволяют снизить потери и повысить устойчивость проектов.

Компании, внедряющие системный подход к управлению рисками, способны реализовывать проекты в срок, в рамках бюджета и с высоким уровнем качества. Это подтверждает, что риск-менеджмент является не только инструментом минимизации потерь, но и важным фактором конкурентоспособности в строительной сфере.

Предложенные методы оценки рисков позволяют повысить предсказуемость строительных проектов, снизить неопределенность и минимизировать потенциальные убытки. Практическая реализация таких инструментов, как цифровое проектирование, оптимизация логистических процессов и применение контрактных механизмов управления рисками, способствует повышению устойчивости строительной отрасли. Внедрение системного подхода к управлению рисками позволяет строительным компаниям достигать поставленных целей в рамках запланированных сроков и бюджета, обеспечивая стабильность и эффективность реализации проектов.

Digital Transformation and SME Development in Kazakhstan: Evidence, Constraints, and Policy Priorities

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Abstract

This article examines the digital transformation of small and medium-sized enterprises (SMEs) in Kazakhstan using official statistics and traceable institutional sources. The analysis distinguishes observed outcomes from survey findings and forecasts. Official statistics show that SMEs accounted for 40.9 per cent of GDP in 2025, while Mastercard's 2025 survey reported widespread adoption of digital payments. E-commerce and IT-service exports also expanded, but these aggregate gains do not establish that all firms possess advanced digital capabilities. The article argues that Kazakhstan has developed strong digital foundations, while skills, finance, rural connectivity and the effective use of business data remain important constraints. Policy recommendations focus on targeted training, interoperable public infrastructure, responsible data use and differentiated support for micro and rural enterprises.

Keywords: digital transformation; SMEs; Kazakhstan; digital payments; e-commerce; digital inclusion

1. Introduction

Digital transformation has become a central element of Kazakhstan's economic modernisation strategy. For SMEs, digital tools can lower transaction costs, expand market access and improve record keeping. At the same time, the adoption of a payment application or social-media account is not equivalent to an integrated digital business model. A credible assessment must therefore separate basic adoption, organisational capability and measurable economic outcomes.

SMEs are systemically important to Kazakhstan. The Bureau of National Statistics reported that their share of GDP increased from 38.9 per cent in 2024 to 40.9 per cent in 2025 (Bureau of National Statistics, 2026). As of 1 October 2025, Kazakhstan had 2.176 million operating SME entities employing 4.522 million people (Bureau of National Statistics, 2025). These figures provide the economic context for policies aimed at improving productivity through digitalisation.

2. Analytical Framework

The resource-based view treats data, software, skills and organisational routines as resources that may support competitive advantage when firms can combine them effectively (Barney, 1991). Dynamic-capabilities theory adds that firms must be able to identify technological opportunities, adopt suitable tools and reconfigure processes as markets change (Teece, Pisano, & Shuen, 1997). The technology–organisation–environment framework further directs attention to infrastructure, firm-level readiness and the regulatory or market environment (Tornatzky & Fleischer, 1990).

This study uses a descriptive analytical design. It draws on national business statistics, an official government report on e-commerce, a Mastercard survey, an Accion project report and official digital-sector reporting. Survey percentages are treated as results for the relevant survey

sample, not as population parameters. Forecasts from commercial providers are excluded because the underlying methodology and data are not fully public.

3. Evidence on SME Digitalisation

3.1 SME scale and digital payments

Mastercard's third SME Confidence Index reported that 89 per cent of surveyed Kazakh SMEs had adopted digital payments. It also reported that 66 per cent were confident about the following twelve months, 91 per cent considered staff training important and 90 per cent wanted better access to development programmes (Mastercard, 2025). Between the survey's 2022 and 2024 observations, e-commerce payment use increased from 64 to 79 per cent, card payments from 61 to 64 per cent and mobile payments from 53 to 66 per cent. These results document broad use of transactional tools, but the survey release does not by itself demonstrate productivity effects.

Indicator	Observed value	Source
SME share of GDP, 2025	40.9%	BNS (2026)
Operating SME entities, 1 Oct. 2025	2.176 million	BNS (2025)
People employed by SMEs, 1 Oct. 2025	4.522 million	BNS (2025)
Surveyed SMEs using digital payments	89%	Mastercard (2025)

Source: Bureau of National Statistics (2025, 2026) and Mastercard (2025).

3.2 E-commerce and the technology ecosystem

Kazakhstan's government reported an e-commerce market volume of 3.2 trillion tenge in 2024, equal to 14.5 per cent of retail trade (Prime Minister of Kazakhstan, 2025). The same source described consumer protection, logistics and domestic-producer participation as continuing policy priorities. These issues matter for SMEs because platform access does not automatically guarantee fair visibility, affordable fulfilment or effective dispute resolution.

Official digital-sector reporting indicates that IT-service exports reached USD 1.142 billion in 2025 and that Astana Hub residents accounted for USD 633 million of exports (Ministry of Artificial Intelligence and Digital Development, 2026). These figures describe the technology ecosystem rather than SME digitalisation directly, but they indicate a growing domestic supply of digital services and expertise.

3.3 Capability and inclusion constraints

The Accion and Mastercard Strive programme in Kazakhstan and Uzbekistan illustrates why adoption depends on solution design, data practices and partnerships. Its work with Beksar and MayaSoft found that small firms require a clear value proposition, segment-specific support and usable links between transaction data and finance (Accion, 2026). The project is informative but should not be interpreted as a nationally representative survey.

Four constraints follow from the evidence. First, basic payment adoption may coexist with weak accounting, inventory and customer-management integration. Second, microenterprises may lack the time and skills needed to evaluate vendors or protect business data. Third, rural firms face different connectivity and logistics conditions from firms in Almaty or Astana. Fourth, digital credit scoring can widen access to finance but also creates risks related to consent, data quality and opaque decision rules.

4. Policy Implications

Policy should move from general promotion toward differentiated capability building. Training programmes should be linked to observable business processes such as inventory control, online fulfilment, cybersecurity and tax reporting. Support should be tiered by firm size, sector and location rather than measured only by participant counts.

Government platforms can reduce administrative costs when services are interoperable and designed around complete business journeys. Public agencies should publish stable machine-readable indicators on service use, completion time and user outcomes. For finance, regulators and providers should encourage responsible use of transaction data, transparent consent and avenues for firms to correct inaccurate information.

5. Limitations

The study relies on secondary data and does not estimate a causal effect of digitalisation on firm productivity. Official statistics and private surveys use different units of observation and reference periods. The Mastercard and Accion evidence is therefore used to describe specific samples and programmes, while national statistics are used for economy-wide SME indicators. Future research should link firm-level technology use to productivity, survival and employment outcomes.

6. Conclusion

Kazakhstan has established strong foundations for SME digitalisation: SMEs account for a rising share of GDP, digital payments are widely used among surveyed firms, e-commerce is substantial and the domestic IT-services ecosystem is expanding. The evidence nevertheless supports a cautious conclusion. Transactional adoption is not the same as organisational transformation, and benefits will remain uneven unless skills, rural access, data governance and business-process integration improve. A policy focus on measurable capabilities and differentiated support offers a more credible path than relying on headline adoption rates alone.

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ESG Strategy and Corporate Performance in Kazakhstan's Energy Sector: A Comparative Analysis of Leading Enterprises

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Abstract

This study examines the relationship between Environmental, Social, and Governance (ESG) strategy adoption and corporate performance within Kazakhstan's energy sector through a comparative analysis of six leading enterprises: Samruk-Kazyna, KazMunayGas, Samruk-Energy, Karachaganak Petroleum Operating (KPO), Tengizchevroil (TCO), and KazTransOil. Using a qualitative comparative case study approach grounded in secondary data from corporate sustainability reports, annual reports, and peer-reviewed academic studies, the research investigates how ESG governance frameworks, environmental performance metrics, technology adoption, and transparency mechanisms vary across state-owned and joint-venture enterprises. The findings reveal that while all examined enterprises have made measurable progress in emission reductions, resource efficiency, and governance reform, significant disparities persist in reporting frameworks, technology deployment, and investment scale. International joint ventures (KPO, TCO) demonstrate comparatively stronger environmental performance outcomes, whereas national champions (KMG, Samruk-Energy) exhibit more comprehensive strategic alignment with national carbon neutrality targets. The study also identifies greenwashing risks arising from inconsistent ESG ratings and limited standardisation. These results carry important implications for sustainable business strategy in resource-dependent economies.

Keywords: ESG strategy; corporate performance; energy sector; Kazakhstan; sustainability reporting; carbon neutrality

1. Introduction

Kazakhstan stands as Central Asia's largest economy and one of the world's most resource-dependent nations, with the oil and gas sector alone accounting for approximately 16% of gross domestic product (GDP) and 53% of total exports (KMG Annual Report, 2025). This heavy reliance on hydrocarbon extraction places the country at a critical juncture: the global transition toward decarbonisation, coupled with mounting investor pressure for environmental accountability, demands that Kazakhstan's energy enterprises reconcile economic imperatives with sustainability commitments. The urgency of this challenge is amplified by the nation's ambitious climate pledges, including a 15% reduction in greenhouse gas (GHG) emissions by 2030 relative to 1990 levels and a long-term carbon neutrality target for 2060 (Samruk-Kazyna Sustainability Report, 2024).

Kazakhstan has progressively embedded itself within the international climate governance architecture. The country ratified the Kyoto Protocol in 2009, acceded to the Paris Agreement in 2016, and subsequently joined the Global Methane Pledge. Domestically, the government has adopted a comprehensive Strategy for Achieving Carbon Neutrality by 2060, which delineates sectoral responsibilities and establishes a national framework for low-carbon development. Within this framework, the Samruk-Kazyna Sovereign Wealth Fund—the umbrella organisation for

Kazakhstan's largest state-owned enterprises—occupies a uniquely consequential position, as its portfolio companies are collectively responsible for approximately 33% of total national CO2 emissions (Samruk-Kazyna Sustainability Report, 2024).

The concept of ESG has emerged as a dominant paradigm in contemporary corporate governance, offering a tripartite framework for evaluating organisational performance beyond traditional financial metrics. Environmental criteria encompass emissions, resource use, and ecological stewardship; social criteria address labour practices, community engagement, and human capital development; governance criteria evaluate board structure, ethical conduct, and transparency. In the context of Kazakhstan's energy sector, ESG adoption is not merely a voluntary corporate initiative but increasingly a strategic necessity shaped by regulatory mandates, international obligations, and market expectations.

Despite the growing prominence of ESG discourse, empirical research examining its practical implementation and performance implications within Kazakhstan's energy sector remains limited. Most existing studies have focused on Western European or North American contexts, where regulatory environments, market structures, and stakeholder expectations differ markedly from those in post-Soviet resource economies. This gap is significant because the dynamics of ESG adoption in emerging economies—characterised by state ownership, carbon-intensive industrial legacies, and evolving institutional frameworks—may diverge substantially from patterns observed in developed markets.

This study seeks to address this gap by posing the following research question: *How do ESG strategies differ across leading enterprises in Kazakhstan's energy sector, and what is the relationship between these strategies and corporate performance outcomes?* To answer this question, the paper undertakes a comparative case study analysis of six enterprises: Samruk-Kazyna (sovereign wealth fund), KazMunayGas (national oil and gas company), Samruk-Energy (national power generation company), Karachaganak Petroleum Operating (international joint venture), Tengizchevroil (international joint venture), and KazTransOil (national oil transportation company). These enterprises collectively represent the full spectrum of organisational forms, ownership structures, and operational scales within Kazakhstan's energy landscape.

The paper is structured as follows. Section 2 reviews the relevant literature on ESG theory, corporate sustainability, and energy sector transformation. Section 3 outlines the methodology, including the comparative case study design and data sources. Section 4 presents the analysis and findings, organised by enterprise and by thematic dimension. Section 5 discusses the implications of these findings for sustainable business strategy, identifies challenges including greenwashing risks, and articulates the link between ESG performance and corporate competitiveness. Section 6 concludes with a summary of contributions and directions for future research.

2. Literature Review

2.1 ESG Theory and Conceptual Foundations

The theoretical foundations of ESG are rooted in stakeholder theory, which posits that corporations bear responsibilities not only to shareholders but to a broader constellation of stakeholders including employees, communities, regulators, and the natural environment (Freeman, 1984). This perspective challenges the shareholder primacy doctrine articulated by Friedman (1970) and provides a normative basis for integrating environmental and social considerations into corporate governance. The ESG framework operationalises stakeholder theory by translating broad ethical principles into measurable criteria that can be assessed, reported, and compared across organisations.

A complementary theoretical lens is provided by the resource-based view (RBV) of the firm, which suggests that capabilities related to environmental management, social responsibility, and governance quality may constitute sources of competitive advantage (Hart, 1995). According to

this perspective, investments in pollution prevention, stakeholder engagement, and governance reform generate proprietary resources—technical expertise, reputational capital, regulatory goodwill—that are difficult for competitors to imitate. In the context of carbon-intensive industries such as oil and gas, the RBV implies that proactive ESG strategies may enhance long-term resilience by reducing regulatory risk, attracting capital, and preserving social licence to operate.

Institutional theory offers a further explanatory framework, particularly relevant to the Kazakhstani context. DiMaggio and Powell (1983) identified three mechanisms of institutional isomorphism—coercive, mimetic, and normative—that drive organisational convergence toward shared practices. In Kazakhstan's energy sector, coercive pressures emanate from international climate agreements and national regulations; mimetic pressures arise as enterprises emulate the practices of perceived industry leaders; and normative pressures are exerted through professional standards, certification bodies, and reporting frameworks such as the Global Reporting Initiative (GRI) and the Task Force on Climate-related Financial Disclosures (TCFD).

2.2 Corporate Sustainability in the Energy Sector

The global energy sector occupies a paradoxical position in sustainability discourse: it is simultaneously the primary driver of anthropogenic climate change and the locus of some of the most ambitious corporate sustainability initiatives. International oil and gas companies have increasingly adopted net-zero commitments, methane reduction targets, and diversification strategies aimed at renewable energy. However, scholars have noted that the pace and sincerity of these commitments vary widely, and the risk of "greenwashing"—the practice of overstating environmental performance for reputational gain—remains a persistent concern. The tension between economic imperatives and environmental obligations is particularly acute in the extractive industries, where capital-intensive infrastructure, long asset lifecycles, and commodity price volatility create powerful incentives to defer or dilute sustainability investments.

A growing body of empirical research has sought to evaluate whether corporate sustainability initiatives translate into measurable environmental improvements or whether they primarily serve symbolic purposes. The concept of "substantive versus symbolic" CSR, articulated by Marquis, Toffel, and Zhou (2016), distinguishes between sustainability programmes that produce tangible operational changes and those that are designed primarily for external communication. In the context of oil and gas operations, substantive CSR would manifest as investments in emission control technologies, monitoring infrastructure, and process redesign, whereas symbolic CSR would take the form of high-level commitments, participation in voluntary initiatives, and selective reporting of favourable metrics.

Recent academic research has examined ESG practices and emission dynamics in Kazakhstan's oil and gas sector, focusing on companies such as Shell, Eni, and KPO. A key finding from this body of work is that while the overall emission trend among these companies is downward, it is accompanied by periodic deviations that raise questions about the consistency and reliability of corporate environmental performance (preprints.org, 2025). The same research highlights a critical concern regarding ESG ratings: in only 6 out of 10 cases do different ESG rating agencies produce consistent assessments of the same company. This inconsistency undermines the credibility of ESG as a comparative performance metric and has prompted the European Union to develop regulatory frameworks for ESG disclosure transparency (preprints.org, 2025). The finding that 40% of ESG ratings are inconsistent across agencies is particularly alarming, as it implies that investors, regulators, and other stakeholders may be making decisions based on unreliable or contradictory information.

The literature also emphasises the role of technology adoption in driving environmental performance improvements. Technologies such as Leak Detection and Repair (LDAR) systems, automated environmental monitoring, and robotic inspection represent tangible operational manifestations of ESG commitments. The deployment of such technologies has been associated

with measurable reductions in methane emissions, air pollutants, and resource waste, lending empirical support to the resource-based view's prediction that environmental investments yield tangible performance dividends.

2.3 Energy Sector Transformation in Kazakhstan

Kazakhstan's energy sector transformation must be understood within the broader context of the country's post-Soviet economic transition and its integration into global energy markets. The sector is characterised by a dual structure: national champions such as KazMunayGas and Samruk-Energy, which are majority state-owned and operate under the Samruk-Kazyna umbrella; and international joint ventures such as KPO and TCO, which bring together foreign operators (Eni, Shell, Chevron, Lukoil) with the national company as minority or equal partners.

The national climate policy framework imposes differentiated obligations on these enterprises. Samruk-Kazyna, as the sovereign wealth fund, has developed a Low Carbon Development Concept that was approved by its Board of Directors in 2022 and envisions three scenarios: Deep Decarbonisation (aligned with a 1.5°C pathway), Decarbonisation (2–3°C pathway), and Business as Usual (≥4°C pathway). This scenario-based approach reflects a sophisticated understanding of climate uncertainty and provides a strategic compass for portfolio companies (Samruk-Kazyna Sustainability Report, 2024).

Existing scholarship has noted that the transition to sustainable energy systems in resource-dependent economies presents distinctive challenges, including the need to balance economic development objectives with environmental obligations, the presence of carbon-intensive legacy assets with long operational lifespans, and institutional capacities that may be still developing. In Kazakhstan, these challenges are compounded by the sector's strategic importance to national revenue, employment, and geopolitical positioning.

3. Methodology

3.1 Research Design

This study employs a qualitative comparative case study approach, which is particularly appropriate for investigating complex phenomena within their real-world contexts (Yin, 2018). The comparative design enables systematic identification of similarities and differences across enterprises with varying ownership structures, operational scales, and strategic orientations. Rather than seeking statistical generalisation, the case study method facilitates analytical generalisation—the extension of theoretical insights from specific cases to broader propositions about ESG strategy and corporate performance.

Six enterprises were selected for analysis based on their significance within Kazakhstan's energy sector and the availability of comprehensive ESG-related data:

1. Samruk-Kazyna — the sovereign wealth fund that serves as the parent organisation for Kazakhstan's largest state-owned enterprises, providing strategic direction on sustainability and climate action.
2. KazMunayGas (KMG) — the national oil and gas company, responsible for approximately 26% of domestic oil production, 17% of gas production, 55% of transport, and 80% of refining capacity (KMG Annual Report, 2025).
3. Samruk-Energy — the national power generation company, which operates both conventional and renewable energy assets.
4. Karachaganak Petroleum Operating (KPO) — an international joint venture comprising Eni (29.25%), Shell (29.25%), Chevron (18%), Lukoil (13.5%), and KMG (10%), operating the Karachaganak field.
5. Tengizchevroil (TCO) — an international joint venture operating the Tengiz field, with Chevron as a lead partner.

6. KazTransOil — the national oil transportation company, responsible for pipeline infrastructure and oil logistics.

3.2 Data Sources

The study draws exclusively on secondary data from the following sources:

- **Corporate sustainability and annual reports:** Samruk-Kazyna Sustainability Report 2024 (sk.kz); KMG Annual Report 2025 (ar2025.kmg.kz); Samruk-Energy corporate disclosures (samruk-energy.kz); KPO sustainability reports (kpo.kz); TCO corporate website disclosures (tengizchevroil.com); KazTransOil corporate disclosures (kaztransoil.kz).
- **Academic studies:** Peer-reviewed and preprint research, including the study published on preprints.org (November 2025) analysing ESG practices and emission dynamics in Kazakhstan's oil and gas companies.
- **National policy documents:** Climate commitments, international agreements, and strategic frameworks referenced in corporate reports.

3.3 Analytical Framework

The analysis is organised around six thematic dimensions derived from the ESG literature and the available data:

1. **Regulatory alignment and strategic governance:** The extent to which enterprises align their strategies with national and international climate commitments, including board-level oversight and governance codes.
2. **Environmental performance:** Quantitative metrics on emissions, pollutant reductions, resource efficiency, and waste management.
3. **Technology adoption:** Deployment of advanced monitoring, detection, and mitigation technologies.
4. **Investment in sustainability:** Financial commitments to environmental protection, social infrastructure, and renewable energy.
5. **Transparency and reporting:** Adoption of international reporting standards (GRI, TCFD, IFRS S2) and the frequency and depth of sustainability disclosures.
6. **Social performance:** Community investment, local content policies, workforce development, and stakeholder engagement.

For each enterprise, data were extracted along these dimensions and subsequently subjected to cross-case comparison to identify patterns, divergences, and best practices.

3.4 Data Analysis Procedure

The analysis followed a three-stage procedure. First, data were extracted from each source and organised into a structured matrix categorised by the six thematic dimensions identified in the analytical framework. This matrix enabled systematic within-case analysis, ensuring that each enterprise's ESG profile was comprehensively documented before cross-case comparison was undertaken. Second, a cross-case comparison was conducted, identifying patterns of convergence and divergence across enterprises along each thematic dimension. This comparison was facilitated by the construction of a summary table (see Section 4.7) that juxtaposed key performance metrics across all six enterprises. Third, the findings were interpreted through the theoretical lenses outlined in the literature review—stakeholder theory, the resource-based view, and institutional theory—to assess the extent to which observed patterns confirm, extend, or challenge existing theoretical propositions about ESG adoption in resource-dependent economies.

3.5 Limitations

The reliance on secondary data entails certain limitations. Corporate sustainability reports are self-prepared and may reflect reporting bias, as enterprises have discretion over which metrics to disclose and how to frame their performance. The absence of standardised ESG metrics across enterprises complicates direct comparison, as different companies may use different baselines, measurement methodologies, and reporting boundaries. Additionally, the study does not

incorporate primary data from interviews or surveys, which could provide richer insights into decision-making processes, organisational culture, and the lived experience of ESG implementation within these enterprises. The temporal scope of the data also varies across enterprises: some metrics reflect multi-year trends (e.g., KPO's emission reduction since the study period, TCO's performance since 2000), while others represent single-year snapshots, limiting the ability to assess temporal dynamics uniformly. These limitations are acknowledged and addressed through triangulation across multiple data sources where possible, including cross-referencing corporate reports with academic research findings.

4. Analysis and Findings

4.1 Samruk-Kazyna: Strategic Orchestrator of National Decarbonisation

As the sovereign wealth fund overseeing Kazakhstan's largest state-owned enterprises, Samruk-Kazyna occupies a unique strategic position in the national ESG landscape. Its portfolio companies are collectively responsible for approximately 33% of total national CO2 emissions, conferring upon the fund an outsized role in determining whether Kazakhstan will meet its climate commitments (Samruk-Kazyna Sustainability Report, 2024).

The fund's carbon footprint was measured at 72.2 million tonnes of CO2 in 2021, comprising 61.6 million tonnes of direct emissions and 10.7 million tonnes of indirect emissions. In response, Samruk-Kazyna established a strategic goal of achieving a 10% net reduction in carbon footprint by 2032, using 2021 as the baseline year. This target, while modest in absolute terms, represents a significant undertaking given the carbon-intensive nature of the portfolio and the projected growth trajectories of several constituent companies.

A landmark development was the approval of the Low Carbon Development Concept by the Board of Directors in 2022. This strategic document analyses three scenarios: (1) Deep Decarbonisation, aligned with a 1.5°C global warming pathway; (2) Decarbonisation, aligned with a 2–3°C pathway; and (3) Business as Usual, corresponding to a ≥4°C pathway. The scenario-based approach demonstrates an understanding of climate uncertainty and provides a flexible framework for adaptive strategy formulation. The fund has also implemented an Energy and Resource Saving Programme extending to 2027, which operationalises efficiency targets across portfolio companies.

From a governance perspective, Samruk-Kazyna's role is principally that of a strategic orchestrator, setting directional guidance and performance expectations for its subsidiaries. The Low Carbon Development Concept serves as a top-down framework that cascades into company-specific programmes, as evidenced by the initiatives undertaken by KMG, Samruk-Energy, and KazTransOil examined below.

Table 2. Samruk-Kazyna Carbon Footprint and Targets

Metric	Value
Total CO_2 emissions (2021)	72.2 million tonnes
Direct emissions	61.6 million tonnes
Indirect emissions	10.7 million tonnes
Reduction target by 2032	10% (vs 2021 baseline)
Share of national CO_2 emissions	~33%

Source: Samruk-Kazyna Sustainability Report (2024)

4.2 KazMunayGas (KMG): National Champion with Long-Horizon Decarbonisation Ambitions

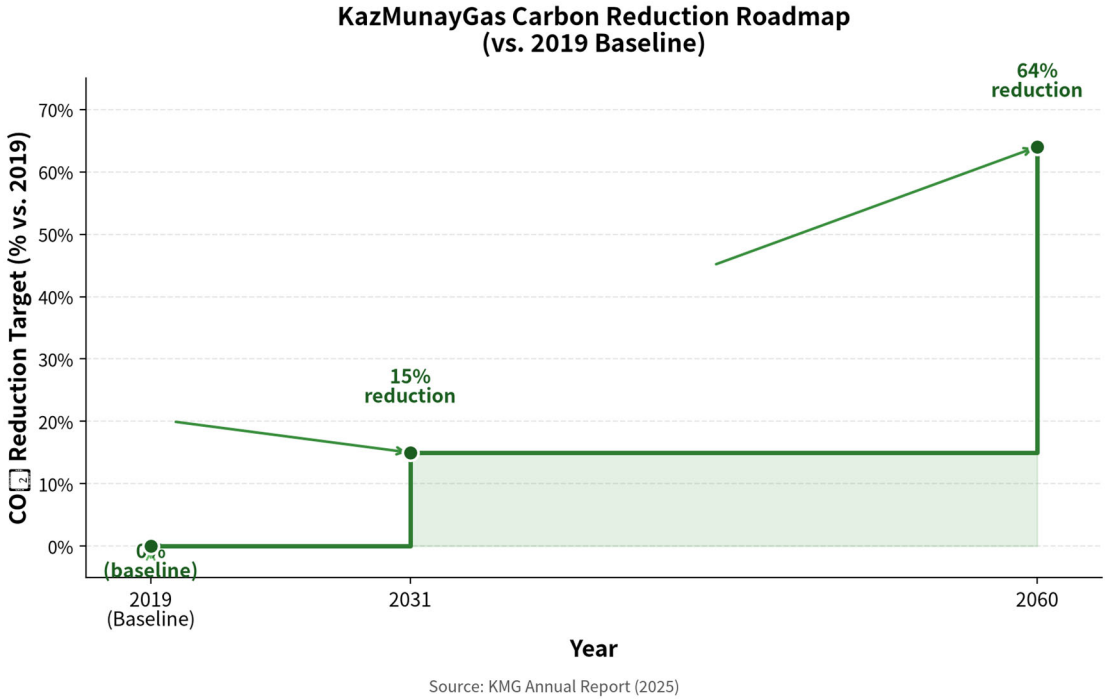
KazMunayGas is the national oil and gas company and a central pillar of Kazakhstan's hydrocarbon economy. Given that oil accounts for 16% of GDP and 53% of exports, KMG's strategic decisions carry macroeconomic significance. The company provides approximately 26% of national oil production, 17% of gas production, 55% of oil transport, and 80% of refining capacity (KMG Annual Report, 2025).

Environmental Strategy. KMG has developed a low-carbon development programme extending to 2060, with interim targets of a 15% CO2 reduction by 2031 and a 64% reduction by 2060, relative to 2019 baseline levels. The programme is notable for its long time horizon, reflecting both the scale of the transformation required and the company's commitment to a gradual rather than disruptive transition.

A significant component of KMG's environmental strategy is methane emissions management. The company has been a participant in the Global Methane Initiative since 2017 and supports the World Bank's initiative to eliminate routine gas flaring by 2030. In 2024, KMG deployed a Leak Detection and Repair (LDAR) system at two production facilities, marking the first operational implementation of this technology within the company. In the same year, KMG submitted its first methane emissions inventory report to the United Nations Environment Programme (UNEP) and joined the Oil and Gas Methane Partnership (OGMP 2.0), signalling a commitment to international reporting transparency.

Governance Reform. In 2025, KMG approved a new Corporate Governance Code that strengthened the company's ESG focus. This development reflects an institutional isomorphic process, wherein the company aligns its governance practices with international standards in response to both coercive pressures (regulatory requirements) and normative pressures (professional standards and investor expectations).

Strategic Assessment. KMG's ESG strategy is characterised by ambitious long-term targets and progressive adoption of international frameworks. However, the modesty of the interim target (15% by 2031) relative to the ultimate goal (64% by 2060) suggests that the most significant reductions are deferred to later periods, raising questions about the pace of near-term action. The company's methane management initiatives, particularly the LDAR deployment and OGMP 2.0 partnership, represent concrete operational measures that lend credibility to its strategic commitments.



KazMunayGas Carbon Reduction Roadmap (vs. 2019 Baseline)

Table 3. KMG Operational Profile and ESG Commitments

Metric	Value
Share of national oil production	26%
Share of gas production	17%
Share of oil transport	55%
Share of refining capacity	80%
CO_2 reduction target by 2031	15% (vs 2019)
CO_2 reduction target by 2060	64% (vs 2019)
LDAR deployment	2 facilities (2024)
Methane reporting frameworks	OGMP 2.0, UNEP

Source: KMG Annual Report (2025)

4.3 Samruk-Energy: Integrating Renewables into the National Power Grid

Samruk-Energy is the national power generation company and operates within the Samruk-Kazyna portfolio. Its Development Strategy 2024–2033 explicitly incorporates net carbon footprint reduction as a strategic goal and positions ESG principles as a key development priority (samruk-energy.kz).

Environmental Performance. Samruk-Energy has demonstrated measurable environmental performance improvements in recent years. Pollutant emissions were reduced from 354,922 tonnes in 2023 to 345,373 tonnes in 2024, representing a year-on-year decrease of approximately 2.7%. More impressively, volatile organic compound (VOC) emissions were reduced from 274.5 tonnes to 168.6 tonnes over the same period—a reduction of approximately 38.6%. These reductions reflect operational improvements and investments in pollution control technologies.

Climate Risk Management. In 2025, Samruk-Energy launched a climate risk management project based on the TCFD (now IFRS S2) framework. This initiative represents a proactive step toward identifying and quantifying climate-related financial risks, including physical risks (e.g., extreme weather events affecting infrastructure) and transition risks (e.g., regulatory changes, market shifts). The adoption of TCFD/IFRS S2 aligns the company with emerging international best practice in climate risk disclosure.

International Standards. Samruk-Energy maintains certification across multiple international management standards: ISO 9001 (quality management), ISO 14001 (environmental management), ISO 45001 (occupational health and safety), ISO 50001 (energy management), and ISO 37001 (anti-bribery management). This comprehensive standards adoption reflects a holistic approach to ESG integration, spanning environmental, social, and governance dimensions.

Renewable Energy Portfolio. A distinguishing feature of Samruk-Energy's strategy is its active development of renewable energy assets. The company operates renewable energy subsidiaries including Samruk Green Energy, the First Wind Power Plant, and the Moynak Hydroelectric Power Plant. This diversification into renewables positions Samruk-Energy as a potential driver of Kazakhstan's energy transition, although the relative contribution of renewables to the company's total generation capacity remains limited compared to its conventional assets.

4.4 Karachaganak Petroleum Operating (KPO): International Best Practice in Environmental Performance

KPO is an international joint venture operating the Karachaganak field, one of the world's largest gas and condensate fields. The ownership structure comprises Eni (29.25%), Shell (29.25%), Chevron (18%), Lukoil (13.5%), and KMG (10%). This multinational composition brings together operators with extensive global experience in environmental management, which is reflected in KPO's ESG performance.

Production and Environmental Performance. In 2025, KPO achieved production of 136.453 million barrels of oil equivalent. Despite this substantial production volume, the company has demonstrated world-class environmental performance. The gas utilisation rate reached 99.95%, meaning that virtually all associated gas is captured and used rather than flared—a benchmark achievement in the industry (kpo.kz).

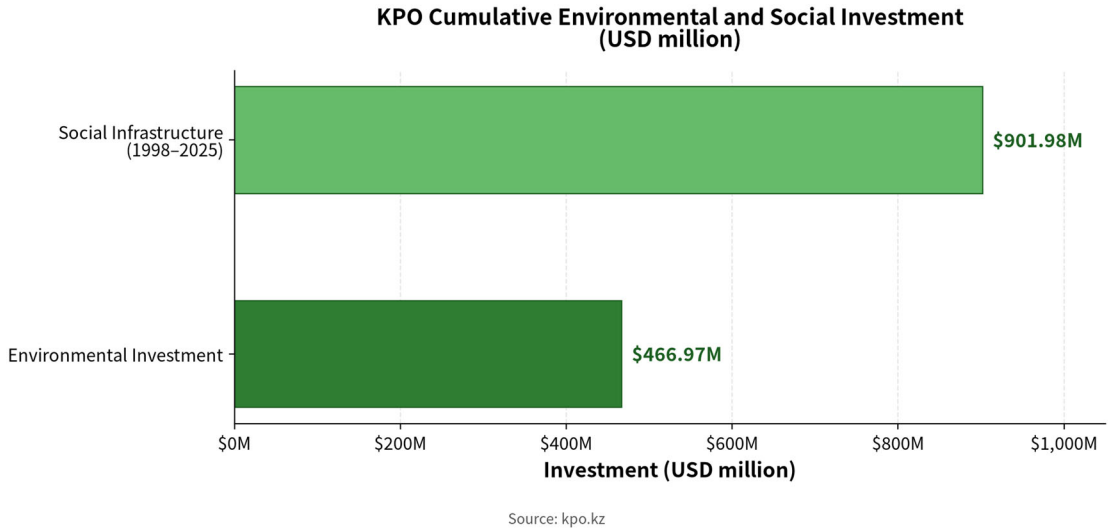
Over the study period, KPO achieved a 44.9% reduction in gross atmospheric emissions. Specific pollutant reductions include: sulphur dioxide (SO2) reduced by 59.3%; nitrogen dioxide (NO2) reduced by 38.1%; and VOCs reduced by 40.3%. Overall, specific pollutant emissions (emissions per unit of production) decreased by 51.3%. These reductions are attributed to a comprehensive ESG strategy that integrates environmental management into operational decision-making (preprints.org, 2025; kpo.kz).

Environmental Investment. KPO's total environmental investment amounts to $466.97 million, underscoring the substantial financial resources committed to environmental protection. This level of investment reflects both the regulatory requirements imposed on international operators and the operational imperatives of managing a complex, high-pressure gas condensate field.

Monitoring and Standards. KPO operates an ISO 14001:2015-compliant environmental monitoring system that includes 18 stationary automatic monitoring stations. This infrastructure enables real-time detection of pollutant levels and facilitates rapid response to environmental incidents. The company has published sustainability reports since 2008, adopting GRI standards since 2017, which represents one of the longest sustainability reporting track records among Kazakhstan's energy enterprises.

Social Performance. KPO's social infrastructure investment totals $901.98 million (1998–2025), with 268 facilities constructed in the Atyrau and West Kazakhstan regions. The company employs approximately 4,000 personnel and has registered 7,139 Kazakhstani vendors, reflecting a substantial commitment to local content development and community investment.

Academic Validation. KPO's environmental performance has been validated by academic research. A study published on preprints.org (November 2025) specifically attributed KPO's 44.9% emission reduction to its comprehensive ESG strategy, noting that the company's downward emission trend, while subject to periodic deviations, demonstrates the effectiveness of systematic environmental management. The same study, however, raised concerns about ESG rating consistency, finding that ratings were consistent in only 6 out of 10 cases across different rating agencies.



KPO Cumulative Environmental and Social Investment (USD million)

4.5 Tengizchevroil (TCO): Technology-Driven Environmental Excellence

Tengizchevroil operates the Tengiz field, one of the deepest and most technically challenging super-giant oil fields in the world. The company is a joint venture led by Chevron, and its ESG strategy reflects the technological sophistication and environmental rigour characteristic of major international oil companies.

Air Emissions Reduction. TCO has achieved a 78% reduction in air emissions per tonne of oil produced since 2000, representing one of the most significant environmental performance improvements among the enterprises examined in this study. This achievement reflects sustained investment in emission control technologies and process optimisation over more than two decades (tengizchevroil.com, 2026).

Water Resource Management. Approximately 50% of water used in TCO's production cycle is reused, demonstrating effective water resource management in an arid region where water scarcity is an emerging concern. The company employs multi-stage wastewater treatment processes, including reverse osmosis technology, which enables the recycling of produced water for operational use.

Waste Management. TCO has implemented a comprehensive waste management programme that encompasses more than 30 types of waste. As of the first quarter of 2026, approximately 35% of total waste was recycled. This performance reflects a systematic approach to waste characterisation, segregation, and processing.

Monitoring Technology. A notable feature of TCO's environmental strategy is the deployment of an Automated Environmental Emissions Monitoring System (AEMS). This system provides continuous, real-time monitoring of air emissions, enabling the company to identify emission sources, track performance against targets, and respond promptly to operational anomalies. The AEMS represents a tangible manifestation of the resource-based view's prediction that environmental investments generate proprietary technological capabilities.

4.6 KazTransOil: Digital Transformation for Environmental Stewardship

KazTransOil is the national oil transportation company, responsible for the pipeline infrastructure that moves crude oil across Kazakhstan and to export terminals. While its operational profile differs from upstream producers, the company faces distinct environmental challenges related to storage tank emissions, pipeline integrity, and spill prevention.

Tank Modernisation. KazTransOil is modernising its tank park using a combination of environmental and digital technologies. A key innovation is the deployment of modern pontoon technology, which reduces atmospheric emissions from storage tanks by up to 95%. Pontoon technology works by floating on the surface of stored oil, thereby minimising the vapour space above the liquid and reducing evaporative losses.

Robotic Inspection. The company has implemented advanced robotic inspection systems, including the TBIT (Tank Bottom Inspection Tool) and BZS systems, which employ AI-powered data analysis to assess the structural integrity of storage tanks. These systems utilise Magnetic Flux Leakage (MFL) and Eddy Current (EC) methods to detect corrosion, cracking, and other defects without requiring tank decommissioning and manual entry. This approach simultaneously enhances safety (by reducing human exposure to hazardous environments) and environmental protection (by enabling early detection of potential leak pathways).

Strategic Assessment. KazTransOil's ESG strategy is distinguished by its emphasis on digital transformation as a driver of environmental performance. The integration of AI-powered inspection, advanced NDT (non-destructive testing) methods, and pontoon technology demonstrates that ESG objectives can be advanced through technological innovation in midstream operations, not only in upstream production.

4.7 Cross-Case Comparative Analysis

Table 1 synthesises the key ESG performance metrics across the six enterprises.

Table 1. Comparative ESG Performance Summary

Enterprise	Ownership	Key Environmental Metric	Technology Highlights	Reporting Framework
Samruk-Kazyna	State (sovereign fund)	72.2 Mt CO2 (2021); 10% reduction target by 2032	Scenario-based planning (1.5°C/2-3°C/≥4°C)	Sustainability Report 2024
KazMunayGas	State (national company)	15% CO2 reduction by 2031; 64% by 2060 (vs. 2019)	LDAR (2 facilities, 2024); OGMP 2.0	Annual Report 2025; UNEP methane report
Samruk-Energy	State (national company)	Pollutants: 354,922t → 345,373t (2023–2024); VOCs: 274.5t → 168.6t	TCFD/IFRS S2 project (2025)	Multiple ISO certifications
KPO	International JV	44.9% emission reduction; 99.95% gas utilisation	18 automatic monitoring stations; ISO 14001:2015	GRI since 2017; reports since 2008
TCO	International JV	78% air emissions reduction per tonne (since 2000)	AEMS; reverse osmosis water treatment	Corporate disclosures
KazTransOil	State (national company)	Up to 95% emission reduction via pontoon technology	Robotic inspection (TBIT, BZS); AI analysis; MFL/EC	Corporate disclosures

The comparative analysis reveals several important patterns:

Ownership and Performance. International joint ventures (KPO and TCO) tend to demonstrate stronger absolute environmental performance outcomes, as measured by emission reductions and resource efficiency. KPO's 44.9% reduction in gross atmospheric emissions and 99.95% gas utilisation rate, and TCO's 78% reduction in air emissions per tonne of oil, surpass the performance metrics reported by national champions. This finding is consistent with the expectation that international operators bring advanced environmental management practices, technologies, and standards from their global operations.

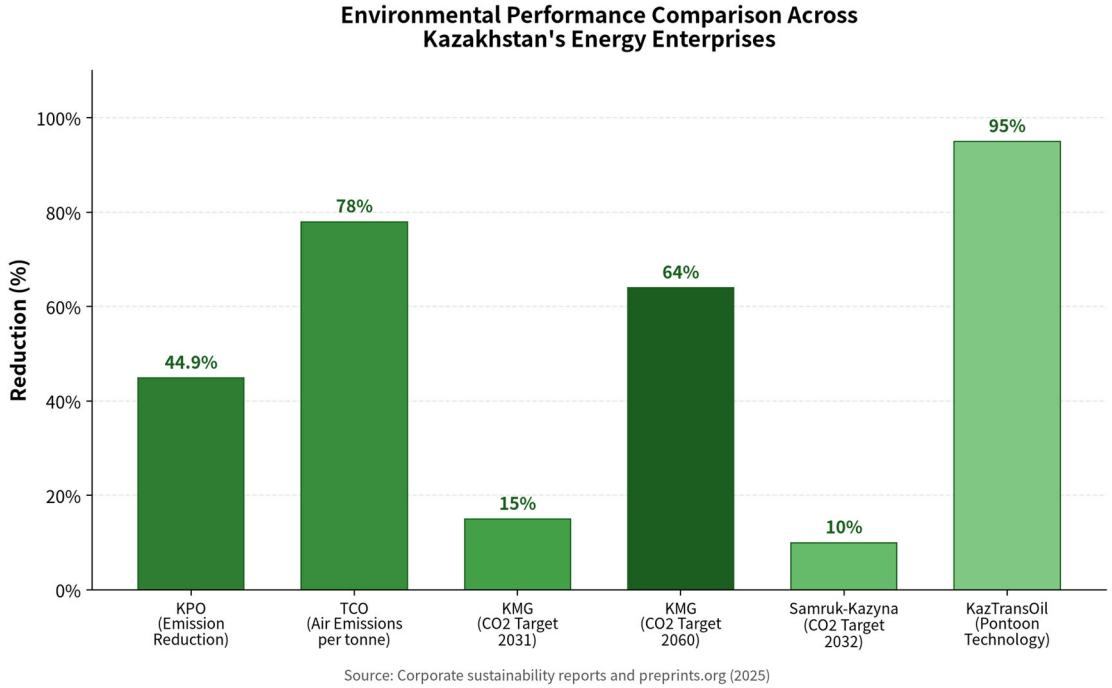
Strategic Ambition versus Operational Delivery. National champions exhibit more comprehensive strategic alignment with national carbon neutrality targets but lag in near-term operational delivery. KMG's 15% reduction target by 2031 is modest relative to KPO's and TCO's demonstrated performance, suggesting that the most significant reductions are backloaded to later decades. This pattern may reflect the challenges of transforming large, state-owned enterprises with legacy infrastructure and diverse stakeholder obligations.

Technology as a Differentiator. Technology adoption emerges as a key differentiator across enterprises. KPO's 18 stationary monitoring stations, TCO's AEMS, KMG's LDAR system, and KazTransOil's AI-powered robotic inspection represent distinct technological responses to environmental challenges. The diversity of technologies reflects the heterogeneity of operational contexts: upstream production requires methane detection and gas utilisation; midstream transport requires tank integrity and spill prevention; power generation requires pollutant and VOC management.

Reporting Transparency. KPO stands out for its long sustainability reporting history (since 2008, GRI standards since 2017), while Samruk-Energy's adoption of the TCFD/IFRS S2 framework in 2025 represents the most recent advancement in climate-related financial disclosure. KMG's

OGMP 2.0 partnership and UNEP methane reporting demonstrate a commitment to specialised, issue-focused reporting frameworks. However, the absence of a unified reporting standard across enterprises limits comparability and transparency.

Social Investment. KPO's $901.98 million social infrastructure investment and 268 community facilities represent the most substantial social performance commitment quantified in this study. The company's registration of 7,139 Kazakhstani vendors reflects a systematic approach to local content development, while its workforce of approximately 4,000 employees underscores its economic significance in the Atyrau region.



Environmental Performance Comparison Across Kazakhstan's Energy Enterprises

Table 4. Technology Adoption Across Enterprises

Enterprise	Technology	Function
KMG	LDAR system	Methane leak detection at 2 facilities
KPO	18 automatic monitoring stations	Real-time pollutant detection
TCO	AEMS	Continuous air emissions monitoring
TCO	Reverse osmosis	Water recycling (50% reuse rate)
KazTransOil	Pontoon technology	95% storage tank emission reduction
KazTransOil	TBIT/BZS robotic inspection	AI-powered tank integrity assessment
Samruk-Energy	TCFD/IFRS S2 framework	Climate risk management (2025)

Source: Corporate sustainability reports and disclosures

Table 5. International Standards and Reporting Frameworks

Enterprise	Standards/Frameworks	Reporting Since
KPO	ISO 14001:2015, GRI	2008 (GRI since 2017)
Samruk-Energy	ISO 9001, 14001, 45001, 50001, 37001	—
KMG	OGMP 2.0, UNEP methane report, Corporate Governance Code (2025)	—
Samruk-Kazyna	Low Carbon Development Concept (2022)	Sustainability Report 2024

Source: Corporate reports and disclosures

5. Discussion

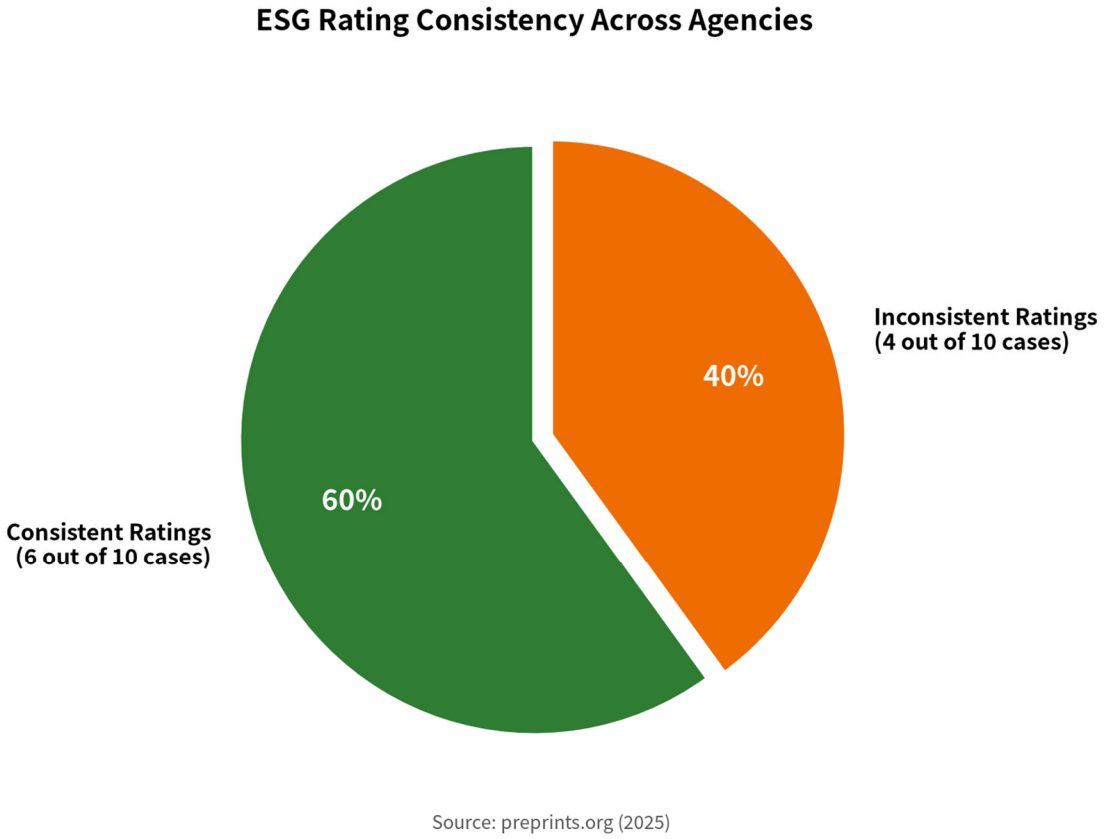
5.1 ESG Performance and Corporate Competitiveness

The findings of this study provide support for the proposition, derived from the resource-based view, that ESG investments can generate competitive advantages. KPO's world-class gas utilisation rate (99.95%) and 44.9% emission reduction have been validated by academic research as outcomes of a comprehensive ESG strategy (preprints.org, 2025), demonstrating that environmental excellence and operational efficiency are mutually reinforcing rather than competing objectives. Similarly, TCO's 78% reduction in air emissions per tonne of oil reflects decades of sustained investment in environmental technology, which has enhanced the company's operational efficiency and regulatory compliance capacity.

However, the relationship between ESG performance and corporate competitiveness is mediated by ownership structure and strategic context. International joint ventures, with access to parent companies' global expertise and technologies, are better positioned to achieve rapid environmental improvements. National champions, while demonstrating strong strategic commitment, face greater inertia due to legacy assets, broader socio-economic obligations, and the political economy of state ownership. This finding aligns with institutional theory's prediction that coercive and normative pressures drive ESG adoption but that organisational responses vary according to resource endowments and institutional contexts.

5.2 The Challenge of Greenwashing

A critical challenge identified in this study is the risk of greenwashing—both at the level of individual enterprises and at the systemic level of ESG assessment. The academic research examining ESG practices in Kazakhstan's oil and gas sector found that ESG ratings produced by different agencies were consistent in only 6 out of 10 cases (preprints.org, 2025). This inconsistency undermines the reliability of ESG ratings as a comparative performance metric and creates opportunities for selective disclosure and reputational management.



Source: preprints.org (2025)

ESG Rating Consistency Across Agencies

Several factors contribute to greenwashing risk in Kazakhstan's energy sector. First, the absence of mandatory, standardised ESG reporting requirements means that enterprises can choose which metrics to report and which to omit, potentially presenting a selectively favourable picture. Second, the long time horizons of decarbonisation targets (e.g., KMG's 2060 carbon neutrality commitment) create a temporal gap between strategic announcements and verifiable outcomes, allowing companies to claim ambition without near-term accountability. Third, the complexity of environmental metrics—particularly methane emissions, which require sophisticated measurement infrastructure—means that reported figures may not fully capture actual performance.

The European Union's development of regulatory frameworks for ESG disclosure transparency represents an important external pressure that may eventually influence Kazakhstani enterprises, particularly those engaged in export relationships with EU markets. The adoption of standardised frameworks such as GRI, TCFD/IFRS S2, and OGMP 2.0 by the enterprises examined in this study represents a positive trend, but the diversity of frameworks in use underscores the need for greater harmonisation.

5.3 Implications for Sustainable Business Strategy

The findings carry several implications for sustainable business strategy in Kazakhstan's energy sector and, by extension, in other resource-dependent economies:

1. Strategic Integration over Compliance. The enterprises demonstrating the strongest environmental performance—KPO and TCO—have integrated ESG considerations into operational decision-making rather than treating them as compliance obligations. KPO's ISO 14001:2015-compliant monitoring system and TCO's AEMS exemplify this integration, embedding environmental performance management into daily operations rather than relegating it to periodic reporting cycles.

2. Technology as a Strategic Enabler. Across all six enterprises, technology adoption is a primary driver of environmental performance. The diversity of technologies deployed—LDAR for methane detection, AEMS for real-time air monitoring, robotic inspection for tank integrity, pontoon technology for emission reduction, and reverse osmosis for water recycling—demonstrates that ESG strategy must be tailored to the specific operational context of each enterprise. Investment in proprietary environmental technologies creates capabilities that are difficult for competitors to replicate, consistent with the resource-based view.

3. Governance as a Foundation. Samruk-Kazyna's Board of Directors' approval of the Low Carbon Development Concept, KMG's new Corporate Governance Code (2025), and Samruk-Energy's comprehensive ISO certifications illustrate that governance reform is a prerequisite for credible ESG strategy. Board-level oversight ensures that ESG considerations are embedded in strategic decision-making rather than confined to operational units.

4. The Renewables Transition. Samruk-Energy's development of renewable energy subsidiaries (Samruk Green Energy, First Wind Power Plant, Moynak HPP) represents an early-stage diversification strategy that could position the company as a leader in Kazakhstan's energy transition. However, the pace of renewable capacity addition remains insufficient to fundamentally alter the energy mix, highlighting the need for accelerated investment and policy support.

5. Social Licence to Operate. KPO's $901.98 million social infrastructure investment and 268 community facilities demonstrate that social performance is not merely a philanthropic addendum but a strategic investment in operational stability and stakeholder trust. In regions where energy enterprises operate, community support is essential for maintaining operational continuity, particularly in the context of increasing public awareness of environmental issues.

5.4 Carbon-Intensive Legacy Assets

A structural challenge facing all enterprises examined in this study is the presence of carbon-intensive legacy assets with long operational lifespans. Kazakhstan's major oil and gas fields—Tengiz, Karachaganak, and Kashagan—represent multi-decade investments that cannot be rapidly decommissioned or converted without severe economic consequences. This reality imposes a pragmatic constraint on decarbonisation trajectories, necessitating a balance between ambitious long-term targets and the operational realities of asset management. The scenario-based approach adopted by Samruk-Kazyna, which explicitly models a Business as Usual (≥4°C) pathway alongside decarbonisation scenarios, represents an honest acknowledgement of this uncertainty.

6. Conclusion

This study has examined the ESG strategies and corporate performance outcomes of six leading enterprises in Kazakhstan's energy sector through a comparative case study analysis. The findings reveal a sector in transition, characterised by genuine progress in environmental performance, governance reform, and technology adoption, but also marked by significant disparities across enterprises and persistent challenges related to greenwashing, measurement consistency, and carbon-intensive legacy assets.

Several key conclusions emerge from the analysis. First, international joint ventures (KPO, TCO) tend to achieve superior environmental performance outcomes, reflecting their access to global expertise, technologies, and management practices. KPO's 44.9% emission reduction, 99.95% gas utilisation rate, and $466.97 million environmental investment, along with TCO's 78% reduction in air emissions per tonne of oil, represent benchmarks for the sector. Second, national champions (KMG, Samruk-Energy) demonstrate stronger strategic alignment with national carbon neutrality targets but face greater implementation challenges, as evidenced by the modesty of near-term reduction targets relative to long-term ambitions. Third, technology adoption—including LDAR systems, automated environmental monitoring, robotic inspection, and AI-powered data analysis—is a critical driver of environmental performance across all enterprises. Fourth, the risk of greenwashing remains a systemic concern, with ESG rating consistency at only 60% (preprints.org, 2025), underscoring the need for standardised reporting frameworks and independent verification.

The study contributes to the literature on ESG in emerging economies by providing empirically grounded insights into the dynamics of ESG adoption in a resource-dependent, post-Soviet context. It demonstrates that theoretical frameworks derived from stakeholder theory, the resource-based view, and institutional theory are applicable to Kazakhstan's energy sector, but that their manifestations are shaped by distinctive contextual factors including state ownership, carbon-intensive industrial legacies, and evolving institutional capacities.

Future research should extend this analysis through longitudinal studies tracking ESG performance over time, primary data collection through interviews with corporate decision-makers, and quantitative analysis of the relationship between ESG performance and financial outcomes. Additionally, comparative studies across Central Asian countries would provide valuable insights into the role of national institutional contexts in shaping ESG strategy and outcomes.

The broader implication of this study is that the transition to sustainable energy systems in resource-dependent economies is neither uniform nor straightforward. It requires sustained strategic commitment, substantial investment, technological innovation, and governance reform, pursued within the constraints of economic imperatives and institutional realities. The Kazakhstani experience demonstrates that ESG adoption in such contexts is shaped by a complex interplay of international obligations, national policy frameworks, ownership structures, and organisational

capabilities. Kazakhstan's energy enterprises have taken significant steps along this path, but the journey toward carbon neutrality by 2060 will demand sustained effort, transparency, and accountability at every level of the corporate and governmental system.

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THE ROLE OF ARTIFICIAL INTELLIGENCE IN STUDENTS' ACADEMIC PROCESS AND PROJECT MANAGEMENT

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ABSTRACT
This paper examines how university students use Artificial Intelligence tools in their academic work — how often, for what purposes, and with what consequences for productivity and academic integrity. Drawing on survey data from 120 students collected via a structured Google Forms questionnaire, the study finds that AI adoption is already near-universal: 70.6% of respondents use AI tools every day, and ChatGPT and Google Gemini account for the largest share of that activity. Students rely on AI chiefly to generate ideas and structure their writing (82.4%), to simplify difficult course material (58.8%), and to create visual presentations (47.1%). Three quarters of respondents report that AI has saved them time and improved the quality of their work, yet the ethical picture is considerably more complicated. Just over half the sample takes an intermediate position on whether AI use violates academic integrity — neither fully endorsing nor fully rejecting it — reflecting a broader institutional uncertainty that universities have yet to resolve. The paper closes with practical recommendations for AI governance policy, curriculum design, and integrity frameworks.
Keywords: *artificial intelligence, generative AI, higher education, academic integrity, project management, quantitative research*

1. INTRODUCTION
1.1 Background and Relevance
Few technological shifts have reached the everyday life of university students as quickly as generative artificial intelligence. When OpenAI released ChatGPT in November 2022, it compressed what might have been a decade of gradual adoption into a matter of months (OpenAI, 2022). By the 2025–2026 academic year, AI tools had become part of ordinary student routine at institutions across the world — not an occasional experiment, but a regular companion for writing assignments, preparing presentations, and working through unfamiliar material. A survey by Coursera (2023) found that more than 70% of students now describe AI as an integral part of how they study.

This trajectory raises questions that educators and institutions cannot afford to defer. Does consistent AI use genuinely deepen learning, or does it quietly erode the habits of mind — sustained attention, independent reasoning, tolerance for difficulty — that higher education is meant to cultivate? When a student submits work that AI helped produce, are they engaging in academic dishonesty, or simply using a tool in the same spirit that previous generations used calculators or spellcheckers? And if universities cannot agree on the answers, how should they write policy? These are not abstract concerns: the decisions made in the next few years will shape what a university education actually means.

UNESCO (2023) has argued that blanket restrictions on AI are both impractical and counterproductive, and that the more productive institutional response is to develop a culture of purposeful, critical, and ethically grounded AI use. That argument seems right, but it places considerable responsibility on universities to understand first what students are actually doing with AI — which tools they use, why, how much they trust them, and how they themselves think about the ethical boundaries. In Georgia, as in many countries, systematic empirical data on these questions is scarce. The present study is an attempt to contribute some.

1.2 Research Objectives

The study sets out to describe AI tool use among university students with enough specificity to be useful for policy and curriculum development. Concretely, it seeks to:

- Establish how frequently students use AI tools as part of their academic work.
- Identify which tools are most widely used and examine what drives their popularity.
- Determine the specific purposes for which students turn to AI — including idea generation, material simplification, presentation design, text editing, and technical tasks.
- Assess whether AI use has measurable effects on productivity, and whether those effects involve time, quality, or both.
- Examine how much students trust the factual accuracy of AI-generated information.
- Explore student views on AI use and academic integrity, and on the question of formal institutional recognition of AI as a legitimate academic tool.

2. THEORETICAL FRAMEWORK

2.1 Literature Review

Scholarship on AI in higher education has accumulated rapidly since 2022, and it has not produced a settled consensus. The debate tends to organise around two poles. Researchers sympathetic to AI integration point to genuine pedagogical possibilities: tools that can explain concepts at whatever level a student needs, provide instant feedback, and free up time for work that requires more complex thinking. Those more sceptical worry that students who outsource cognitive effort to AI are not simply saving time but forfeiting the very process through which learning occurs.

Kasneci et al. (2023), writing in Computers and Education: Artificial Intelligence, find evidence that AI can increase student engagement and support personalised learning in ways that a single instructor working with a large cohort simply cannot replicate. They are careful, however, to note the risks: students who rely on AI as a crutch may develop a kind of learned helplessness, reaching for the tool whenever a task feels difficult rather than working through the difficulty themselves.

Cotton et al. (2023) press this concern further. Their argument is not that AI is bad for students but that the manner of use matters enormously. A student who uses AI to generate a first draft they then interrogate, revise, and build on is doing something quite different from a student who copies the output and submits it unchanged. The former is using AI as a thinking partner; the latter is substituting AI for thinking altogether. From the perspective of student productivity, Sallam (2023) provides useful complementary data: more than 65% of AI-using students in his sample reported reducing the time they spent on individual assignments by between 30 and 40%. Whether that saved time goes toward deeper engagement with the subject or simply toward other activities is a question his study does not resolve, but it is the right question to ask.

The integrity debate has been particularly knotty. Perkins (2023) points out that the traditional definition of plagiarism — taking credit for another person's intellectual labour — does not map cleanly onto AI-generated text, which has no human author and does not belong to anyone in the conventional sense. Holmes et al. (2022) have proposed a workable middle path: treat disclosed and appropriately attributed AI use as acceptable, and reserve the misconduct label for cases where students present AI output as entirely their own work without acknowledgement.

2.2 Key Terminology

Artificial Intelligence (AI): A set of computational systems built to carry out tasks that would normally require human cognitive capacities — reading and generating text, recognising images, reasoning under uncertainty, and so on. The field includes machine learning, deep learning, and natural language processing as major sub-domains (Russell & Norvig, 2021).

Generative AI: A branch of AI specifically concerned with producing original content in response to user prompts. The output may be text, images, audio, video, or code. ChatGPT, Google Gemini, and Anthropic's Claude are the most widely used examples in educational contexts (Feuerriegel et al., 2024).

Academic Integrity: A commitment to honesty and fairness in all academic work, covering the accurate attribution of sources, independent completion of assessed tasks, and transparent disclosure of any assistance received. The International Center for Academic Integrity (2021) describes its core values as honesty, trust, fairness, respect, and responsibility.

Project Management: The organised coordination of tasks, timelines, and resources toward a defined objective. In a student context this typically means planning how a group will divide work, setting internal deadlines, tracking progress, and maintaining quality control over the final product (Project Management Institute, 2021).

3. METHODOLOGY

3.1 Research Design

The study uses a quantitative, descriptive research design. The choice reflects the nature of the questions being asked: the goal is to measure and describe patterns of AI use — how frequent, what kind, with what perceived effects — rather than to establish why those patterns exist or to test causal hypotheses. As Creswell (2014) notes, descriptive research is appropriate precisely when the priority is an accurate account of current conditions, and a standardised survey administered to all participants on the same terms is well suited to that purpose.

3.2 Instrument

Data were collected through a structured online questionnaire built on Google Forms. The platform was chosen for practical reasons — it is free, familiar to students, and supports anonymous responses — but also because it generates automatic summaries that facilitate preliminary analysis. The questionnaire contained nine items: a mix of single-choice and multiple-choice questions, and one five-point Likert-scale item measuring trust in AI-provided information. All items were written to correspond directly to the research objectives stated above.

3.3 Sample and Data Collection

One hundred and twenty students completed the questionnaire voluntarily and anonymously during the 2024–2025 academic year. Participants were recruited by convenience sampling — that is, they were students accessible to the research team within the current academic environment rather than a randomly selected cross-section of any defined population. No names, student identification numbers, or other identifying details were collected.

The sample skews toward second-year students, who account for 76.5% of respondents; the remaining 23.5% are spread across first, third, and fourth year and postgraduate levels. Convenience sampling does limit the extent to which findings can be generalised beyond this group, and that limitation should be kept in mind when interpreting the results. Nevertheless, a sample of 120 provides a considerably more robust evidential base than much of the early literature in this area. Future work should draw on larger and more representative samples, and would benefit from supplementing survey data with in-depth interviews.

4. RESULTS AND ANALYSIS

4.1 Adoption and Tool Preferences

The most immediate finding is how thoroughly AI has entered students' daily working lives. Seven in ten respondents (70.6%) use AI tools every day; a further 23.5% use them several times a week. Taken together, 94.1% of the sample engages with AI on a regular, systematic basis. Only 5.9% describe their use as infrequent. For most of these students, AI is no longer a novelty they occasionally experiment with; it has the status of a standard academic resource, comparable in regularity to a textbook or a search engine. Kasneci et al. (2023) noted a similar pattern emerging in other national contexts and compared it to the early adoption of the internet within universities — a technology that within a few years moved from peripheral curiosity to structural fixture of academic life.

ChatGPT is used by 82.4% of respondents, making it by some distance the most prevalent tool in the sample. Google Gemini comes second at 76.5%, followed by Claude (Anthropic) at 41.2%, and Gamma and Kimi, each cited by 29.4% of respondents. A further 23.5% reported using tools not covered by these categories. The dominance of ChatGPT and Gemini is not surprising given their early market presence and the fact that Gemini sits within the Google ecosystem — students who already use Docs, Slides, and Gmail encounter it naturally. Claude's 41.2% share is striking for a tool that has been marketed far less aggressively than its main competitors. Equally notable is Gamma's significant presence: designed specifically for presentation creation, its use by nearly a third of respondents suggests that students are working with AI across different content types, not limiting it to text generation alone.

4.2 Academic Uses and Productivity

When asked what they use AI for, 82.4% of students identified idea generation and structural planning — using AI to help them decide what to write about and how to organise it before they begin. This is perhaps the most revealing finding in the dataset. It suggests that for most students the primary value of AI is not that it writes for them, but that it helps them get started and move from an empty page to a workable framework. The second most common use, cited by 58.8% of respondents, is simplifying difficult course material, which aligns with what Sallam (2023) describes as AI's most significant pedagogical contribution: its capacity to explain the same concept at different levels of complexity, functioning in effect as a patient, always-available tutor. Visual presentation design (47.1%), text editing and grammar checking (41.2%), and coding or technical tasks (23.5%) round out the picture. The relatively modest share for coding reflects the composition of the sample, which draws predominantly from social science and business programmes.

A related finding concerns group project work. All 120 respondents found AI at least partially useful for team-based tasks such as planning, distributing responsibilities, and developing ideas collectively; none reported that it provided no benefit at all. Within that unanimity, 64.7% described AI as 'very helpful' in this context and 35.3% as 'partially helpful.' This is worth noting because group project coordination has generally been thought of as a distinctly human activity. The data suggest students are finding practical ways to use AI as an organisational aid in exactly this domain.

On productivity more broadly, three quarters of respondents (76.5%) report that AI has both saved them time and improved the quality of their output. A further 17.6% say AI saves time without making a noticeable difference to quality, and only 5.9% report no significant effect. The time-saving finding is consistent with Sallam's (2023) data showing 30–40% reductions in assignment completion time among regular AI users. The more interesting question is what students do with the time they save: the 17.6% who report efficiency gains without quality improvements may be illustrating a pattern of use that is productive in a narrow sense but not educationally enriching.

4.3 Trust, Integrity, and Institutional Legitimacy

On a five-point scale asking how much they trust factual information provided by AI, respondents distributed as follows: score of 1 (no trust): 0%; score of 2: 11.8%; score of 3: 23.5%; score of 4: 41.2%; score of 5 (full trust): 23.5%. The modal score is 4, and 64.7% of students placed themselves in the high-trust range. These numbers warrant careful interpretation. Cotton et al. (2023) have documented the problem of AI 'hallucinations' — instances where the model produces plausible-sounding but factually wrong information with apparent confidence. A student who trusts AI output at level 4 or 5 without routinely verifying it against primary sources is taking a real risk. The more encouraging reading is that the most common score is 4 rather than 5: most students stop short of unconditional trust, which at least leaves room for critical evaluation.

The integrity question produced the study's most nuanced pattern of responses. A plurality — 52.9% — took an intermediate position: they felt that AI use 'partially violates' integrity because some portion of the work is effectively produced by a machine. A further 23.5% said AI does not violate integrity provided it is used as a supplementary aid rather than a replacement for the student's own thinking. The remaining 23.5% took the strongest view: that any reliance on AI compromises independent thought and therefore constitutes a breach. The majority in the middle are not being evasive. They are accurately reflecting an ethical situation that is genuinely unresolved. As Perkins (2023) has argued, the framework universities have historically used to define misconduct was developed before tools like ChatGPT existed, and applying it to AI-assisted work produces results that feel both too strict in some cases and too permissive in others.

On the question of formal institutional recognition, 58.8% of respondents believe universities should legitimise AI as an academic tool, framing this as an unavoidable response to technological change. Just under a quarter (23.5%) take the opposite view, arguing that formal legitimisation would lower educational quality — a concern that echoes Cotton et al.'s (2023) warnings about the long-term atrophy of independent cognitive skills. The remaining 17.6% are undecided. Taken together, these three findings — on trust, integrity, and legitimacy — point to the same conclusion: students are navigating a landscape that their institutions have not yet mapped. The diversity of positions is itself evidence that clear policy guidance is overdue.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Key Findings

This study set out to describe how university students use AI tools in their academic work. The picture that emerges from 120 respondents is one of deep, routine integration rather than selective or experimental adoption. The principal findings can be summarised as follows:

- AI use is essentially universal in this sample. 70.6% of students use AI every day; 94.1% do so at least weekly. For most respondents, AI is now a standard feature of academic life rather than an optional add-on.
- ChatGPT (82.4%) and Google Gemini (76.5%) are the dominant platforms, but Claude (41.2%) and Gamma (29.4%) also command significant shares, and many students use multiple tools for different purposes.
- Students use AI most often to generate ideas and organise their thinking (82.4%), and to make sense of complex material (58.8%). This suggests the primary function of AI, at least as students describe it, is cognitive scaffolding rather than outright text substitution.
- The productivity effects are predominantly positive: 76.5% of students report that AI has both saved time and improved work quality. The 17.6% who report only time savings hint at a pattern of use that is efficient but not educationally enriching.
- Trust in AI-generated information is high: 64.7% of respondents rate their trust at 4 or 5 on a five-point scale. Given documented risks of AI hallucination, this warrants attention in information literacy education.

- Academic integrity in the AI era remains ethically contested. Most students (52.9%) occupy an intermediate position; the remaining 47.1% are evenly divided between those who see no integrity problem and those who see a serious one.
- A majority (58.8%) supports formal institutional recognition of AI as a legitimate academic resource.

5.2 Recommendations

1. Develop a clear institutional AI policy. Universities need to move from silence or vague prohibition to explicit, workable guidelines. A good policy would specify which kinds of tasks and assessments permit AI assistance, what disclosure is required, and what constitutes misconduct. Without this, students will continue to improvise their own ethical frameworks, with predictably inconsistent results.

2. Integrate AI literacy into curricula. Knowing how to use AI is not the same as knowing how to use it well. Institutions should incorporate dedicated instruction on evaluating AI outputs critically, recognising the tool's limitations and biases, and understanding the ethical dimensions of AI-assisted work (Cotton et al., 2023).

3. Build habits of verification. The trust data in this study suggest that many students accept AI outputs without sufficient scrutiny. This is an information literacy problem as much as an AI problem, and it calls for explicit instruction in how to check AI-generated claims against authoritative sources.

4. Update academic integrity frameworks. The traditional plagiarism framework does not map cleanly onto AI-assisted work. Universities should develop clearer definitions of what constitutes acceptable AI use and what does not, building on models like Holmes et al.'s (2022) disclosure-based approach.

5. Expand the research base. This study's convenience sample captures one slice of one academic environment. Future research should work with larger and more diverse samples, include multiple institutions, and use qualitative methods — interviews, focus groups, observation — to get beneath the surface of what survey responses can reveal.

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Alternative Financial Instruments in the Digital Economy: The Role of Crowdfunding in Kazakhstan

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Abstract:
The article provides a comprehensive analysis of crowdfunding as an alternative and innovative source of financing, its significance for the development of the modern economy, and prospects for its application in the Republic of Kazakhstan. Key crowdfunding models and principles of their functioning are examined, and their advantages and limitations are identified. Particular attention is paid to a comparative analysis of the development of crowdfunding in Kazakhstan and the United States of America, including a study of successful practices, statistical indicators, and the main differences in the structural and institutional conditions of the market.

Key barriers hindering the spread of crowdfunding in Kazakhstan have been identified: insufficient public awareness, limited access to international platforms, and an inadequate regulatory framework. The concluding section of the article outlines promising areas for the development of crowdfunding in the country, including possible measures of state support, the creation of national specialised platforms, and the development of integration with international crowdfunding ecosystems.

Keywords: crowdfunding, financing, start-ups, charity, investments, Kazakhstan.

Crowdfunding (from the English words "crowd" and "funding") is a method of collective financing in which funds for a project are collected from a large number of people via online platforms. This financing mechanism allows start-ups, creative teams, public organisations and individuals to attract investment from a wide audience without the intermediation of traditional financial institutions.

In today's world, project financing has become one of the key challenges for start-ups, entrepreneurs, creative individuals and social initiatives. Traditional methods of raising capital, such as bank loans, venture capital investments and government grants, are often either unavailable or too burdensome for project initiators. In these conditions, crowdfunding is becoming increasingly popular as a method of collective financing, in which funds for the implementation of an idea are collected from a large number of people via online platforms.

Crowdfunding is not only an alternative but also an innovative mechanism for attracting financing, combining the capabilities of digital technologies, social networks, and the sharing economy. It democratises access to capital by creating conditions under which any individual or company can obtain funding directly from an interested audience, bypassing traditional financial institutions.

In recent years, crowdfunding has become one of the most popular tools for financing start-ups, social initiatives, creative and business projects around the world. In Kazakhstan, this mechanism is only gaining popularity, but it is already demonstrating high potential. With the help of crowdfunding, entrepreneurs, artists, charitable organisations and technology start-ups gain access to funds without having to turn to banks or venture investors.

Crowdfunding is a powerful tool that can change the market for financing start-ups and social initiatives in Kazakhstan. However, its development requires the creation of favourable conditions, including raising public awareness, legislative support, the development of local platforms and integration with international platforms.

Crowdfunding has already proven its effectiveness in developed countries such as the United States, the United Kingdom, Germany, China, and Japan, where this market is estimated to be worth tens of billions of dollars. For example, since its launch in 2009, the largest platform, Kickstarter, has helped raise more than $7 billion for various projects, and the total volume of the crowdfunding market in the United States in 2024 exceeded $17 billion.

Crowdfunding has not yet reached this level of development in Kazakhstan, but interest in it is gradually growing. The first local platforms, such as StartTime.kz and Crowdfunding.kz, have already appeared in the country, as well as entrepreneurs who successfully use international platforms to attract investment. Nevertheless, this market faces a number of constraints, including a weak legal framework, low public awareness, mistrust of online financing, and limited access to international platforms.

Comparing the situation in Kazakhstan and the United States, there is a significant gap in the amount of funds raised, the number of successful projects, and the level of public involvement. While in the United States, crowdfunding has become an important tool for financing innovative start-ups, the film industry, music, and social initiatives, in Kazakhstan, this mechanism is still perceived primarily as a way to raise funds for charity or one-off small projects. However, crowdfunding has enormous potential in Kazakhstan, and with the right conditions in place, it could become a powerful driver of entrepreneurship, innovation, and social activism.

Unlike traditional methods of raising capital, crowdfunding is based on mass participation: investors can invest small amounts in projects that interest them, and initiators receive the necessary start-up capital without strict conditions for repayment.

Firstly, funds are raised through digital platforms such as Kickstarter, Indiegogo, Boomstarter, StartTime.kz and others.

Secondly, funding does not come from a single large investor, but from a multitude of people who are interested in the success of the project.

Thirdly, participation in crowdfunding campaigns is voluntary, which makes this process accessible to a wide range of people.

Fourthly, crowdfunding offers various financing models, including donations, investments, pre-orders, and lending.

Depending on the form of interaction between project initiators and investors, there are several basic models of crowdfunding.

Reward-based crowdfunding (Reward-based Crowdfunding)

This is one of the most popular models, where contributors receive certain rewards for supporting the project. Most often, these rewards include a finished product, merchandise (T-shirts, souvenirs), exclusive access to content, participation in private events, etc.

One example is the Kickstarter platform, where start-ups raise funds for the production of gadgets, games, films, books and other projects. One successful campaign was Pebble, a project to develop smart watches, which raised over $10 million.

Equity crowdfunding (Equity Crowdfunding)

With this model, investors receive a stake in the business or company by financing the project. It is similar to venture capital investment, but with lower barriers to entry: virtually anyone can invest, not just professional funds.

The key platforms in this area are Seedrs (a British platform that allows start-ups to raise funds by offering investors a stake in the company) and Crowdcube (a platform that has provided funding to companies such as Monzo Bank and BrewDog), which help start-ups attract investment by offering investors a stake in the company.

Credit crowdfunding (Peer-to-peer lending, P2P-кредитование)

In this case, users provide loans to other users (individuals or businesses) with the possibility of repayment with interest. This is an alternative to bank lending, where borrowers can obtain money on more favourable terms.

One of the world's largest P2P lending platforms offering such services is LendingClub, where users can lend money to each other without the involvement of banks.

Charitable crowdfunding (Donation-based Crowdfunding)

This type of crowdfunding is based on voluntary donations. People support social, medical or educational projects without expecting any financial return.

The most well-known platform is GoFundMe, which is actively used to raise funds for charitable causes. Planeta.ru is a Russian crowdfunding platform that raises money for social initiatives and charity.

Royalty crowdfunding (Royalty Crowdfunding)

A less common type of crowdfunding, in which investors receive a percentage of the project's future profits. For example, musicians or filmmakers may offer investors a share of the revenue from album or film sales. A good example is ArtistShare, a platform where musicians raise funds to create albums and share a portion of future profits with investors.

Crowdfunding is still in its infancy in Kazakhstan, but its potential is growing thanks to the digitalisation of the economy and the development of financial technologies. However, despite growing interest in crowdfunding in Kazakhstan, this financing mechanism faces a number of problems that limit its development. One of the key difficulties is low public awareness. Many Kazakhstani citizens are unaware of the possibilities of crowdfunding or perceive it exclusively as a form of charity, whereas in the US and Europe it has long been used to finance businesses and start-ups. This is due to the lack of educational programmes and courses, the lack of successful and widely known Kazakhstani cases, as well as low levels of financial literacy in alternative financing methods.

Another serious problem is limited access to international platforms. Kazakhstani projects cannot fully participate in major crowdfunding services such as Kickstarter and Indiegogo, as these platforms do not support Kazakhstan as a region for registering campaigns. As a result, local entrepreneurs lose the opportunity to attract foreign investment. To circumvent this restriction, some projects are registered through third countries, such as the United States or the United Kingdom, but this entails additional costs and legal complications. There are also intermediaries who help launch crowdfunding campaigns on behalf of companies registered in supported countries, but their services also require additional financial investment.

Inadequate legislative regulation creates additional barriers. Kazakhstan does not yet have a clear legal framework regulating the activities of crowdfunding platforms and protecting the rights of investors. The lack of mechanisms to protect investors from fraud, uncertainty regarding the taxation of funds raised, and weak protection of the intellectual property of project initiators all make this method of financing less attractive and increase the risks for both project authors and their sponsors.

Mistrust of online platforms and internet financing also hinders the development of crowdfunding in the country. Kazakhstanis traditionally prefer more familiar methods of financing,

such as bank loans, government grants or the use of personal savings. Concerns relate to the lack of government control over platforms, the risk that the project initiator will not fulfil their promises, and the weak legal liability of campaign organisers.

In addition, Kazakhstan does not yet have a developed market for crowdfunding platforms. Currently, there are only a few such services operating in the country, such as StartTime.kz and Crowdfunding.kz, but their audience and functionality are significantly inferior to their international counterparts, which limits their potential for raising large sums of money.

Despite these difficulties, crowdfunding in Kazakhstan has significant potential. In the coming years, we can expect to see new solutions and initiatives aimed at promoting it. The development of local crowdfunding platforms, the introduction of convenient functionality, support for multi-currency payments, and integration with international payment systems will help attract more users. It is also important to ensure investor protection, for example through risk insurance and the use of escrow accounts, while the transparency of platforms can be improved through public reporting and rating systems for campaign organisers.

The review by the Astana International Financial Centre and Dasco Group focuses on the potential for development of the creative industry in Kazakhstan. In particular, experts note that it has become one of the country's priorities in recent years. For example, the National Development Plan of the Republic of Kazakhstan until 2029 emphasises the strategic importance of creative industries for economic diversification and growth.

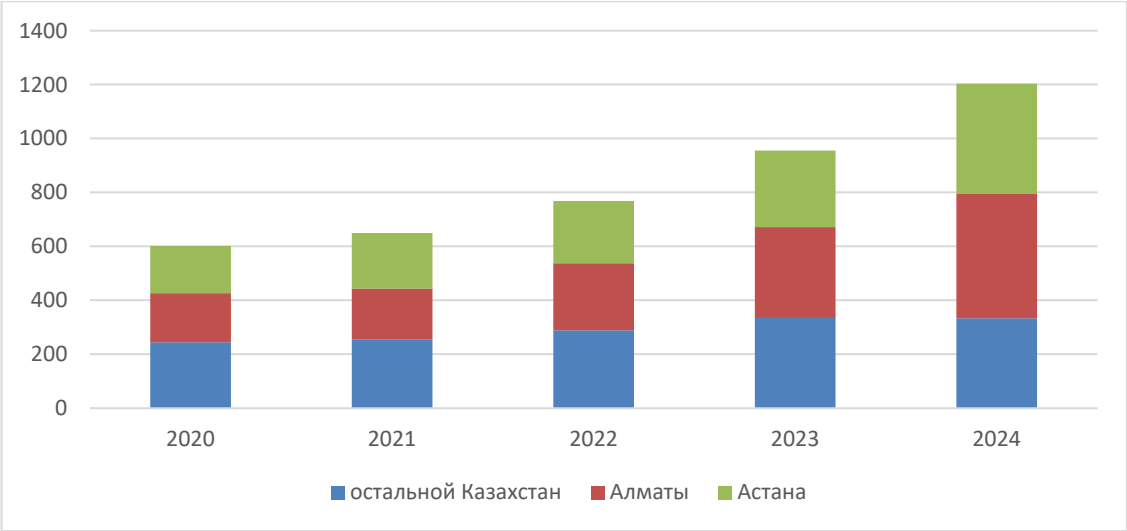
According to statistics, since 2017, the creative economy has grown 3.2 times in nominal terms, but its contribution to the country's GDP remains relatively modest at around 1%. Kazakhstan lags behind most developed countries in this respect, indicating significant potential for further growth in the sector.

The largest "modern" creative industry in Kazakhstan, with a 38% share, is IT and video game development: the GDP of this industry amounted to 459 billion tenge, with most of it coming from software development. The rest of the modern industries account for only 138 billion tenge, including television (99 billion), cinema (23 billion), photography (14 billion) and music (1.7 billion).

As for the "traditional" sectors, architecture, fashion and design remain the largest, accounting for 24% of the country's creative economy GDP, or 286 billion tenge. This is followed by cultural and leisure activities with 132 billion tenge, including theatres and concerts, as well as libraries and museums with 81 billion and folk crafts with 60 billion tenge.

Business and employment in Kazakhstan's creative economy. In 2024, there were 41,800 businesses operating in the creative industries, of which 12,300 were legal entities and 29,500 were individual entrepreneurs. Over the past seven years, the number of entities has increased 2.7 times, accounting for 2% of the total number of registered economic entities. The number of employees increased from 106,700 in 2019 to 141,500 by mid-2024.

Gross value added (GVA) of the creative economy in Kazakhstan. The indicator has shown growth in recent years, reaching 1.2 trillion tenge in 2024.



Note: Creative economy GDP (in billion tenge) and its share in Kazakhstan's GDP (in %), 2019-2024.

Source: National Statistics Bureau of the Agency for Strategic Planning and Research of the Republic of Kazakhstan

Government support can play a key role in the development of crowdfunding. The development of a legal framework that protects the rights of investors and project initiators, the introduction of tax incentives for entrepreneurs using crowdfunding, and the creation of educational programmes will significantly increase confidence in this financing mechanism. One example is the United States, where the Securities and Exchange Commission (SEC) regulates crowdfunding platforms, ensuring transaction transparency and investor protection.

Astana and Almaty are the leaders in terms of the number of creative industry entities, accounting for 67% of all legal entities in the industry.

Opportunities for the AIFC to develop Kazakhstan's creative economy. The Astana International Financial Centre can strengthen its role in supporting creative industries in the country. As of October 2024, 324 companies operating in this field, mainly in the IT sector, are registered with the AIFC.

The analytical review by the Astana International Financial Centre and Dasco Group presents five solutions proposed by the AIFC to create a dynamic ecosystem that promotes creativity and entrepreneurship. These include:

- using the venture studio tool to stimulate innovation;
- creation of a venture fund at the AIFC to support start-ups, including creative projects;
- using the AIFC's intellectual property system to protect and manage creative assets;
- attracting crowdfunding for creative projects;
- tokenisation of assets.

Note: Number of entities by sector of Kazakhstan's creative economy, 2017-2024, in units.

Source: National Statistics Bureau of the Agency for Strategic Planning and Research of the Republic of Kazakhstan

To increase trust in crowdfunding, successful cases must be actively promoted. Holding conferences and forums, attracting well-known personalities such as bloggers and entrepreneurs, and providing media support for start-ups that have successfully completed crowdfunding campaigns can play an important role in shaping a positive image for this method of financing.

Another promising area is integration with blockchain technologies. The use of blockchain will increase the transparency of crowdfunding platforms, eliminate fraudulent schemes, and introduce smart contracts that automatically distribute the funds raised depending on the fulfilment of the stated goals. For example, the Kickstarter platform migrated its infrastructure to blockchain back in 2022, which increased the level of security and user trust.

Kazakhstan can also integrate into the global crowdfunding market by signing agreements with international platforms and creating conditions for local projects to enter the global market. This could include developing legal mechanisms for registering Kazakhstani projects on major international platforms, attracting foreign investors through crowdfunding campaigns, and using Kazakhstan as a hub for crowdfunding initiatives in Central Asia.

Although crowdfunding in Kazakhstan faces a number of serious barriers, its prospects look promising. If favourable conditions can be created – developing local platforms, securing government support, promoting successful cases and introducing new technologies – this financing mechanism could become an important part of the country's economic system. In the coming years, we can expect to see growing interest in crowdfunding, especially among young entrepreneurs, start-up developers and social activists. This will allow Kazakhstan to participate more actively in the global process of digital transformation and innovative development.

With the right approach, crowdfunding can become a powerful driver of small and medium-sized business development, stimulate innovation processes, and contribute to the support of socially significant initiatives. The combined efforts of the state, business, and society will help this tool take an important place in the country's economy and form a new culture of entrepreneurship and collective investment. In the coming years, we can expect to see active growth, especially in areas such as technology start-ups, creative industries, charity and ecology. All this opens up new

opportunities for both business and society, giving people the chance to participate directly in the creation of meaningful projects and the shaping of the country's future.

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ЦИФРОВЫЕ КАДРЫ ДЛЯ УМНЫХ ПРЕДПРИЯТИЙ «ЗЕЛЕНОЙ ЭКОНОМИКИ» КАЗАХСТАНА: ОСОБЕННОСТИ ПОДГОТОВКИ И УПРАВЛЕНИЯ

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Аннотация. Анализ роли цифрового персонала в обеспечении функционирования и развития “умных” предприятий “зеленой экономики” в условиях цифровой трансформации, декарбонизации и меняющихся требований рынка труда , с учетом современных научных достижений, нормативно - правовых документов, актуальных тенденций социально-экономического развития Республики Казахстан .рольцифровизацию персонала в обеспечении функционирования и развития “умных” предприятий “зеленой экономики” в условиях цифровой трансформации , декарбонизации и меняющихся требований рынка труда, с учетом современных научных достижений и нормативных требований .Правовые документы, современные тенденции социально - экономического развития Республики Казахстан.

Исследование проводится с использованием системного и сравнительного подходов, анализа нормативно - правовых документов Республика Казахстан в отношении цифровизации, развития искусственного интеллекта, перехода к “зеленой экономике” и достижения углеродной нейтральности, а также анализа современных исследований в области цифровых и “зеленых” компетенций, образования и рынка труда .

Авторы доказали, что цифровая трансформация и переход Казахстана к более экологически устойчивой модели развития создают качественно новые требования к человеческому капиталу . Для “умных” предприятий “зеленой экономики” недостаточно готовить специалистов, обладающих только цифровыми или только экологическими знаниями . Необходимо развивать комплексный набор компетенций: цифровая грамотность, работа с данными и искусственным интеллектом, экологическое мышление, понимание основ сохранения ресурсов .декарбонизация, способность к непрерывному обучению и самостоятельному поиску технологических решений .

Подготовка цифровых специалистов для “зеленой экономики” должна рассматриваться как одно из условий достижения стратегических целей Казахстана , включая переход к низкоуглеродному развитию и достижение углеродной нейтральности к 2060 году . Особое внимание уделяется обновлению образовательных программ , развитию партнерских отношений между университетами и промышленными предприятиями , расширению практико - ориентированной подготовки , развитию системы непрерывного образования и повышению роли корпоративного обучения . Управление такими специалистами также требует изменения традиционных подходов : необходимо расширять самостоятельность работников , стимулировать инновационную инициативу , создавать возможности для удаленной гибридной занятости , профессионального роста и постоянного повышения квалификации .

Ключевые слова: цифровая экономика, зеленая экономика, Казахстан, цифровая рабочая сила, зеленые навыки, цифровые навыки, искусственный интеллект, образование, человеческий капитал, непрерывное образование, декарбонизация, углеродная нейтральность.

ВВЕДЕНИЕ

В современных условиях капитал человеческого капитала становится одним из факторов конкурентоспособности предприятий . Если на индустриальном этапе развития экономики эффективность во многом сократилась по объёму материальных ресурсов и производственных мощностей, то в условиях цифровых трансформаций всё большее значение приобретают знания, навыки, умеют взаимодействовать с цифровыми технологиями и самостоятельно находить новые способы решения производственных задач.

Особенно актуальным данный вопрос становится для предприятий, которые одновременно осуществляют цифровую и экологическую трансформацию. Такие организации можно условно определить как “умные” предприятия “зеленой экономики”- предприятия, использующие цифровые технологии, автоматизацию, большие данные, искусственный интеллект, сенсорные системы и интеллектуальное управление для повышения экономической эффективности при одновременном снижении негативного воздействия на окружающую среду.

Для Республики Казахстан эта проблема имеет особое значение. Казахстан располагает значительным природно-ресурсным потенциалом, а структура экономики исторически характеризуется высокой ролью добывающей промышленности, энергетики, металлургии, транспорта и сельского хозяйства. Поэтому переход к ресурсосберегающей и низкоуглеродной модели развития предполагает не только внедрение новых технологий, но и глубокое изменение требований к работникам.

В 2013 году в Казахстане была утверждена Концепция по переходу Республики Казахстан к “зеленой экономике”. Документ определил необходимость системной трансформации экономики с учетом повышения благосостояния населения, эффективного использования ресурсов и снижения нагрузки на окружающую среду.

Следующим важным этапом стало утверждение Стратегии достижения углеродной нейтральности Республики Казахстан до 2060 года. Стратегия предполагает последовательную трансформацию экономики с учетом климатических рисков, технологического развития, экономической эффективности и социальных последствий перехода.

Одновременно Казахстан активно развивает цифровую инфраструктуру и человеческий капитал. Концепция развития искусственного интеллекта на 2024-2029 годы отдельно выделяет человеческий капитал как одно из ключевых направлений государственной политики в сфере ИИ.

Таким образом, цифровизация и экологизация экономики Казахстана развиваются не изолированно друг от друга. Наоборот, именно их сочетание формирует новое пространство спроса на специалистов.

Современный работник “умного” предприятия должен не просто выполнять установленную технологическую операцию. Он должен уметь работать с данными, использовать цифровые инструменты, интерпретировать показатели производительности и экологической эффективности, взаимодействовать с автоматизированными системами и искусственным интеллектом, выявлять возможности сокращения потребления энергии и ресурсов.

Следовательно, возникает необходимость формирования нового типа специалиста-цифрового кадра “зеленой экономики”, сочетающего профессиональные знания, цифровые компетенции и экологическое мышление.

РЕЗУЛЬТАТЫ ИССЛЕДОВАНИЯ

Цифровизация и “зеленая экономика” Казахстана

Переход к цифровой экономике предполагает изменение способов производства, управления, коммуникации и использования ресурсов. Цифровые технологии позволяют собирать и анализировать значительные объемы информации, автоматизировать отдельные операции, прогнозировать состояние оборудования, оптимизировать логистику и контролировать производственные процессы.

В условиях “зеленой экономики” эти возможности приобретают дополнительное значение. Цифровые технологии позволяют не только повысить производительность предприятия, но и контролировать его воздействие на окружающую среду.

Например, цифровые системы могут использоваться для:

· мониторинга потребления электроэнергии;
· контроля расхода воды;
· управления производственными выбросами;
· прогнозирования технического состояния оборудования;
· оптимизации транспортных маршрутов;
· управления отходами;
· мониторинга состояния сельскохозяйственных земель;
· интеллектуального управления зданиями;
· прогнозирования производства электроэнергии из возобновляемых источников;
· формирования экологической отчетности;
· оценки углеродного следа продукции.

В Казахстане уже сформирована система статистического мониторинга показателей “зеленой экономики”, включающая показатели углеродной и энергетической производительности, энергоемкости ВВП, доли электроэнергии из возобновляемых источников, образования и переработки отходов, производительности и нагрузки на водные ресурсы.

Следовательно, деятельность предприятия постепенно становится объектом одновременного экономического и экологического измерения. Работник нового поколения должен понимать оба этих измерения.

Особенно актуально это для таких отраслей Казахстана, как:

1. нефтегазовая промышленность;
2. горнодобывающая промышленность;
3. металлургия;
4. электроэнергетика;
5. возобновляемая энергетика;
6. сельское хозяйство;
7. водное хозяйство;
8. строительство;
9. транспорт и логистика;
10. управление отходами;
11. городская инфраструктура;
12. промышленная автоматизация.

В этих секторах цифровая трансформация непосредственно связана с повышением эффективности использования природных ресурсов.

Особенности человеческого капитала “умного” предприятия

Для Казахстана особенно важно понимать, что цифровая трансформация предприятия не может быть сведена исключительно к закупке программного обеспечения, оборудования или внедрению искусственного интеллекта.

Если организация приобретает современное оборудование, но сотрудники не умеют эффективно использовать его возможности, цифровая инвестиция не дает ожидаемого результата.

Поэтому человеческий капитал необходимо рассматривать как связующее звено между технологией и экономическим результатом.

Современный специалист должен обладать одновременно несколькими группами компетенций.

Рисунок 1. Основные элементы подготовки цифровых кадров для “умных” предприятий “зеленой экономики” Казахстана

Основные элементы подготовки цифровых кадров для “умных” предприятий “зеленой экономики” Казахстана

Именно сочетание данных компонентов позволяет говорить о подготовке полноценного цифрового кадра “зеленой экономики”.

ОСНОВНЫЕ СОСТАВЛЯЮЩИЕ ПОДГОТОВКИ СПЕЦИАЛИСТОВ

1. Специальные знания в области “зеленой экономики”

Первой составляющей подготовки специалиста должны стать знания о принципах устойчивого и низкоуглеродного развития.

Работник должен понимать:

· сущность “зеленой экономики”;

· принципы рационального использования природных ресурсов;

· основы энергоэффективности;

· основы обращения с отходами;

· значение возобновляемых источников энергии;

· принципы циркулярной экономики;

· основные направления декарбонизации;

· климатические риски;

· основы экологического менеджмента;

· взаимосвязь экологических и экономических показателей.

Для Казахстана это особенно важно в связи с реализацией Стратегии достижения углеродной нейтральности до 2060 года.

Специалист предприятия должен понимать, что экологическая эффективность не является исключительно задачей экологического отдела. Она становится частью производственного, финансового, инвестиционного и кадрового управления.

2. Цифровые компетенции

Второй важнейшей составляющей являются цифровые компетенции.

Базового умения пользоваться офисными программами уже недостаточно. Для “умного” предприятия необходимы специалисты, которые способны работать с цифровыми системами непосредственно в рамках своей профессиональной деятельности.

К таким компетенциям можно отнести:

· анализ данных;

· использование цифровых платформ;

· работа с облачными технологиями;

· применение искусственного интеллекта;

· визуализация данных;

· основы информационной безопасности;

· работа с автоматизированными системами;

· цифровое моделирование;

· использование сенсорных технологий;

· цифровой мониторинг производственных процессов.

Концепция развития искусственного интеллекта Казахстана на 2024-2029 годы предусматривает развитие человеческого капитала наряду с развитием данных, инфраструктуры, научных исследований и регулирования ИИ.

Таким образом, цифровая подготовка кадров должна рассматриваться не как дополнительная образовательная услуга, а как необходимый компонент современной профессиональной подготовки.

3. Формирование экологически ориентированного поведения

Наличие теоретических знаний само по себе не гарантирует экологически ответственного поведения работника.

Необходимо формировать у специалиста понимание непосредственной связи между экологической ответственностью и экономической эффективностью предприятия.

Например, сотрудник должен понимать, что:

· перерасход энергии увеличивает себестоимость продукции;

· утечки воды приводят не только к экологическим, но и к экономическим потерям;

· производственные отходы могут представлять собой неиспользованный ресурс;

· избыточные транспортные операции увеличивают расходы и выбросы;

· неэффективное оборудование снижает производительность и повышает экологическую нагрузку.

Таким образом, экологическое мышление должно превращаться в часть профессионального мышления.

Особое значение это имеет для предприятий Казахстана, осуществляющих деятельность в регионах с высокой нагрузкой на водные, земельные и энергетические ресурсы.

Исследования по Казахстану показывают, что развитие “зеленых навыков” требует более глубокого включения экологической проблематики в образование и

профессиональную подготовку, поскольку сами по себе представления работников об экологичности не всегда означают наличие необходимых профессиональных компетенций.

4. Навыки самообучения

Четвертой составляющей являются навыки непрерывного образования.

Современная цифровая технология может измениться за несколько лет, а иногда - за несколько месяцев. Поэтому образование, полученное в университете, не может рассматриваться как окончательная профессиональная подготовка.

Специалист должен постоянно:

· изучать новые технологии;

· осваивать цифровые инструменты;

· повышать квалификацию;

· анализировать лучшие практики;

· проходить краткосрочные курсы;

· участвовать в профессиональных сообществах;

· самостоятельно изучать специализированную литературу;

· применять новые знания непосредственно на рабочем месте.

В Казахстане одним из инструментов такого подхода является развитие платформы Skills Enbek, интегрированной с экосистемой Электронной биржи труда. При поддержке ПРООН на платформе расширялся набор онлайн-курсов, в том числе по Data Science, Python, информационной безопасности, управлению продуктами и HR.

Следовательно, концепция непрерывного образования постепенно становится важнейшим элементом развития человеческого капитала Казахстана.

Компетенции	Характеристика
Базовые цифровые	Использование компьютеров, цифровых платформ, офисных программ, информационных систем и современных средств коммуникации
Аналитические	Сбор, обработка, визуализация и интерпретация данных для принятия решений
Профессиональные	Использование цифровых инструментов и специализированных технологий в конкретной отрасли
Экологические	Понимание принципов ресурсосбережения, энергоэффективности, декарбонизации и экологического менеджмента
ИИ-компетенции	Использование инструментов искусственного интеллекта для анализа, прогнозирования и оптимизации процессов
Социальные	Эффективная коммуникация с коллегами, руководителями, клиентами и партнерами в цифровой среде
Образовательные	Способность самостоятельно получать новые знания и использовать цифровые ресурсы для повышения квалификации
Инновационные	Способность находить новые решения, инициировать изменения и участвовать в технологических проектах
Управленческие	Использование цифровых инструментов для планирования, контроля и оценки деятельности работников
Проектные	Участие в междисциплинарных проектах цифровой и экологической трансформации

Эффективное сочетание данных компетенций позволит сформировать работника, способного не только выполнять профессиональные обязанности, но и участвовать в технологической модернизации предприятия.

ОСОБЕННОСТИ ПОДГОТОВКИ КАДРОВ В КАЗАХСТАНЕ

Одной из главных проблем подготовки кадров для “умных” предприятий является несоответствие между скоростью технологического развития и скоростью обновления образовательных программ.

Предприятия могут внедрять искусственный интеллект, промышленный интернет вещей, автоматизированные системы контроля, цифровые двойники и интеллектуальные системы управления быстрее, чем образовательные организации успевают включать соответствующие компетенции в учебные планы.

В результате возникает разрыв между:

образованием → квалификацией выпускника → требованиями предприятия.

Для сокращения данного разрыва необходимо усилить взаимодействие между университетами, колледжами, научными организациями, государственными органами и бизнесом.

Особенно перспективным является создание совместных образовательных программ предприятий и университетов.

Например, для энергетического предприятия можно сформировать программу:

“Цифровая энергетика + возобновляемая энергетика + искусственный интеллект + экологический менеджмент”.

Для горнодобывающего предприятия:

“Цифровая добыча + автоматизация + анализ данных + экологическая безопасность”.

Для сельского хозяйства:

“Цифровое сельское хозяйство + спутниковый мониторинг + искусственный интеллект + рациональное использование воды и земель”.

Для городской инфраструктуры:

“Умный город + энергоэффективность + цифровое управление + экологический мониторинг”.

Такой подход позволит уйти от подготовки узких специалистов и сформировать специалистов нового междисциплинарного типа.

РЕГИОНАЛЬНАЯ СПЕЦИФИКА КАЗАХСТАНА

При подготовке кадров необходимо учитывать существенные различия между регионами Казахстана.

Для крупных городов - Астаны и Алматы - особенно актуальны цифровые услуги, искусственный интеллект, финтех, умные здания, интеллектуальная транспортная система и цифровое государственное управление.

Для Карагандинской, Ұлытау, Павлодарской и других индустриальных территорий особое значение имеют цифровизация промышленности, автоматизация, энергоэффективность, экологический мониторинг и декарбонизация.

Для западных регионов Казахстана важными направлениями являются цифровая трансформация нефтегазовой отрасли, снижение углеродной интенсивности, экологическая безопасность и развитие новых энергетических технологий.

Для южных и сельскохозяйственных регионов особую роль играют цифровое сельское хозяйство, управление водными ресурсами, мониторинг земель, интеллектуальное орошение и повышение эффективности использования сельскохозяйственных ресурсов.

Следовательно, единая государственная система подготовки кадров должна дополняться региональной специализацией.

РОЛЬ ОБРАЗОВАТЕЛЬНЫХ ОРГАНИЗАЦИЙ

Университеты и колледжи должны перейти от преимущественно дисциплинарного подхода к междисциплинарной модели подготовки.

Вместо разделения:

IT-специалист → эколог → инженер → экономист

необходимо формировать:

цифровой специалист, понимающий экономические и экологические последствия принимаемых решений.

Для этого целесообразно:

1. включать основы “зеленой экономики” в программы подготовки IT-специалистов;
2. включать цифровые технологии в экологические и инженерные программы;
3. развивать дисциплины по искусственному интеллекту;
4. создавать лаборатории цифрового моделирования;
5. развивать проектное обучение;
6. увеличивать количество практик на предприятиях;
7. привлекать представителей бизнеса к разработке образовательных программ;
8. использовать реальные производственные данные в учебных проектах;
9. развивать микроквалификации и короткие программы переподготовки;
10. создавать программы повышения квалификации для действующих работников.

Особое внимание необходимо уделять преподавателям. Невозможно подготовить специалиста для цифровой экономики, если преподаватель сам не имеет достаточного уровня цифровых компетенций.

УПРАВЛЕНИЕ ЦИФРОВЫМИ КАДРАМИ НА “УМНЫХ” ПРЕДПРИЯТИЯХ

Подготовка квалифицированных кадров сама по себе не гарантирует их эффективного использования. Не менее важным вопросом является управление такими сотрудниками.

Цифровые специалисты имеют ряд особенностей. Они, как правило, ценят возможность профессионального развития, самостоятельность, участие в инновационных проектах и возможность самостоятельно выбирать инструменты решения задач.

Поэтому традиционная модель управления, основанная исключительно на жестком контроле, для таких работников может быть недостаточно эффективной.

Можно выделить следующие особенности управления цифровыми кадрами “зеленой экономики” Казахстана.

1. Повышение уровня доверия к специалистам

Работникам необходимо предоставлять определенную степень самостоятельности.

Если сотрудник отвечает за цифровую оптимизацию производственного процесса, ему следует предоставлять возможность самостоятельно анализировать проблему и предлагать решения.

Это способствует развитию ответственности и инициативности.

2. Развитие гибридной и дистанционной работы

Цифровизация позволяет выполнять значительную часть аналитических, проектных и управленческих функций дистанционно.

Для Казахстана это особенно актуально с учетом территориальной протяженности страны.

Высококвалифицированный специалист может находиться в одном регионе, а цифровая команда или предприятие - в другом.

Поэтому развитие гибридных форм занятости позволяет предприятиям расширять географию поиска кадров.

3. Стимулирование саморазвития

Работнику необходимо предоставить возможность обучаться не только за пределами предприятия, но и непосредственно в рамках рабочего процесса.

Эффективными инструментами могут стать:

· корпоративные образовательные платформы;

· оплачиваемые курсы;

· внутренние академии;

· профессиональные сертификаты;

· участие в конференциях;

· наставничество;

· внутренние проектные команды;

· программы переподготовки.

4. Поддержка инициативности

На “умном” предприятии работник должен быть заинтересован не только в выполнении должностной инструкции, но и в поиске возможностей для совершенствования процессов.

Целесообразно использовать:

· конкурсы инновационных предложений;

· внутренние хакатоны;

· проектные команды;

· систему премирования за экономию ресурсов;

· премирование за снижение экологической нагрузки;

· программы “бережливого производства”;

· корпоративные акселераторы инноваций.

Например, если сотрудник предложил цифровое решение, позволившее предприятию сократить потребление электроэнергии, часть полученного экономического эффекта может быть направлена на его премирование.

В таком случае возникает прямая связь:

инициатива работника → цифровое решение → экономия ресурсов → экономический эффект предприятия → вознаграждение сотрудника.

5. Формирование карьерных траекторий

Цифровой специалист должен видеть возможность профессионального роста.

Перспективной является модель:

специалист → ведущий специалист → руководитель проекта → руководитель цифровой трансформации → директор по цифровому/устойчивому развитию.

При этом карьерный рост должен зависеть не только от формального стажа, но и от реально приобретенных компетенций.

“ЗЕЛЕНЫЕ” НАВЫКИ КАК НОВЫЙ ЭЛЕМЕНТ КОНКУРЕНТОСПОСОБНОСТИ

В международной практике все больше внимания уделяется формированию навыков, необходимых для экологически устойчивой экономики. Международная организация труда рассматривает развитие навыков для “зеленых” рабочих мест как важное условие подготовки работников к структурным изменениям экономики и справедливому переходу.

Для Казахстана эта проблема имеет дополнительное значение в связи с необходимостью одновременного решения двух задач:

первая - повышение производительности и технологической конкурентоспособности;

вторая - снижение ресурсоемкости и углеродной интенсивности экономики.

Поэтому конкурентоспособным специалистом становится не просто человек, владеющий цифровыми инструментами, а человек, который понимает, как с помощью этих инструментов повысить эффективность использования ресурсов.

Например, специалист по анализу данных на “умном” предприятии должен уметь ответить не только на вопрос:

“Какие производственные показатели ухудшились?”

но и на вопросы:

“Почему увеличилось потребление энергии?”

“Как изменение технологического режима повлияет на выбросы?”

“Можно ли спрогнозировать возникновение аварийной ситуации?”

“Каким образом цифровая система позволит сократить отходы?”

Таким образом, происходит интеграция цифрового и экологического мышления.

НЕПРЕРЫВНОЕ ОБРАЗОВАНИЕ КАК ОСНОВА КАДРОВОЙ ПОЛИТИКИ

Для предприятий Казахстана переход к непрерывному образованию становится особенно важным из-за ускорения технологических изменений.

Работодатель должен перестать рассматривать обучение сотрудника только как расходы.

Обучение является инвестиционным ресурсом, поскольку повышение компетенций сотрудника может привести к:

· росту производительности;

· сокращению производственных ошибок;

· снижению аварийности;

· сокращению энергозатрат;

· уменьшению материальных потерь;

· повышению качества продукции;

· развитию инновационной активности;

· появлению новых продуктов и услуг.

Исследования рынка труда Казахстана также указывают на наличие дефицита квалифицированных специалистов и необходимость развития цифровых навыков. По данным OECD, уровень базовых цифровых навыков населения Казахстана исторически отставал от среднего уровня стран OECD, что создавало риск возникновения дефицита компетенций по мере цифровизации предприятий.

При этом статистическая система Казахстана продолжает регулярно обновлять показатели цифровой грамотности населения и использования цифровых технологий предприятиями. В 2026 году Бюро национальной статистики обновляет динамические ряды по цифровой грамотности, использованию цифровых технологий крупными и средними предприятиями, интернет-пользованию и другим показателям.

Следовательно, развитие цифровых навыков должно стать не разовой кампанией, а постоянным процессом.

МОДЕЛЬ ПОДГОТОВКИ ЦИФРОВОГО КАДРА “ЗЕЛЕНОЙ ЭКОНОМИКИ” КАЗАХСТАНА

На основании проведенного исследования предлагается следующая модель подготовки специалиста:

Этап 1. Базовое образование

Формирование фундаментальных профессиональных и цифровых знаний.

Этап 2. Экологическая специализация

Изучение принципов зеленой экономики, ресурсосбережения, экологического менеджмента и декарбонизации.

Этап 3. Цифровая специализация

Освоение анализа данных, искусственного интеллекта, автоматизации, цифрового моделирования и цифровых платформ.

Этап 4. Практическая подготовка

Работа над реальными задачами предприятий.

Этап 5. Непрерывное образование

Регулярное обновление компетенций после трудоустройства.

Этап 6. Инновационная деятельность

Участие в проектах по цифровой и экологической модернизации предприятия.

Рисунок 2. Предлагаемая модель формирования цифровых кадров “зеленой экономики” Казахстана

Данная модель соответствует современной тенденции, при которой цифровой и экологический переходы рассматриваются как взаимосвязанные процессы. Международные исследования рынка труда также показывают, что зеленый и цифровой переход способны создавать новые рабочие места при условии соответствующих инвестиций в развитие навыков и переподготовку работников.

ОБСУЖДЕНИЕ

Казахстан находится в ситуации, когда цифровая трансформация экономики совпадает с необходимостью структурной экологической перестройки.

Это создает как риски, так и возможности.

К рискам можно отнести:

1. дефицит специалистов с междисциплинарными компетенциями;
2. несоответствие образовательных программ требованиям бизнеса;
3. недостаточное количество практико-ориентированного обучения;
4. неравномерность цифровых возможностей регионов;
5. недостаточную подготовленность части работников к непрерывному обучению;
6. риск вытеснения отдельных профессий вследствие автоматизации;
7. недостаточную интеграцию экологических компетенций в техническое образование.

К возможностям относятся:

1. создание новых высокотехнологичных рабочих мест;
2. развитие возобновляемой энергетики;
3. цифровизация промышленности;
4. развитие интеллектуального сельского хозяйства;
5. формирование новых экологических сервисов;
6. развитие рынка анализа экологических данных;
7. создание новых цифровых продуктов;
8. рост производительности труда;
9. повышение ресурсной эффективности предприятий.

Важным является то, что развитие “зеленой” экономики не должно рассматриваться исключительно как экологическая задача. Оно связано с созданием новых рынков, технологий, профессий и моделей занятости.

В 2026 году Всемирный банк отмечает среди приоритетов сотрудничества с Казахстаном развитие цифровой связанности, управление природными ресурсами, повышение производительности частного сектора и создание более качественных рабочих мест. Одновременно поддерживаются направления энергетической эффективности, возобновляемой энергетики и устойчивого управления ресурсами.

Это означает, что вопрос кадров становится центральным элементом одновременно цифровой, экологической и экономической политики.

ВЫВОДЫ

В целом можно сделать вывод о том, что важнейшим условием развития “зеленой” и цифровой экономики Казахстана является наличие человеческого капитала, способного работать в условиях быстрого технологического и структурного изменения экономики.

Казахстан располагает необходимой стратегической основой для такого перехода. Концепция по переходу к “зеленой экономике”, Стратегия достижения углеродной нейтральности до 2060 года и Концепция развития искусственного интеллекта на 2024-2029 годы формируют взаимодополняющие направления государственной политики.

При этом наличие нормативных документов само по себе не обеспечит достижение поставленных целей. Необходима подготовка специалистов, способных реализовывать данные преобразования непосредственно на уровне предприятий.

Важнейшими составляющими подготовки цифровых кадров для “умных” предприятий “зеленой экономики” Казахстана должны стать:

1.Специальные знания в области “зеленой экономики”. Специалист должен понимать принципы устойчивого развития, рационального использования ресурсов, энергоэффективности, декарбонизации и экологического менеджмента.

2. Цифровые компетенции.

Работник должен владеть современными цифровыми инструментами, уметь работать с данными, использовать цифровые платформы и понимать возможности искусственного интеллекта.

3. Экологическое мышление.

Специалист должен понимать, что экологическая эффективность непосредственно связана с экономическими результатами предприятия.

4. Навыки самообучения.

Работник должен быть способен самостоятельно приобретать новые знания и постоянно обновлять профессиональные компетенции.

5. Инновационное мышление.

Работник должен быть ориентирован не только на выполнение существующих операций, но и на поиск новых способов повышения эффективности предприятия.

Еще одним важным вопросом является управление данными кадрами.

Руководству предприятий необходимо отходить от исключительно административной модели управления и переходить к модели, основанной на доверии, ответственности и инициативности работников.

Необходимо:

1. повышать самостоятельность специалистов;
2. делегировать полномочия;
3. развивать гибридные формы занятости;
4. создавать условия для непрерывного обучения;
5. поддерживать инициативные проекты;
6. внедрять материальное и нематериальное стимулирование инноваций;
7. создавать прозрачные карьерные траектории;
8. оценивать работников не только по количеству выполненных операций, но и по создаваемой ими экономической и экологической ценности.

Особенно важно связать систему мотивации работников с показателями цифровой и экологической эффективности предприятия.

Если сотрудник с помощью цифровой технологии смог сократить расход электроэнергии, воды, сырья или объем отходов, это должно отражаться не только в экологической статистике, но и в системе оценки его профессиональной деятельности.

Таким образом, возникает новая логика управления:

цифровые компетенции + экологические компетенции + непрерывное образование + инициативность → цифровая и экологическая модернизация предприятия → рост производительности → снижение ресурсных затрат → повышение конкурентоспособности.

Для Казахстана развитие такого кадрового потенциала имеет стратегическое значение. Успешная реализация перехода к низкоуглеродной и цифровой экономике будет зависеть не только от объема инвестиций в технологии, но и от способности образовательной системы и бизнеса сформировать специалистов нового поколения.

Следовательно, цифровой кадр “зеленой экономики” Казахстана - это не просто IT-специалист и не только эколог. Это профессионал, способный соединить отраслевые знания, цифровые технологии, искусственный интеллект, экологическую ответственность и непрерывное саморазвитие.

Именно такой тип человеческого капитала способен стать одним из ключевых факторов формирования “умных” предприятий и конкурентоспособной “зеленой экономики” Республики Казахстан.

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The Relationship Between Green Marketing Strategy and Corporate Social Responsibility

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Abstract

In today's consumer terrain, the integration of green marketing strategy and corporate social responsibility is very significant. The integration has led to production of quality products, alignment of brands with their respective values and the impact of the general market to society and well-being. This study seeks to understand the synergies between green marketing and corporate social responsibility from the following dimensions; historical evolution, theoretical underpinnings, challenges and the role of regulations in the market. The study will use key theoretical frameworks such as Stakeholder theory, the Triple Bottom Line, Shared value concept and diffusion of innovation to achieve the study's goals. Findings from literature indicate that integrating Green Marketing and CSR poses critical challenges such as green washing, cost considerations and measuring effectiveness. To avert these challenges, recommendations such as transparency and investing in sustainable practices was fronted. Summative, embracing the synergies between Green Marketing and CSR benefit both the businesses but also society and environment paving way for a more sustainable and equitable future.

Keywords

Green marketing; Corporate social responsibility; Synergies; Challenges; Sustainability; Regulations

1. Introduction

Management of a steady business is not easy, especially in a diversified customer base. Harnessing the synergies between Green Marketing Strategy and Corporate Social responsibility in any business fosters sustainability, fosters brand loyalty and address general challenges of equity and satisfaction. In today's market, consumers have been multifaceted especially on the value of products, they not only buy products based in its value but also seek to share the beliefs of the brands such that they also play a role in not only building a healthier world but also a more equitable society. This phenomenon has placed the integration between CSR and Green Marketing very critical within pillars of corporate principles. Green marketing is predominantly associated with companies' sustainability from production to end-to-life solutions. CSR on the other hand involves specific actions that affect regulation, promotion of societal good and environmental steward. According to Deshmukh and Tare, the synergy between the two promote brand loyalty and customer satisfaction (2023). Incorporating theoretical frameworks such as Stakeholder theory, the Triple Bottom Line, Shared value concept and diffusion of innovation, this study seeks to highlights synergies between green marketing strategy and corporate social responsibility. Additionally, this study will work on the following lenses; historical, theoretical, challenges, and regulations' role.

Important Aspects and Moments in the Integration of CSR and Green Marketing

The integration between CSR and Green marketing has had to evolve from the 1980s to what it is now (Mukonza & Swarts, 2020). Here is a historical narrative of how integrated marketing evolved. The reintegration of the 1989 Exxon Valdez oil spill provided a sobering reminder of the damage that corporate irresponsibility can do to the environment. According to Kirsch, this terrible incident raised public awareness of corporate environmental disasters and underscored the need for environmentally friendly business operations and corporate social responsibility (CSR) (2020).

The 1992 Rio Earth Summit was a turning point in the world's environmental conversation. Global environmental and sustainability issues were the main emphasis of the United Nations Conference on Environment and Development held in Rio de Janeiro (Sajna-Kunowsky, 2021). The role of corporations in promoting sustainable practices was highlighted by adopting Agenda 21, a comprehensive action plan for sustainable development.

Eco-labeling became a widely used tool in green marketing during the 1990s. With the popularity of eco-labels like Energy Star and Fair-Trade certifications, customers are now more equipped to choose environmentally friendly products (Tiboni-Oschilewski et al., 2024). These names evolved to represent ethical and sustainable consumption.

The International Organization for Standardization (ISO) adopted the ISO 14001 standard in 1996, giving businesses a foundation to create efficient environmental management systems (Ociepa-Kubicka et al., 2021). The broad implementation of these principles signified a change toward more environmentally friendly company operations and showed a dedication to environmental stewardship.

Businesses were prompted to reevaluate their environmental effect and implement greener practices after the Kyoto Protocol, which was adopted in 1997, set emission reduction goals for industrialized countries (Kim et al., 2020). Further improving accountability and transparency in CSR endeavors is the Global Reporting Initiative (GRI), founded in 2000 and established sustainability reporting guidelines.

As more businesses realized that corporate social responsibility (CSR) could foster long-term success and stakeholder connections, the concept gradually gained traction and became a standard business practice in the 2000s. The need for a comprehensive strategy that incorporates CSR and green marketing is highlighted by this evolution, which is a reflection of a growing awareness of the significance of enterprises' effects on the environment and society. Businesses that successfully integrate CSR and green marketing will face new opportunities and difficulties as they highlight their involvement in tackling global crises and creating a more sustainable future.

Literature Review

Several conceptual models and theoretical frameworks from marketing, management, and sustainability can be used to understand better and study the relationship between green marketing and corporate social responsibility. These offer an organized method of analyzing the fundamental forces, facilitators, and results of the convergence of green marketing and corporate social responsibility.

Stakeholder Theory

According to stakeholder theory, organizations must consider the interests and impacts of all stakeholders, not just shareholders, employees, customers, suppliers, local communities, and the natural environment. This is directly consistent with the fundamental ideas of green marketing and CSR, which emphasize the need for businesses to have a more holistic view of their role and responsibilities in society. Using stakeholder theory, we can examine how green marketing and CSR initiatives assist businesses in better engaging and providing value for various stakeholder groups. Eco-aware consumers, for instance, might be more devoted to green brands that exhibit a strong commitment to corporate social responsibility (CSR) (Freudenreich et al., 2020). Green product developments can also benefit workers, suppliers, and local communities by generating jobs and stimulating the local economy.

Triple Bottom Line (3BL) Framework

The traditional single-bottom-line focus on profitability is expanded to include a company's social and environmental performance under the triple-bottom-line (3BL) paradigm. It implies that for a firm to be truly sustainable, profit, people, and the environment must all be considered and optimized. Since green marketing focuses on the sustainability and environmental impact of goods and services, it is intrinsically linked to the "planet" component of the 3BL. In the meantime, the 3BL's "people" factor strongly corresponds with the CSR's social responsibility elements, including ethical governance, community involvement, and fair labor standards (Zaharia R. M & Zaharia R., 2021). Analyzing green marketing and CSR projects through the 3BL lens can help businesses find synergies and trade-offs and establish more holistic, balanced approaches to sustainability. For example, a green product is more expensive to produce, affecting its profitability, but it also benefits society by generating jobs.

Shared Value Concept

According to Michael Porter and Mark Kramer's shared value approach, companies can generate economic value while adding value to society by attending to its demands and problems. It highlights how business success and social advancement are strategically aligned. Green marketing strategies and CSR initiatives serve as means for businesses to identify and profit from shared value possibilities (Roszkowska-Menkes, 2021). For instance, creating environmentally friendly items can reduce their adverse effects on the environment, create new revenue sources, and satisfy consumer demand for sustainable solutions. Similarly, a company's social license to operate, brand reputation, and employee engagement can all be strengthened by community-focused CSR programs. The shared value framework pushes businesses beyond defensive, compliance-driven approaches to sustainability and CSR, instead actively seeking commercial possibilities that benefit both the organization and its stakeholders.

Diffusion of Innovations Theory

The diffusion of innovations theory, popularized by Everett Rogers, investigates how new ideas, technology, or behaviors spread through a society over time. It identifies important variables, including perceived relative benefit, compatibility, trialability, complexity, and observability, that affect the rate and scope of adoption. This model can help explain how advances in CSR and green marketing spread throughout society and the economy (Lee, 2021; Zhou et al., 2020). For example, customer adoption rates and wider industry acceptance may be impacted by the relative advantage of green products in terms of environmental advantages and the observability of a company's CSR commitments. Understanding the diffusion dynamics of CSR and green marketing can assist businesses in creating more successful plans for expanding good impact and gaining traction in the public eye. It also implies that social media, communication platforms, and opinion leadership are crucial for spreading technologies focused on sustainability.

These theoretical frameworks and conceptual models offer insightful prisms through which to examine the complex interactions between corporate social responsibility and green marketing. By implementing these methodical techniques, corporations can acquire a more profound comprehension of the operational, strategic, and behavioral aspects that facilitate the convergence of these two ideas and generate enduring benefits for the industry and the community.

2. Materials and Methods

This study reviewed and synthesized existing scholarly articles and theoretical frameworks on green marketing Strategy and CSR. The review analyzed historical analysis, theories and examination of different empirical research findings as a way to fully work out on the relationship between green marketing and CSR. The study utilized qualitative approach to analyze and interpret data. Moreover, comparative analysis is utilized to compare and contrast different approaches to Green Marketing and CSR integration, as well as to evaluate the effectiveness of various strategies and initiatives. Data collection was drawn from literature and case studies to provide real-work examples and practical insight into the implementation and outcomes of recommendations. Relevance, credibility and representativeness was the criteria indicators that were used to ensure inclusion of diverse analysis from literature.

3. Results

From literature and analysis, there is a growing tendency by corporations to integrate green marketing strategies and CSR in their day-to-day processes. This trend underscores the underrated importance for businesses to align their marketing strategies with sustainability initiatives to fully meet with consumer expectations and foster brand loyalty. Additionally, this literature highlighted that businesses that effectively communicate their sustainability efforts through green marketing strategies can enhance brand reputation, attract environmentally conscious consumers, and differentiate themselves in competitive markets. Therefore, corporations that integrate CSR and green marketing strategies into business operations lead to tangible benefits such as cost savings, improved employee morale, and enhanced community relations.

The studies also indicated the challenges which include; greenwashing, cost implications of implementing sustainable practices, and the need for effective measurement and evaluation of sustainability initiatives. To address these challenges, literature recommended corporations demonstration of transparency, authenticity and accountability. Generally, the findings section underscores the importance of a holistic approach to sustainability that integrates Green Marketing and CSR into business strategies.

4. Discussion

The discussion sections work to contextualize the study findings within literature while emphasizing their significance for businesses, consumers, and society at large. The string correlation between consumer’s preference and sustainable products and brands underscores the growing importance of sustainability in contemporary markets. Literature presents synergies’ opportunities such as; enhancement of brand reputation and innovation. Additionally, the synergies between the two highlights the need for businesses to adopt a holistic approach to sustainability that integrates green marketing and CSR into their core business practices. Recommendations fronted include; transparency, authenticity and accountability as key indicators that continuously evaluating and improving sustainability initiatives.

While the rise of CSR and green marketing provides tremendous business potential, it also brings obstacles that must be carefully navigated. One such challenge is greenwashing, which puts businesses in danger. Greenwashing creates false environmental claims, drastically harming a company's brand if customers feel duped (Rehman et al., 2022). To address this, businesses must ensure that their green marketing activities are founded on actual sustainability practices, supported by tangible actions and open communication. According to Rehman et al., with the market saturated with "green" claims, people are becoming more skeptical of superficial marketing practices. To gain and keep consumers' trust, businesses must demonstrate a genuine commitment to sustainability and avoid greenwashing (2022).

Cost considerations are also an essential factor in implementing sustainable methods. While introducing environmentally friendly technologies, materials, and processes may demand initial investments, the long-term benefits of resource efficiency and waste reduction can eventually balance these costs (Mukonza & Swarts, 2020). When implementing greener practices, businesses must carefully consider the financial implications and potential returns on investment.

According to Mukonza and Swarts, it can also be challenging to gauge the effectiveness of CSR and green marketing campaigns (2020). Companies must build vital metrics that accurately evaluate the impact of their sustainability activities and show good results. Companies may successfully communicate their environmental and social responsibility commitments to stakeholders and establish trust in their green projects by setting clear targets and monitoring progress against these criteria.

On regulations, government regulations significantly impact how CSR and green marketing strategies are implemented. Tight environmental restrictions are an effective stimulant that forces businesses to adopt sustainable practices. Government regulations that focus on emissions, waste management, and resource conservation establish a system of regulations that encourage businesses to take environmental stewardship seriously (Chung, 2020). In addition to providing unambiguous guidelines for sustainability, these rules level the playing field by guaranteeing that every business is held to the same environmental standards.

Governments frequently use a range of incentives to get companies to implement green practices. Companies that invest in eco-friendly technologies and activities are frequently rewarded with tax cuts, subsidies, and grants. These financial incentives make it more economically feasible for businesses to adopt green initiatives by helping offset the costs of implementing sustainable practices (Chung, 2020). Governments encourage businesses to actively pursue sustainability goals and incorporate them into their business strategy by offering observable rewards for sustainable behavior.

Incentives and restrictions from the government also have a significant impact on how consumers behave and how markets function. Governments can shape consumer preferences and increase demand for environmentally friendly items by enforcing labeling standards for eco-friendly goods or providing tax incentives for buying environmentally friendly products (Chung, 2020). As a result, businesses that value sustainability will find it easier to compete in the market, which will spur innovation in the green economy. The advancement of environmental sustainability and social responsibility on a global scale ultimately depends on the cooperative efforts of government laws, incentives, and corporate activities.

5. Conclusions

To sum up, the integration of green marketing and corporate social responsibility (CSR) signifies a substantial paradigm shift in contemporary business operations, propelled by the increasing demands of consumers for environmentally sensitive, ethical, and sustainable activities. This synergy goes beyond a simple moral requirement to benefit businesses, society, and the environment. From a historical, theoretical, and applied perspective, corporate social responsibility (CSR) and green marketing are complementary and necessary for sustained success and favorable results. This integration is a potent catalyst for positive change, pushing innovation, building customer trust and loyalty, and eventually generating a more equitable and sustainable future for future generations. Embracing the synergies between CSR and Green Marketing is not just a strategic imperative but also a moral obligation that displays a dedication to people, the planet, and prosperity as businesses negotiate the complexity of today's global concerns.

Author Contributions

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Chemical Sciences

УДК 665.63

ОБЕССМОЛИВАНИЕ НАФТАЛАНСКОЙ НЕФТИ ПРИРОДНЫМ БЕНТОНИТОМ

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Аннотация

Keywords: Naftalan crude oil, de-resining, bentonite, adsorption, resin-asphaltene substances, naphthenic hydrocarbons, oil treatment.

Ключевые слова: нафталанская нефть, обессмоливание, бентонит, адсорбция, смолисто-асфальтеновые вещества.

Актуальность: Нафталанская нефть обладает уникальными лечебными свой-ствами, но высокое содержание смолисто-асфальтеновых веществ 18-22% ограничивает её применение в медицине и нефтехимии.

Цель: Обосновать эффективность адсорбционного обессмоливания нафталанской нефти активированным бентонитом Казахского месторождения.

Методология: Лабораторная перколяция через неподвижный слой бентонита при 60°C, соотношение нефть:сорбент 10:1. Содержание САВ определяли по ГОСТ 11858-66.

Результаты: Однократная адсорбция снизила содержание смол с 19,4% до 4,1%, асфальтенов с 2,3% до 0,4%. Выход целевого продукта 87,6%.

Научная новизна: Установлены оптимальные параметры обессмоливания нафталанской нефти местным бентонитом.

Практическая значимость: Технология позволяет получать медицинское и техническое сырье с содержанием САВ <5%.

ВВЕДЕНИЕ

Нафталанская нефть месторождения Нафталан является уникальным природным лечебным средством благодаря высокому содержанию нафтеновых углеводородов 75-80% и низкой сернистости 0,25% (Мамедов, 2020). По данным ВОЗ, нафталанотерапия эффективна при 70 видах заболеваний опорно-двигательного аппарата и кожи.

Основным фактором, ограничивающим применение нафталанской нефти, является высокое содержание смолисто-асфальтеновых веществ (САВ) – 18-22%. САВ вызывают аллергические реакции при наружном применении, повышают коксуемость и снижают стабильность нефтепродуктов при переработке (Исмаилов, 2021).

Существующие методы деасфальтизации пропаном и селективной очистки фенолом характеризуются выходом целевого продукта 60-65% и высокими энергозатратами. Адсорбционная очистка природными глинами – перспективная альтернатива благодаря доступности и низкой себестоимости (Bhattacharyya, 2018).

Цель работы – определить эффективность активированного бентонита Казахского месторождения для обессмоливания нафталанской нефти и установить оптимальные технологические параметры процесса.

МАТЕРИАЛ И МЕТОДИКА

Объект исследования – нафталанская нефть. Физико-химическая характеристика: плотность при 20°C 0,927 г/см³, кинематическая вязкость при 50°C 42,3 мм²/с, температура застывания -12°C, содержание смол 19,4%, асфальтенов 2,3%, серы 0,25%, парафинов 0,8%.

В качестве адсорбента использован бентонит Казахского месторождения, Гянджа-Казахская зона. Минеральный состав: монтмориллонит 72%, кварц 15%, кальцит 8%, полевые шпаты 5% (Гасанов, 2019). Емкость катионного обмена 92 мг-экв/100г, удельная поверхность 68 м²/г.

Бентонит подвергали кислотной активации 15%-ным раствором HCl в течение 4 ч при 90°C, отмывали до pH 6,5, сушили при 110°C и измельчали до фракции 0,25-0,5 мм.

Обессмоливание проводили методом перколяции. В стеклянную колонку диаметром 20 мм загружали 10 г активированного бентонита. Через слой сорбента пропускали 100 г нефти со скоростью 1 объем/час при температуре 60°C. Элюат – обессмоленная нефть. Сорбент регенерировали промывкой толуолом.

Содержание смол и асфальтенов определяли адсорбционным методом по ГОСТ 11858-66. Групповой углеводородный состав – методом жидкостно-адсорбционной хроматографии. Коксуемость – по Конрадсону, ГОСТ 19932-99. Все опыты в 3-кратной повторности.

РЕЗУЛЬТАТЫ И ИХ ОБСУЖДЕНИЕ

Адсорбционная очистка обеспечила глубокое удаление смолисто-асфальтеновых компонентов (Таблица 1). Содержание смол снизилось в 4,7 раза, асфальтенов в 5,8 раза.

Суммарное содержание САВ уменьшилось с 21,7% до 4,5%, что переводит нефть из категории "высокосмолистых" в "малосмолистые" по ГОСТ 31378-2009.

Влияние адсорбционной очистки на состав нафталанской нефти.

Таблица 1.

Показатели	Исходная нефть	После очистки	Степень очистки,%
Смолы, % мас	19,4±0,6	4,1 ±0,2	78,9
Асфальт,% мас	2,3± 0,1	0,4 ±0,1	82,6
Сумма САВ,% мас	21,± 0,6	4,5 ±0,2	79,3
Нафтеновые , УВ% мас	76,2 ±1,1	88,9 ±0,9	-
Коксуемость,%	7,8 ±0,3	0,42± 0,05	94,6
Выхд продукта, %	-	87,6 ±1,2	-

Снижение коксуемости с 7,8% до 0,42% свидетельствует о пригодности очищенной нефти для процессов термического и каталитического крекинга. Рост содержания нафтеновых углеводородов до 88,9% повышает биологическую активность продукта, что важно для медицинских целей (Алиев, 2022).

Механизм адсорбции обусловлен взаимодействием полярных функциональных групп смол (-OH, >C=O, -COOH, -NH) с бренстедовскими кислотными центрами на поверхности монтмориллонита. Асфальтены, имеющие конденсированную ароматическую

структуру, удерживаются за счет π-π взаимодействия с силоксановыми слоями и образования водородных связей (Мирзаев, 2021).

Оптимальная температура процесса 60°C. При 40°C вязкость нефти высокая, скорость диффузии САВ к поверхности сорбента снижается, степень очистки падает до 62%. При 80°C начинается десорбция легкокипящих нафтенов, выход продукта снижается до 81%.

Регенерация бентонита толуолом при 80°C восстанавливает 92% исходной адсорбционной емкости. Сорбент выдерживает 4-5 циклов адсорбция-регенерация без существенной потери активности, что снижает себестоимость очистки до 45 манат/т нефти.

ВЫВОДЫ

1.Адсорбция на активированном бентоните Казахского месторождения снижает содержание смолисто-асфальтеновых веществ в нафталанской нефти с 21,7% до 4,5% при выходе целевого продукта 87,6%.

2.Оптимальные параметры обессмоливания: температура 60°C, соотношение нефть:бентонит 10:1, размер фракции сорбента 0,25-0,5 мм.

3.Коксуемость очищенной нефти 0,42% позволяет использовать её как сырье для нефтехимических процессов и как основу для медицинских препаратов.

4.Регенерация сорбента толуолом обеспечивает 4-5 рабочих циклов. Себестоимость очистки 45 манат/т, что в 2,8 раза ниже пропановой деасфальтизации.

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DE-RESINING OF NAFTALAN CRUDE OIL USING NATURAL BENTONITE.

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SUMMARY

Background: Naftalan crude oil is a unique therapeutic agent due to its high content of naphthenic hydrocarbons 75–80% and low sulfur 0.25%. However, the high concentration of resin-asphaltene substances 18–22% limits its application in medicine and petrochemistry by causing allergic reactions and increasing coke formation.

Objective: To evaluate the efficiency of adsorptive de-resining of Naftalan crude oil using activated bentonite from the Kazakh deposit, Azerbaijan.

Methods: Laboratory percolation through a fixed bed of acid-activated bentonite at 60°C, oil:sorbent ratio 10:1. Resin and asphaltene content was determined according to GOST 11858-66.

Results: Single-stage adsorption reduced resin content from 19.4% to 4.1% and asphaltenes from 2.3% to 0.4%. The yield of de-resined product was 87.6%. Coke-forming tendency decreased from 7.8% to 0.42%. The sorbent withstands 4–5 regeneration cycles with toluene.

Conclusions: Activated bentonite provides deep purification of Naftalan oil to a resin-asphaltene content <5%, making it suitable for medical formulations and as petrochemical feedstock. The process cost is 45 AZN/ton, 2.8 times lower than propane deasphalting.

Biological Sciences

The Role of Quantum Chemistry in Catalyst Design for Chemical Technologies and Nanoengineering

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Abstract

Quantum chemistry has become one of the central intellectual and practical tools in modern catalyst design because it links atomic-scale electronic structure to measurable catalytic performance. In chemical technologies and nanoengineering, where catalyst behavior is governed by subtle changes in composition, coordination environment, morphology, defect structure, support interactions, and operating conditions, quantum-chemical methods provide a framework for rationalizing activity, selectivity, and stability before large-scale experimental screening is undertaken. The emergence of density functional theory (DFT), post-Hartree–Fock methods for benchmark calculations, ab initio molecular dynamics, embedded quantum mechanics/molecular mechanics approaches, and more recently machine learning integrated with quantum chemistry has transformed catalyst discovery from a largely empirical enterprise into a predictive discipline. These methods are now routinely used to identify active sites, map reaction pathways, quantify adsorption energetics, interpret spectroscopic signatures, construct scaling relations, and reveal the origin of structure–property relationships in homogeneous, heterogeneous, electrochemical, photocatalytic, and single-atom catalytic systems (Nørskov et al., 2009; Seh et al., 2017; Sankar et al., 2020; Casillo et al., 2025).

In nanoengineered systems, the importance of quantum chemistry is even more pronounced. Nanocatalysts expose a high density of undercoordinated atoms, strain fields, interfaces, ligands, and support-mediated electronic effects that are difficult to isolate experimentally but can be examined directly through theory. Quantum-chemical analysis helps distinguish geometric effects from electronic effects, predict the consequences of size and shape changes, and guide the stabilization of metastable yet highly active structures such as single atoms, subnanometer clusters, defect-rich oxides, and heterostructured interfaces (Negreiros et al., 2012; Cao et al., 2016; Kraushofer et al., 2022). At the same time, the field faces important challenges related to

functional accuracy, dynamic restructuring, solvation, electric fields, entropy, and the complexity gap between model catalysts and working materials. This review examines the conceptual foundations, methodological developments, and practical applications of quantum chemistry in catalyst design, with special emphasis on its role in emerging chemical technologies and nanoengineering. The review also outlines current limitations and future directions, arguing that the next phase of catalyst innovation will rely on tighter integration between quantum chemistry, operando characterization, data science, and autonomous experimentation (Lewis et al., 2023; Du et al., 2024; Shao et al., 2025).

1. Introduction

Catalysis underpins the manufacturing of fuels, fertilizers, polymers, pharmaceuticals, fine chemicals, and an increasing number of sustainable technologies for carbon management, hydrogen production, and environmental remediation. Because catalysts accelerate reactions without being consumed, their design determines both the economics and environmental profile of chemical technologies. Historically, catalyst discovery relied heavily on intuition, heuristic composition rules, and trial-and-error experimentation. While empirical exploration remains important, the rising complexity of catalytic materials and the urgent demand for high-performance sustainable processes have made purely empirical approaches inadequate. The central question is no longer whether theory can contribute to catalyst development, but how deeply theory can shape the entire design cycle.

Quantum chemistry addresses this challenge by describing the electronic structure of molecules and materials from first principles or semi-empirical approximations grounded in quantum mechanics. Since catalytic transformations are governed by bond breaking and bond formation, charge transfer, orbital interactions, spin effects, and the stabilization of transition states, quantum chemistry is uniquely positioned to explain why a catalyst works and how it can be improved. The theoretical description of adsorption energies, activation barriers, reaction intermediates, and the distribution of electrons across active sites offers a mechanistic language that can be translated into practical design descriptors such as d-band position, binding energy windows, acid–base strength, redox flexibility, ligand field effects, or vacancy formation energy (Hammer and Nørskov, 2000; Nørskov et al., 2009; Medford et al., 2015).

The role of quantum chemistry has expanded in parallel with advances in computing and methodology. DFT has become the workhorse of computational catalysis because it balances reasonable accuracy and tractable cost for molecules, surfaces, nanoparticles, and extended solids. Benchmark wavefunction-based methods help validate difficult cases, especially in open-shell transition-metal chemistry and bond activation problems where electronic correlation is strong. Molecular dynamics and free-energy methods provide access to finite-temperature behavior, fluxionality, solvent effects, and interface structure. More recently, machine learning models trained on quantum-chemical data have accelerated high-throughput screening and enabled the exploration of chemical spaces that would otherwise remain inaccessible (Gensch et al., 2022; Lewis et al., 2023; Casillo et al., 2025).

Catalyst design in nanoengineering particularly benefits from this theoretical maturity. Nanoscale materials differ fundamentally from bulk materials because their catalytic behavior depends on finite size, exposed facets, defects, support interactions, and local heterogeneity. Two catalysts with identical elemental composition can differ dramatically in performance if their nanostructure changes the electronic density at the active site. Quantum chemistry provides one of the few routes for disentangling these interdependent variables. It allows the identification of the actual active ensemble, whether it is a terrace atom, a step edge, a single supported metal atom, an oxygen vacancy next to a dopant, or a transient interfacial motif formed only under reaction conditions (Cao et al., 2016; Sankar et al., 2020; Kraushofer et al., 2022).

This review discusses how quantum chemistry informs rational catalyst design across major catalytic domains relevant to chemical technologies and nanoengineering. The aim is not only to summarize computational methods, but also to show how theoretical insights translate into design principles for catalyst discovery, optimization, and scale-relevant implementation (Fig 1).

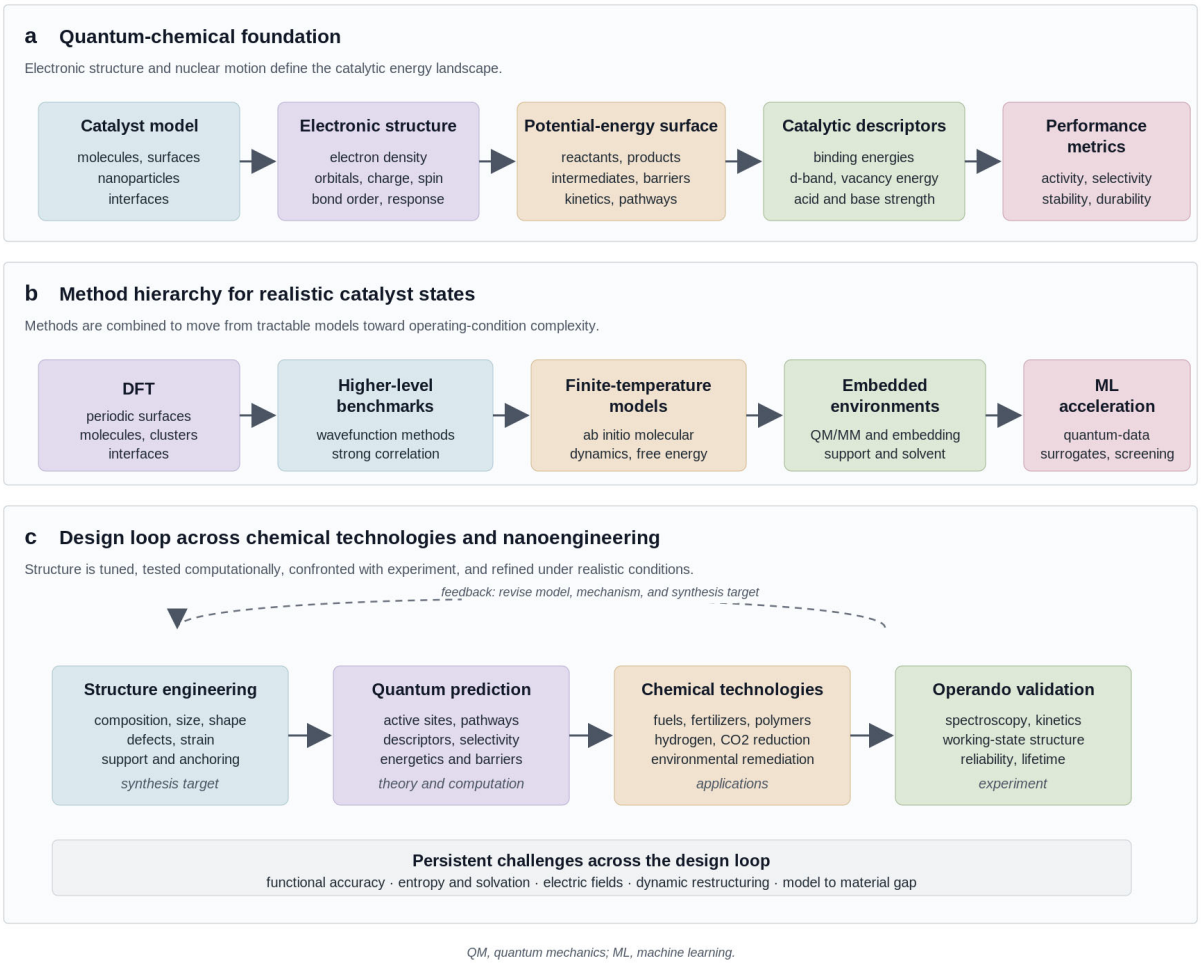

Figure 1. Quantum chemistry as a unifying engine of catalyst design for chemical technologies and nanoengineering. a, *Quantum-chemical foundation.* A catalyst model (molecules, surfaces, nanoparticles, interfaces) is described by electronic structure (electron density, orbitals, charge, spin, bond order and response), which defines the potential-energy surface connecting reactants, products, intermediates, transition states, kinetics and pathways. From this surface, catalytic descriptors (binding energies, d-band center, vacancy formation energy, acid and base strength) are extracted and converted into performance metrics (activity, selectivity, stability, durability). **b**, *Method hierarchy for realistic catalyst states.* DFT underpins periodic surfaces, molecules, clusters, and interfaces; higher-level wavefunction benchmarks validate strongly correlated transition-metal states and difficult barriers; finite-temperature models (ab initio molecular dynamics and free-energy surfaces) capture fluxionality, solvent reorganization, and coverage effects; QM/MM embedding captures confinement and support and solvent effects; and ML surrogates trained on quantum-chemical data drive uncertainty-aware high-throughput screening. **c**, *Closed design loop across chemical technologies and nanoengineering.* Structure engineering (composition, size, shape, defects, strain, support and anchoring) feeds quantum prediction (active sites, pathways, descriptors, selectivity, energetics and barriers), which informs chemical technology targets (fuels, fertilizers, polymers, hydrogen, CO_2 reduction, environmental remediation); operando validation through spectroscopy, kinetics, working-state structure, reliability and lifetime closes the loop and feeds back to revise model, mechanism, and synthesis

target. Persistent challenges that span the entire loop are functional accuracy, entropy and solvation, electric fields, dynamic restructuring, and the model-to-material gap.

2. Conceptual Foundations of Quantum Chemistry in Catalysis

At the heart of quantum chemistry lies the idea that catalytic performance emerges from electronic structure. The arrangement and energy of electrons determine bond order, charge distribution, spin state, orbital overlap, and the thermodynamic stability of reactive intermediates. In catalysis, these quantities control adsorption, activation, and product release. For example, if adsorption is too weak, reactants do not activate; if it is too strong, intermediates poison the surface. The catalytic optimum often lies in a narrow energetic window, which is why quantum-chemical predictions of adsorption and activation energies are so useful in catalyst design (Hammer and Nørskov, 2000; Nørskov et al., 2009).

The theoretical framework commonly begins with the Born–Oppenheimer approximation, which separates nuclear and electronic motion and allows the construction of potential energy surfaces. On these surfaces, minima correspond to intermediates and stationary saddle points to transition states. Catalytic rates and selectivities depend on the topology of these surfaces: the depth of adsorption wells, the height of elementary barriers, and the competition between parallel pathways. Quantum chemistry enables the explicit calculation of these quantities and therefore the identification of rate-determining steps and selectivity-defining transitions.

Density functional theory became transformative because it recast the many-electron problem in terms of the electron density rather than the many-electron wavefunction. The Hohenberg–Kohn theorems established that the ground-state electron density uniquely determines system properties, and the Kohn–Sham formulation made practical calculations possible through effective single-particle orbitals (Hohenberg and Kohn, 1964; Kohn and Sham, 1965). In catalysis, this framework is especially powerful because it can treat periodic surfaces, nanoparticles, coordination complexes, and hybrid interfaces within a broadly unified formalism.

Chemical reactivity concepts derived from quantum chemistry also inform catalyst design. Frontier orbital theory, hardness and softness, charge transfer tendencies, local electrophilicity and nucleophilicity, spin density, and bond order analysis are used to rationalize why certain sites are active. Conceptual DFT further links reactivity to descriptors such as Fukui functions and chemical potential, which can help interpret adsorption preferences and activation patterns in complex catalysts (Parr and Yang, 1989). While such descriptors do not replace explicit reaction-path calculations, they often accelerate hypothesis generation and materials screening.

Another important conceptual advance is the descriptor-based view of catalysis. Rather than computing full microkinetic models for every candidate material, researchers often seek one or a few calculated quantities that correlate with catalytic performance. Adsorption energies of key intermediates, d-band centers of transition metals, vacancy formation energies in oxides, or hydrogen binding energies in electrocatalysts are typical examples. When descriptors are linked to activity through scaling relations or volcano plots, they provide practical maps for catalyst design (Nørskov et al., 2009; Medford et al., 2015). Although descriptor approaches simplify complex chemistry, they remain among the most influential ways quantum chemistry has guided catalyst optimization.

3. Quantum-Chemical Methods Used in Catalyst Design

The most widely used tool in computational catalysis is DFT. Generalized gradient approximation functionals such as PBE remain common because of their efficiency and robust performance across diverse systems, while hybrid functionals and dispersion-corrected approaches are increasingly employed when electronic localization, charge transfer, or weak interactions are important (Perdew et al., 1996; Grimme et al., 2010). For nanoporous materials, layered structures, adsorption in molecular crystals, and metal–organic frameworks, dispersion interactions can

substantially alter predicted energetics and geometries, making correction schemes essential rather than optional.

Despite its versatility, DFT is not a single method but a family of approximations, and functional choice can influence predicted trends. Transition-metal catalysis is especially sensitive because partially filled d shells, spin-state energetics, and self-interaction errors can lead to uncertainty in reaction barriers and redox energetics. Consequently, benchmark studies against higher-level wavefunction methods are important for validating mechanistic conclusions in difficult cases. Coupled-cluster methods, multireference approaches, and localized correlation techniques are computationally expensive, but they provide valuable reference data for small clusters, molecular active-site models, and key transition states.

For homogeneous catalysis and enzyme-inspired systems, wavefunction methods remain particularly important where strong correlation or near-degeneracy is significant. Metalloenzymes and redox-active coordination complexes often present electronic structures beyond the comfortable reach of semi-local DFT. In such cases, the role of quantum chemistry is not merely predictive but diagnostic, helping determine whether the underlying electronic problem demands a multiconfigurational treatment (Orio and Pantazis, 2021).

Ab initio molecular dynamics extends quantum chemistry into the finite-temperature regime by allowing atomic motion on electronically derived potential energy surfaces. This is crucial for understanding fluxional nanoclusters, solvent reorganization, interfacial water networks, ion-coupled reactions, and the dynamic restructuring of catalysts under operating conditions. Static zero-Kelvin structures can be misleading for catalytic systems that change geometry or oxidation state while functioning. Dynamic simulations, although expensive, reveal ensembles rather than isolated structures and thereby bring theory closer to experimental reality.

Quantum mechanics/molecular mechanics embedding is another important strategy, especially for large catalytic environments such as zeolites, MOFs, solvated clusters, and biomimetic systems. In these approaches, the reactive center is treated quantum mechanically while the broader environment is described at lower cost. This allows the inclusion of confinement, electrostatics, and long-range structural effects that would otherwise be neglected.

Finally, machine learning is now being integrated into quantum chemistry rather than replacing it. Surrogate models trained on DFT data accelerate geometry optimization, energy prediction, reaction path screening, and materials discovery. The most promising approaches preserve the physical interpretability of quantum descriptors while enabling exploration of far larger chemical spaces than conventional DFT alone can handle (Gensch et al., 2022; Lewis et al., 2023; Casillo et al., 2025). In this sense, quantum chemistry has evolved from a stand-alone computational technique into the data-generating engine of modern catalyst informatics.

4. From Electronic Structure to Design Principles

The practical value of quantum chemistry in catalyst design depends on its ability to convert raw electronic information into generalizable principles. One of the most important is the relation between adsorption strength and catalytic turnover. Too weak a surface–adsorbate interaction prevents activation, whereas too strong a bond inhibits desorption or subsequent transformation. This balance is often visualized through volcano relationships, were activity peaks at intermediate binding energies. Quantum-chemical calculations provide the adsorption descriptors that define the position of a catalyst on such plots (Nørskov et al., 2009; Medford et al., 2015).

Another principle is the role of electronic structure tuning through composition and strain. Alloying can shift the d-band or modify charge transfer between atoms, thereby changing adsorption energetics. In nanostructures, lattice strain introduced by core–shell architectures, heterointerfaces, or support-induced mismatch can modulate the occupancy and energy distribution of surface orbitals. DFT calculations have shown how tensile or compressive strain

influences the binding of oxygenated, hydrogenated, or carbon-containing intermediates, making strain engineering a theoretically guided route to performance optimization (Deng et al., 2023).

Defects and low-coordination sites also illustrate how quantum chemistry converts atomic irregularity into design knowledge. Step edges, kinks, vacancies, dopants, and grain boundaries often exhibit reactivity distinct from ideal terraces because their coordination environment alters local electronic density and orbital overlap. In oxide catalysts, oxygen vacancies may activate molecules by stabilizing reduced intermediates or facilitating lattice oxygen participation. In metal catalysts, undercoordinated atoms often bind reactants more strongly, though sometimes at the cost of selectivity or stability. Theoretical analysis allows these trade-offs to be evaluated before synthesis.

Scaling relations have played an especially influential role in rational catalyst design. Adsorption energies of chemically related intermediates often correlate across catalyst families, reducing the dimensionality of the design problem. Yet scaling relations also impose limits: if a catalyst binds two crucial intermediates inextricably, it may be impossible to optimize both simultaneously. One of the major contemporary goals in catalyst nanoengineering is to break unfavorable scaling relations by using dual sites, interfaces, confinement, dynamic charge redistribution, or non-classical active ensembles. Quantum chemistry is central to identifying where such deviations are possible and how they arise.

In addition, quantum chemistry aids the interpretation of spectroscopic fingerprints. Vibrational frequencies, X-ray absorption features, core-level shifts, electron localization patterns, and spin densities predicted computationally can be compared with in situ or operando measurements. This feedback loop helps confirm the nature of active sites and reaction intermediates, thereby refining structure–activity models. In this way, theory moves beyond prediction and becomes an interpretive partner of experiment (Fig.2).

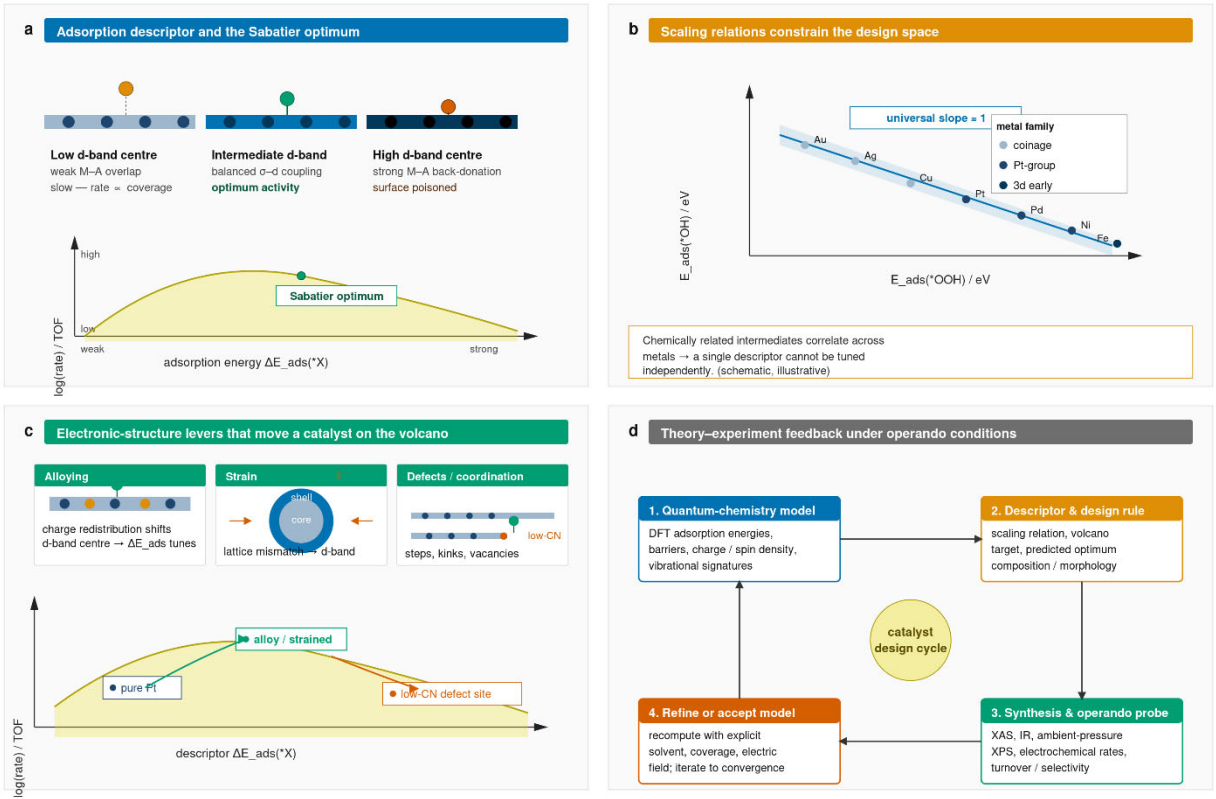

Fig. 2. From quantum-chemical descriptors to actionable catalyst design principles. Quantum chemistry converts electronic-structure quantities into a small set of descriptors that govern catalytic turnover, and these descriptors are strong enough to organise the design space but

constrained enough to require physics-aware tuning. **a**, The Sabatier optimum. Adsorption energy ΔE_ads(*X) of a key surface intermediate is the dominant descriptor: low d-band centres give weak M–A overlap and rate-limited by coverage (left); intermediate d-band centres balance σ–d coupling and deliver maximum activity (centre); high d-band centres over-bind and poison the surface (right). Each surface is a schematic Au/Ag/Pt/Ni-like slab of four metal atoms (blue) with an adsorbate (orange = reactant; green = optimally bound; red = poisoning). The volcano curve below collapses these three regimes onto one axis, with the Sabatier optimum at the apex. **b**, Scaling relations constrain how far a single descriptor can move. Adsorption energies of chemically related intermediates (here E_ads(*OH) versus E_ads(*OOH), as introduced in the SABRE/oxygen-reduction literature but presented schematically across coinage, Pt-group and 3d-early metals) lie on a near-universal line of slope ≈ 1 with a narrow confidence band, so optimising one intermediate automatically weakens or strengthens another. **c**, Three electronic-structure levers — alloying (charge redistribution and d-band shift), strain (core–shell lattice mismatch and d-band narrowing/widening) and defects/coordination (steps, kinks, vacancies, low-CN sites) — shift a catalyst sideways along the same volcano. The arrows track a qualitative trajectory of "pure Pt → alloy/strained → low-CN defect site" without assigning numerical activity gains. **d**, The hypothesis-feedback cycle that makes the workflow operational: (1) a quantum-chemistry model returns DFT adsorption energies, barriers, charge/spin densities and vibrational fingerprints; (2) these are condensed into a descriptor and design rule (scaling line, volcano target, predicted composition/morphology); (3) synthesis and operando probes (XAS, IR, ambient-pressure XPS, electrochemical rates, turnover and selectivity) provide reality checks; (4) the model is refined with explicit solvent, coverage and electric field and the loop is iterated until convergence. Geometric quantities are schematic and do not correspond to specific DFT structures.

5. Quantum Chemistry in Homogeneous Catalyst Design

Homogeneous catalysis remains one of the clearest demonstrations of the power of quantum chemistry because the active site is often molecularly well-defined. Transition-metal complexes used in hydrogenation, C–C coupling, olefin polymerization, CO2 reduction, and selective oxidation can be described in terms of ligand effects, oxidation-state changes, coordination geometry, and elementary organometallic steps such as oxidative addition, migratory insertion, transmetallation, and reductive elimination. Quantum-chemical calculations clarify how ligand electronics and sterics shape these steps and allow rational adjustment of catalyst scaffolds.

A major contribution of theory has been the distinction between thermodynamic and kinetic control in ligand design. Electron-rich ligands may accelerate oxidative addition but hinder reductive elimination, while bulky ligands may destabilize catalyst resting states yet lower selectivity-defining barriers by enforcing favorable transition-state geometries. By mapping full catalytic cycles, quantum chemistry reveals which ligand features improve turnover and which simply relocate the energetic bottleneck.

Modern ligand discovery platforms increasingly depend on computational descriptors derived from quantum chemistry. Steric maps, buried volumes, donor strengths, molecular electrostatic potentials, and computed reaction barriers can be assembled into searchable design spaces, allowing inverse design of catalysts tailored to specific transformations (Gensch et al., 2022). This approach is particularly attractive in fine chemical synthesis, where modest energetic differences can lead to large improvements in regioselectivity, chemoselectivity, or enantioselectivity.

Another important role of quantum chemistry in homogeneous catalysis is the identification of non-innocent behavior. Ligands, counterions, or solvent molecules that appear spectator-like may in fact participate directly in proton shuttling, spin-state crossover, or transient bond formation. Similarly, the formal oxidation state assigned from intuition may differ from the electronically relevant state revealed by quantum analysis. Such insights are essential when designing redox-

flexible catalysts for challenging transformations such as N2 activation, C–H functionalization, and CO2 reduction.

The boundaries between homogeneous and heterogeneous catalysis are also increasingly blurred in nanoengineered systems. Ligand-protected clusters, organometallic fragments immobilized on surfaces, and atomically dispersed sites on oxides often combine molecular and materials-like features. Quantum chemistry is ideally suited to these frontier systems because it can treat the local active center with the molecular precision required while still accounting for surface or support effects (Ortuño and López, 2019).

6. Heterogeneous Catalysis and Surface-Mediated Design

In heterogeneous catalysis, the active site is embedded in an extended material, and catalytic behavior depends on surface composition, structure, adsorbate coverage, and support interactions. Here DFT has become indispensable because it can treat periodic surfaces and calculate adsorption geometries, transition states, and reaction networks. Industrially relevant processes such as ammonia synthesis, hydrogen evolution, oxygen reduction, Fischer–Tropsch chemistry, methanol synthesis, and hydrocarbon activation have all been re-examined through first-principles catalysis.

One of the most influential contributions of quantum chemistry has been the formulation of reactivity trends across metal surfaces. The adsorption energy of key intermediates often varies systematically with the electronic structure of the metal, enabling the identification of catalysts that are intrinsically too inert or too reactive. These concepts, combined with microkinetic analysis, have reshaped how catalyst screening is performed and shifted the field away from purely empirical composition searches (Hammer and Nørskov, 2000; Nørskov et al., 2009).

Surface heterogeneity, however, complicates simple trend analysis. Real catalysts expose multiple facets, defects, reconstructions, and metal–support interfaces. Quantum chemistry helps prioritize which motifs deserve attention. For example, step sites may dominate bond scission, while terraces control hydrogenation; oxide supports may stabilize cationic metal species that differ profoundly from metallic nanoparticles; adsorbates themselves may induce restructuring that alters subsequent reactivity. In supported gold systems, such support-mediated electronic and structural effects are especially important, and computational studies have shown that catalytic behavior often originates from the interface rather than from the metal particle alone (Sankar et al., 2020).

Quantum chemistry also enables the mechanistic interpretation of selectivity in complex surface reactions. In biomass upgrading, CO2 hydrogenation, and selective oxidation, multiple parallel pathways compete on the same catalyst. DFT-based free-energy and microkinetic analyses can distinguish why one surface favors C–O cleavage while another favors hydrogenation or coupling. These distinctions are crucial for chemical technologies seeking not merely high conversion but also product specificity, atom economy, and process intensification.

A continuing challenge is the pressure and materials gap between model calculations and real catalysts. Surface coverages under reaction conditions may differ strongly from ultra-high-vacuum assumptions, and nanoparticle catalysts can restructure dynamically in response to adsorbates. Even so, quantum chemistry remains the only practical route to establishing a mechanistic baseline from which these complexities can be addressed systematically rather than heuristically.

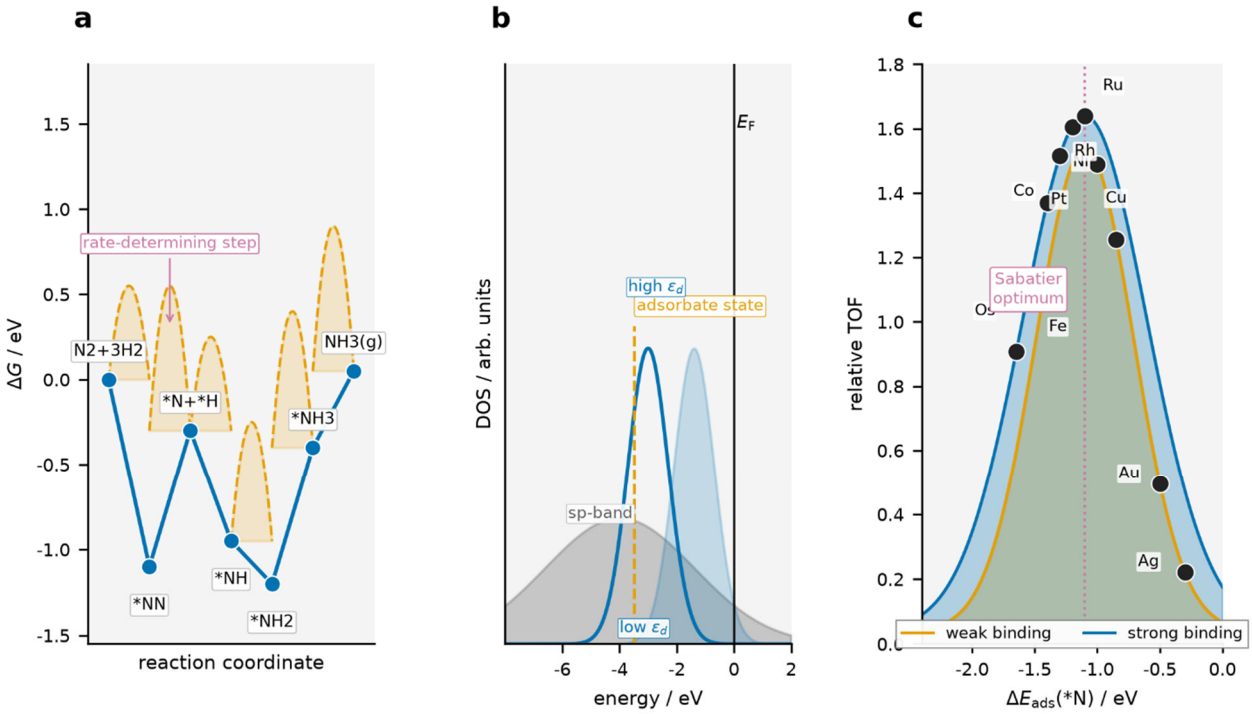

Figure 3. Quantum-chemistry-driven workflow for rational surface-catalyst design. (a) Gibbs free-energy profile along a representative heterogeneous catalytic cycle. DFT-computed enthalpies of the seven intermediates — N_2+3H_2, *NN, *N+*H, *NH, *NH_2, *NH and NH(g) — are connected by dashed orange transition-state arcs whose heights encode the activation free energy at each elementary step; the largest arc, marked by the highlighted callout *rate-determining step*, governs the overall turnover. **(b)** D-band structure of the metal substrate. The broad grey sp-band sets the reference DOS; the dark-blue peak is the d-band in its low-ε_d state (e.g. Au-, Ag-like) and the shaded light-blue peak is the same band shifted to a high ε_d (e.g. Pt-, Ni-like). The vertical black line marks the Fermi level E_F, and the orange dashed line shows the position of the adsorbate-induced resonance — moving ε_d upward slides this resonance across E_F and strengthens binding. **(c)** Sabatier volcano: relative turnover frequency plotted against the adsorption energy ΔE_ads(*N) of the rate-limiting intermediate. The orange branch (weak binding) and the blue branch (strong binding) both pass through a maximum; the pink dotted line marks the Sabatier optimum at ΔE_ads(*N) ≈ −1.1 eV. Black markers place representative 3d (Cu, Ni, Co, Fe), 4d (Ru, Rh, Pd-like Pt) and 5d (Os, Ag, Au) metals along a single descriptor axis, showing directly how a single DFT-computed quantity — the d-band centre ε_d — reorders catalytic metals on a continuous activity scale. The numbers on each plot give energies in eV and turnover frequencies in relative units.

7. Nanocatalysis and the Unique Value of Quantum Chemistry at the Nanoscale

Nanocatalysts are not simply small versions of bulk catalysts. Their finite size creates discrete ensembles of atoms, high surface-to-volume ratios, altered coordination environments, and strong susceptibility to support and ligand effects. As a consequence, their catalytic properties are extraordinarily sensitive to geometry and electronic structure. Quantum chemistry plays a uniquely important role in nanocatalysis because nanoscale reactivity often depends on features that are inaccessible to continuum models or overly simplified descriptors (Negreiros et al., 2012; Cao et al., 2016).

One major theme is size dependence. Clusters containing only a few atoms may exhibit catalytic properties that change non-monotonically with size because electronic shells, geometric motifs, and charge distribution evolve discretely rather than continuously. A 13-atom cluster may behave differently from a 20-atom cluster not only because of more sites, but because the orbital structure

and spin distribution have changed. Quantum-chemical calculations make these effects visible and allow the identification of “magic sizes” or unusually reactive motifs.

Shape dependence is equally important. Cubic, octahedral, rod-like, and branched nanoparticles expose different proportions of facets, edges, and corners. DFT studies have shown that these sites can favor different elementary steps, which explains why nanocrystal morphology strongly influences catalytic selectivity and stability (Cao et al., 2016). In this sense, nanoengineering and quantum chemistry are deeply coupled: controlled synthesis defines morphology, while theory explains its catalytic consequence.

Another powerful area is cluster-support interaction. Supported nanoparticles may donate or accept charge from oxides, carbons, nitrides, or sulfides. Interfacial polarization can activate molecules, stabilize reactive intermediates, or modify sintering resistance. In reducible oxides, support oxygen vacancies or polarons may participate directly in the catalytic cycle. Quantum chemistry reveals whether the support acts as an inert scaffold, an electronic modulator, or an active co-catalyst.

Nanocatalysts are also frequently fluxional. Rather than remaining rigid during turnover, small clusters may rearrange in response to adsorbates and temperature. In some systems, the active structure is not the lowest-energy bare cluster, but an adsorbate-stabilized isomer accessible only under reaction conditions. This challenges static catalyst pictures and underscores the need for ensemble-based quantum-chemical descriptions. Such insights are indispensable for designing stable yet adaptive nanocatalysts for industrial conditions.

8. Single-Atom Catalysts and Atom-Efficient Design

Single-atom catalysts have emerged as one of the most exciting directions in catalyst nanoengineering because they maximize atom efficiency while often creating highly specific electronic environments. In these systems, isolated metal atoms are stabilized on supports such as carbons, oxides, nitrides, sulfides, or MOFs. Their coordination environment may resemble that of homogeneous catalysts, yet they function in a heterogeneous context. Quantum chemistry is indispensable for identifying the structure of these isolated sites and understanding their unique catalytic behavior (Kraushofer et al., 2022; Hussain et al., 2024; Shao et al., 2025).

The main theoretical challenge in single-atom catalysis is that “single atom” is not a complete structural description. The same metal may adopt different oxidation states, spin states, and coordination geometries depending on neighboring heteroatoms, vacancies, and adsorbates. DFT calculations are therefore used to determine whether the active motif is, for example, M–N4 in a carbon matrix, a cationic atom anchored at an oxide vacancy, or a transiently reduced site under reductive conditions. Without this structural resolution, activity trends remain difficult to generalize.

Single-atom catalysts are especially attractive for electrocatalysis because their local electronic structure can often be tuned to optimize binding of oxygenated, nitrogenous, or carbonaceous intermediates. Quantum chemistry helps predict whether such sites favor proton-coupled electron transfer, whether they suppress competing hydrogen evolution, and whether they can break conventional scaling relations through asymmetric coordination or dual-site effects. Recent DFT studies on carbon-supported single-atom catalysts have shown how subtle changes in coordination number and neighboring dopants can shift selectivity across oxygen reduction, CO2 reduction, nitrogen reduction, and hydrogen evolution regimes (Shao et al., 2025).

At the same time, theory has highlighted the vulnerabilities of single-atom catalysts. They may aggregate under working conditions, change oxidation state dynamically, or rely on support defects that are difficult to reproduce uniformly. Quantum chemistry therefore assists not only in activity optimization, but also in stability analysis by estimating migration barriers, binding energies to the support, and the thermodynamic driving force for clustering. This is a good example of how theory supports practical catalyst engineering rather than only idealized performance prediction.

9. Quantum Chemistry in Electrocatalyst Design

Electrocatalysis has become one of the most active areas of quantum-chemical catalyst design because sustainable energy technologies depend on efficient electrode materials for reactions such as hydrogen evolution, oxygen evolution, oxygen reduction, CO2 reduction, and nitrogen reduction. In these systems, theory must account not only for surface chemistry but also for charge, potential, solvation, electric fields, and proton-coupled electron transfer. Despite these added complexities, DFT has become foundational in electrocatalysis, providing activity descriptors, selectivity maps, and mechanistic interpretation for diverse electrode materials (Seh et al., 2017; Chen et al., 2019; Yang et al., 2022).

A key theoretical advance has been the computational hydrogen electrode framework, which allows free-energy changes for proton–electron transfer steps to be related to electrode potential. This made it possible to construct electrocatalytic free-energy diagrams and compare catalysts systematically. Such analyses have been especially influential in the study of oxygen reduction and CO2 reduction, where theoretical overpotentials derived from intermediate binding energetics help rank candidate materials (Seh et al., 2017).

Quantum chemistry has also clarified why many electrocatalytic reactions are subject to strong scaling constraints. For example, materials that bind *OH weakly often bind *OOH weakly as well, limiting achievable overpotential reductions. As in thermal catalysis, the nanoengineering objective is often to disrupt these correlations by exploiting strain, alloying, interfaces, single-atom motifs, or flexible coordination environments. DFT is central to evaluating whether such strategies truly alter the energetics of critical intermediates or merely redistribute activity among similar sites.

For CO2 and N2 reduction, the importance of theory is even greater because selectivity is highly sensitive to local environment and multiple multi-electron pathways compete. DFT helps determine whether a catalyst favors CO, formate, methanol, methane, ammonia, or hydrogen as the dominant product pathway, though the accuracy of such predictions depends strongly on treatment of solvation and potential. Still, without quantum chemistry, rational navigation of these complex reaction networks would be extremely difficult (Yang et al., 2022).

Current frontiers include constant-potential methods, explicit solvation, field effects, and dynamic interface simulations. These developments are moving electrocatalytic quantum chemistry beyond static gas-phase-corrected models toward more realistic electrochemical environments. Even where absolute predictions remain uncertain, comparative mechanistic insight from theory continues to guide the synthesis of better-performing electrocatalysts.

10. Photocatalysis, Excited States, and Photoelectrochemical Systems

Photocatalysis poses a distinct challenge because catalyst performance depends not only on ground-state reaction energetics but also on light absorption, exciton generation, charge separation, recombination, and the alignment of electronic bands with redox potentials. Quantum chemistry contributes at multiple levels: it helps design light-harvesting materials, predicts adsorption and surface reaction energetics, analyzes defect states, and clarifies the fate of photogenerated carriers (Du et al., 2024).

In semiconductor photocatalysts such as TiO2 and related oxides, DFT has been extensively used to analyze surface terminations, vacancy states, dopant effects, and the adsorption/activation of water, CO2, and pollutants. Such calculations are essential for understanding how surface defects can either improve activity by trapping reactive carriers or reduce performance by promoting recombination. Theoretical insight is therefore central to defect engineering in photocatalyst nanoengineering.

For photoelectrocatalytic and hybrid systems, quantum chemistry helps align molecular and materials perspectives. Sensitized interfaces, cocatalyst deposition, heterojunction design, and charge-transfer bridges can all be evaluated in terms of electronic coupling and band alignment.

In this area, theory often works hand in hand with spectroscopy, helping assign transient states and identify the charge-transfer bottleneck.

Excited-state photocatalysis requires methods beyond standard ground-state DFT in many cases. Time-dependent DFT, constrained DFT, nonadiabatic dynamics, and embedded approaches are increasingly used to study charge separation and excited-state reactivity. Although these techniques remain more computationally demanding and less routine than ground-state DFT, they are crucial for truly predictive photocatalyst design.

Photocatalysis also intersects strongly with nanostructuring. Quantum confinement, plasmonic enhancement, facet-selective cocatalyst deposition, and nanoscale heterointerfaces can dramatically alter light-driven performance. Quantum chemistry helps determine whether observed enhancements arise from band shifts, improved charge separation, hot-carrier effects, or simply better adsorption energetics. This mechanistic discrimination is essential if photocatalyst optimization is to move beyond empirical nanofabrication.

11. Metal–Organic Frameworks, Zeolites, and Confined Catalytic Environments

Porous crystalline materials such as MOFs and zeolites occupy a special place in catalyst design because they combine site isolation, tunable coordination chemistry, and nanoscale confinement. In such systems, quantum chemistry serves two parallel purposes: it characterizes the intrinsic reactivity of nodes, linkers, or guest molecules, and it evaluates how confinement modifies thermodynamics, transition-state stabilization, and diffusion pathways (Bernales et al., 2017; McCarver et al., 2021; Yu et al., 2023).

In MOF catalysis, DFT has been used to identify open-metal-site reactivity, linker functionalization effects, and the role of cooperative node–linker environments. Because these materials often incorporate coordinatively unsaturated metal centers in a porous scaffold, they provide a bridge between homogeneous and heterogeneous catalysis. Quantum chemistry clarifies how the framework environment perturbs metal electronic structure and whether catalytic activity originates from isolated sites, defects, guest-induced activation, or framework decomposition products.

For photocatalytic MOFs, theory helps tune band gaps, charge separation pathways, and adsorption geometry of reactants at photoactive centers. Computationally guided design of functionalized MOFs has shown that linker substitution, node identity, and heterometal incorporation can systematically shift optical and catalytic properties (Bernales et al., 2017; Yu et al., 2023). This is particularly relevant to CO2 reduction and pollutant degradation, where both adsorption affinity and photoredox ability must be optimized simultaneously.

Zeolites and other confined catalytic solids also demonstrate the value of quantum chemistry in complex reaction environments. Acid strength, framework topology, and confinement-induced entropy all shape reaction selectivity. Quantum-chemical calculations have been instrumental in explaining why some pores favor cracking, others alkylation, and still others shape-selective isomerization. Because confinement can stabilize transition states differently from adsorbed intermediates, these materials often provide opportunities to go beyond simple surface scaling relations.

12. Operando Complexity: Solvent, Coverage, Fields, and Dynamic Restructuring

One of the most important lessons of recent years is that catalysts are not static objects. Under realistic conditions, they change. Adsorbates accumulate, oxidation states shift, solvent reorganizes, local pH varies, electric fields develop, ligands dissociate, and nanostructures reconstruct. The role of quantum chemistry has therefore expanded from calculating idealized mechanisms to describing dynamic catalytic environments.

Solvent is a particularly important factor in liquid-phase catalysis, electrocatalysis, and biomass upgrading. Implicit solvation models are convenient but can miss hydrogen-bonding networks, proton relays, and interfacial structuring. Explicit solvent and ab initio molecular dynamics provide

richer mechanistic insight, though at higher computational cost. These methods are increasingly necessary when the energy landscape is strongly shaped by solvent-mediated stabilization of charged or polar intermediates.

Coverage effects also matter because the binding energy of a given species may change with surface population. Under catalytic turnover, a surface may be crowded with spectators or co-adsorbates that alter site availability and reaction barriers. Microkinetic modeling combined with DFT helps transform isolated elementary-step energetics into realistic turnover predictions by accounting for competition among adsorbates.

Dynamic restructuring may be the most difficult challenge of all. In many working catalysts, especially nanoclusters, supported single atoms, copper-based CO2 reduction catalysts, and reducible oxides, the active site that exists under reaction conditions may differ from the one present before catalysis begins. Quantum chemistry helps identify plausible restructuring pathways, but full predictive control remains difficult because the relevant configuration space is large. This is where integration with operando spectroscopy becomes essential.

Importantly, these complexities do not reduce the value of quantum chemistry; they redefine it. Rather than expecting one optimized structure to explain all behavior, researchers increasingly use theory to describe ensembles, transitions, and condition-dependent site populations. This shift represents a maturation of computational catalysis from static mechanism mapping to realistic catalyst-state modeling.

13. Machine Learning, High-Throughput Screening, and Autonomous Discovery

The newest phase of catalyst design combines quantum chemistry with machine learning and automation. Because quantum-chemical calculations are expensive relative to simple descriptor models but cheap relative to broad experimental campaigns, they serve as the data backbone for model training. High-throughput DFT workflows generate adsorption energies, reaction barriers, band structures, and formation energies across thousands of candidates. Machine learning then interpolates or extrapolates within these spaces to identify promising regions for deeper exploration (Lewis et al., 2023; Casillo et al., 2025).

This integration is especially powerful for ligand discovery, alloy screening, and nanomaterial compositional design. Instead of testing a handful of intuitive candidates, researchers can navigate enormous spaces defined by metal identity, coordination environment, dopants, facet exposure, or support type. Computational ligand platforms illustrate how quantum descriptors can be embedded into searchable chemical maps that support inverse catalyst design (Gensch et al., 2022).

Nevertheless, machine learning does not remove the need for quantum chemistry. The predictive value of any data-driven model depends on the fidelity of the underlying electronic-structure calculations and the representativeness of the training set. If DFT systematically misrepresents a reaction family or misses condition-dependent restructuring, machine learning may merely accelerate the propagation of those errors. Consequently, the most promising strategies are hybrid: physics-informed models, uncertainty-aware screening, active learning loops, and iterative validation against experiment.

Autonomous discovery platforms may become especially important in nanoengineering, where synthesis variables and structural heterogeneity create large multidimensional search spaces. Quantum chemistry can prioritize hypotheses, machine learning can manage combinatorial complexity, and robotic experimentation can test candidates rapidly. In such closed-loop systems, theory becomes not just a source of explanation but a real-time driver of catalyst innovation.

14. Limitations and Persistent Challenges

Despite its major successes, quantum chemistry does not yet offer a fully predictive universal solution to catalyst design. Functional dependence in DFT remains a significant issue, especially for strongly correlated oxides, open-shell transition-metal complexes, and redox-active intermediates.

Small changes in functional choice can affect relative site stability, spin-state ordering, and barrier heights. For catalytic screening this may be acceptable when trends are robust, but for fine mechanistic discrimination the uncertainty can be consequential.

Entropy and free energy are also recurrent sources of approximation. Many catalytic studies still rely primarily on electronic energies corrected by simplified vibrational models. This is often sufficient for comparative trends, but it can fail in liquid-phase systems, flexible adsorbates, and confined environments where entropic contributions are substantial. Likewise, kinetic relevance is sometimes inferred from thermodynamic descriptors alone, even though kinetics and thermodynamics may diverge.

Another challenge is scale. Industrial catalysts are rarely perfect crystals or isolated complexes. They are multicomponent, defect-rich, often partially amorphous materials operating under non-equilibrium conditions. Bridging the gap between atomistic calculations and reactor-level performance requires multiscale thinking, including transport, deactivation, sintering, poisoning, and process integration. Quantum chemistry can identify intrinsic reactivity but not by itself predict plant-scale productivity.

Interpretability can also become an issue in large-scale computational screening. When thousands of materials are ranked by descriptor values, there is a risk of prioritizing numerical performance over chemical understanding. The most useful role of quantum chemistry is not just to compute faster than experiment, but to explain why a catalyst behaves as it does. Mechanistic transparency remains critical if theoretical predictions are to guide transferable design principles.

15. Future Perspectives

The future of quantum chemistry in catalyst design will likely be defined by realism, integration, and automation. Realism means better descriptions of operating environments: constant potential, explicit electrolyte, dynamic restructuring, solvent fluctuations, excited states, and multiscale coupling. Integration means closer feedback between theory and operando measurements so that computed structures and mechanisms can be continuously confronted with experimental evidence. Automation means the deployment of active learning and autonomous workflows in which quantum chemistry helps choose the next most informative catalyst to synthesize or the next mechanistic question to test.

Single-atom catalysts, dual-site catalysts, high-entropy materials, and hybrid interfaces are likely to remain key design targets because they offer opportunities to circumvent traditional scaling constraints. Quantum chemistry will be essential in these areas not simply for ranking materials, but for recognizing when new electronic motifs emerge that cannot be captured by older bulk-based intuitions.

Another important direction is the development of benchmark-quality reference sets for catalytic chemistry. If machine learning and high-throughput screening are to become routine, they will require robust calibration against trustworthy quantum-chemical standards. Better uncertainty quantification, reproducible workflows, and standardized data curation will therefore become as important as methodological sophistication.

Finally, the distinction between theoretical and experimental catalyst design is likely to continue fading. As computational predictions become more directly connected to synthesis pathways, spectroscopic observables, and process metrics, quantum chemistry will function less as a supporting discipline and more as a co-equal engine of catalyst innovation.

16. Conclusions

Quantum chemistry has fundamentally altered the logic of catalyst design in chemical technologies and nanoengineering. Its greatest contribution is not merely the calculation of energies, but the creation of a mechanistic framework linking atomic-scale electronic structure to catalytic function. Through DFT, wavefunction methods, molecular dynamics, embedding strategies, and machine learning integration, researchers can now identify active sites, compare pathways, predict trends,

and rationalize complex structure–property relationships across homogeneous, heterogeneous, electrochemical, photocatalytic, and porous catalytic materials.

In nanoengineered catalysts, where local structure, support interaction, and dynamic behavior strongly determine performance, quantum chemistry is particularly indispensable. It reveals why size, shape, strain, coordination, defects, and confinement matter and how these variables can be controlled to improve activity, selectivity, and durability. At the same time, the field must continue addressing persistent challenges involving functional accuracy, environmental realism, restructuring, and the translation of atomistic insight to practical catalyst performance.

Overall, the role of quantum chemistry in catalyst design is best understood as both explanatory and generative. It explains existing catalytic behavior with growing depth and it generates new hypotheses, descriptors, and candidate materials with increasing speed. As theory becomes more tightly integrated with nanoengineering, spectroscopy, data science, and autonomous experimentation, it will remain central to the next generation of catalysts for sustainable chemical technologies.

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Philological Sciences

Speech and Communication Strategies in the Professional Training of Seafarers: Linguocultural Features of Maritime Discourse

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Introduction:

One of the foundations of communication theory is the theory of speech acts, which is considered as a strategy and tactics of speech behavior. The implementation of communication is largely associated with the addressee's attempt to influence the interlocutor. In accordance with pragmatic goals, the speaker chooses a certain speech program, which is organized based on the goal of the relationship, it is precisely this communicative strategy that forms a certain "vector" of the relationship. The more precisely (more adequately) the communicative strategy is chosen, the more successful the results of the speech relationship are for the speaker.

The concepts of communicative strategy and tactics are actively used in modern studies of various discourses. In many cases, communicative strategy is associated with motives, intention, some general (macro) goal and chooses a more adequate way to achieve it. This task is solved by communicative (speech) tactics, which are defined as one or more actions that implement strategies (Isers 2006:110).

Discussion:

For successful communication, it is not enough for a person to possess linguistic and speech norms; the communicator must know what typical units are accepted in the discourse he needs.

G. Pocheptsov cites an interesting differentiation of communication:

1) hierarchical (with a priority of direct communication);

2) democratic (with a priority of feedback)

(Почепцов, 2001:35).

The first type of communication is characterized by a command form, and the second by persuasion. The author characterizes hierarchical and democratic communication in the following table:

Democratic Communication		Hierarchical communication
Feedback	Priority Connection	Direct
Free Person	Receiver	Subordinate
Persuasion	Communicative Action	Command/Order
Dialogue	Communication Type	Monologue
Many/Multiple	Texts	one

Professional business relations are a special communicative situation. They consist of a number of components, the change of which leads to a change in the communicative situation, which requires a change in the language means used and, moreover, a variation in the entire speech act: addressee, addressee, their relationship, tone of communication (official, neutral or friendly), purpose of communication, method (verbal, non-verbal, mixed), form of communication (oral/written, contact/distance), place of communication (Belikov, Krisin 2001:61).

In order to prepare professional personnel in society, the competencies of all professions must be well studied, and among them, speech competence will occupy an important place, without which successful professional relations are impossible.

Professional competence is considered to be knowledge of a certain nature and scope, general and specific skills that are necessary to perform specific professional actions and achieve set goals. Any professional competencies are based on general, universal competencies. These are personality traits that are necessary to achieve professional success in any field. They include the following knowledge and skills:

1.Social competence (knowledge of the rules of behavior in society, knowledge of etiquette, cooperation skills, leadership qualities, the ability to organize the work of a work group, the ability to adapt to a changing environment);

a) Cultural competence (mastery of the cultural code of a given society, tolerance towards other cultures);

b) Communication competence (knowledge of literary vocabulary and grammatical norms, oral and written speech skills.

2. The ability to choose appropriate communication tactics and strategies for a specific relationship situation; personal competencies (self-confidence, ability for self-education and self-development, independent work skills, analytical abilities of the person, willpower, ability to overcome difficulties, etc.).

In different professions, the specific weight of communicative competence within the framework of professional communication is undoubtedly different. For example, possession of special terminology, development of oral and written speech, knowledge of the use of communication strategies and tactics, possession of oratory, the ability not to succumb to external influence- all this is more important for a lawyer than for a watchman. The same can be said about sailors who occupy different positions in the hierarchy of the ship's crew: the above-mentioned skills and knowledge are more important for the captain and his assistants than for mechanics who are responsible for the smooth operation of the engine room. Nevertheless, communication competence, we are deeply convinced of, is an essential component of the professional competence of any seafarer, which is explained by the need for coordinated work of the crew in extreme situations that so often arise in the professional activities of seafarers.

At the same time, we must remember that the modern world is multicultural, so successful intercultural communication is a necessary condition for any professional activity. Moreover, the selection of appropriate communication strategies and tactics is an essential component of professional competence.

Professional activity is a type of interaction between people that is carried out on the basis of a certain type of activity and is aimed at achieving a specific result. Its purpose is determined by the labor requirements of specific subjects and the type of organization and is based on the development of an effective strategy of cooperation, joint relations, which leads to successful professional activity.

Professional relations, unlike everyday household and interpersonal relations, are often of a forced nature and are more strictly regulated from a normative, organizational and cultural point of view. According to E. Zaretskaya, "in professional relations between employees of an organization, two interrelated aspects appear: interaction and interdependence. Interaction is determined by production technologies and job responsibilities and is oriented towards agreed actions for the purpose of creating a product or service" (Зарецкая, 1998:48).

Professional relations affect the quality of activity, and professional activity requires readiness and professional relations.

There is no single definition of professional relations in the scientific literature. According to A. A. Derkach, in the socio-psychological literature, the concept of "business relations" is usually used, which is aimed at ensuring high efficiency of negotiations, meetings and official correspondence, public speeches. In a particular professional field, business relations have their own specifics and are called professional, sometimes service, official, statutory. Business relations are a type of relations that are normatively approved, strictly regulated and function in some field to solve certain tasks (Социальная психология 2001:98).

Knowledge of terminology, the ability to establish connections between previously known and new terms, the ability to use scientific concepts and terms in the practical analysis of production situations, knowledge of the peculiarities of professional speech style are linguistic competences of professional communication.

The ability to control emotions, manage dialogue in accordance with the requirements of professional activity, compliance with ethical norms and etiquette requirements are behavioral competences.

Professional speech often violates the norms of the literary language in almost all professional fields, intensively uses professional jargon / slang. In particular, this tendency is strong in maritime professional communication.

Representatives of various sciences (psychologists, sociologists, linguists) are interested in the study of professional speech, which undoubtedly indicates the interdisciplinary nature of this problem, but, unfortunately, so far only the features of several professional discourses have been more or less covered: the speech of politicians and diplomats, the professional discourse of lawyers, medical professionals, the formation of the speech of actors and teachers, etc. Unfortunately, there are more theoretical monographs that cover the speech of gender or age groups, and there is little material on the features of maritime professional speech.

Maritime communication is a complex type of intercultural professional communication. Maritime communication is formal or informal. The former (with rare exceptions) is mainly conducted in the international language of seafarers- English, while the latter is multilingual, since there are many linguocultural groups in international crews.

During professional training, all sailors must understand and grasp the fact that maritime activity, unfortunately, is a risky activity. Special attention is paid to the rescue of sailors, the rescue of cargo, the rescue of the ship, and the protection of the environment from pollution. That is why a whole series of signaling signals has been developed, through which the crew can inform the port, another ship, about the distress and ask for help. Despite modern technologies, Morse code, a semiotic code built on combinations of dots and dashes, is still used in maritime communication. It is interesting that if the lives of sailors are in danger, they send the SOS signal (three dots, three

dashes, three dots), that is, as one long sound signal, although it is widely believed that the signal is represented by the abbreviation SOS:
Save our souls» (спасите наши души) или
«Save our ship» (спасите наш корабль).
In our opinion, the characterization of maritime communication, depending on the scale of its functioning, is different for official and unofficial relations. Since the ship's crew is on the high seas for a long time, in addition to business relations and the performance of duties, there is also unofficial relations between crew members in their free time.
In official situations, the relationship between sailors is mainly local communication, which takes place within the professional collective of sailors, while in unofficial relations, the proportion of intra-group and interpersonal relations is quite intense. The point is that within one crew, different micro-groups united by different degrees of proximity are distinguished.
a) by professional specialization or status
(mechanics, navigators, sailors);
b) from an ethnic or ethnic-regional point of view (English, Russians, Ukrainians, Georgians, Filipinos, etc.);
c) by confessional characteristics
(Christians, Muslims, Buddhists, etc.);
c) there are fewer microgroups due to age
(young inexperienced and elderly experienced sailors);
d) groups due to gender factors are gradually increasing.
Of course, intragroup and interpersonal communication between all crew members also takes place in these microgroups, which demonstrates the complexity of
maritime communication, where two types of communication are opposed to each other: hierarchical and democratic. Among communicative actions, command prevails; as for the type of communication, G. Pocheptsov's concept includes only monologue, but dialogue prevails in maritime communication, which is due to the fact that the superior often addresses the subordinate to clarify information, and a classic dialogue is held between them:

Quest. of the superior	1st probable answer of the subordinate	2nd probable answ
How is anchor?	Clear anchor!	Foul anchor!
	Якорь чист!	Якорь не чист!
	The anchor is clean!	The anchor is not clean!

Even when a direct order comes from a superior, a subordinate must repeat the order to avoid inaccuracy (this requirement is strictly enforced in the military fleet, but in merchant shipping this requirement is relaxed):

Superior's order	1st extended response of subordinate	2nd short response of sub
Steer the course!	Yes sir, steer the course!	Yes sir!
Steer the course!	Yes steer the course!	Yes!
Keep moving!	Yes Keep moving!	Yes!

In speech practice, knowledge of cultural background information is of particular importance when a ship's crew, upon entering a foreign port, has to interact with representatives of the local port service (the port master, customs officers, the pilot). Maritime literature describes many cases when the failure of professional communication is caused by a linguistic and ethnic barrier.
The international community in 1973 raised the issue of the use of a single (English) language, standardized and generally accepted terminology and phraseology, which is due to the bitter experience that humanity has, in particular, linguistic misunderstanding has repeatedly become a direct cause of border disasters. Taking into account the changes taking place in modern seafaring, the Maritime Safety Committee decided in 1992 to create a more complex dictionary than the

SMNV, which later became known as the SMCP (Standardized Maritime Communication Phrases). Knowledge of the existing document is necessary for certification for all officers working on ships of more than 500 tonnage.

In Georgia, the relevant standards have been adopted in accordance with the above-mentioned international documents: see the "Georgian Maritime Code" (http://www.economy.ge/uploads/kanonmdebloba/transporti/Sazgvao_kodeqsi.pdf); the Law of Georgia "On Education and Certification of Seafarers" (http://www.economy.ge/uploads/kanonmdebloba/transporti/mezgvaurta_ganatleba_da_sertificireba.pdf). It is also worth considering that a number of articles and provisions have been added to the "Georgian Maritime Code" in accordance with the "International Convention on Standards of Training and Watchkeeping for Certified Seafarers" (International STCW Convention; Russian: ПДНВ), which was revised in 2010 in Manola.

According to statistics, 20% of maritime accidents are related to language problems in intercultural communication. The vast majority of modern maritime crews are multinational and, accordingly, multilingual. Crew members directly enter into professional dialogue with each other, where speech problems often arise. The need for intercultural communication in the maritime sphere is very high, since when entering different ports, crew members have verbal contact with port workers, customs officers, pilots, etc. The ship's captain and the pilot hired in the port must be able to establish successful communication for safety reasons.

The matter is further complicated by the fact that during informal communication in microgroups, sailors still speak their national language, and when addressed by a member of another microgroup, some have difficulty switching from one language code to another.

From a sociolinguistic perspective, the following types of discourse are distinguished:

a) scientific;

b) political;

c) legal;

d) business;

f) advertising. The matter is further complicated by the fact that during informal communication in microgroups, sailors still speak their national language, and when addressed by a member of another microgroup, some have difficulty switching from one language code to another.

From a sociolinguistic perspective, the following types of discourse are distinguished:

a) scientific;

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f) advertising.

Maritime discourse is characterized by: Maritime discourse is characterized by:

1) patterned speech and a high proportion of clichéd constructions;

2) laconicism and terminological abundance;

3) regulation of the business relationship of communicants and, therefore, a role-based character in accordance with the status of the person concerned;

All of these nuances are achieved by various means and methods, without which it would be impossible to achieve the goals of understanding and communication in professional maritime relations. It is assumed that the participants in these speech acts have similar professional education, a special certificate confirming knowledge of the English language and undergo practice in typical situations. As for the oral or written form of communication, both are active in maritime activities, but depending on the situation, sometimes the oral, sometimes the written form prevails. For example, the business relationship of the ship's crew members is largely oral, but the relationship of the ship's captain with the port management requires filling out a lot of standard

documents. The development of navigation and the scientific and technical revolution have led to another interesting form of business negotiations- official correspondence by e-mail is currently actively used), which in itself raises the need to study the structure and linguistic characteristics of electronic business correspondence. Maritime communication is characterized by a high level of economy in the use of linguistic units. Spoken phrases are condensed, broad, extended sentences are not used, a high proportion of terminology serves the laconicism of the phrase and the accuracy of information. Duplicity, ambiguity, approximate information are not allowed in maritime communication. Accuracy and speed of understanding are of particular importance in maritime communication, since extreme situations are frequent and the fate of sailors depends on the quick and joint actions of all crew members. It can be said that misunderstanding of maritime communication automatically leads to emergency situations (see the examples given above), therefore, possession of maritime terminology and
phraseology should be automatic, since a sailor should not waste time building a phrase correctly.
In most cases, typical phrases used in professional communication have a clichéd character:
Starboard the helm! Port the helm!
In most cases, typical phrases used in professional communication have a clichéd character:
Starboard the helm! Right steering wheel!
Port the helm! Left steering wheel!
Watch you steering!
Clichéd phrases can also be varied:
Get the port (starboard) anchor ready!
My heading is …
For quick response, naval commands are characterized by maximum speech compression, for example:

Language Full phrase	Compressed phrase
Continue to follow the same course!	The same course!
Stop moving immediately!	Stop moving!

The methods of achieving compression are different: in the first case, the construction of the phrase is compressed as a result of ellipsis, the hearer is omitted, and the subject is implied in the role data of the communicants. In the second case, the adverb is compressed.
In the conditions of modern globalization, it has become more convenient to develop a single clichéd maritime phraseology, which undoubtedly simplifies intercultural maritime relations.

Conclusion:

Thus, in a modern multicultural society, in the conditions of globalization and trade economy, the importance of successful communication has increased significantly, including in the professional sphere. Maritime communication is a complex type of intercultural professional communication. Maritime communication is official or unofficial. The first of these is mainly (with rare exceptions) conducted in the international language of sailors- English, and the second is multilingual, since there are many linguocultural groups in international crews.
The training of any professional is focused on the development of professional competence, an important part of which is communicative competence- the knowledge and skills necessary to understand the speech behavior of others and adequately implement one's own speech program.

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Commands and Their Means of Expression in English

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Introduction:

Speech act is an elementary unit of speech communication. The basis of a speech act is the speaker's desire to have an emotional impact on the addressee through informative or non-informative, official or unofficial communication situations. In the structure of language and in speech communication, forms of expression of emotions occupy an important place.

Means of expressing will can be an order, a prohibition, a warning, a request, advice. In the field of speech act, imperative forms play a large role, which express the will of one of the persons.

The grammatical category of verb change is represented by the verb, showing the speaker's attitude to the content of the utterance, or the attitude of the situation to the real world. The verb is a grammatical means of modal meanings. The imperative is an ancient linguistic category that is constantly being replenished with new forms. The imperative is a universal category in languages of various groups and systems (e.g. English, Russian, Georgian, Hungarian, Azerbaijani, Uzbek, etc.), and in each of them it has its own characteristics.

In all fields of human activity- be it technology or medicine, linguistics or engineering, maritime affairs or other ... there are individuals who express the will of the individual, and these people are older than others either in age or in position.

Interest in the forms expressing the will of the subject of speech is explained by the imperative meaning of expression, the diversity of its systematization and, at the same time, the expression of the concepts of the functional-semantic field of special monographic works.

The scientist A.B. Bondarenko and his scientific works on this topic are noteworthy.

The content of the thought expressed by the speaker may be understood as a possibility or desire, as an obligation or necessity. The speaker's assessment of what he or she says, and therefore the relationship between what he or she says and reality, is called modality.

Discussion:

The category of the verb is a grammatical category in the verb system that determines the modality of the action, i.e. expresses the relationship of the action to reality. Thus, the category of the verb is a grammatical means of expressing modality. The category of the verb is determined by the speaker's intention. Intention is the goal of speech, due to which the speech act is performed. The interpretation of the categories of the verb forms the position of the speaking subject and is attributed to the egocentric category, the subject personally evaluates the action as desirable, possible or probable.

The meaning of the command in English is as follows:

Order/Command- a command that must be obeyed;

Directive- general instructions issued by the state;

Instructions- a statement that helps a person understand what is required of him;

Regulation- an official rule;

Request- a request, especially a polite one.

In English, a command is also expressed by an exclamatory sentence, in which the verb is in the imperative mood.

Since the second half of the 20th century, changes in the leading concepts have begun, and in modern concepts, the central place has been taken by spoken language, the speech act, which is

already considered an important part of human life and creativity. Researchers have drawn attention to imperative sentences, which, with their semantic-pragmatic properties, are very closely related to the communicative situation, since the adequate interpretation of commands depends on the diversity of the communicative act. Language objects can convey all kinds of meanings of an imperative sentence- from the most non-categorical, softened, polite to the harsh, clear, insistent and categorical.

According to A.B. Bondarenko, the functional-semantic category has a field structure, the main characteristic of which is the combination of semantic functions of different linguistic levels. The functional-semantic field has its center- a group of forms that express the meaning of a given field with unambiguous accuracy. Peripheral forms are arranged around the center. Passing through the peripheries, each field gradually falls within the framework of other fields through transitions and intersections, and ultimately all fields form a single continuous structure of the language system. The core of the functional-semantic field of the exclamatory sentence category, around which peripheral means expressing the modality of the exclamatory sentence are grouped, are imperative sentences, where the hearer is expressed by a verb in a command form. We will divide them into two groups: exclamatory sentences with a polite and clear categorical tone. By adding the word “Please” to the structure of the imperative sentence, the expressed idea is given a polite tone;

-Papa, please try to act like a human being”-she said.

To achieve greater expressiveness in exclamatory sentences, the so-called “tags” are used: “will you”; “won you”; “shall we”... In these cases, the motive for committing the action is a scolding or invitation: “Let s sit down, shall we?”

An exclamatory sentence will be strengthened if the emphatic “do” is used at the beginning of the sentence. In this case, the insistent and categorical character of the verb is expressed. According to G.A. Weikhman, this type of imperative sentence is characteristic of women's speech and South American dialects: “Do shut up!” Such a stylistic device (inserting “do” before the verb does not cause any grammatical changes) : “do hurry up, please!!”

In spoken language, general questions with the auxiliary verbs “will” ,”shall”
“should”,”would” are common, which express a very gentle and polite request: “Will you ?
please signal it, than, so that I may be put ashore?”

Particular attention should be paid to the use of special interrogative sentences in exclamatory sentences with different emotional-semantic shades, from irritation, threat, mockery to advice and desire:

“How about eating?”

To express tactful polite pressure in exclamatory sentences, modal verbs are usually used: “can”, “could”, “may”, “must”- “You can try it again”,

“you must decide”, the verb “must” is often used in commands and orders: “You must do it by tomorrow”. The verb “may” is often used in written instructions and orders: “Visitors may not bring alcoholic drinks”.

Sometimes in real life situations, verbs in the future tense are used to express categorical orders, rudeness, and familiarity: “She shall get out.” “Shall” in the 3rd person is also used to express commands in more formal, written speech. The s is a construction of the subjunctive + shall and is usually used with the passive voice, i.e.-shall be + past tense infinitive (3rd form of the verb):

“The chairman shall be elected annually”

In formal oral and written speech, the construction subject+will is used. This is the impersonal form of a command and is used when the person giving the command is sure that it will definitely be carried out:

“ In emergency the crew will assemble on deck”

t is especially used in written instructions by authorized superiors (captains, directors, etc.) as well as in oral commands: “You will not mention my opinion to anyone”. A more polite form would be: “You mustn’t mention your opinion to anyone”.
If the speaker wants his command to be more rigid/rude and thus show superiority, he should put the 2nd person pronoun-You- in front of the verb in the command, and this makes the command more purposeful:
“You go there. I’ll wait here.”
It is also possible to call someone with the verb “Let”. This is a complex form of the imperative form, which is followed by a noun in the general case or a personal pronoun in the objective case and a substantive verb in the infinitive form without the-to- particle: “Let me hear what they said about me”; ”Let them leave”;
“Let’s have our dinner.”
The following construction is often used in instructions and commands: be+to-infinitive,-to be-verb has only present and past indefinite tense forms (am, is, are, was, were):
“No one is to leave work before 6 o’clock”; “He is to come here tomorrow.”
f we encounter the pronoun-You- in such constructions, this indicates that the command does not belong to the speaker and is given to another person (i.e., the command is indirect):
“Stay here, Tom!”- direct command; “You are to stay here, Tom” (indirect command.
Noteworthy is the use of “should” in the subordinate clause of the addition, where the verb expresses a decision, a clear, firm, insistent request, an order, a proposal, advice.
All verbs with these meanings are followed by “Should” (to decide, to demand, to require, to insist, to advise, to recommend , to suggest, to propose, to agree, to arrange, to order,to command...):
-He ordered that the steamer should be discharged at once.
-The sellers demanded that payment should be made within five days.
-The doctor insists that he should go to the south.
-He recommended that the case postponed.
After these verbs, instead of-should-, the Present Subjunctive is used with the infinitive, (especially in the United States):
-The sellers demanded that payment be made within five days.
-He ordered that the steamer be discharged at once.
-The verb-to insist is often followed by the gerundive:
-The doctor insists on his going to the south.
-It is also common to use the objective case + infinitive after verbs expressing commands:
-He ordered the steamer to be discharged at once.
I share the opinion of B.B. Buzarov, who notes in his works that from the standpoint of lexical-grammatical theory, sentence-free exclamatory sentences are two-membered formations, the subject-predicate composition of which is made possible by the main member of this sentence. Despite the fact that such sentences are one-membered externally, they are two-membered internally, since the representation of the subject and the representation of the predicate are in agreement with each other.
In imperative sentences with a verbless imperative, the imperative intention is expressed by such parts of speech as a noun, adverb, gerund, and others. Most often, in imperative sentences with a verbless exclamatory sentence, the adverb is used:
“Away!”-he cried harshly;
“Down, Pilot”
“Forward!-said Holmes.
The second most common form of command is the noun:
“Dinner”-said he. This is an example of a command, a standard, template form that is used in official spheres:

“Port!”; “Starboard!”; ”Midships!”; “Steady!”
Orders expressed in negative gerund constructions have the meaning of prohibition and belong to the rules of behavior in public places:
“No Smoking!”; “No Parking!”
In English, prohibition is mainly expressed by the following lexemes: prohibit, forbid, ban, veto, outlow, taboo, embargo, interdict.
Prohibit, ban, forbid-are institutionalized prohibitions of a broader meaning (parliament, court, legislative and administrative bodies);
Veto, outlaw, taboo, embargo, interdict- are more narrowly specialized prohibitions with a limited scope of social references.
The lexeme Veto- functions as a marker of prohibition in relations between parliaments and parliaments;
The lexeme Outlaw- as a marker of legal prohibition
The lexeme Taboo- as a marker of sociocultural prohibition;
The lexeme Interdict- as a marker of religious and legal prohibitions;
The lexeme Embargo- as a marker of trade prohibition.

Conclusion:
Thus, it can be safely said that the English language is quite rich in means of expressing commands, which are a major part of our daily life and our speech.
The means of expressing commands and prohibitions require further in-depth study and comparison with similar means in other languages, since they are an important part of the human speech act and through them social and industrial actions are carried out in society.
It is a pleasant fact that scientists and researchers have drawn attention to imperative sentences, which, with their semantic-pragmatic properties, are very closely related to the communicative situation, it is precisely on the diversity of the communicative act that the adequate interpretation of the command depends.

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Envoyer des commentaires

Psychological Sciences

Psychoeducational interventions for reducing emotional distress in women with cancer during rehabilitation

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Abstract

Cancer is associated not only with physical impairment but also with substantial psychological burden, including anxiety, depressive symptoms, fear, emotional tension, changes in self-perception, and difficulties in social adaptation. These problems are particularly relevant among women with breast cancer and malignancies of the reproductive system, for whom treatment may additionally affect body image, femininity, interpersonal relationships, and social functioning. The aim of this review was to analyze the role of psychoeducational and related psychological interventions in reducing emotional distress and facilitating psychological adaptation during cancer rehabilitation. Four Russian-language studies addressing emotional distress, psychological and psychotherapeutic rehabilitation, social support, and psychological interventions in women with cancer were analyzed. The reviewed evidence indicates a high prevalence of emotional distress and anxiety-depressive symptoms among cancer patients and demonstrates the potential benefits of interventions combining psychoeducation, cognitive-behavioral techniques, relaxation and self-regulation training, psychological support, and work with illness-related beliefs. Particular attention should be given to the development of adaptive coping skills, acceptance of the illness situation, mobilization of personal resources, and effective use of social support. The findings support the integration of structured psychoeducational components into comprehensive rehabilitation programs for women with cancer.

Keywords: *psychoeducation, cancer, breast cancer, rehabilitation, emotional distress, anxiety, depression, psychological intervention, social support.*

Introduction

Advances in cancer diagnosis and treatment have increased survival rates and, consequently, have shifted attention toward the long-term psychological and social consequences of cancer. Rehabilitation therefore extends beyond the restoration of physical functioning and includes psychological adaptation, social reintegration, and improvement of quality of life. Kiryukhina et al. emphasize that psychological rehabilitation represents an integral component of comprehensive cancer rehabilitation and should facilitate patients' adaptation to illness and improve their quality of life.

Emotional distress may occur at different stages of the cancer trajectory. Anxiety, depression, fear of recurrence, uncertainty regarding treatment outcomes, altered body image, and disruption of social roles can persist beyond active treatment and interfere with recovery. According to Kiryukhina et al., adaptation among cancer patients is directly associated with anxiety and depression, while persistent emotional symptoms may contribute to secondary psychological disturbances, neurotic fixation, and demoralization.

The magnitude of this problem is demonstrated by studies of emotional distress in oncology. Chulkova et al. analyzed distress among patients undergoing diagnostic assessment and hospitalization and found that more than 40% reported elevated levels of illness- and treatment-related emotional experiences. Women were particularly represented among patients reporting high emotional tension. Breast cancer patients were identified as one of the groups with the greatest need for professional psychological assistance.

The psychological consequences of breast and reproductive system cancers may be particularly complex because they affect not only health but also body image, femininity, sexuality, family relationships, and perceived social value. Berezantsev et al. reported that women following breast cancer surgery frequently experienced anxiety, uncertainty about the future, lowered mood, sleep disturbances, concerns about recurrence, reduced social participation, and fears related to changes in appearance and interpersonal relationships.

These findings suggest a need for psychological interventions that provide patients not only with emotional support but also with knowledge and practical skills for managing psychological reactions to cancer. Psychoeducation may be particularly suitable for this purpose because it can combine information about common emotional reactions with training in self-regulation, coping, cognitive restructuring, communication, and the effective use of social resources.

The aim of this review was to analyze evidence concerning psychoeducational and related psychological approaches to reducing emotional distress and supporting psychological adaptation in women with cancer during rehabilitation.

Materials and Methods

A narrative analytical review was conducted using four Russian-language publications addressing psychological rehabilitation and psychosocial adaptation among cancer patients, with particular attention to women with breast cancer and cancers of the reproductive system.

The analysis included the study by Chulkova et al. on emotional distress and psychological rehabilitation in cancer patients; the study by Berezantsev et al. examining clinical and psychological aspects of rehabilitation following breast cancer treatment; the study by Kiryukhina et al. describing principles and methods of psychological and psychotherapeutic rehabilitation in oncology; and the study by Orlova examining predictors of subjective social support among women with cancers of the reproductive system.

The publications were analyzed according to four thematic domains: **(1)** prevalence and manifestations of emotional distress; **(2)** psychological targets of rehabilitation; **(3)** components of psychological and psychoeducational interventions; and **(4)** psychological and social resources potentially facilitating successful rehabilitation.

Because the selected publications differed substantially in their designs, samples, outcome measures, and types of psychological intervention, quantitative meta-analysis was not performed. Instead, findings were integrated using narrative thematic synthesis.

Results

Emotional distress as a target of cancer rehabilitation

The reviewed studies consistently demonstrate that psychological distress constitutes an important component of the cancer experience. Chulkova et al. screened 4,113 patient forms, including 2,113 completed in an outpatient diagnostic setting and 2,000 during hospitalization. Among outpatients, 41% reported emotional experiences outside the normative range, while 44% of hospitalized patients reported abnormal levels of emotional tension.

Breast cancer patients appeared particularly psychologically vulnerable. In a more detailed sample of 35 women aged 32–66 years, 74.3% were in the postoperative period. The most common initial reactions to the diagnosis were shock (54.8%), fear (19.4%), and denial (16.1%). Furthermore, 57.1% reported treatment-related fears, most commonly concerning pain and changes in physical appearance.

Similar findings were reported by Berezantsev et al. in 110 women who had undergone radical surgery for breast cancer. Borderline mental disorders were identified in 68.18% of the sample, while 31.82% demonstrated subclinical psychological disturbances. Among diagnosed conditions, mixed anxiety-depressive adjustment reactions and prolonged depressive reactions were observed, demonstrating the relevance of anxiety and depressive symptoms as major rehabilitation targets.

Kiryukhina et al. provide further evidence from a substantially larger oncology sample. Their assessment of 1,030 hospitalized cancer patients using the Hospital Anxiety and Depression Scale indicated clinically relevant psychological problems across different cancer localizations and treatment settings. During treatment, elevated emotional symptoms were reported in radiology and chemotherapy departments, while among 295 patients evaluated in 2018, pronounced anxiety was identified in 18%, depression in 10%, and particularly high combined symptom severity in 25% of cases.

Together, these findings indicate that emotional distress is not limited to diagnosis but may continue during treatment and rehabilitation, supporting systematic psychological screening throughout the cancer trajectory.

Psychoeducational components of psychological rehabilitation

The analyzed literature suggests that effective psychological rehabilitation should combine emotional support with the acquisition of practical psychological skills. Kiryukhina et al. describe psychological assistance as including work with anxiety, fear, irritability and depressed mood; identification of internal psychological resources; training in self-regulation and relaxation; formation of an adaptive attitude toward illness; expansion of behavioral strategies; and effective use of external support.

These elements closely correspond to the functional structure of psychoeducation. Rather than positioning the patient as a passive recipient of psychological assistance, psychoeducational work may help her understand emotional reactions, recognize maladaptive patterns, and acquire techniques that can subsequently be used independently.

This principle is particularly important during rehabilitation, when contact with healthcare professionals may become less intensive while patients continue to face uncertainty, fear of recurrence, altered social roles, and difficulties returning to everyday life. Accordingly, the development of self-management skills may provide a bridge between professional psychological care and independent long-term adaptation.

Kiryukhina et al. specifically emphasize techniques that patients can subsequently practice independently. Their rehabilitation program included breathing exercises, visualization, meditation, relaxation, and art therapy. Group interventions also incorporated emotional expression, psychological support, identification of recovery resources, and training in relaxation, visualization, and meditation for reducing anxiety and fear.

Evidence from interventions in women with breast cancer

The study by Berezantsev et al. provides the clearest evidence in the reviewed literature for combining educational and psychotherapeutic approaches. Their intervention included suggestive methods such as hypnotherapy, autogenic training and Jacobson relaxation, together with rational approaches including **cognitive-behavioral psychotherapy and short-term educational programs**. Intervention selection was individualized according to coping strategies, psychological defense mechanisms, and quality-of-life assessment.

Thirty-five women received group or individual hypnotherapy, with 10–20 sessions per patient; 19 of them were additionally trained in self-hypnosis and Jacobson relaxation. Ten patients underwent individual cognitive-behavioral therapy consisting of 7–12 sessions. Cognitive work targeted dysfunctional beliefs contributing to anxiety and reduced emotional well-being, including

beliefs concerning social reactions to cancer, misconceptions about malignant disease, and unrealistic expectations regarding rapid return to previous levels of functioning.

Clinically meaningful positive changes were observed following these interventions. Quality-of-life indicators improved following both hypnotherapy and cognitive-behavioral therapy. Cognitive-behavioral intervention was associated with improvements in psychological functioning, independence, social relationships, and the spiritual domain. Anxiety and depression scores on the Hamilton scales also decreased after both types of psychotherapy.

These findings are particularly relevant to psychoeducational intervention design. They suggest that providing information alone may be insufficient. Educational material can be combined with cognitive restructuring and practical self-regulation training so that patients acquire both an understanding of their psychological reactions and concrete tools for modifying them.

Social support as a psychoeducational resource

Another important dimension concerns the patient's social environment. Orlova studied 28 women with cancers of the reproductive system and 48 healthy women and demonstrated significant differences in several dimensions of perceived social support. Women with cancer showed higher scores for reliable alliance, emotional attachment, reliance on authority, and care/protection.

Importantly, acceptance of the illness situation and acceptance of oneself within that situation were identified as major predictors of subjective social support among women with cancer. The patients also demonstrated a strong orientation toward cooperation with their social environment, emotional closeness, reliance on others' resources, and the need to experience themselves as important to others.

These results expand the potential scope of psychoeducation. A rehabilitation program aimed at emotional distress should therefore address not only individual emotional regulation but also communication and help-seeking behavior. Teaching patients how to recognize their need for support, communicate this need to family members, and use available social resources may strengthen psychological adaptation.

Discussion

The reviewed evidence supports a multidimensional understanding of emotional distress in women undergoing cancer treatment and rehabilitation. Distress arises from the interaction of illness-related threat, uncertainty, treatment burden, altered body image, dysfunctional beliefs, reduced social functioning, and changes in interpersonal relationships. Consequently, psychological rehabilitation is unlikely to be optimally effective when restricted to a single therapeutic mechanism.

A psychoeducational model offers a useful framework for integrating these dimensions. The findings of Chulkova et al. demonstrate the importance of early identification of emotional distress, particularly among women with breast cancer. Their results indicate that psychological difficulties are common and can include shock, fear, denial, and concerns regarding treatment and appearance. Thus, screening may represent the first stage of a differentiated psychoeducational intervention, allowing the intensity and content of subsequent psychological support to be adapted to individual needs.

The results reported by Berezantsev et al. indicate that emotional distress is connected with maladaptive beliefs and coping mechanisms rather than representing an isolated emotional response. Their cognitive-behavioral intervention targeted distorted beliefs concerning cancer, social attitudes, and rehabilitation, while relaxation-based interventions provided patients with practical self-regulation skills. This combination is particularly compatible with psychoeducation because it connects three mechanisms: knowledge, cognitive processing, and behavioral skill acquisition.

The findings of Kiryukhina et al. further support this model. Psychological rehabilitation included self-regulation and relaxation training, development of a more adaptive attitude toward illness, expansion of behavioral strategies, and appropriate use of external support. These components suggest that psychoeducation in cancer rehabilitation should not be reduced to simply providing medical or psychological information. Its therapeutic potential lies in translating information into psychological competencies that can be applied independently in everyday life.

Social support represents another important mechanism. Orlova's findings demonstrate that acceptance of the illness situation and self-acceptance are associated with subjective perceptions of social support, while women with reproductive cancers place considerable importance on emotional closeness and cooperation with others. Psychoeducational interventions may therefore benefit from including modules devoted to interpersonal communication, identification of available support resources, requesting assistance, maintaining family relationships, and adapting social roles following treatment.

Taken together, the reviewed findings allow a preliminary conceptual structure for psychoeducational rehabilitation to be proposed. Such an intervention may include: education about common psychological responses to cancer; recognition and monitoring of emotional distress; cognitive work with dysfunctional illness-related beliefs; relaxation and self-regulation training; development of adaptive coping strategies; strengthening of self-acceptance; and effective mobilization of family and social support.

An important feature of this approach is patient autonomy. During active treatment, psychological support may be provided directly by healthcare professionals, whereas during rehabilitation women increasingly need to manage emotional reactions outside the clinical setting. Teaching techniques that can be practiced independently may therefore contribute to continuity of psychological care.

At the same time, the evidence reviewed here has important methodological limitations. The included studies differ considerably in patient populations, cancer localization, stage of treatment, psychological assessment instruments, and intervention approaches. Not all studies directly evaluated structured psychoeducational programs, and the available evidence does not permit conclusions regarding the independent effect of psychoeducation compared with other psychological interventions. The findings should therefore be interpreted primarily as a theoretical and empirical basis for the development and subsequent testing of structured psychoeducational rehabilitation programs.

Conclusion

Emotional distress is a significant component of the cancer experience and may persist across diagnosis, treatment, and rehabilitation. Women with breast cancer and cancers of the reproductive system may experience anxiety, depressive symptoms, fear, changes in body image, dysfunctional illness-related beliefs, and difficulties in social adaptation. The reviewed studies indicate that psychological rehabilitation can address these problems through a combination of cognitive, emotional, behavioral, and social mechanisms.

Psychoeducational approaches appear particularly promising because they can integrate information about psychological reactions to cancer with cognitive-behavioral techniques, relaxation and self-regulation skills, adaptive coping strategies, self-acceptance, and effective use of social support. Evidence from women with breast cancer suggests that individually selected psychological interventions incorporating cognitive-behavioral and educational components are associated with reduced anxiety and depressive symptoms and improved quality of life.

Therefore, structured psychoeducational interventions may represent a valuable component of comprehensive rehabilitation for women with cancer. Further controlled studies are required to

evaluate their effectiveness specifically in reducing emotional distress and to determine the optimal content, duration, format, and timing of such programs.

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Medical Sciences

SCIENTIFIC PERSPECTIVES ON EPILEPSY: INTEGRATING NEUROIMMUNOLOGY, GENETICS, PRECISION PHARMACOTHERAPY, TRANSLATIONAL MEDICINE, EMERGING THERAPEUTIC INNOVATIONS, AND COMPREHENSIVE CLINICAL MANAGEMENT STRATEGIES

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ABSTRACT
Epilepsy is a heterogeneous and multifactorial neurological disorder characterized by recurrent seizures arising from pathological neuronal hyperexcitability and hypersynchronous network activity. Contemporary scientific understanding has progressively expanded beyond a predominantly electrophysiological model toward an integrated framework encompassing neuroimmunology, genetics, molecular neuroscience, precision pharmacotherapy, translational medicine, and comprehensive clinical management. This scientific perspective examines epilepsy as a dynamic systems disorder in which genetic susceptibility, ion-channel dysfunction, altered neurotransmission, synaptic remodeling, neuroinflammation, oxidative stress, mitochondrial impairment, metabolic disturbances, vascular abnormalities, and structural brain pathology interact to initiate and sustain epileptogenesis. Particular emphasis is placed on neuroimmune mechanisms, including microglial and astrocytic activation, cytokine signaling, blood–brain barrier dysfunction, and autoimmune processes involving neuronal surface and intracellular antigens. The recognition of autoimmune epilepsy has strengthened the rationale for immunological evaluation and mechanism-based interventions in selected patients. Genetic and epigenetic investigations have simultaneously revealed substantial molecular heterogeneity involving ion channels, synaptic proteins, developmental pathways, mammalian target of rapamycin signaling, transcriptional regulation, DNA methylation, histone modification, and regulatory non-coding RNAs. These discoveries provide an increasingly sophisticated foundation for molecular classification and individualized therapeutic strategies. The therapeutic landscape continues to evolve through advances in antiseizure pharmacotherapy, therapeutic drug monitoring, pharmacogenomics, pharmacovigilance, immunotherapy, targeted molecular treatment, neuromodulation, metabolic interventions, and emerging disease-modifying approaches. Nevertheless, pharmacoresistance remains a major clinical challenge, while adverse drug reactions, drug interactions, comorbidities, treatment adherence, and unequal access to specialized care continue to influence outcomes. Precision pharmacotherapy therefore requires integration of clinical phenotype, genetic and molecular characteristics, pharmacokinetic and pharmacodynamic information, biomarkers, therapeutic response, and patient-specific risk factors. Advanced neuroimaging, electrophysiology, multi-omics technologies, computational neuroscience, artificial intelligence, and digital health are increasingly enabling earlier diagnosis, improved epileptogenic network characterization, prognostic assessment, and individualized treatment selection. Translational research provides an essential bridge between mechanistic discoveries and clinically applicable interventions, particularly in the pursuit of antiepileptogenic and neuroprotective therapies capable of modifying disease progression rather than merely suppressing seizures. The contemporary epilepsy science supports a multidisciplinary, precision-oriented paradigm integrating molecular mechanisms, neuroimmune regulation, genetic architecture, advanced diagnostics, pharmacological innovation, safety surveillance, and personalized clinical care. Continued interdisciplinary collaboration and rigorous translational investigation are essential to overcome pharmacoresistance, reduce neurological and psychosocial burden, improve

therapeutic safety, and establish more predictive, preventive, and disease-modifying approaches to epilepsy management worldwide. The clinical implications of this integrated model extend across the lifespan and across etiological subtypes, including developmental, structural, genetic, autoimmune, metabolic, post-traumatic, vascular, infectious, and neurodegenerative epilepsies. Age-dependent differences in neurodevelopment, pharmacokinetics, comorbidity profiles, and treatment vulnerability further reinforce the necessity of individualized care. Comprehensive management should consequently incorporate seizure control, cognitive and psychiatric assessment, and prevention of medication-related harm, psychosocial support, patient education, and continuous reassessment of therapeutic effectiveness. Future research should prioritize validated biomarkers, mechanistically informed clinical trials, longitudinal real-world evidence, interoperable data systems, and equitable implementation of innovative technologies. Such approaches may accelerate the transition from reactive seizure management toward precision prevention, early intervention, and durable improvement in neurological function and quality of life. This transformation requires patient-centered, evidence-based, ethically responsible implementation of emerging scientific discoveries.

INTRODUCTION

Epilepsy is a chronic neurological disorder characterized by an enduring predisposition to generate epileptic seizures, accompanied by significant neurobiological, cognitive, psychological, and social consequences. As one of the most common neurological diseases worldwide, epilepsy affects millions of individuals across diverse populations and remains a major contributor to disability, healthcare burden, and reduced quality of life. Despite substantial advances in neuroscience, diagnostic technologies, and pharmacological treatment, epilepsy continues to represent a complex clinical challenge due to its heterogeneous etiology, unpredictable disease course, variable therapeutic response, and persistent occurrence of drug-resistant cases. The multifaceted nature of epilepsy requires a comprehensive scientific approach that integrates molecular neuroscience, immunology, genetics, pharmacology, clinical medicine, and translational research.

Historically, epilepsy was primarily considered a disorder of abnormal electrical activity within the brain, with therapeutic strategies focused mainly on controlling seizure occurrence through modulation of neuronal excitability. However, recent scientific discoveries have significantly expanded this perspective, demonstrating that epilepsy involves complex interactions among neuronal networks, immune pathways, genetic determinants, metabolic processes, vascular mechanisms, and environmental influences. Current evidence supports the concept that epileptogenesis is a dynamic biological process involving progressive alterations in cellular signaling, synaptic organization, inflammatory responses, and neural network connectivity. This evolving understanding has shifted epilepsy research from symptom suppression toward identification of underlying mechanisms responsible for disease initiation, progression, and therapeutic resistance.

A major advancement in contemporary epilepsy science is the recognition of immune dysregulation and neuroinflammation as important contributors to disease pathogenesis. The central nervous system possesses sophisticated immune regulatory mechanisms involving microglia, astrocytes, cytokines, chemokines, complement pathways, and interactions between neural and immune cells. Disruption of these mechanisms can promote neuronal hyperexcitability, synaptic dysfunction, and pathological network synchronization. Inflammatory mediators, oxidative stress pathways, and impaired neurovascular regulation have been implicated in multiple epilepsy conditions, including autoimmune epilepsy, post-traumatic epilepsy, infection-related epilepsy, and epilepsy associated with neurodegenerative processes. These findings have

stimulated research into immunological biomarkers and therapeutic strategies aimed at modifying disease progression.

The concept of multidimensional pathogenesis has become fundamental to understanding epilepsy as a complex neurological syndrome rather than a single disease entity. Genetic abnormalities affecting ion channels, neurotransmitter receptors, synaptic proteins, and neuronal development pathways contribute to inherited and developmental epileptic disorders. Acquired epilepsies may arise following traumatic brain injury, stroke, central nervous system infections, tumors, metabolic disturbances, or inflammatory disorders. In addition, epigenetic modifications, mitochondrial dysfunction, impaired energy metabolism, and alterations in the blood–brain barrier contribute to the development and persistence of epileptic networks. This biological complexity explains the variability in clinical manifestations, treatment response, and prognosis observed among patients with epilepsy.

Advances in diagnostic science have transformed the evaluation and classification of epilepsy. Traditional diagnostic approaches based on clinical observation and electroencephalography have been enhanced by high-resolution neuroimaging, molecular genetic analysis, biomarker discovery, artificial intelligence applications, and computational neuroscience. Modern diagnostic frameworks increasingly emphasize the identification of specific disease mechanisms, epileptogenic networks, and predictive biological signatures. These innovations allow earlier diagnosis, improved classification, more accurate localization of seizure-generating regions, and better selection of therapeutic interventions.

Pharmacological management remains the foundation of epilepsy treatment, with antiseizure medications representing the primary therapeutic approach for controlling seizures and improving patient outcomes. Modern antiseizure drugs act through diverse molecular mechanisms, including modulation of voltage-gated ion channels, enhancement of inhibitory neurotransmission, suppression of excitatory signaling, and regulation of synaptic vesicle function. Although these therapies have significantly improved seizure control for many patients, major challenges remain, including pharmacoresistance, adverse drug reactions, drug interactions, cognitive and psychiatric effects, and variability in individual treatment responses. Approximately one-third of patients continue to experience uncontrolled seizures despite appropriate pharmacological therapy, emphasizing the urgent need for innovative therapeutic strategies.

The emergence of precision medicine has introduced a new paradigm in epilepsy management by integrating genetic, molecular, clinical, and pharmacological information to guide individualized treatment decisions. Precision pharmacotherapy aims to optimize medication selection, dosing strategies, and therapeutic monitoring according to patient-specific characteristics. Pharmacogenomic research has revealed genetic variations influencing drug metabolism, transporter activity, receptor sensitivity, and susceptibility to adverse effects. These discoveries provide opportunities for improving treatment effectiveness while minimizing medication-related complications.

Pharmacovigilance has become an essential component of modern epilepsy care due to the long-term nature of antiseizure medication use and the potential for clinically significant adverse effects. Continuous evaluation of medication safety, real-world effectiveness, drug interactions, and rare complications is necessary to maintain an optimal balance between therapeutic benefits and risks. Systematic pharmacovigilance approaches, including post-marketing surveillance, electronic health record analysis, and observational studies, contribute to safer prescribing practices and improved patient outcomes.

Therapeutic safety is particularly important in epilepsy because many patients require lifelong treatment, often involving multiple medications and complex clinical considerations. Adverse effects such as severe hypersensitivity reactions, hepatotoxicity, hematological abnormalities, metabolic complications, reproductive risks, and neuropsychiatric effects may substantially

influence treatment adherence and quality of life. Therefore, individualized risk assessment, therapeutic drug monitoring, patient education, and multidisciplinary clinical supervision are essential components of effective epilepsy management.

Clinical prognostication represents another rapidly advancing area of epilepsy research. Accurate prediction of seizure recurrence, treatment response, remission probability, cognitive outcomes, and progression toward drug-resistant epilepsy remains a major clinical objective. Integration of clinical variables with neuroimaging data, electrophysiological characteristics, genetic information, and molecular biomarkers may improve prognostic accuracy and enable early identification of patients requiring alternative therapeutic strategies.

The development of translational neuroscience has accelerated the movement of epilepsy research from experimental discoveries toward clinical applications. Investigations into molecular mechanisms, immune pathways, neural networks, and therapeutic targets are generating new opportunities for disease-modifying interventions. Emerging approaches, including targeted molecular therapies, immunomodulation, gene-based treatments, advanced neuromodulation technologies, and artificial intelligence-assisted clinical decision systems, represent promising directions for the future of epilepsy care.

Despite remarkable scientific progress, significant challenges remain in achieving comprehensive control of epilepsy worldwide. Limited access to specialized diagnostic services, disparities in treatment availability, social stigma, inadequate awareness, and unequal healthcare resources continue to affect millions of individuals. Addressing these challenges requires international cooperation, interdisciplinary research, healthcare innovation, and implementation of evidence-based strategies that integrate scientific discoveries into clinical practice.

Contemporary epilepsy science is undergoing a transformative transition toward an integrated and precision-oriented framework. The convergence of neuroimmunology, molecular pathogenesis, advanced diagnostics, precision pharmacotherapy, pharmacovigilance, therapeutic safety science, clinical prognostication, and translational research provides a foundation for developing more effective, safer, and individualized approaches to epilepsy prevention, diagnosis, and treatment. This evolving scientific landscape offers new possibilities for improving patient outcomes and advancing global neurological healthcare.

The global burden of epilepsy extends beyond its neurological manifestations, encompassing substantial medical, psychological, socioeconomic, and public health consequences. Individuals living with epilepsy frequently experience limitations in education, employment opportunities, social participation, and personal independence due to unpredictable seizures, medication-related effects, and persistent societal stigma. The complexity of epilepsy requires healthcare systems to move beyond a seizure-control model toward comprehensive disease management strategies that address neurological function, mental health, cognitive performance, safety concerns, and overall quality of life. Consequently, modern epilepsy care increasingly emphasizes multidisciplinary collaboration involving neurologists, clinical pharmacologists, neuroscientists, genetic specialists, psychologists, rehabilitation professionals, and public health experts.

The recognition of epilepsy as a network disorder has significantly influenced contemporary research perspectives. Rather than representing isolated abnormalities within specific brain regions, epileptic activity is now understood as a consequence of pathological interactions among distributed neural circuits. Alterations in structural and functional connectivity, abnormal synchronization patterns, and impaired regulation of excitation–inhibition balance contribute to seizure generation and propagation. Network-based approaches have improved understanding of epileptogenic zones and provided new opportunities for developing targeted interventions. Advanced computational models, connectomic analyses, and personalized network mapping are increasingly being incorporated into epilepsy research to improve diagnostic precision and therapeutic planning.

A growing body of evidence highlights the importance of cellular and molecular mechanisms involved in neuronal resilience, vulnerability, and repair. Neuronal survival following injury or repeated seizure activity depends on complex interactions between inflammatory signaling, oxidative stress regulation, apoptosis pathways, neurotrophic factors, and cellular energy metabolism. Dysregulation of these processes may contribute not only to seizure generation but also to progressive neurological impairment. Understanding these mechanisms has encouraged investigations into neuroprotective therapies designed to preserve neuronal function and prevent long-term pathological changes.

The role of inflammation in epilepsy has expanded from a secondary pathological phenomenon to a potential therapeutic target. Experimental and clinical studies demonstrate that inflammatory cascades may influence seizure threshold, neuronal excitability, synaptic remodeling, and disease progression. Activation of innate immune responses, including toll-like receptor signaling, inflammasome activation, and cytokine-mediated pathways, has been associated with epileptogenic processes. These discoveries have stimulated interest in anti-inflammatory and immunomodulatory approaches that could complement traditional antiseizure therapies. However, identifying appropriate therapeutic targets remains challenging because immune responses also play essential physiological roles in maintaining brain homeostasis and repair.

Autoimmune mechanisms represent a particularly important area of epilepsy investigation. Autoimmune epilepsy may occur when immune responses target neuronal surface proteins, intracellular antigens, or synaptic components, resulting in altered neuronal signaling and seizure activity. The identification of specific autoantibodies has improved recognition of immune-mediated epilepsy and highlighted the importance of early diagnosis. Timely immunological evaluation and appropriate treatment may prevent irreversible neurological damage in selected patients. These developments demonstrate the increasing importance of integrating immunological assessment into modern epilepsy diagnostic pathways.

Genetic research has fundamentally transformed the understanding of epilepsy etiology. The identification of pathogenic variants associated with ion channel dysfunction, neurotransmitter regulation, synaptic development, and metabolic pathways has provided new explanations for previously unexplained epilepsy cases. Genetic findings have also demonstrated significant variability in disease expression, even among individuals with similar mutations, emphasizing the influence of additional biological and environmental factors. Future advances in genomic medicine may enable increasingly precise molecular classification and facilitate targeted therapeutic interventions.

The emergence of epigenetics has further expanded understanding of how environmental influences and biological experiences regulate epilepsy-related processes. Epigenetic modifications can influence gene expression without altering DNA sequences and may contribute to neuronal adaptation, inflammatory regulation, and long-term changes in brain function. Mechanisms involving DNA methylation, histone modification, and regulatory RNA molecules are being investigated as potential biomarkers and therapeutic targets. These findings suggest that epilepsy development may involve complex interactions between inherited susceptibility and acquired biological changes.

Metabolic regulation represents another essential component of epilepsy biology. The brain requires continuous energy availability to maintain electrical activity and synaptic communication. Disturbances in glucose transport, mitochondrial function, lipid metabolism, and cellular energy pathways may increase neuronal susceptibility to hyperexcitability. The clinical success of metabolic therapies, particularly ketogenic dietary interventions in selected patient populations, demonstrates the therapeutic relevance of targeting metabolic mechanisms. Future research may identify additional metabolic pathways suitable for pharmacological modulation.

The advancement of biomarker research remains a critical priority for improving epilepsy diagnosis and management. Currently, clinical assessment relies heavily on seizure history, electroencephalographic findings, and imaging results; however, these approaches may not fully capture underlying biological variability. Molecular, inflammatory, genetic, metabolic, and electrophysiological biomarkers could provide valuable information regarding disease classification, treatment selection, therapeutic response, and prognosis. The integration of multiple biomarker domains through systems biology and artificial intelligence approaches represents a promising direction for personalized epilepsy medicine.

The therapeutic landscape of epilepsy continues to evolve through the development of innovative pharmacological and non-pharmacological approaches. New-generation antiseizure medications have expanded treatment options by providing improved tolerability profiles and novel mechanisms of action. However, the challenge of pharmacoresistance remains unresolved, requiring continued investigation into mechanisms underlying inadequate treatment response. Research into drug transport mechanisms, receptor alterations, inflammatory pathways, and genetic determinants of pharmacoresistance may contribute to the discovery of strategies capable of overcoming therapeutic failure.

Combination therapy remains an important component of epilepsy management, particularly among patients with persistent seizures. However, polytherapy increases the complexity of medication management and may elevate the risk of drug interactions and adverse effects. Clinical pharmacology principles, including pharmacokinetic assessment, pharmacodynamic evaluation, and therapeutic drug monitoring, are therefore essential for optimizing treatment regimens. Individualized medication management aims to achieve maximum seizure control while minimizing toxicity and maintaining patient quality of life.

Pharmacovigilance has gained increasing importance as the number of available antiseizure medications continues to expand. Clinical trials, although essential, may not detect all safety concerns due to limited sample sizes, restricted patient populations, and relatively short observation periods. Real-world surveillance provides additional information regarding rare adverse events, long-term complications, medication adherence, and comparative treatment effectiveness. Integration of pharmacovigilance data into clinical guidelines supports evidence-based prescribing and improves patient safety.

The future of epilepsy treatment is increasingly focused on disease modification rather than symptomatic suppression alone. Current antiseizure therapies primarily reduce seizure frequency but generally do not prevent the development of epilepsy following brain injury or other initiating events. Disease-modifying approaches aim to interfere with epileptogenic mechanisms before permanent network changes occur. Potential strategies include immune regulation, neuroprotection, genetic correction, metabolic modulation, and targeted molecular therapies. Although many approaches remain experimental, they represent a major frontier in epilepsy research.

The integration of precision medicine, artificial intelligence, and translational neuroscience provides a foundation for the next generation of epilepsy care. Future clinical models are expected to incorporate comprehensive biological profiling, continuous digital monitoring, predictive analytics, and individualized therapeutic algorithms. These advances may allow clinicians to identify optimal treatment strategies earlier, prevent complications, and improve long-term outcomes.

The background of contemporary epilepsy science reflects a transition from a traditional seizure-centered framework toward a multidimensional understanding of disease mechanisms and personalized healthcare. The integration of immunological insights, molecular discoveries, advanced diagnostics, precision pharmacotherapy, pharmacovigilance, and translational innovation represents a transformative pathway toward improved prevention, treatment, and

management of epilepsy worldwide. Continued interdisciplinary research will be essential for translating scientific discoveries into effective clinical solutions and achieving a new era of individualized neurological care.

The transformation of epilepsy research during the past decades reflects a broader evolution in neuroscience from descriptive clinical observation toward mechanistic and predictive medicine. Modern investigations increasingly focus on identifying the biological determinants that influence seizure generation, disease progression, treatment response, and long-term neurological outcomes. This paradigm shift has been facilitated by remarkable advances in molecular biology, high-throughput sequencing, neuroimaging, computational neuroscience, and pharmacological sciences. As a result, epilepsy is now recognized not as a single pathological condition but as a diverse group of neurological disorders sharing the common feature of recurrent seizures while differing substantially in molecular architecture, clinical behavior, and therapeutic requirements.

A fundamental challenge in epilepsy research remains the identification of reliable indicators that distinguish different biological subtypes of disease. Conventional clinical classifications, although valuable for diagnosis and treatment selection, may not fully represent the underlying mechanisms driving epilepsy in individual patients. The development of molecularly informed classification systems may improve the precision of diagnosis and enable more effective therapeutic targeting. Such approaches integrate clinical characteristics with genomic, transcriptomic, proteomic, metabolomic, immunological, and neurophysiological data to generate comprehensive biological profiles. This movement toward precision phenotyping represents a major advancement in personalized epilepsy management.

The interaction between genetic susceptibility and acquired environmental influences represents a central theme in modern epilepsy pathogenesis. Although genetic factors play a significant role in many epilepsy syndromes, the presence of a genetic predisposition alone does not always determine disease development. Environmental factors, including brain injury, infection, inflammation, metabolic disturbances, and developmental abnormalities, may interact with genetic vulnerability to initiate epileptogenic processes. Understanding these gene–environment interactions is essential for identifying preventive strategies and developing interventions capable of modifying disease risk before the onset of chronic epilepsy.

Global translational research efforts are increasingly important for overcoming the remaining challenges in epilepsy science. Collaboration among academic institutions, healthcare systems, biotechnology organizations, and patient communities can facilitate the movement of discoveries from laboratory environments into clinical practice. Shared databases, international registries, and multidisciplinary research networks provide valuable resources for understanding disease variability and developing globally applicable solutions.

The management will likely depend on the successful integration of multiple scientific disciplines into a unified precision medicine framework. Advances in immunology, genetics, molecular pharmacology, computational neuroscience, artificial intelligence, and digital health are creating unprecedented opportunities to redefine epilepsy diagnosis and treatment. By combining mechanistic understanding with individualized clinical strategies, the field is moving toward a future in which epilepsy care is more predictive, preventive, effective, and patient-centered.

Therefore, contemporary epilepsy science represents a rapidly evolving discipline characterized by integration, innovation, and translational advancement. The convergence of immune mechanisms, multidimensional pathogenesis, next-generation diagnostics, precision pharmacotherapy, pharmacovigilance, therapeutic safety science, clinical prognostication, and global research collaboration provides a comprehensive foundation for addressing current limitations and achieving transformative improvements in epilepsy prevention and management worldwide.

Epilepsy represents one of the most prevalent and clinically significant chronic neurological disorders affecting populations worldwide. Characterized by a persistent predisposition to generate epileptic seizures and associated neurobiological, cognitive, psychological, and social consequences, epilepsy constitutes a major global health challenge. The disorder affects individuals across all age groups, geographical regions, ethnic backgrounds, and socioeconomic environments, producing substantial individual disability and placing considerable burdens on healthcare systems. Despite remarkable progress in neuroscience, pharmacology, genetics, neuroimaging, and immunology, epilepsy continues to be associated with diagnostic complexity, therapeutic limitations, medication-related complications, and significant unmet clinical needs.

Historically, epilepsy was primarily conceptualized as a disorder of abnormal electrical activity resulting from excessive neuronal synchronization. Although this fundamental concept remains valid, contemporary research has substantially expanded this perspective by demonstrating that epilepsy represents a complex biological disease involving multiple interacting mechanisms at molecular, cellular, network, and systemic levels. Current understanding recognizes epilepsy as a dynamic disorder characterized by disturbances in neuronal excitability, impaired inhibitory control, abnormal synaptic organization, neuroinflammatory activation, genetic susceptibility, metabolic dysfunction, vascular alterations, and progressive remodeling of neural circuits.

The modern concept of epilepsy has therefore evolved from a purely electrophysiological disorder toward a multidimensional neurological condition in which abnormal electrical activity represents the final manifestation of complex underlying biological processes. This paradigm shift has transformed research priorities from simply controlling seizures toward understanding epileptogenesis, identifying disease-modifying interventions, and developing personalized therapeutic strategies.

The global impact of epilepsy extends beyond seizure occurrence. Individuals with epilepsy frequently experience impaired quality of life, cognitive dysfunction, psychiatric comorbidities, educational limitations, occupational challenges, social stigma, and increased mortality risk. Sudden unexpected death in epilepsy, seizure-related injuries, treatment complications, and psychiatric disorders contribute substantially to disease burden. These consequences highlight the importance of comprehensive management strategies that address not only seizure control but also neurological function, psychological well-being, and social integration.

The scientific understanding of epilepsy has undergone remarkable transformation over centuries. Early interpretations often associated epilepsy with supernatural or unexplained phenomena, reflecting limited understanding of neurological mechanisms. The development of modern neuroscience gradually established epilepsy as a disorder of brain function, with pioneering discoveries in neurophysiology demonstrating the relationship between abnormal neuronal activity and seizure generation.

The introduction of electroencephalography represented a major milestone by providing objective evidence of abnormal electrical patterns associated with epilepsy. This technological advancement transformed diagnosis and allowed clinicians to classify seizure disorders according to electrophysiological characteristics. However, subsequent research revealed that electroencephalographic abnormalities represented only one component of a much broader pathological process.

The discovery of neurotransmitter systems, ion channels, synaptic mechanisms, and molecular signaling pathways fundamentally changed understanding of seizure generation. Research demonstrated that epileptic activity emerges from disruptions in the delicate balance between neuronal excitation and inhibition. Excessive glutamatergic transmission, impaired gamma-aminobutyric acid-mediated inhibition, abnormal ion channel function, and altered synaptic connectivity became recognized as central contributors to epileptic network formation.

Pharmacological development followed this expanding biological understanding. Early antiseizure medications were discovered through empirical observation, while modern drug development increasingly focuses on specific molecular targets. Although numerous effective medications have been introduced, most remain symptomatic therapies that suppress seizures without preventing the underlying development of epilepsy. This limitation represents one of the central challenges driving contemporary epilepsy research.

Epilepsy affects millions of individuals globally and represents a major contributor to neurological disability. The disease burden is particularly significant in low- and middle-income countries, where limited healthcare resources, inadequate access to diagnostic technologies, medication shortages, and social stigma contribute to poor outcomes. Although effective treatments exist, a substantial proportion of individuals worldwide remain untreated or undertreated due to healthcare inequalities.

The epidemiology of epilepsy demonstrates considerable variation according to age, geographic region, genetic background, environmental exposures, and healthcare accessibility. The highest incidence rates occur among young children and older adults, reflecting the influence of developmental abnormalities, genetic disorders, neurodegenerative processes, vascular disease, and acquired neurological injuries.

Childhood epilepsy represents a particularly important clinical challenge because seizures occurring during critical periods of brain development may interfere with cognitive maturation, language acquisition, behavioral regulation, and educational achievement. Developmental epileptic encephalopathies represent severe examples in which epileptic activity itself contributes to neurological deterioration beyond the effects of the underlying genetic or structural abnormality.

In older adults, epilepsy frequently develops secondary to cerebrovascular disease, neurodegenerative disorders, tumors, and traumatic injuries. Management in this population is complicated by increased medication sensitivity, polypharmacy, altered pharmacokinetics, and higher prevalence of cognitive impairment. These age-related differences emphasize the importance of individualized therapeutic strategies throughout the lifespan.

Epileptogenesis refers to the complex biological process through which a normal brain becomes capable of generating spontaneous recurrent seizures. This process may occur following various initiating events, including traumatic brain injury, stroke, infection, autoimmune inflammation, developmental abnormalities, genetic mutations, or metabolic disturbances. Importantly, epileptogenesis is not an immediate event but rather a progressive transformation involving multiple interacting cellular and molecular mechanisms.

Following an initiating insult, the brain undergoes a cascade of pathological responses including neuronal injury, inflammatory activation, oxidative stress, disruption of the blood–brain barrier, synaptic reorganization, neuronal loss, and abnormal network connectivity. These changes gradually create a hyperexcitable environment capable of sustaining epileptic activity.

Neuroinflammation represents one of the most important components of epileptogenesis. Activation of microglia and astrocytes following injury leads to increased production of inflammatory mediators, including cytokines and chemokines. These molecules influence neuronal excitability by modifying ion channel expression, altering neurotransmitter receptor function, and affecting synaptic plasticity.

Oxidative stress and mitochondrial dysfunction further contribute to epileptogenesis by impairing neuronal energy regulation and increasing vulnerability to cellular damage. Because neurons require substantial energy resources to maintain membrane potential and synaptic communication, disturbances in mitochondrial function can significantly influence seizure susceptibility.

Structural remodeling of neuronal networks represents another major mechanism. Following injury or chronic seizure activity, abnormal axonal sprouting, synaptic reorganization, and changes in neuronal connectivity may create recurrent excitatory circuits capable of maintaining epileptic activity. These network alterations explain why epilepsy may persist even after the initial cause has resolved.

The comprehensive analysis further demonstrates that the pathophysiological evolution of epilepsy is strongly influenced by the interaction between acute neurological insults and long-term adaptive responses within the central nervous system. Following traumatic brain injury, stroke, infection, prolonged seizures, or developmental abnormalities, the brain initiates a cascade of molecular and cellular events that may initially represent protective mechanisms but subsequently contribute to epileptic transformation. These processes include inflammatory activation, disruption of neuronal connectivity, altered synaptic plasticity, cellular stress responses, and progressive changes in network excitability. The findings indicate that the transition from a normal brain state to an epileptic condition occurs through a prolonged and dynamic process rather than an immediate pathological event.

GOAL

The goal of this scientific perspective is to establish an integrated, multidisciplinary framework for understanding epilepsy through contemporary neuroimmunology, genetics, molecular neuroscience, precision pharmacotherapy, pharmacovigilance, advanced diagnostics, translational medicine, and comprehensive clinical management. It seeks to clarify mechanisms of epileptogenesis, identify opportunities for individualized intervention, improve therapeutic safety and effectiveness, and promote development of predictive, preventive, and disease-modifying strategies.

RESULTS AND DISCUSSION

The investigation reveals that neuronal network synchronization is a critical determinant of seizure initiation and propagation. Epileptic seizures emerge when groups of neurons become excessively synchronized due to alterations in intrinsic neuronal properties and intercellular communication. Abnormal synchronization involves both local cortical circuits and distributed brain networks, demonstrating that epilepsy represents a disorder of connectivity and information processing. Advanced electrophysiological studies and computational modeling have shown that changes in network topology, including abnormal connectivity between functional hubs, contribute to seizure generation and maintenance.

The findings emphasize the importance of pathological neuronal plasticity in epilepsy progression. Although neuroplasticity is essential for learning, memory, and adaptation, excessive or improperly regulated plastic changes may promote epileptic network development. Following injury or chronic seizure activity, neurons undergo structural remodeling involving dendritic growth, axonal sprouting, synaptic reorganization, and altered receptor expression. These modifications increase the probability of recurrent excitation and create stable epileptogenic circuits. The results suggest that targeting maladaptive plasticity mechanisms may represent an important strategy for future disease-modifying therapies.

The analysis identifies abnormalities in chloride homeostasis as an important contributor to impaired inhibitory neurotransmission. The effectiveness of GABAergic inhibition depends on appropriate regulation of intracellular chloride concentrations through chloride transporter systems. During early development, neurological injury, and certain epilepsy syndromes, alterations in chloride transporter expression may cause GABA signaling to become less inhibitory or even excitatory. This mechanism provides an explanation for reduced responsiveness to

conventional GABA-enhancing therapies in specific epilepsy populations and highlights the importance of molecularly targeted interventions.

The findings demonstrate that astrocytic dysfunction plays a significant role in epilepsy pathogenesis. Astrocytes maintain extracellular ion balance, regulate neurotransmitter concentrations, provide metabolic support, and participate in synaptic communication. Dysfunctional astrocytes exhibit impaired potassium buffering, reduced glutamate clearance, altered energy metabolism, and increased production of inflammatory mediators. These abnormalities contribute to extracellular accumulation of excitatory substances and promote neuronal hyperexcitability. The recognition of astrocytes as active participants in epilepsy represents a major advancement beyond neuron-centered disease models.

The investigation also highlights the importance of oligodendrocytes and myelin integrity in epilepsy development. Although less extensively studied than neurons and astrocytes, oligodendrocytes contribute to rapid neuronal communication through maintenance of myelin structures. Alterations in white matter organization and impaired axonal conduction may influence seizure propagation and network synchronization. Diffusion-based neuroimaging studies increasingly demonstrate abnormalities in white matter pathways among individuals with epilepsy, supporting the involvement of broader brain structural networks.

The results indicate that vascular and endothelial mechanisms contribute substantially to epilepsy pathophysiology. Cerebral blood flow regulation, endothelial function, angiogenesis, and vascular permeability influence neuronal metabolism and inflammatory responses. Abnormal vascular remodeling and impaired neurovascular coupling may contribute to seizure susceptibility by disrupting oxygen delivery, metabolic regulation, and barrier function. These findings support investigation of vascular biomarkers and endothelial-targeted therapies in epilepsy research.

The analysis confirms the involvement of apoptosis, necroptosis, autophagy, and other regulated cell-death pathways in epilepsy progression. Recurrent seizures and chronic inflammation may trigger neuronal injury through multiple mechanisms, including mitochondrial failure, oxidative stress, and activation of cell-death signaling cascades. However, cellular responses are highly context-dependent, as some mechanisms may contribute to neuronal survival while others promote degeneration. Understanding these pathways may allow development of interventions that preserve neuronal function without interfering with physiological repair processes.

The findings reveal that neurodevelopmental mechanisms are particularly important in childhood epilepsy. Developing neural networks demonstrate unique characteristics involving synaptic formation, receptor expression, myelination, and metabolic regulation. Genetic disruptions affecting these developmental processes may lead to severe epileptic encephalopathies associated with cognitive impairment, developmental delay, and neurological dysfunction. Early molecular diagnosis and targeted therapeutic intervention are therefore essential for improving developmental outcomes.

The investigation demonstrates that aging significantly influences epilepsy susceptibility and progression. Age-related changes in neuronal resilience, immune regulation, vascular function, mitochondrial capacity, and neurodegenerative processes contribute to increased epilepsy risk among older adults. Late-onset epilepsy frequently occurs in association with cerebrovascular disease, neurodegeneration, and systemic metabolic disorders. These findings highlight the importance of age-specific diagnostic approaches and therapeutic strategies.

The results further demonstrate the relationship between epilepsy and neurodegenerative mechanisms. Chronic seizure activity may accelerate neuronal damage through inflammation, oxidative stress, excitotoxicity, and abnormal protein regulation. Conversely, neurodegenerative disorders may increase seizure susceptibility through network disruption and cellular dysfunction. The interaction between epilepsy and neurodegeneration represents an expanding research field with implications for biomarker development and neuroprotective therapy.

The analysis identifies immune–metabolic interactions as a critical component of epilepsy biology. Immune activation influences metabolic pathways, while metabolic dysfunction modifies immune responses and neuronal excitability. This bidirectional relationship creates a complex regulatory environment in which inflammation, mitochondrial function, and energy metabolism continuously influence disease progression. Understanding these interactions may reveal new therapeutic opportunities targeting multiple biological pathways simultaneously.

The findings demonstrate the importance of epigenetic regulation in determining individual susceptibility to epilepsy. Environmental exposures, inflammation, injury, and metabolic stress can modify gene expression through epigenetic mechanisms without changing DNA sequences. Altered DNA methylation patterns, histone modifications, and regulatory RNA expression contribute to changes in neuronal excitability, immune activity, and synaptic function. These mechanisms provide a molecular explanation for differences in disease severity and treatment response among individuals with similar clinical diagnoses.

The investigation confirms that pharmacological response variability in epilepsy is strongly influenced by biological heterogeneity. Patients with identical seizure classifications may exhibit different therapeutic outcomes because of differences in molecular pathways, genetic profiles, drug metabolism, immune status, and network organization. These findings strongly support implementation of precision medicine strategies incorporating pharmacogenomics, biomarkers, and individualized therapeutic monitoring.

The results demonstrate that therapeutic drug monitoring combined with molecular information provides superior optimization compared with concentration-based approaches alone. Plasma drug levels provide valuable information regarding exposure but do not fully explain differences in therapeutic response or toxicity. Integration of pharmacokinetic data with genetic, metabolic, and clinical information allows more accurate prediction of medication effectiveness and adverse effects.

The analysis highlights the emerging role of artificial intelligence in understanding epilepsy pathophysiology. Machine-learning approaches are capable of identifying complex relationships among clinical variables, neuroimaging findings, electrophysiological patterns, genomic information, and molecular biomarkers. These computational methods provide new opportunities for predicting disease progression, identifying high-risk individuals, optimizing treatment strategies, and discovering novel therapeutic targets.

The findings demonstrate that epilepsy research is increasingly moving toward a systems medicine framework. This approach integrates multiple biological levels, including genes, molecules, cells, circuits, organs, and environmental factors, to create a comprehensive understanding of disease mechanisms. Systems-based models are particularly valuable because epilepsy results from interactions among numerous pathways rather than dysfunction of a single biological component.

The results establish that epilepsy pathophysiology represents a complex network disorder involving molecular abnormalities, cellular dysfunction, immune activation, metabolic disturbances, genetic influences, and progressive remodeling of neuronal circuits. The accumulated evidence supports a transition from traditional symptomatic treatment approaches toward integrated precision neuroscience strategies focused on early detection, individualized therapy, prevention of epileptogenesis, and development of disease-modifying interventions. Continued advancement in translational research will be essential for converting mechanistic discoveries into clinically effective strategies capable of improving outcomes for individuals affected by epilepsy worldwide.

Epilepsy represents one of the most complex neurological disorders characterized by an enduring predisposition to generate spontaneous and recurrent seizures due to abnormal, excessive, and hypersynchronous neuronal activity. The pathophysiology of epilepsy extends far beyond transient disturbances of electrical activity and involves a sophisticated interplay of genetic

susceptibility, molecular alterations, cellular dysfunction, synaptic remodeling, immune activation, metabolic disturbances, vascular abnormalities, and progressive changes in neuronal network organization. Modern neuroscience increasingly recognizes epilepsy as a dynamic systems disorder in which multiple biological pathways converge to produce pathological hyperexcitability and impaired regulation of neuronal circuits.

Historically, epilepsy was primarily interpreted as a disorder of abnormal electrical discharge within localized brain regions. Although this electrophysiological perspective remains fundamental, contemporary research has expanded understanding of epilepsy into a multidimensional biological framework. Current evidence indicates that epileptogenesis—the transformation of normal neural networks into seizure-generating systems—is driven by complex interactions among excitatory and inhibitory neurotransmission, ion-channel regulation, inflammatory mechanisms, oxidative stress, mitochondrial dysfunction, neuroplasticity alterations, and environmental influences.

The pathological foundation of epilepsy involves disruption of the physiological equilibrium between neuronal excitation and inhibition. Under normal conditions, the central nervous system maintains a highly regulated balance between excitatory glutamatergic pathways and inhibitory γ-aminobutyric acid (GABA)-mediated mechanisms. Epileptic disorders emerge when this equilibrium becomes persistently disturbed, resulting in increased neuronal excitability, abnormal synchronization, and excessive propagation of electrical activity through interconnected brain networks.

The pathophysiological mechanisms underlying epilepsy vary considerably depending on etiology, age of onset, genetic background, anatomical localization, environmental exposures, and associated neurological conditions. Structural epilepsy resulting from tumors, cortical malformations, stroke, trauma, or hippocampal sclerosis demonstrates different biological characteristics compared with genetic epilepsies, autoimmune epilepsies, metabolic epilepsies, and unknown-origin epilepsy syndromes. Nevertheless, common molecular pathways frequently converge across different epilepsy types, including neuroinflammation, altered synaptic transmission, neuronal injury, and network reorganization.

Understanding epilepsy pathophysiology is essential for advancing modern therapeutic strategies. Traditional antiseizure medications primarily suppress seizure activity by modifying neuronal excitability; however, they rarely prevent epileptogenesis or reverse established pathological processes. Therefore, contemporary research increasingly focuses on disease-modifying approaches targeting the fundamental mechanisms responsible for epilepsy development and progression.

The expanding body of experimental and clinical evidence further demonstrates that epilepsy pathophysiology is governed by a complex interaction between molecular vulnerability and environmental triggers. The findings indicate that disease manifestation depends not only on the presence of individual pathogenic mechanisms but also on the cumulative influence of multiple biological stressors affecting neuronal stability. Genetic predisposition, inflammatory activation, metabolic imbalance, traumatic events, infections, vascular injury, and developmental abnormalities interact through convergent molecular pathways that ultimately determine seizure susceptibility and disease progression.

The analysis reveals that neuronal excitability is regulated by an extensive network of molecular systems rather than isolated mechanisms. Voltage-gated ion channels, neurotransmitter receptors, intracellular signaling cascades, transcriptional regulators, and metabolic pathways function together to maintain neuronal equilibrium. Disruption of this integrated regulatory system produces progressive instability within neural circuits. The findings demonstrate that even subtle molecular alterations can generate significant functional consequences when amplified through interconnected biological networks.

A significant observation emerging from recent research is the importance of calcium signaling abnormalities in epilepsy development. Calcium ions serve as essential intracellular messengers involved in neurotransmitter release, gene expression, synaptic plasticity, and neuronal survival. However, excessive calcium influx caused by prolonged neuronal activation results in mitochondrial stress, activation of destructive enzymes, oxidative injury, and impaired cellular regulation. Abnormal calcium dynamics contribute not only to acute seizure generation but also to long-term epileptogenic remodeling.

The findings indicate that potassium homeostasis represents another fundamental mechanism controlling neuronal excitability. Extracellular potassium concentration strongly influences neuronal membrane potential and firing thresholds. During epileptic activity, impaired potassium buffering by astrocytes and altered potassium channel function may facilitate abnormal depolarization and synchronization. Dysfunction of potassium regulatory mechanisms contributes to the persistence of hyperexcitable states and represents a potential target for future therapeutic intervention.

The analysis demonstrates that sodium-channel abnormalities remain among the most clinically relevant molecular mechanisms in epilepsy. Sodium channels regulate rapid neuronal depolarization and action potential propagation. Genetic variants affecting sodium-channel structure or function may produce diverse epilepsy phenotypes ranging from mild seizure disorders to severe developmental epileptic encephalopathies. The findings support the concept that molecular characterization of sodium-channel dysfunction can guide therapeutic selection and improve personalized treatment strategies.

The investigation further identifies calcium-channel alterations as important contributors to epileptic network instability. Voltage-dependent calcium channels regulate neurotransmitter release and neuronal excitability. Abnormal calcium-channel activity influences synchronization, synaptic remodeling, and seizure propagation. Pharmacological modulation of calcium-channel function continues to represent an important component of antiseizure therapy and a potential area for future precision interventions.

The results highlight the emerging importance of synaptic vesicle regulation and neurotransmitter release mechanisms in epilepsy pathogenesis. Proteins involved in synaptic transmission, vesicle docking, membrane fusion, and neurotransmitter recycling play essential roles in maintaining neuronal communication. Genetic abnormalities affecting these processes may disrupt synaptic organization and produce epilepsy syndromes with variable clinical manifestations. These findings expand the molecular understanding of epilepsy beyond classical ion-channel disorders.

The analysis confirms that transcriptional regulation and molecular signaling pathways undergo substantial changes during epileptogenesis. Following neurological injury or chronic seizure activity, neurons modify expression of genes involved in inflammation, metabolism, plasticity, stress responses, and survival. These transcriptional changes represent attempts by the nervous system to adapt; however, persistent alterations may stabilize pathological states. Identification

The recognition of autoimmune epilepsy has fundamentally transformed contemporary concepts of epileptogenesis by establishing that adaptive immune responses may directly initiate and sustain epileptic activity independent of traditional structural or metabolic abnormalities. Until relatively recently, recurrent seizures associated with autoimmune disorders were generally considered secondary manifestations of inflammatory encephalitis or nonspecific neurological injury. However, advances in neuroimmunology have demonstrated that immune-mediated mechanisms constitute distinct pathogenic processes capable of producing isolated or predominant epileptic syndromes. The identification of neuronal autoantibodies directed against synaptic proteins, neurotransmitter receptors, ion channels, and intracellular neuronal antigens

has significantly expanded diagnostic criteria and introduced immunotherapy as an essential component of treatment for selected patient populations.

The accumulated evidence indicates that autoimmune epilepsy develops through highly coordinated interactions between humoral and cellular immune responses. B lymphocytes produce pathogenic autoantibodies targeting neuronal surface proteins, whereas T lymphocytes, macrophages, microglia, and antigen-presenting cells amplify inflammatory responses through cytokine secretion and direct cytotoxic activity. These adaptive immune mechanisms interact closely with innate inflammatory pathways, resulting in persistent neuronal dysfunction, synaptic remodeling, blood–brain barrier disruption, and chronic cortical hyperexcitability. Rather than representing isolated immunological abnormalities, autoimmune epilepsies therefore exemplify the complex integration of immune regulation with neuronal physiology.

Among the neuronal autoantibodies identified during the past two decades, antibodies directed against leucine-rich glioma-inactivated protein one have attracted considerable attention because of their strong association with faciobrachial dystonic seizures and limbic encephalitis. Patients frequently present with rapidly progressive focal seizures, cognitive decline, behavioral disturbances, memory impairment, and characteristic magnetic resonance imaging abnormalities involving the medial temporal lobes. Importantly, seizures associated with leucine-rich glioma-inactivated protein one antibodies often demonstrate limited responsiveness to conventional antiseizure medications while responding dramatically to early immunotherapy. These observations provide compelling clinical evidence that immune-mediated neuronal dysfunction may be reversible when recognized promptly.

Contactin-associated protein-like two antibodies represent another important cause of autoimmune epilepsy. Contactin-associated protein-like two is a neuronal membrane protein involved in the organization of voltage-gated potassium channels at the juxtaparanodal regions of myelinated axons. Autoantibody-mediated disruption of this protein alters neuronal conduction, synaptic transmission, and cortical excitability, leading to seizures, peripheral nerve hyperexcitability, autonomic dysfunction, cognitive impairment, and psychiatric manifestations. Clinical improvement following corticosteroids, intravenous immunoglobulin, plasma exchange, or B-cell-depleting therapies further supports the pathogenic role of adaptive immune responses in these disorders.

N-methyl-D-aspartate receptor antibody-associated encephalitis has become one of the most extensively investigated autoimmune neurological disorders because of its characteristic clinical presentation and substantial responsiveness to immunotherapy. Although psychiatric symptoms, movement disorders, cognitive impairment, and autonomic instability frequently dominate the clinical picture, seizures constitute a major neurological manifestation in many patients. Pathogenic antibodies reduce the surface expression of N-methyl-D-aspartate receptors through receptor internalization rather than direct neuronal destruction, thereby altering excitatory neurotransmission and network stability. This reversible mechanism explains why early immunological treatment frequently results in significant neurological recovery despite severe clinical presentation.

Additional neuronal autoantibodies directed against gamma-aminobutyric acid receptors, alpha-amino-three-hydroxy-five-methyl-four-isoxazolepropionic acid receptors, glycine receptors, dipeptidyl-peptidase-like protein six, metabotropic glutamate receptors, and glutamic acid decarboxylase further illustrate the remarkable diversity of autoimmune epilepsies. Each antibody targets distinct molecular components involved in synaptic communication, resulting in unique clinical phenotypes while sharing common immunopathological mechanisms characterized by altered neurotransmission, inflammatory activation, and neuronal hyperexcitability. The expanding spectrum of autoimmune neurological diseases continues to reshape diagnostic

algorithms by emphasizing the importance of comprehensive immunological evaluation in patients presenting with unexplained or rapidly progressive epilepsy.

A particularly important finding emerging from recent investigations is that autoimmune epilepsy frequently occurs in the absence of classical encephalitic manifestations. Some individuals present primarily with recurrent focal seizures, subtle cognitive dysfunction, or treatment-resistant epilepsy without fever, altered consciousness, or widespread inflammatory changes on conventional neuroimaging. Such observations underscore the importance of maintaining clinical suspicion for autoimmune mechanisms in patients exhibiting unusually rapid disease progression, unexplained pharmacoresistance, inflammatory cerebrospinal fluid findings, coexisting autoimmune disorders, or characteristic seizure semiology. Early recognition remains essential because delayed immunotherapy may permit irreversible neuronal injury and persistent neurological disability.

Histopathological investigations of autoimmune epilepsy further support the central role of adaptive immune responses. Surgical specimens frequently demonstrate lymphocytic infiltration, activated microglia, reactive astrocytes, complement deposition, neuronal antibody binding, and inflammatory cytokine expression within epileptogenic tissue. These pathological findings indicate that humoral and cellular immune responses cooperate to disrupt neuronal homeostasis through mechanisms extending well beyond isolated antibody-mediated receptor dysfunction. Furthermore, considerable overlap exists between autoimmune and innate inflammatory pathways, suggesting that therapeutic approaches targeting both adaptive and innate immune activation may provide greater clinical benefit than strategies directed toward single molecular targets.

The therapeutic implications of autoimmune epilepsy have significantly influenced contemporary clinical practice. Conventional antiseizure medications remain important for symptomatic seizure control; however, immunomodulatory therapies frequently determine long-term neurological outcomes. Corticosteroids suppress inflammatory gene expression, reduce cytokine production, stabilize the blood–brain barrier, and inhibit lymphocyte activation. Intravenous immunoglobulin exerts multiple immunoregulatory effects through neutralization of pathogenic antibodies, modulation of complement activation, regulation of Fc receptor signaling, and suppression of inflammatory cytokine production. Plasma exchange physically removes circulating autoantibodies and inflammatory mediators from the bloodstream, whereas monoclonal antibodies such as rituximab selectively deplete B lymphocytes responsible for antibody production. These therapeutic strategies illustrate the transition from purely symptomatic seizure management toward mechanism-based treatment directed at underlying disease processes.

Despite remarkable progress, numerous questions remain regarding the pathogenesis of autoimmune epilepsy. The factors initiating loss of immune tolerance, determinants of antibody specificity, mechanisms governing blood–brain barrier penetration, interactions between peripheral and central immune responses, and predictors of therapeutic responsiveness remain incompletely understood. Continued investigation into these mechanisms is expected to facilitate earlier diagnosis, improve biomarker development, and identify novel immunological targets capable of preventing chronic epileptogenesis.

Genetic discoveries have revolutionized epilepsy research by demonstrating that alterations in the human genome influence virtually every aspect of epileptogenesis, including neuronal development, synaptic organization, ion channel function, neurotransmitter signaling, inflammatory regulation, pharmacological responsiveness, and long-term clinical outcomes. Rather than representing rare causes of childhood epilepsy alone, genetic factors are now recognized as major contributors to both inherited and acquired seizure disorders. Contemporary genomic investigations have identified hundreds of epilepsy-associated genes, revealing

extraordinary molecular heterogeneity and highlighting the complex interaction between inherited susceptibility and environmental influences.

The reviewed evidence indicates that pathogenic genetic variants frequently affect proteins responsible for regulating neuronal membrane excitability. Voltage-gated sodium channels play essential roles in action potential initiation and propagation, and mutations affecting these channels produce profound alterations in neuronal firing characteristics. Depending upon the specific molecular defect, sodium channel mutations may enhance persistent inward current, impair channel inactivation, reduce inhibitory interneuron function, or alter neuronal developmental processes. These diverse mechanisms illustrate how apparently similar clinical phenotypes may arise through distinct molecular pathways requiring individualized therapeutic approaches.

Voltage-gated potassium channels similarly regulate neuronal repolarization and membrane stability. Dysfunction of these channels prolongs membrane depolarization, increases repetitive neuronal firing, and lowers seizure threshold. Calcium channels contribute additional complexity by regulating neurotransmitter release, intracellular calcium signaling, gene transcription, and synaptic plasticity. Mutations affecting calcium channel subunits have been associated with generalized epilepsies, developmental epileptic encephalopathies, cerebellar dysfunction, and neurodevelopmental disorders, emphasizing their broad physiological importance.

Beyond ion channels, numerous epilepsy-associated genes encode proteins involved in synaptic transmission. Synaptic vesicle proteins regulate neurotransmitter packaging, trafficking, docking, and exocytosis, thereby ensuring precise neuronal communication. Mutations disrupting these processes alter the balance between excitatory and inhibitory neurotransmission, producing network instability and epileptogenesis. Similarly, pathogenic variants affecting gamma-aminobutyric acid receptors, glutamate receptors, postsynaptic scaffolding proteins, cell adhesion molecules, and intracellular signaling complexes impair synaptic organization and contribute to chronic neuronal hyperexcitability.

The mammalian target of rapamycin signaling pathway has emerged as one of the most extensively investigated molecular networks involved in epilepsy. This evolutionarily conserved signaling cascade regulates cellular growth, metabolism, protein synthesis, autophagy, neuronal migration, and synaptic plasticity. Hyperactivation of mammalian target of rapamycin signaling has been identified in tuberous sclerosis complex, focal cortical dysplasia, hemimegalencephaly, and several developmental epileptic disorders. Persistent pathway activation promotes abnormal neuronal growth, cortical malformation, gliosis, inflammatory activation, and network hyperexcitability. The clinical success of mammalian target of rapamycin inhibitors in selected genetic epilepsies provides compelling evidence that targeted molecular therapy can modify disease mechanisms rather than merely suppress seizures.

Transcriptomic investigations have revealed widespread alterations in gene expression within epileptic brain tissue extending far beyond inherited genetic mutations. Recurrent seizures, neuroinflammation, oxidative stress, and structural injury collectively influence transcriptional regulation of genes involved in neurotransmission, metabolism, apoptosis, immune activation, mitochondrial function, and synaptic remodeling. These dynamic changes illustrate that epileptogenesis represents an evolving biological process characterized by continuous molecular adaptation rather than a static pathological state.

Epigenetic regulation provides an additional layer of molecular complexity. DNA methylation, histone acetylation, chromatin remodeling, and non-coding RNA activity modify gene expression without altering the underlying nucleotide sequence. Experimental studies consistently demonstrate seizure-induced epigenetic modifications affecting genes regulating inflammatory signaling, neuronal survival, synaptic plasticity, and ion channel expression. Importantly, many epigenetic alterations remain potentially reversible, creating opportunities for therapeutic

intervention through pharmacological modulation of chromatin structure and transcriptional activity.

MicroRNAs have attracted particular interest because of their extensive regulatory influence over neuronal differentiation, inflammatory activation, apoptosis, and synaptic organization. Numerous epilepsy-associated microRNAs demonstrate altered expression within epileptic brain tissue, cerebrospinal fluid, and peripheral circulation. Certain microRNAs promote inflammatory signaling and neuronal degeneration, whereas others exert neuroprotective effects through suppression of apoptosis or enhancement of inhibitory neurotransmission. Experimental manipulation of specific microRNAs has produced encouraging antiepileptogenic effects in animal models, suggesting that RNA-based therapeutics may become valuable components of future precision medicine strategies.

The integration of genomics, transcriptomics, epigenomics, proteomics, and metabolomics has substantially expanded current understanding of epilepsy as a systems-level disorder involving interconnected molecular networks rather than isolated pathogenic genes. These multidimensional approaches have revealed extensive interactions among genetic susceptibility, immune activation, mitochondrial dysfunction, oxidative stress, structural remodeling, and environmental influences. Consequently, contemporary epilepsy research increasingly emphasizes network biology and systems neuroscience to identify shared molecular pathways capable of explaining disease heterogeneity while simultaneously providing novel therapeutic opportunities.

The genetic and molecular mechanisms constitute fundamental determinants of epileptogenesis, influencing disease initiation, progression, pharmacological responsiveness, and prognosis. Continued integration of molecular diagnostics into clinical practice is expected to accelerate the development of precision therapeutics, facilitate earlier intervention, and ultimately improve long-term outcomes for individuals affected by this complex neurological disorder.

Structural abnormalities of the central nervous system constitute one of the most extensively documented causes of epilepsy and continue to represent a major focus of clinical and translational research. The evidence synthesized from neuropathological investigations, advanced neuroimaging, molecular studies, and surgical series demonstrates that disruption of normal brain architecture significantly alters neuronal connectivity and network organization, thereby facilitating the development of epileptogenic circuits. Structural epilepsies encompass a diverse spectrum of pathological conditions, including developmental cortical malformations, hippocampal sclerosis, traumatic brain injury, cerebrovascular disease, intracranial neoplasms, vascular malformations, and acquired lesions resulting from inflammatory or infectious processes. Although these disorders differ substantially in their etiology and histopathological characteristics, they converge upon common biological mechanisms involving neuronal loss, synaptic remodeling, gliosis, neuroinflammation, and abnormal network synchronization.

Developmental abnormalities of cortical formation represent particularly important causes of epilepsy during infancy, childhood, and early adulthood. Cortical development is a highly coordinated biological process requiring precise regulation of neural stem cell proliferation, neuronal migration, differentiation, axonal guidance, synaptogenesis, and programmed cell death. Disruption of any of these developmental stages may produce permanent abnormalities of cortical architecture that predispose affected individuals to recurrent seizures. Contemporary neuroimaging and molecular genetic investigations have significantly improved the recognition of these developmental disorders, revealing structural lesions that were previously undetectable using conventional diagnostic techniques.

Focal cortical dysplasia remains among the most common structural abnormalities identified in patients undergoing epilepsy surgery for medically refractory focal epilepsy. Histopathological examination demonstrates disorganized cortical lamination, dysmorphic neurons, abnormal glial

proliferation, and altered expression of proteins regulating neuronal development and synaptic function. These structural abnormalities generate highly excitable neuronal networks characterized by impaired inhibitory interneuron function, aberrant synaptic connectivity, and persistent inflammatory activation. The close relationship between focal cortical dysplasia and mammalian target of rapamycin pathway dysregulation further illustrates the interaction between developmental biology and molecular signaling during epileptogenesis.

Other developmental malformations, including polymicrogyria, pachygyria, lissencephaly, schizencephaly, heterotopia, and hemimegalencephaly, similarly disrupt cortical organization through abnormalities of neuronal migration and differentiation. Although these disorders differ in their anatomical appearance and genetic basis, they frequently share common pathophysiological features characterized by abnormal cortical circuitry, defective synaptic integration, altered neurotransmitter receptor expression, and impaired neuronal network maturation. Clinical manifestations often include developmental delay, intellectual disability, motor impairment, and pharmacoresistant epilepsy, reflecting the extensive involvement of neural systems beyond seizure generation alone.

Hippocampal sclerosis remains the most frequently identified pathological substrate in mesial temporal lobe epilepsy and represents one of the best-characterized structural mechanisms of epileptogenesis. Histologically, hippocampal sclerosis is characterized by selective neuronal loss within the hippocampal formation, extensive reactive gliosis, mossy fiber sprouting, synaptic reorganization, inflammatory activation, and extracellular matrix remodeling. These structural changes profoundly alter hippocampal circuitry, facilitating recurrent excitation and impaired inhibitory regulation. Although hippocampal sclerosis has traditionally been viewed as a consequence of prolonged seizures, increasing evidence suggests a bidirectional relationship in which pre-existing structural vulnerability promotes seizures while recurrent seizures further accelerate hippocampal degeneration. This reciprocal interaction contributes to the progressive nature of temporal lobe epilepsy and explains the frequent development of pharmacoresistance in affected individuals.

Traumatic brain injury represents another major cause of acquired structural epilepsy and provides a valuable model for investigating the biological sequence leading from acute neurological injury to chronic epileptogenesis. Mechanical trauma initiates a complex cascade involving neuronal necrosis, diffuse axonal injury, cerebral edema, hemorrhage, excitotoxicity, mitochondrial dysfunction, oxidative stress, inflammatory activation, and blood–brain barrier disruption. During the subsequent latent period, progressive synaptic remodeling, gliosis, axonal sprouting, and extracellular matrix alterations transform injured neural tissue into chronically hyperexcitable networks. Experimental studies have demonstrated that this latent phase provides a critical therapeutic window during which disease-modifying interventions may prevent or attenuate epileptogenesis before spontaneous seizures become established.

Cerebrovascular disease has emerged as the leading cause of epilepsy among older adults, reflecting global demographic aging and improved survival following acute stroke. Both ischemic and hemorrhagic cerebrovascular events produce neuronal injury through energy failure, excitotoxicity, oxidative stress, inflammatory activation, and vascular remodeling. The resulting structural changes alter cortical connectivity, disrupt inhibitory neuronal circuits, and facilitate hypersynchronous neuronal firing. Chronic cerebral hypoperfusion, white matter disease, and microvascular pathology further contribute to epileptogenesis by promoting progressive neurodegeneration and inflammatory activation. The strong association between epilepsy and cerebrovascular disease emphasizes the importance of vascular health in maintaining long-term neuronal stability.

Intracranial neoplasms also represent significant structural causes of epilepsy, particularly low-grade gliomas and glioneuronal tumors. Seizure generation in tumor-associated epilepsy results

from multiple interacting mechanisms including direct cortical infiltration, compression of adjacent neuronal tissue, and disruption of neurotransmitter homeostasis, inflammatory activation, vascular abnormalities, and alterations in extracellular ionic composition. Tumor cells themselves may release excitatory neurotransmitters, growth factors, cytokines, and extracellular vesicles capable of modifying surrounding neuronal activity. These observations highlight the dynamic interactions between neoplastic tissue and the surrounding cerebral microenvironment in promoting epileptogenesis.

The structural epilepsies demonstrate that disruption of normal brain architecture initiates progressive biological processes extending well beyond the original lesion. Persistent neuroinflammation, synaptic remodeling, glial activation, mitochondrial dysfunction, and vascular alterations collectively contribute to chronic neuronal hyperexcitability, reinforcing the concept that structural abnormalities interact closely with molecular and immunological mechanisms throughout disease progression.

CONCLUSION

- Contemporary epilepsy science demonstrates that epilepsy should no longer be conceptualized solely as a disorder of abnormal electrical activity or recurrent seizures, but rather as a complex, heterogeneous, and dynamically evolving neurological condition arising from interactions among molecular, cellular, genetic, immune, metabolic, vascular, structural, and network-level mechanisms. The evidence synthesized in this scientific perspective supports an integrated understanding of epileptogenesis in which neuronal hyperexcitability and hypersynchronization emerge from disturbances involving excitation–inhibition balance, ion-channel function, synaptic organization, glial activity, neuroinflammation, oxidative stress, mitochondrial function, and progressive remodeling of neural circuits. Such multidimensional pathophysiology explains substantial differences in clinical phenotype, treatment response, disease progression, and prognosis among individuals with apparently similar epilepsy classifications.
- Neuroimmunological research has substantially expanded the therapeutic and diagnostic framework of epilepsy. Microglial and astrocytic activation, inflammatory signaling, blood–brain barrier disruption, and adaptive immune responses demonstrate that immune mechanisms can participate directly in epileptogenesis. Recognition of autoimmune epilepsy, particularly disorders associated with neuronal antibodies, reinforces the importance of early etiological investigation and mechanism-directed treatment in appropriately selected patients. At the same time, genetic and epigenetic discoveries have established that molecular heterogeneity is a central determinant of disease susceptibility, phenotype, pharmacological response, and prognosis. Variations affecting ion channels, synaptic proteins, developmental pathways, and signaling networks such as mammalian target of rapamycin illustrate the potential of molecular classification to guide increasingly individualized therapeutic decisions.
- The therapeutic implications of these advances are considerable. Antiseizure medications remain fundamental to seizure management, yet persistent pharmacoresistance demonstrates the limitations of approaches focused exclusively on symptomatic suppression. Precision pharmacotherapy therefore represents an essential evolution in clinical practice, integrating patient phenotype, molecular characteristics, pharmacokinetics, pharmacodynamics, pharmacogenomics, comorbidities, drug interactions, therapeutic drug monitoring, and treatment tolerability. Pharmacovigilance must remain an integral component of this framework because long-term antiseizure treatment can produce clinically significant adverse reactions and interactions that influence adherence, safety, and quality of life. Comprehensive clinical management should consequently extend beyond seizure frequency to include cognitive, psychiatric, developmental, reproductive, psychosocial, functional, and safety outcomes.

- Advanced neuroimaging, electrophysiology, genomics, transcriptomics, proteomics, metabolomics, computational neuroscience, artificial intelligence, and digital health provide powerful opportunities to improve diagnosis, phenotyping, prognostication, and therapeutic selection. Nevertheless, technological sophistication alone cannot guarantee clinical benefit. Biomarkers and predictive algorithms require rigorous validation, reproducibility, clinically meaningful endpoints, transparent methodology, and appropriate integration into multidisciplinary care. Translational research is therefore critical for converting mechanistic discoveries into interventions that demonstrate genuine effectiveness and safety in real-world populations.
- A particularly important future objective is the development of disease-modifying and antiepileptogenic strategies. Current antiseizure therapies predominantly suppress seizures after pathological networks have become established, whereas future interventions should ideally prevent or attenuate the biological transformation that produces chronic epilepsy. Immunomodulation, neuroprotection, metabolic regulation, targeted molecular therapies, gene-based approaches, advanced neuromodulation, and other mechanism-specific interventions may contribute to this objective. However, their clinical implementation requires carefully designed experimental and clinical studies capable of establishing long-term efficacy, safety, patient selection criteria, and therapeutic durability.
- The future of epilepsy management depends on convergence rather than isolation of scientific disciplines. Neuroimmunology, genetics, molecular neuroscience, precision pharmacology, pharmacovigilance, advanced diagnostics, artificial intelligence, and translational medicine should be integrated within a patient-centered and evidence-based clinical framework. Such integration can facilitate earlier diagnosis, more accurate etiological classification, individualized treatment selection, improved safety surveillance, and more reliable prediction of disease trajectories. Equally important, equitable access to diagnostic technologies, essential antiseizure medicines, specialized neurological services, and innovative therapies must remain a global priority. Reducing disparities in epilepsy care is necessary to translate scientific progress into meaningful population-level health improvement.
- So, the emerging paradigm of epilepsy medicine is increasingly predictive, preventive, personalized, and mechanism-oriented. Continued interdisciplinary collaboration, rigorous translational investigation, longitudinal real-world evidence, validated biomarkers, ethically responsible technological implementation, and patient-centered clinical decision-making will be essential for overcoming persistent therapeutic limitations. The integration of scientific discovery with comprehensive clinical management offers a realistic pathway toward reducing pharmacoresistance, preventing disease progression, minimizing treatment-related harm, improving quality of life, and ultimately transforming epilepsy care from predominantly reactive seizure control toward precision prevention and durable neurological health.

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Historical Sciences

Историко-культурное наследие региона Ұлытау: современные направления сохранения, исследования и популяризация

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Аннотация

В статье рассматривается историко-культурное значение региона Ұлытау в истории Казахстана, а также современные направления сохранения, исследования и популяризации его историко-культурного наследия. Охарактеризованы особенности археологических памятников, исторических мавзолеев, средневековых городищ и объектов наследия эпохи Улуса Жошы, расположенных на территории Ұлытау. Особое внимание уделено научно-исследовательской, реставрационной, музейной и культурно-просветительской деятельности Национального историко-культурного и природного музея-заповедника «Ұлытау».

Кроме того, рассматриваются вопросы цифровизации историко-культурного наследия, проведения археологических исследований, реставрации и развития культурного туризма. Определены актуальные проблемы сохранения и эффективной популяризации исторического наследия региона, обоснована необходимость повышения его национального и международного значения посредством научного изучения историко-культурных объектов Ұлытау, внедрения цифровых технологий и совершенствования туристической инфраструктуры.

Ключевые слова: Ұлытау, историко-культурное наследие, исторические памятники, Улус Джучи, музей-заповедник, археология, реставрация, цифровизация, культурный туризм.

Ведение

Ұлытау – регион, имеющий особое историко-культурное значение и занимающий важное место в историческом пространстве Казахстана и тесно связанный с политической, духовной и цивилизационной историей Великой степи. На его территории сосредоточены археологические памятники различных исторических эпох, средневековые мавзолеи, древние городища, каменные изваяния и балбалы, петроглифы, мемориальные сооружения и другие объекты материального и духовного наследия. Данные историко-культурные объекты являются важными источниками для изучения политических, социально-экономических и культурных процессов, происходивших на территории Великой степи. В этой связи сохранение, научное изучение и популяризация историко-культурного наследия

региона Ұлытау имеют не только региональное, но и общенациональное, а также международное значение.

Особенность историко-культурного пространства Ұлытау проявляется во взаимосвязи природного ландшафта с объектами исторического наследия. Священные горы и речные долины, археологические комплексы, древние поселения и мемориальные сооружения формируют целостный историко-культурный ландшафт. Поэтому научное и практическое значение имеет рассмотрение исторического наследия Ұлытау не только как совокупности отдельных памятников, но и как единого историко-культурного пространства, в котором природные и культурные компоненты находятся в тесной взаимосвязи.

Историческое значение Ұлытау определяется его ролью в формировании и развитии цивилизации Великой степи. В древности и Средневековье регион являлся одним из важных пространств политического, экономического и культурного взаимодействия кочевых обществ. На территории Ұлытау сохранились историко-археологические памятники, относящиеся к эпохам тюркских государств, огузо-кыпчакского периода, Улуса Жошы и Казахского ханства. Эта историческая преемственность позволяет рассматривать Ұлытау как один из важных научных центров изучения исторической памяти Казахстана, традиций национальной государственности и культурного наследия.

Историко-культурное значение Ұлытау приобретает дополнительную актуальность в контексте современных административных и общественно-политических изменений. Образование в 2022 году области Ұлытау как самостоятельной административно-территориальной единицы создало новые возможности для системного изучения, сохранения и популяризации историко-культурного наследия региона. Проведение в том же году в Ұлытау Первого Национального курултая Республики Казахстан подчеркнуло особую роль региона в формировании национальной исторической памяти, укреплении гражданской идентичности и реализации государственной культурной политики.

В этой связи современное изучение историко-культурного наследия региона Ұлытау не должно ограничиваться исследованием отдельных памятников. Оно предполагает комплексное рассмотрение вопросов их сохранения в контексте единого историко-культурного ландшафта, введения в научный оборот, цифровизации, реставрации, а также эффективного использования их культурно-познавательного и туристского потенциала. Данные задачи определяют актуальность исследования исторического наследия Ұлытау с точки зрения его сохранения на национальном уровне и дальнейшего представления в международном научно-культурном пространстве.

Анализ

Ұлытау имеет особое значение с точки зрения политической власти кочевников, распространявшейся в Средние века на эти пространства. Отсюда начинали свои походы сакские племенные объединения. Через эти территории также проходили многочисленные отряды гуннов, искавших новые территории для расселения в условиях постепенного ухудшения природно-климатической обстановки в степи, обусловленного длительным периодом засухи. Ұлытау являлся одним из важных опорных регионов для правителей Тюркских каганатов. Впоследствии через этот регион проходили миграционные потоки кангаро-печенегских племен, подвергавшихся давлению со стороны огузов и направлявшихся в западном направлении, в сторону причерноморских степей. В последующие исторические периоды Ұлытау приобрел политическое значение в рамках Кимакского каганата, Кыпчакского ханства и, позднее, государства Чингизидов. В 1223 году территория Ұлытау была определена в качестве места расположения одной из крупнейших орд, выделенных Чингисханом во владение Жошы, что связывает регион с историей формирования и развития Улуса Жошы.

По мнению историков, Ұлытау известен богатым информационным и материальным наследием, связанным с периодами кангаро-печенегов, огузо-кыпчаков, Ак-Орды и Казахского ханства в истории Великой степи. Здесь концентрировались степные властные структуры, контролировавшие товары, перевозившиеся торговцами вдоль Сырдарьи в Сибирь и в обратном направлении.

Научное и летописное изучение Ұлытау в мировой историографии ведется непрерывно от трудов Геродота и Страбона до современных археологических исследований и раскопок. Древнегреческие историки оставили ценные сведения о саках-исседонах, царские погребальные курганы которых располагались на западных отрогах Ұлытау. Письменные сведения об огузах и кыпчаках Ұлытау также оставил Мухаммед аль-Идриси.

Однако после эпохи Чингисхана Ұлытау превратился в своего рода охраняемую территорию, посещение которой иностранными путешественниками и исследователями было ограничено. В трудах средневековых путешественников, таких как Вильгельм Рубрук, Плано Карпини и Марко Поло, мы не встречаем сведений о быте и традициях Ұлытау как орды или центра Улуса Жошы.

Первые письменные сведения об Ұлытау в источниках среднеазиатских летописцев появляются лишь начиная с эпохи Амира Тимура. Шашские и самаркандские летописцы оставили сведения о походах Абдаллаха Хана и Амира Тимура в казахскую степь. Полную генеалогию династии Джучидов можно найти в труде Кадыргали Жалаири.

С усилением Московского государства, а впоследствии с расширением Российского государства в направлении казахской степи в Улытау стали все чаще направляться посольства и военные экспедиции, представители которых тщательно изучали географию расселения местного населения, его историю, традиции и быт. Особенно в период правления Петра I активизировался сбор археологических и этнографических материалов из «отдалённых окраин», в том числе с территории, соответствующей современному Казахстану. Этот процесс сопровождался незаконными и разрушительными раскопками, проводившимися так называемыми «курганными грабителями», не имевшими отношения к научной археологии и преследовавшими преимущественно корыстные цели, в частности извлечение прибыли из найденных золотых артефактов.

Богатые сведения об Ұлытау содержатся в дневнике капитана Н.П. Рычкова, составленном во время его путешествия в 1771 году. Он находился в составе карательного отряда, направленного для преследования волжских калмыков-торгаутов.

В историографии эпохи династии Чингизидов особое место занимает труд Я.П. Гавердовского «Обозрение киргиз-кайсацской степи», опубликованный в 1804 году и существенно изменивший устоявшиеся представления об истории этого периода. В нем роль Ұлытау в осмыслении истории империи Чингисхана представлена совершенно с иной точки зрения.

Историческая топография А.И. Левшина, записи М. Красовского, материалы Ш. Уалиханова являются бесценными источниками для исследователей данного региона. Многотомные труды А. Маргулана, материалы, связанные с поисково-разведочными работами К. Сатпаева, а также археологические данные Ж. Смаилова позволили значительно углубить изучение истории Ұлытау.

На современном этапе вопросы сохранения историко-культурного наследия Ұлытау приобретают новое содержание. Образование области Ұлытау в 2022 году создало новые возможности для систематизации работы по управлению, изучению, охране и включению историко-культурного наследия региона в туристический оборот. В области сформированы институциональные структуры, ответственные за охрану историко-культурного наследия, одновременно ведутся археологические исследования, реставрационные работы,

развивается музейное дело, осуществляется цифровизация архивных документов и реализуются мероприятия по развитию культурного туризма.

Историко-культурное наследие области Ұлытау отличается хронологическим и типологическим многообразием. Здесь сохранились культурные слои, относящиеся к различным историческим периодам от древнейших эпох до средневековья и более поздних исторических периодов.

В настоящее время на территории области Ұлытау насчитывается более 360 памятников истории и культуры. Из них 12 имеют статус памятников истории и культуры республиканского значения, более 350 относятся к памятникам местного значения.

К памятникам истории и культуры республиканского значения относятся мавзолеи Жошы хана, Алаша хана, Болған ана, Аяққамыр, культовое сооружение Домбауыл, комплекс Ақмешит-әулие, городище Басқамыр, мавзолеи Дүзен, Айранбай (Бескүмбез), Кетебай, Лабақ и Мақат. Указанные объекты историко-культурного наследия входят в число особо значимых объектов не только региона, но и всего государства.

Кроме того, каменные изваяния, петроглифы, древние поселения и городища, расположенные на территории Ұлытау, являются важными источниками для изучения древней и средневековой истории региона.

Особое место в сохранении и популяризации историко-культурного наследия занимает национальный историко-культурный и природный музей-заповедник «Ұлытау», находящийся в ведении Министерства культуры и информации Республики Казахстан. По площади музей-заповедник является крупнейшим в Казахстане и занимает территорию 147 тыс. га.

В число объектов историко-культурного наследия национального историко-культурного и природного музея-заповедника «Ұлытау» входят мавзолеи Алаша хана, Жошы хана, Домбауыл, Болған ана, городище Басқамыр и другие памятники. На официальных информационных ресурсах музея-заповедника историко-культурные объекты региона представлены с отдельными описаниями и научно-познавательной информацией о них.

Необходимо отметить, что в 2018-2020 годах за счет средств республиканского бюджета осуществлялось строительство визит-центра национального историко-культурного и природного музея-заповедника «Ұлытау», который начал принимать посетителей с 2021 года. Визит-центр ориентирован на широкое ознакомление населения с историко-культурным наследием региона Ұлытау и обеспечение качественного обслуживания туристов. В состав визит-центра входят административное здание и общежитие. В административном здании расположены рабочие кабинеты, информационно-экспозиционный зал, большой и малый конференц-залы и другие помещения. Общая площадь центра составляет 1 598,6 м². На базе визит-центра проводятся выставки, лекции, экскурсии, встречи и другие культурные мероприятия.

Реализация вышеуказанных проектов, направленных на развитие туристического кластера, способствовала значительному увеличению числа посещений сакрального региона в последние годы. Туристы в основном посещают мавзолеи Жошы хана, Алаша хана и Домбауыл, Ханскую ставку, комплекс Ақмешит-әулие, визит-центр и музей. Значительную часть туристического потока составляют посетители из городов Жезказгана, Сатпаева, Астаны и Алматы. Среди иностранных туристов, посетивших исторические памятники музея-заповедника в указанный период, были граждане США, Канады, Франции, Германии, Великобритании, Австрии, Венгрии, Японии, Южной Кореи, Турции, Российской Федерации, Монголии, Узбекистана, Кыргызстана и других стран. Общее количество посетителей составило более 55 тыс. человек в 2022 году и более 77 тыс. человек в 2023 году.

Основные задачи национального историко-культурного и природного музея-заповедника «Ұлытау» связаны с сохранением памятников истории и культуры, охраной

музейных предметов, проведением научно-исследовательских работ, реставрацией, развитием культурно-просветительской деятельности и широкой популяризацией историко-культурного наследия.

Научно-реставрационные работы направлены на сохранение первоначальных архитектурных, художественных и историко-культурных особенностей памятников, а также обеспечение их сохранности для будущих поколений. В последние годы научно-реставрационные работы проведены на 11 из 12 памятников истории и культуры республиканского значения. В частности, в 2013 году работы были проведены на ритуально-обрядовом сооружении Домбауыл (VIII-IX вв.), в 2014 году на мавзолее Болған ана, в 2020 году на мавзолее Жошы хана, в 2021 году на мавзолее Алаша хана, а в 2024 году на мавзолее Кетебай.

В течение последних лет на территории музея-заповедника «Ұлытау» также систематически проводятся археологические раскопки. Особое внимание уделяется исследованию древних металлургических поселений в районе села Талдысай. Кроме того, проводились археологические исследования исторических объектов, относящихся к эпохе Золотой Орды.

Научно-просветительская деятельность музея-заповедника осуществляется также посредством подготовки и выпуска печатной продукции, организации выставок и экскурсий, проведения научных встреч и лекций. Данная работа способствует популяризации исторического наследия не только среди специалистов, но и среди широкой общественности.

Значимую роль в историко-культурном наследии региона занимает памятники эпохи Улуса Жошы. Мавзолей Жошы хана, мавзолеи Болған ана, Аяққамыр и другие исторические объекты позволяют изучать материальное наследие этого периода.

Научное изучение истории Улуса Жошы позволяет по-новому осмыслить средневековую историю Казахстана, традиции государственности и политические процессы, происходившие в Великой степи. В этой связи в последние годы изучение и популяризация исторической личности Жошы хана и наследия Улуса Жошы стали одним из важных направлений государственной культурной политики.

В ходе визита Главы государства Касым-Жомарта Токаева в Ұлытау значительное внимание было уделено вопросам увековечения имени Жошы хана, превращения его мавзолея в объект культурного туризма и популяризации истории Золотой Орды на международном уровне. В последующие годы данные инициативы получили продолжение в рамках проведения научных конференций, выставок, экспедиций, музейных проектов, а также развития объектов туристической инфраструктуры.

В 2019 году Глава государства Касым-Жомарт Токаев посетив Улытау и, выступая на международном туристическом форуме «Ұлытау-2019», отметил необходимость увековечения имени Жошы хана, основателя Золотой Орды, и привлечения международного внимания к его исторической личности. В частности, было подчеркнуто, что превращение мавзолея Жошы хана в объект культурного туризма является важной задачей. Впоследствии постановлением Правительства Республики Казахстан от 31 декабря 2019 года № 1059 был утвержден План мероприятий, в который был включен вопрос строительства историко-культурного комплекса, посвященного Жошы хану. В результате в 2021 году в Ұлытау был создан современный историко-культурный комплекс «Жошы хан». В экспозиции комплекса представлены копии экспонатов, относящихся к соответствующей исторической эпохе и происходящих из региона Ұлытау. Кроме того, в составе комплекса предусмотрены гостиница, помещение столовой и кинозал.

Кроме того, в 2024 году научные и культурные мероприятия, посвященные 800-летию Улуса Жошы, способствовали широкому представлению исторического значения области. В

их числе были выставки, научные круглые столы, историко-этнографические экспедиции и межмузейные проекты. Проведение данных мероприятий способствовало укреплению роли региона Ұлытау как научно-культурного центра по изучению и популяризации истории Улуса Жошы.

Одним из важных результатов работы в данном направлении стала организация выставки «Историко-культурное наследие периода Золотой Орды (Улуса Жошы)», посвященной 800-летию Улуса Жошы. В рамках выставки широкой общественности были представлены археологические материалы, относящиеся к периоду Золотой Орды, архитектурные фрагменты мавзолеев, монеты, керамические изделия, карты, копии рукописей и другие музейные материалы.

Работа в данном направлении продолжилась и в 2025 году. В частности, выставка «Историко-культурное наследие периода Золотой Орды (Улуса Жошы)» была представлена на других музейных площадках Казахстана, что свидетельствует о продолжении работы по научному и культурному представлению наследия Улуса Жошы.

Вместе с тем в текущем году научное изучение историко-культурного наследия Улуса Жошы получило новый импульс и на международном уровне. 19-20 мая 2026 года в городе Астане под эгидой ЮНЕСКО состоялся международный симпозиум «Золотая Орда – модель степной цивилизации: история, археология, культура, идентичность». В международном научном мероприятии, открывшемся с участием Президента Республики Казахстан Касым-Жомарта Токаева, приняли участие около 350 делегатов из более чем 20 стран мира, среди которых историки, археологи, культурологи, эксперты в сфере культурного наследия и представители международного научного сообщества.

В ходе симпозиума в междисциплинарном формате обсуждались политическое, экономическое, культурное и духовное наследие Улуса Жошы, его роль в формировании историко-цивилизационного пространства Центральной Евразии, археологические и письменные источники, вопросы исторической памяти и культурной преемственности. Проведение симпозиума под эгидой ЮНЕСКО продемонстрировало, что изучение и сохранение наследия Улуса Жошы имеют значение не только в контексте национальной истории, но и как часть общего евразийского историко-культурного наследия. В этой связи современные исследования международного научного сообщества, направленные на изучение Улуса Жошы как важного исторического феномена степной цивилизации, повышают актуальность научного изучения, сохранения и международной популяризации историко-культурного наследия Ұлытау.

После образования области Ұлытау, в соответствии с постановлением акимата от 19 августа 2022 года № 09/02, при Управлении культуры, развития языков и архивного дела было создано коммунальное государственное учреждение «Центр сохранения историко-культурного наследия». Основными задачами учреждения являются выявление, учет, охрана, консервация, реставрация, популяризация и обеспечение использования памятников истории и культуры, расположенных на территории области. В соответствии с указанными задачами ежегодно за счет средств областного бюджета проводятся реставрационные работы и археологические раскопки на памятниках истории и культуры местного значения.

Кроме того, в 2023 году за счет средств областного бюджета был запущен туристический информационный портал «Visit Ulytau», предназначенный для систематизации и распространения информации о достопримечательностях, туристических маршрутах и сервисах региона. В настоящее время данный проект является одним из значимых направлений работы в сфере цифровизации, которая выступает важным элементом развития туристической отрасли.

В целом в регионе на постоянной основе реализуются мероприятия, направленные на развитие туризма. Так, с 25 по 28 сентября 2023 года по инициативе национального историко-культурного и природного музея-заповедника «Ұлытау» на базе визит-центра был проведен учебный семинар по подготовке экскурсоводов, гидов и тур-менеджеров области. Цель мероприятия заключалась в содействии развитию, продвижению и популяризации культурного туризма в регионе посредством подготовки конкурентоспособных и квалифицированных экскурсоводов, гидов и специалистов в сфере туризма.

Следует отметить, что историко-культурное наследие области является одним из ключевых ресурсов развития культурно-познавательного туризма. Вместе с тем наличие значительного количества исторических памятников само по себе не является достаточным условием для обеспечения устойчивого роста туристического потока. Эффективное развитие туристической отрасли предполагает комплексный подход, включающий совершенствование туристических маршрутов, повышение транспортной доступности, развитие дорожной и туристической инфраструктуры, объектов размещения и общественного питания, обеспечение стабильной мобильной и цифровой связи, а также подготовку квалифицированных гидов, экскурсоводов и других специалистов в сфере туризма.

Одновременно развитие туристического потенциала региона должно осуществляться с учетом необходимости сохранения историко-культурного наследия. Увеличение туристического потока способствует популяризации объектов наследия и повышению их культурной и экономической значимости, однако одновременно может приводить к усилению антропогенной нагрузки на памятники. В связи с этим важное значение приобретают эффективное регулирование туристической посещаемости, соблюдение установленного режима охранных зон, создание необходимой информационной инфраструктуры и проведение систематического мониторинга состояния историко-культурных объектов. Такой комплексный подход позволит обеспечить баланс между доступностью культурного наследия для посетителей, развитием туристической отрасли и долгосрочным сохранением исторических объектов региона.

На современном этапе одним из важных направлений сохранения историко-культурного наследия является цифровизация. Использование цифровых технологий позволяет обеспечить долгосрочное сохранение музейных фондов, архивных документов, археологических объектов и информации об исторических памятниках, ввести их в научный оборот и сделать доступными для широкой общественности.

В 2026 году в области Ұлытау проведена масштабная работа по цифровизации архивных документов. За первые шесть месяцев года было оцифровано около 1,4 млн страниц архивных документов, что на 36% превышает показатель за аналогичный период предыдущего года.

Важно расширить данный опыт и на объекты историко-культурного наследия. В частности, создание цифровых паспортов памятников, уточнение их географических координат, формирование базы фото- и видеоматериалов, 3D-моделирование, создание виртуальных туров и цифровых каталогов музейных предметов следует рассматривать как современные инструменты сохранения культурного наследия региона.

Такая цифровая база позволит не только научным исследователям, но и музейным сотрудникам, обучающимся, туристам и широкой общественности оперативно получать историческую информацию. Вместе с тем цифровизация создает дополнительные гарантии физической сохранности исторических объектов.

Несмотря на значительный объем работы, проводимой в направлении сохранения историко-культурного наследия области Ұлытау и использования его туристического потенциала, ряд проблем по-прежнему остается актуальным.

Во-первых, значительная удаленность исторических памятников друг от друга, а также состояние дорожной инфраструктуры на отдельных участках, ведущих к некоторым объектам, оказывают влияние на стабильное функционирование туристических маршрутов.

Во-вторых, климатические условия региона влияют на продолжительность туристического сезона. В связи с этим наряду с сезонным туризмом необходимо развивать научно-познавательный, музейный, этнографический и цифровой туризм, что позволит расширить возможности круглогодичного посещения региона.

В-третьих, сохраняется потребность в квалифицированных специалистах, способных профессионально представлять историко-культурное наследие региона, в том числе археологах, музееведах, реставраторах, экскурсоводах и менеджерах в сфере историко-культурного туризма.

В-четвертых, актуальной остается задача систематизации информации об исторических памятниках на единой научной основе. Целесообразным представляется создание единой цифровой базы данных, включающей по каждому объекту научное описание, историко-археологические сведения, библиографию, фотодокументальные и картографические материалы, а также сведения об истории проведения реставрационных работ.

В-пятых, необходимо обеспечить более активное включение результатов научных исследований историко-культурного наследия в международный научный оборот. В этих целях важно расширять практику совместных археологических исследований с зарубежными научными организациями, проведения международных научных конференций, подготовки научных публикаций и реализации межмузейных выставочных проектов.

На современном этапе сохранение историко-культурного наследия Улытау не ограничивается охраной отдельных памятников. Данная задача непосредственно связана с формированием национального исторического сознания, развитием научных исследований, продвижением культурного туризма и международной популяризацией исторического наследия Казахстана.

В этом контексте поручения Главы государства, направленные на изучение и популяризацию исторического наследия, имеют стратегическое значение для региона Ұлытау.

Следует отметить, что в 2026 году в области Ұлытау особое внимание уделяется развитию историко-культурного комплекса «Жошы хан». Передача комплекса на баланс областного историко-археологического музея создает дополнительные возможности для укрепления его музейного и научного потенциала.

Перспективное развитие данного объекта важно рассматривать не только в качестве туристической достопримечательности, но и как научно-культурного центра, ориентированного на изучение, музеефикацию и международную популяризацию истории Улуса Жошы и региона Ұлытау.

Вместе с тем современная деятельность в сфере культуры области охватывает одновременно археологические исследования, реставрационные работы, цифровизацию музейных и архивных фондов. Реализация данных направлений во взаимосвязи друг с другом позволит сформировать комплексную модель сохранения историко-культурного наследия.

Заключение

Сохранение историко-культурного наследия региона Улытау представляет собой не только задачу по обеспечению физической сохранности памятников, но и комплексное долгосрочное направление государственной культурной политики, связанное с развитием научных исследований, укреплением национального исторического сознания,

цифровизацией и расширением международного научно-культурного сотрудничества. В современных условиях особую значимость приобретает комплексный подход, предусматривающий взаимосвязь археологических исследований, реставрации, музейной деятельности, цифрового документирования объектов наследия и развития устойчивого культурно-познавательного туризма.

В этой связи дальнейшее развитие области Ұлытау как одного из ключевых центров изучения, сохранения, музеефикации и международной популяризации историко-культурного наследия Казахстана приобретает стратегическое значение. Реализация системных мер по созданию единой цифровой базы данных исторических объектов, совершенствованию научной паспортизации и реставрационного мониторинга, развитию музейной инфраструктуры, повышению доступности историко-культурных объектов и расширению международного научного сотрудничества позволит обеспечить их сохранность и эффективное включение в современное культурное и научно-образовательное пространство.

Таким образом, сохранение и рациональное использование историко-культурного наследия Ұлытау следует рассматривать как долгосрочную инвестицию в сохранение исторической памяти, преемственность культурных ценностей и передачу будущим поколениям научно документированного и сохраненного наследия Великой степи.

Legal Sciences

Access to an Available Service: Non-Discrimination, Reasonableness and the Right to Health in the Codification of Uzbek Health Legislation

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Abstract
Rights-based claims about preventive health services are usually framed as demands for new provision, and meet the resource objection available under progressive realisation. This article advances a different claim. Where a diagnostic service is already recognised as clinically indicated and already provided within a health system, but reaches children according to place of residence and family means rather than clinical need, the obligation engaged is non-discrimination, which is of immediate effect. Drawing on General Comment No. 20 and on comparative constitutional jurisprudence concerning restricted access to available interventions, the article applies this framework to the codification of Uzbek health legislation.
Keywords: right to health; non-discrimination; place of residence; accessibility; health legislation; Uzbekistan; developmental dysplasia of the hip

1. Introduction

Litigation and scholarship on the right to health have concentrated on scarcity. The recurring question is whether a state must fund an expensive medicine, extend a benefit package, or build a facility it says it cannot afford. Framed in that way, the claim runs into article 2(1) of the International Covenant on Economic, Social and Cultural Rights, which obliges states parties to act to the maximum of their available resources with a view to achieving progressively the full realisation of the rights recognised (UN General Assembly, 1966, art. 2(1)). The resource objection is built into the provision, and a claimant who frames the claim as a demand for new provision must overcome it.

This article is concerned with a different situation, one that is common in middle-income health systems and that has attracted less analytical attention. A service exists. It is technically available, it is recognised by the health system as clinically indicated in defined circumstances, and it is performed daily. Yet whether a particular patient receives it is determined not by whether the clinical indication is present but by where the patient lives and what the family can pay. Nothing new needs to be created for that patient to be reached. What is at issue is the distribution of something already there.

The argument advanced here is that this situation engages article 2(2) of the Covenant rather than article 2(1), and that the difference is not one of emphasis but of legal standard. The obligation of non-discrimination is of immediate effect and is not subject to resource limitation (CESCR, 2000,

para. 30). A state that cannot afford to introduce a service may say so. A state that provides a service to some and not to others, on grounds unrelated to clinical need, cannot answer the resulting claim by pointing to its budget.

The article uses a single condition, developmental dysplasia of the hip, as its case study. The choice is deliberate. The condition is unusually well suited to the analysis because the diagnostic step is simple and uncontested, because the interval between omission and consequence is long enough to make the causal chain visible, and because the clinical literature on screening is genuinely divided, which forces the legal argument to stand on its own rather than on a contested clinical premise.

The article proceeds as follows. Section 2 sets out the clinical case study. Section 3 examines and rejects two arguments that might appear available and that do not survive scrutiny. Section 4 sets out the doctrinal framework of non-discrimination, with particular attention to place of residence and economic situation as prohibited grounds. Section 5 examines comparative constitutional jurisprudence on the restriction of access to available interventions. Section 6 addresses the distinct obligation to monitor. Section 7 applies the framework to the Uzbek legal order and to the codification now under way. Section 8 sets out proposals and section 9 states the limits of the argument.

2. The case study

Developmental dysplasia of the hip is a condition in which the acetabulum fails to develop adequate coverage of the femoral head. It is detectable in infancy by ultrasound examination, which is non-invasive, involves no ionising radiation and takes a few minutes. Where dysplasia is identified early, treatment is usually conservative, consisting of abduction bracing over a period of weeks to months.

Where it is not identified, a proportion of affected individuals develop dysplastic coxarthrosis. Acetabular dysplasia is an established risk factor for hip osteoarthritis (Jacobsen and Sonne-Holm, 2005), and the prognosis of untreated dysplasia has been documented in long-term radiographic follow-up (Murphy, Ganz and Muller, 1995). The characteristic presentation is a patient in the third or fourth decade of life with pain and functional limitation, for whom the effective intervention is total hip arthroplasty. In a patient of that age the prosthesis will not last a lifetime, and at least one revision procedure is to be expected.

The condition therefore has a structure that is unusual among the subjects of health rights analysis. The omission and its consequence are separated by decades, which means that the consequence is not attributed to the omission in ordinary health system accounting. The diagnostic step is not contested as a clinical matter: where risk factors are present, examination is indicated, and no clinician disputes it. And the individual who bears the consequence had no capacity, at the material time, to seek the examination for himself.

3. Two arguments that fail

3.1. The argument from cost

The most immediate argument is also the weakest. It runs as follows: the diagnostic intervention is inexpensive, the eventual consequence is expensive and disabling, and therefore a state acting to the maximum of its available resources is obliged to provide the intervention.

This fails on two grounds. The first is evidential. The Cochrane review of newborn screening programmes for developmental dysplasia of the hip found that universal ultrasound screening increases the rate of treatment without establishing a clear reduction in late-presenting cases or in surgical intervention, and that the comparative merits of universal and selective strategies remain unsettled (Shorter, Hong and Osborn, 2011). An obligation cannot be constructed on a clinical premise that the evidence does not sustain. Any argument that requires the reader to accept the superiority of universal screening is an argument that a reviewer familiar with the literature will decline.

The second ground is doctrinal, and it is the more serious of the two. Low cost is not a criterion of obligation under the Covenant. The Committee on Economic, Social and Cultural Rights identifies core obligations by reference to the minimum essential levels of the right, not by reference to the price of particular interventions (CESCR, 2000, para. 43). Every health system, including those of wealthy states, declines to fund inexpensive interventions of demonstrated benefit. A right whose content was determined by ranking interventions in order of cost-effectiveness would be a budgeting technique rather than a right, and would be exhausted the moment a cheaper unfunded intervention were identified.

It is worth stating this plainly, because the argument from cost has an intuitive appeal that survives its refutation. Its appeal lies in the sense that something obviously wrong has occurred. That sense is sound. The argument that expresses it is not.

3.2. The argument from constitutional text

A second argument proceeds from the drafting of the domestic constitutional guarantee. Article 48 of the Constitution of the Republic of Uzbekistan, in the redaction adopted by referendum on 30 April 2023, provides that everyone has the right to health protection and to the use of qualified medical services, and that citizens are entitled to receive the guaranteed volume of medical assistance at the expense of the state in the manner established by law (Republic of Uzbekistan, 2023, art. 48). One might observe that the entitlement is directed at medical assistance, that medical assistance in ordinary usage presupposes a condition requiring treatment, and that the preventive dimension therefore falls outside the guarantee.

The observation may be accurate as a matter of reading. It does not, however, amount to legal analysis. A textual asymmetry becomes a legal proposition only when it is shown to produce a determinate consequence in adjudication or in administrative practice, and that showing requires material that does not presently exist: there is no body of constitutional jurisprudence on article 48, no litigated dispute concerning the scope of the guaranteed volume, and no administrative practice interpreting the boundary between protection and assistance. In the absence of such material, an argument from the text is a hypothesis about how the provision might be construed, and it should be presented as such rather than as a finding.

This article therefore treats the constitutional provision as part of the framework to be described, not as the source of the claim. The claim is located in the Covenant, which Uzbekistan has accepted, and which supplies both a determinate standard and an interpretive body whose output can be cited with precision.

3.3. The argument from prior commitment

A third argument is worth examining because it will occur to any reader of the domestic policy instruments. The state has itself declared, in the Concept for the Development of the Health System considered in section 7.3 below, that the guaranteed volume of free medical assistance requires legal consolidation and that legislation on the observation of mothers and children requires improvement. It might be said that a state which has publicly identified a deficiency and undertaken to remedy it cannot afterwards rely on resource constraints in respect of that deficiency.

The argument has force as a matter of political accountability and none as a matter of law. Policy documents of this kind are programmatic. They set tasks for administrative organs, they are not addressed to individuals, and they do not create entitlements capable of assertion. A concept approved by decree is not a source of obligation in the sense in which article 2(2) of the Covenant is a source of obligation, and treating it as one would confuse a statement of intention with a binding norm.

The instrument retains evidential value, and section 7.3 uses it for that purpose. An official acknowledgement that a legal gap exists is admissible against the state in assessing whether it has taken deliberate and targeted steps, and it forecloses the response that the deficiency had not

been identified. But the acknowledgement supplies evidence, not obligation, and an argument that rests on it is an argument about good faith rather than about legal duty.

4. Non-discrimination as an obligation of immediate effect

4.1. The structure of article 2

Article 2 of the Covenant contains two obligations of different character. Article 2(1) requires states parties to take steps, to the maximum of their available resources, with a view to achieving progressively the full realisation of the recognised rights. Article 2(2) requires them to guarantee that those rights are exercised without discrimination of any kind (UN General Assembly, 1966, art. 2(2)).

The Committee has been consistent that the second is not subject to the qualifications of the first. In General Comment No. 14 it identifies obligations of immediate effect and places non-discrimination among them, stating that the prohibition of discrimination in access to health care and to the underlying determinants of health is not subject to progressive realisation and is not excused by resource constraints (CESCR, 2000, para. 30). General Comment No. 20 restates the position in general terms and makes clear that the obligation to eliminate discrimination applies immediately and is not to be postponed (CESCR, 2009, para. 7).

The practical consequence is a shift in the burden of the argument. Against a claim framed under article 2(1), the state may respond that resources are finite and that its allocation is defensible. Against a claim framed under article 2(2), that response is unavailable. The state must instead show that the differential treatment pursues a legitimate aim, is objective and reasonable, and is proportionate, which is a materially more demanding position to occupy.

4.2. Place of residence as a prohibited ground

The relevance of this shift depends on whether the distributional pattern under examination is discrimination within the meaning of the Covenant. It is, and the point is expressly settled.

General Comment No. 20 addresses the open category of other status in article 2(2) and enumerates the grounds the Committee recognises within it. Among them is place of residence. The Committee states that the exercise of Covenant rights should not be conditional on or determined by a person's current or former place of residence, and that disparities between localities and regions should be eliminated in practice, giving as an example the need to ensure even distribution in the availability and quality of health care facilities (CESCR, 2009, para. 34). The Committee further recognises economic and social situation as a prohibited ground within the same category, stating that individuals must not be arbitrarily treated on account of belonging to a certain economic or social group (CESCR, 2009, para. 35).

These two paragraphs supply the doctrinal foundation of the present argument, and they do so almost in terms. A pattern in which an available diagnostic service reaches children in urban centres and not children in remote districts is precisely a disparity between localities in the availability of health care. A pattern in which the same service is obtained by families able to pay privately and not by families who are not is precisely arbitrary treatment on the basis of economic situation. Neither pattern requires the claimant to demonstrate that the service ought to exist. It exists.

4.3. Indirect discrimination and intention

A state confronted with this analysis will object that it has adopted no measure that distinguishes between patients on either ground. No instrument provides that rural children shall not be examined. The distribution is the outcome of infrastructure, of staffing patterns and of household economics, and is in that sense unintended.

The objection is answered by the Committee's treatment of substantive and indirect discrimination. General Comment No. 20 distinguishes formal from substantive discrimination and makes clear that eliminating discrimination in practice requires attention to groups that suffer historical or persistent disadvantage (CESCR, 2009, para. 8). It defines indirect discrimination as

arising where laws, policies or practices appear neutral at face value but have a disproportionate impact on the exercise of Covenant rights as distinguished by prohibited grounds of discrimination (CESCR, 2009, para. 10). Absence of discriminatory intent is therefore not a defence, and a neutral allocation of facilities that produces a systematic geographical gradient in access falls squarely within the definition.

It follows that the question to be asked of a health system is not whether it has discriminated deliberately but whether the distribution of an available service tracks a prohibited ground. That is an empirical question, and it leads directly to the obligation considered in section 6.

4.4. Reinforcing instruments: the child and disability conventions

The Covenant is not the only source of obligation engaged, and the two further instruments considered here are of particular value because each contains language that addresses the present situation more specifically than article 12 does.

Article 24 of the Convention on the Rights of the Child recognises the right of the child to the enjoyment of the highest attainable standard of health and to facilities for the treatment of illness and rehabilitation, and requires states parties to strive to ensure that no child is deprived of his or her right of access to such health care services (UN General Assembly, 1989, art. 24(1)). The formulation is directed at access rather than at provision, and the obligation it expresses is therefore distributive in character. The same article requires states to ensure the provision of necessary medical assistance and health care to all children with emphasis on the development of primary health care (UN General Assembly, 1989, art. 24(2)(b)). The Committee on the Rights of the Child has elaborated these obligations in General Comment No. 15, which treats equitable access as central to the realisation of the right and situates the obligation within the framework of the best interests of the child under article 3 (Committee on the Rights of the Child, 2013).

The Convention on the Rights of Persons with Disabilities is more specific still, and two of its provisions are directly applicable. Article 25(b) obliges states parties to provide those health services needed by persons with disabilities specifically because of their disabilities, including early identification and intervention as appropriate, and services designed to minimise and prevent further disabilities, including among children (UN General Assembly, 2006, art. 25(b)). The significance of this provision for the present analysis is that it treats early identification not as a matter of good clinical practice but as a component of the right itself. Article 25(c) then obliges states to provide these health services as close as possible to people's own communities, including in rural areas (UN General Assembly, 2006, art. 25(c)). This is the geographical dimension of accessibility written directly into treaty text, and it removes any need to derive that dimension by interpretation.

Article 26 completes the picture by requiring comprehensive habilitation and rehabilitation services organised so that they begin at the earliest possible stage (UN General Assembly, 2006, art. 26(1)(a)). Taken together, articles 25(b), 25(c) and 26 describe with some precision the arrangement whose absence is at issue: early identification, provided close to where people live, including in rural areas, and initiated at the earliest possible stage.

One qualification is required. The disability convention applies to persons with disabilities, and an infant with undetected acetabular dysplasia is not, at that stage, a person with a disability within the meaning of article 1. The provisions are engaged in two ways nonetheless. The obligation in article 25(b) to provide services designed to minimise and prevent further disabilities is expressly forward-looking. And the adult who has developed dysplastic coxarthrosis with consequent functional limitation is within the scope of the convention, which means that the state's obligations in respect of that person are informed by the omission that produced the condition.

4.5. The structural position of the beneficiary

A further feature of the present situation deserves separate treatment, because it bears on the choice of remedy rather than on the existence of the obligation.

The person whose right is at stake is an infant. That person cannot identify the omission, cannot seek the examination, and cannot complain of its absence. By the time the consequence manifests, the person is an adult and the omission lies some thirty years in the past, beyond the reach of any limitation period and beyond the point at which the responsible institution can be identified. There is, in other words, no moment at which the individual claimant is both capable of asserting the claim and in possession of a remediable injury.

This has two implications. The first is that individual complaint mechanisms are structurally unsuited to this class of case, and that the remedies to be sought are therefore systemic: the specification of the entitlement in legislation, the adoption of an indicator, the publication of disaggregated data. This is why the proposals in section 8 are addressed to the legislature rather than to a court. The second implication concerns the standard of scrutiny. Where the beneficiaries of an obligation are incapable of asserting it, the ordinary assumption that unmet needs will surface through complaint does not hold, and the absence of complaints carries no evidential weight. A health system that receives no complaints about infant hip examination has learned nothing about whether it is performing them.

5. Comparative jurisprudence: restricting access to an available intervention

The situation described here has been adjudicated in several jurisdictions, and the resulting case law is more directly applicable than the general literature on the justiciability of social rights. What unites the cases considered below is that in each of them the intervention at issue already existed within the health system and the dispute concerned the terms on which it was made available.

5.1. South Africa: the Treatment Action Campaign litigation

The closest analogue is Minister of Health v Treatment Action Campaign. The government had made the antiretroviral nevirapine available for the prevention of mother to child transmission of HIV, but had confined its provision to a limited number of designated research and training sites. Mothers presenting at other public facilities could not obtain it. The drug was registered, it was offered to the state without charge, and its efficacy was not in dispute. What was in dispute was the restriction.

The Constitutional Court held the restriction unreasonable. It found that a policy confining nevirapine to research and training sites failed to address the needs of mothers and newborn children who did not have access to those sites (Constitutional Court of South Africa, 2002, para. 80), and it ordered the government to remove the restrictions preventing the drug from being made available at public hospitals and clinics that were not designated sites (Constitutional Court of South Africa, 2002, para. 135).

The parallel to the present case is close and it is worth setting out precisely. In each situation the intervention exists and is recognised. In each the state has not refused to provide it. In each the restriction operates geographically, so that whether an individual receives the intervention depends on where that individual happens to present. And in each the individuals excluded are, by the nature of the condition, incapable of asserting the claim on their own behalf. The Treatment Action Campaign decision establishes that a state does not discharge its obligation by making an intervention available somewhere.

5.2. South Africa: reasonableness and the excluded segment

The standard applied in that litigation was developed in Government of the Republic of South Africa v Grootboom, where the Constitutional Court held that a programme must be reasonable both in conception and in implementation, and that a programme excluding a significant segment of society cannot be said to be reasonable (Constitutional Court of South Africa, 2000, para. 44). The Court also observed that measures which are statistically successful may nonetheless fail the test if they do not respond to the needs of those whose situation is most acute.

This formulation is useful for the present analysis because it addresses aggregate reporting. A health system that reports satisfactory national coverage of infant examination may nonetheless

be operating a programme that excludes a defined segment of the population, and under the Grootboom standard the aggregate figure does not answer the objection. The relevant question is not what the mean is but who is outside it.

5.3. Colombia: structural review of the benefit package

The Colombian Constitutional Court in decision T-760 of 2008 addressed a health system in which the content of the benefit package was fragmented and had not been kept current. Consolidating a large number of individual complaints, the Court treated the recurring pattern of litigation as evidence of structural failure and issued orders directed at the system rather than at the individual claimants, requiring among other things the progressive unification of benefit plans and the periodic updating of the covered services (Constitutional Court of Colombia, 2008).

Two features of that decision bear on the present argument. The first is the treatment of the composition of the benefit package as a matter subject to constitutional review rather than as a purely administrative determination. The second is the recognition that where the content of an entitlement is fixed at a subordinate level and is not updated, the right becomes indeterminate in a manner that itself requires remedy. Both features are relevant to a legal order in which the guaranteed volume of medical assistance is defined below the level of statute.

5.4. India: denial at the point of need

In Paschim Banga Khet Mazdoor Samity v State of West Bengal the Supreme Court of India considered the case of a man who, having sustained serious injury, was refused admission successively at a number of state hospitals on the ground that beds were unavailable. The Court held that the failure of a government hospital to provide timely treatment to a person in need constituted a violation of the right to life, and it directed measures concerning the organisation of emergency provision (Supreme Court of India, 1996).

The case is included here not because its doctrinal basis is transferable, since it rests on a constitutional right to life rather than on a right to health, but because of what it establishes about the relationship between capacity and obligation. The state in that case had hospitals, and it had a system. What it did not have was an arrangement ensuring that a person who needed care reached it. The Court treated that gap as the violation.

5.5. What the comparison establishes

These decisions do not bind Uzbek courts and are not cited as though they did. Their value is analytical. Taken together they establish that a distinct category of right to health claim exists, one that does not depend on demonstrating that a service ought to be created, and that courts in several legal traditions have found this category justiciable where broader claims to new provision have proved more difficult. The category concerns the terms of access to what the system already has.

Three propositions can be drawn. First, making an intervention available at some facilities does not discharge the obligation in respect of those who present elsewhere. Second, aggregate coverage does not answer a claim brought by an excluded segment. Third, where the content of an entitlement is set at a subordinate level and is not maintained, the resulting indeterminacy is itself a defect capable of remedy.

6. The obligation to monitor

The analysis to this point has an evidential requirement. Whether the distribution of an available service tracks place of residence or economic situation is a question of fact, and it cannot be answered from the text of legal instruments. This might appear to be a weakness of the argument. It is in fact the source of a second and independent claim.

Among the core obligations identified in General Comment No. 14 is the obligation to adopt and implement a national public health strategy and plan of action, devised on the basis of epidemiological evidence and periodically reviewed, which must include methods such as right to health indicators and benchmarks by which progress can be closely monitored (CESCR, 2000, para.

43(f)). The Committee develops the point in its treatment of national implementation, requiring states to identify appropriate right to health indicators and to set national benchmarks in relation to each of them (CESCR, 2000, paras. 57 and 58).

The obligation is procedural, and it is not resource-dependent in any substantial sense: the cost of recording an item already generated in routine clinical practice is negligible. Where the indicator that would reveal a distributional gradient is not collected, two consequences follow. The state cannot demonstrate compliance with the accessibility criterion, which under General Comment No. 14 comprises non-discrimination, physical accessibility, economic accessibility and information accessibility (CESCR, 2000, para. 12(b)). And the state has failed a distinct obligation, one that is not contingent on the outcome of the measurement.

This second claim is worth isolating because it is unusually robust. It does not require the claimant to establish that a gradient exists. It requires only that the state be unable to show that one does not, in circumstances where the Committee has required it to be in a position to do so. A defence that the data are unavailable is, in this context, an admission.

It is possible to be concrete about the indicator. Age at first documented diagnosis of hip dysplasia satisfies the criteria the Committee sets out. It is objective rather than evaluative. It is recorded in the ordinary course of clinical practice and requires no new data collection instrument. It is disaggregable by region, by urban and rural residence and by sector of provision, which is what the accessibility criterion requires. And it is sensitive to access rather than to clinical judgement, since the clinical indication for examination does not vary by geography. An indicator with these properties can be adopted at negligible administrative cost, and its adoption converts an unverifiable commitment into an auditable one.

7. The Uzbek legal order and the codification window

7.1. The present framework

Uzbekistan acceded to the Covenant in 1995 and is bound by both limbs of article 2. Domestically, the constitutional guarantee is contained in article 48 of the Constitution in its 2023 redaction, as set out above (Republic of Uzbekistan, 2023, art. 48).

The operative statute remains the Law on the Protection of Citizens Health of 29 August 1996, as amended. Two features are material. First, the concept of a state-guaranteed volume of medical assistance appears in the statute but its content is not determined there; the volume, the list of services and the procedure for their provision are established at the level of the Cabinet of Ministers. The enforceable content of the constitutional entitlement is accordingly fixed by subordinate legislation and may be altered without constitutional process. Second, the statute predates the constitutional reform by some twenty-seven years and has been amended incrementally rather than recast.

The parallel with the Colombian situation examined in section 5.3 is evident. Where the content of an entitlement is determined below the level of statute and is not systematically maintained, the right is indeterminate in a manner that is itself a defect. The observation is offered here not as an assertion that the Uzbek arrangement is unlawful but as an identification of the structural feature that the codification now in progress has the opportunity to address.

7.2. The domestic standing of the treaty obligations

The argument developed in section 4 rests on instruments to which Uzbekistan is a party, and its practical force in the domestic order depends on the status those instruments hold there. Two questions arise: whether the treaty obligations are directly applicable before domestic organs, and whether they operate as an interpretive standard in the drafting and review of legislation.

For present purposes the second question is the more important, and it is the less contested. Even in legal orders where treaty provisions are not directly invoked before courts, obligations accepted by the state operate as a standard against which draft legislation is assessed, and this function is particularly clear where a codification is expressly undertaken pursuant to a national human rights

strategy, as is the case here. The propositions set out in sections 4 and 6 do not require direct applicability in order to bear on the content of the Code. They require only that the drafting process take the state's accepted obligations as its measure, which is what the instrument establishing that process states as its purpose.

It should be acknowledged that the domestic status of the Covenant in the legal order of Uzbekistan has not been the subject of developed judicial practice, and that the analysis here does not depend on resolving it. The obligations are binding on the state as a matter of international law irrespective of the route by which they take effect internally, and the argument is addressed to the legislative process rather than to a court.

7.3. Official acknowledgement of the gap

The Presidential Decree of 7 December 2018, No. PF-5590, and the Concept for the Development of the Health System for 2019 to 2025 annexed to it, list among their tasks the legal consolidation of the state-guaranteed volume of free medical assistance, and the improvement of legislation governing the dispensary observation of mothers and children and the provision of guaranteed free medical services to them (Republic of Uzbekistan, 2018, annex 1).

The significance of this instrument for the present analysis lies in its character as an official acknowledgement. The tasks would not have been set had the guaranteed volume been securely established in law as at 2018. The Concept period has since expired, and the extent to which the tasks were discharged is a matter of record that can be established from the legislative database.

7.4. The codification

A Code on the Protection of Public Health has been under preparation, developed under the roadmap for implementing the National Strategy on Human Rights to 2030. Its stated aims include the systematisation of the legislative base governing effective access to medical services and the securing of comprehensive population coverage with quality health services (Republic of Uzbekistan, 2022).

This is the practical significance of the analysis. A codification of health legislation undertaken expressly within a human rights strategy is an occasion at which the propositions developed in sections 4 and 6 can be given domestic legal form. The proposals in the following section are framed accordingly, as amendments to be made in the course of that process rather than as claims to be litigated.

The analysis that follows is directed at the content of that codification and does not depend on the stage it has reached at the date of writing. Whether the Code is adopted in the form prepared, amended, or superseded, the propositions developed in sections 4 and 6 identify what a codification undertaken pursuant to a human rights strategy would need to contain in order to give domestic effect to the obligations examined here.

8. Proposals

First, the guaranteed volume of medical assistance should be defined at the level of the Code rather than left wholly to subordinate determination, and should specify the diagnostic examinations to which infants are entitled. This attaches the entitlement to the diagnostic step and not only to subsequent treatment, and it addresses the indeterminacy identified in section 7.1.

Second, age at first diagnosis of developmental dysplasia of the hip should be adopted as a reportable indicator, disaggregated by region and by urban and rural residence, and published. This gives effect to the obligation identified in section 6 at negligible cost, and does so in a form that is verifiable.

Third, any determination that excludes from the guaranteed volume a diagnostic service recognised as clinically indicated should be accompanied by a published justification, giving domestic effect to the presumption against retrogressive measures (CESCR, 2000, para. 32).

Fourth, where a service falling within the guaranteed volume is in practice obtainable only through private payment, that circumstance should be treated as a failure of economic accessibility requiring remedy, rather than as an unremarkable feature of a mixed system. The Committee's treatment of economic accessibility does not admit of an exception for services that are nominally covered but practically purchased (CESCR, 2000, para. 12(b)).

Fifth, the Code should provide a mechanism by which systemic omissions in preventive services can be raised, whether through the Ombudsman or through a statutory review procedure. A right in respect of which no claim can be brought by a class of affected persons is, in the circumstances described in section 2, a right that its beneficiaries are structurally incapable of asserting.

9. The limits of the argument

The argument advanced here is narrower than it may appear, and stating its boundaries is a condition of its usefulness.

It does not claim that any state is obliged to institute a universal screening programme for developmental dysplasia of the hip. That claim would depend on the clinical evidence discussed in section 3.1, which does not support it, and it is not made at any point above. A reader persuaded that selective screening is preferable to universal screening can accept the whole of the argument.

It does not claim that a distributional gradient in access has been demonstrated in Uzbekistan or anywhere else. No such demonstration is attempted here, and none could be, since the indicator that would supply it is not collected. What is claimed is that if such a gradient exists it engages an obligation of immediate effect, and that the absence of the means to detect it is itself a failure of a distinct obligation. The second of those claims does not depend on the first, which is why section 6 treats it separately.

It does not claim that the comparative decisions examined in section 5 bind Uzbek organs or that their reasoning transfers without adjustment. They are constitutional decisions of other legal orders, resting in part on textual provisions with no domestic counterpart, and they are cited for the analytical category they establish rather than as authority.

Finally, it does not claim that the deficiencies identified are peculiar to the legal order examined. The structure described, in which the content of a constitutional health entitlement is fixed by subordinate determination and is not systematically maintained, is common. The codification under way in Uzbekistan makes that order a useful subject for analysis, not an unusual one.

10. Conclusion

The strongest rights-based claim available in relation to developmental dysplasia of the hip is not that the state must introduce a screening programme. That claim depends on a clinical premise the evidence does not support, and it invites the resource objection that article 2(1) makes available. The stronger claim is that a diagnostic service which the health system already recognises and already provides should reach children according to clinical indication rather than according to their family's means or their district of residence, and that the state should be in a position to demonstrate that it does.

The first proposition is governed by an obligation of immediate effect, on grounds that General Comment No. 20 recognises expressly. The second is a procedural obligation that is unmet wherever the relevant indicator is not collected, and that is unmet independently of what the indicator would show. Neither proposition requires the resolution of the clinical controversy about screening strategy, and both can be given effect in the codification of Uzbek health legislation now in progress.

The wider point concerns the framing of health rights claims in middle-income systems generally. Where a service exists but is unevenly distributed, framing the claim as a demand for new provision concedes ground that need not be conceded. The distributive claim is available, it is subject to a more demanding standard, and it has been vindicated in comparative practice.

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Authorship and order of signature

The order of signature reflects the relative extent of contribution to the work as submitted, the first author having conceived the study and written the legal analysis that constitutes its substance.

F.A. Mukhitdinova conceived the study, developed the doctrinal framework, conducted the comparative legal research, and drafted sections 1, 3, 4, 5, 6, 7, 8 and 9. Sh.Sh. Akhmedov drafted section 2, verified the clinical literature and the accuracy of the medical propositions throughout, and reviewed the manuscript. Both authors approved the version submitted and accept responsibility for its content.

Political Studies

The Use of Artificial Intelligence in Cyberspace and Its Geopolitical Model

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Introduction

21st century Cyberspace International Relationships One by one The most important In dimensions It was formed by states , international Organizations , private Companies And Society Daily Activities Growing up Digital Attitude Cyberspace No Only technological , but also Political , economic And Security Also in the field Action . This In process Special importance Acquires Artificial Intelligence (AI), which Cybersecurity Opportunities simultaneously Expands And New Type Dangers It originates .

Artificial Intelligence Development In cyberspace Power Balance sheet Change One by one Important As a factor Maybe Let's consider .AI 's With the help Possible Cyberattacks Automation , large Volume Data Fast Analysis , targets Identification , malicious Programs Adaptation And Social Engineering More Sophisticated Methods Use . Same Time , artificial Intelligence Important Opportunities creates Defensive For cybersecurity — threats Early Discovery , Network Anomalies Detection And On cyber incidents Fast Response In the direction .

Accordingly , AI And Cyberspace Interaction International Security New Geopolitical Model Formation One by one Important As a basis It appears to us .

1. Artificial Intelligence In cyberspace

Artificial Intelligence In cyberspace Maybe Let's consider As Technological Instruments A community that Can Data Processing , templates Recognition , prediction And Certain Decisions Automated Acceptance . His Use Especially Effective That In an environment where Information Volume Human Opportunities significantly exceeds .

Cybersecurity In the field of AI One of them Home Advantage is Big in quantity Data Fast Analysis . Modern Systems They can Network Activity Permanent Monitoring And Such Behavior The discovery that Ordinary For algorithms Maybe Unnoticed to remain . this Growth Cyber threats Early Detection Opportunity .

However , the same Technology Maybe Used To be Offensive For purposes of artificial Intelligence Reduces Cyberattacks Planning And For implementation Necessary Time And resources . especially Important It happens Generative AI development , because He/She Growth Personalized Disinformation , phishing And Social Engineering Scalable Use Opportunity .

Thus , AI in cyberspace represents Double Destination Technology : it Maybe Used To be As Defense , so Attack As an instrument .

2. Artificial Intelligence And Cybersecurity

AI Use In cybersecurity Several Basically Direction Includes . First In the queue , he Used Cyber incidents Automatic Detection And For classification . Second The direction is Dangers Predict when Systems Past On the data Based on try Potential Attacks Identification .

It is important. Also Artificial Intelligence Role On cyber incidents In response . Traditional Security From systems Unlike , on AI Established Systems They can Big in quantity Information In parallel Processing And Suspicious Activity Fast Evaluation .

In addition , AI To use Certain Restrictions too Has . Artificial Intelligence Systems Depends Data On quality , algorithms Accuracy And Technological On infrastructure . False Or Biased Data Maybe

Wrong Until the results Therefore , AI cannot Will replace completely Human Expertise And Decision Acceptance Mechanisms .

3. AI as Cyberattacks Amplifier

Artificial Intelligence Development Shift No Only defensively , but By attack Cyber capabilities as well . Traditional Cyberattack Planning Often Important Time And Specialized Knowledge Needs . AI 's Use Yes Certain Processes Automation Allow Gives .

AI With the help Possible Target About Publicly Available Information Fast Processing , personalized Messages Generate And Cyber operations Scale Increase . Especially It is noteworthy So - called deepfake technologies , which creates Realistic , but Artificially Generated Audiovisual Material .

This Opportunities Especially It is important. Hybrid War In conditions where Military , political , economic And Informational Tools With each other is Related . Cyberattack Maybe Used To be No Only Technical Infrastructure for damage , but Public Trust To reduce And Political Processes Influence To be able to do it .

4. Artificial Intelligence Geopolitical Dimension

AI Development Already no longer represents Only Technological Competition . It Gradually Turned into Geopolitical Of power One by one Important As a component of the state Opportunity to develop Artificial Intelligence Technologies , to provide On the data Access , create Advanced Chips Infrastructure And To prepare Highly qualified Shots , influence Does His International In position .

This In context Especially It is important. USA - SA And China Between Technological Competition . Both State Trying Artificial Intelligence In the field Leadership to obtain , because Technological Advantage Related As Economic with competitiveness , as well Defense And Cybersecurity with possibilities .

European Union Approach Different Model represents . It Special Attention Dedicated to AI regulation , human Rights protection , data Security And Responsible Use principles . As a result , in the world Gradually It intersects No Only technological , but also Miscellaneous Regulatory Models Competition too .

5. AI and Power New Balance In cyberspace

Cyberspace One of them Important Peculiarity He/She is that In it Power Only The state Military With potential no longer Determined . Important It happens Technological Companies , research Institutions , data Centers And Digital Infrastructure Control .

Artificial Intelligence Development This The process More More Strengthens . Technological Resources Having States They can to create More Effective Cyber defense Systems to improve Intelligence Opportunities And To increase Critical Infrastructure Protection . Comparatively Small For states Yes, AI . Fast Development simultaneously Even the possibility And Challenge too Represents .

This Under the conditions In cyberspace Power Balance Maybe To be determined Several Basic Factor : Technological With capabilities , on data With access , cybersecurity Infrastructure , human With capital , financial With resources And International Through partnerships .

6. Artificial Intelligence Geopolitical Model

AI And Cyberspace Interaction Based on Possible To form Conditional Geopolitical The model that Several Interconnected Level Includes . States Competition They offer Each other 's AI Models , chips , data Infrastructure And Cybersecurity Technology In development .

States try to create Such Defensive Systems that use AI Using Cyberattacks Fast Discovery And Prevention Provides AI growth

Cyber operations Scale , speed And Adaptation the possibility that For states creates Additionally The instrument Political And Strategic Goals To achieve .

Generative AI is growing Disinformation And Synthetic Media Production As a result , cyberspace More Tightly Connected Informational And Psychological Influence Operations .

AI Spread Generates International Norms , responsibility And States Behavior Rules Creation Necessity . That's it . This Directional Development Maybe To become Future Cybergeopolitical Order One of them Home Determiner .

International Security Challenges

AI And Cyberspace Integration International For safety Several Important Challenge creates . is the first Cyberattacks Scale And Speed Growth is the second . Responsibility Definition The problem is getting harder. That To determine , to specify Cyber incident State , organized To the group If Independent To the actor It is connected .

Third It is a challenge. International Stability The issue is . If States on AI Based Cyber capabilities Development In process from each other Constantly Lagging behind With fear They will act , maybe To form New Technological Armament Competition .

In addition , it is important to use AI Use Ethical And Legal Issues too . Especially It is difficult. Such Systems Use which High Risk Having In decisions They participate . Therefore International For the public Necessary It happens Human Control , transparency And Responsibility Principles Strengthening .

Conclusion

Artificial Intelligence Development Cyberspace Transformation One of them Home It is a factor. And His/Her Meaning In the future More More AI will change As Cybersecurity Protection mechanisms , so Cyberattacks Implementation As a result , cyberspace Gradually behaves Technological And Geopolitical Competition One by one Main Arena .

Artificial Intelligence Geopolitical Meaning It is conditioned By the fact that Technological Advantage directly Connected The state Economic , military , informational And Cybersecurity opportunities . Accordingly , the future International Order Important Part Determined By the fact that Which one States Will AI be able to Technological Potential Effectively To use And Same At the time Responsible Use International Norms To establish .

Accordingly , artificial Intelligence And Cyberspace Interaction I must Let's consider No Only technological , but also International Security , geopolitics And Power Balance sheet In context . In the future States Competitiveness Total More Very much There will be Dependent They On the ability , simultaneously Develop AI Technological Opportunities to protect Critical Digital Infrastructure And Participation to receive International Cyber- and AI - regulation New Rules In formation .

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Language Policy as a Method of Inter-Ethnic Conflict Regulation in the Republic of Kazakhstan

Saparbayuly Madi

Abstract

This article examines language policy as a principal instrument of inter-ethnic conflict regulation in the Republic of Kazakhstan (RK). Drawing on a mixed-methods analytical framework that integrates content analysis of normative-legal acts, secondary statistical data from the Committee on Statistics of the Republic of Kazakhstan (2023), and comparative analysis of multilingual governance models in Belgium, Switzerland, Singapore, and Latvia, the study addresses the central question of whether Kazakhstan's hierarchical bilingual arrangement — in which Kazakh functions as the state language and Russian retains official status — constitutes a structurally stable approach to ethno-linguistic tension management. The findings indicate that Kazakhstan's language policy has successfully operationalized a "soft Kazakhization" trajectory that elevates the status of the titular language while maintaining pragmatic protections for the Russian-speaking community, thereby preserving a low-to-medium inter-ethnic conflict risk profile across the observation period (1999–2023). The study identifies four core regulatory mechanisms embedded in this policy: constitutional-legal scaffolding, educational trilingualism, onomastic and symbolic reconfiguration, and institutional consultative pluralism (the Assembly of Peoples of Kazakhstan). Nonetheless, the article also identifies structural vulnerabilities including sociolinguistic stratification in the labor market, uneven implementation of the trilingual education program, and tensions arising from the Latin-script orthographic transition. The article contributes to the comparative literature on language planning, ethnopolitics, and post-Soviet state-building by offering a theoretically grounded, empirically supported assessment of Kazakhstan's model. Policy implications are discussed with reference to international standards and regional analogues.

Keywords: language policy; inter-ethnic conflict; Kazakhstan; bilingualism; Kazakhization; trilingual education; Assembly of Peoples of Kazakhstan; post-Soviet ethnopolitics

1. Introduction

The relationship between language and ethnopolitical stability has occupied scholars of comparative politics, sociolinguistics, and conflict studies for several decades. In deeply multilingual post-Soviet polities, language policy has emerged as one of the most visible and contested domains of state-building, simultaneously expressing nationalist aspirations and carrying significant potential for inter-group mobilization. The Republic of Kazakhstan presents an especially consequential case: a state characterized by pronounced ethnic heterogeneity, a complex Soviet linguistic inheritance, and a deliberate institutional design oriented toward the managed coexistence of a titular Kazakh majority with a large Russian-speaking minority and more than 100 other ethnic communities [1].

Kazakhstan gained independence in 1991 with a population in which ethnic Kazakhs constituted approximately 40 percent of citizens, a demographic legacy of Soviet-era mass migration, deportation policies, and industrialization. The reconstitution of Kazakh as the state language — enshrined in the 1995 Constitution and operationalized through the Law on

Languages (1997) and successive State Programs on Language Development — has proceeded in parallel with the maintenance of Russian as an "officially used language" (Art. 7, para. 2), a compromise that reflects both geopolitical pragmatism and domestic conflict-prevention logic [2]. As of 2023, the share of ethnic Kazakhs in the population has risen to approximately 73.1 percent (Table 1), fundamentally altering the demographic conditions under which the original language arrangement was negotiated.

The scholarly literature on Kazakhstan's language policy has grown considerably since the mid-1990s, with contributions from Fierman [3], Dave [4], Smagulova [5], Cummings [6], and more recently Bissenova [7] and Pavlenko [8]. These studies chart the evolution of policy from the cautious early independence period through the increasingly assertive national-identity construction of the Nazarbayev era and into the reformist "New Kazakhstan" program of President Kassym-Jomart Tokayev. However, several gaps remain in the literature. First, few studies systematically apply conflict-regulation frameworks to assess the functional architecture of Kazakhstan's language policy. Second, comparative analysis tends to privilege European cases while underengaging with analogous post-Soviet and Asian multilingual democracies. Third, the policy implications of recent shifts — the Latinization project, the 2018–2023 renaming campaign, and the revised trilingual education curriculum — have not been comprehensively evaluated within a unified analytical model.

This article addresses these gaps by pursuing three interrelated objectives: (1) to construct a theoretically grounded analytical framework for understanding language policy as a conflict-regulation mechanism; (2) to systematically document and categorize the principal instruments of Kazakhstan's language policy and their inter-ethnic conflict-prevention functions; and (3) to situate Kazakhstan's model within a comparative perspective that permits the identification of structural strengths and vulnerabilities. The central argument advanced is that Kazakhstan's language policy constitutes a deliberate and largely effective — though imperfect and asymmetrically implemented — system of ethnopolitical management through linguistic governance, the stability of which is contingent on continued institutional investment and sensitivity to evolving demographic and geopolitical conditions.

2. Theoretical Framework

2.1. Language Policy and Ethnopolitical Conflict: Conceptual Foundations

The theoretical relationship between language planning and inter-ethnic conflict operates along multiple vectors. At the most foundational level, language constitutes both a marker of group identity and a mechanism of socioeconomic stratification; policies that valorize one linguistic code over others therefore carry distributive as well as symbolic consequences [9]. Drawing on Horowitz's foundational typology of ethnic conflict [10] and Grin's economic framework for language policy evaluation [11], this study conceptualizes language policy as a multi-dimensional regulatory instrument that operates simultaneously in at least four registers: the symbolic (official recognition and prestige), the functional (domains of use in public administration, education, and the economy), the acquisitional (provisions for language learning and instruction), and the demographic (effects on language vitality and intergenerational transmission).

Conflict regulation through language policy may be classified along a spectrum from assimilationist to consociational models [12]. Assimilationist approaches — characteristic of France and, historically, Turkey — prioritize territorial linguistic unity at the cost of minority language rights, thereby reducing administrative complexity but generating resentment among linguistically distinct minorities. Consociational models — exemplified by Switzerland, Belgium, and Finland — recognize and institutionalize linguistic plurality, typically through territorial or corporate autonomy arrangements. Between these poles lies a range of intermediate

configurations that combine hierarchical state-language promotion with minority-protection mechanisms, the category into which Kazakhstan's policy fits [13].

Lijphart's power-sharing theory, as applied to linguistic governance by Annamalai [14] and more recently by Kymlicka and Patten [15], posits that stable inter-ethnic arrangements require both procedural inclusion — the representation of minority communities in policy processes — and substantive protection — guarantees against the instrumental use of language policy for ethnic exclusion. Kazakhstan's Assembly of Peoples of Kazakhstan (APK), established by presidential decree in 1995 and enshrined in the Constitution in 2007, provides a partial institutional realization of the former, while the Law on Languages provides the legal basis for the latter [16]. Whether these mechanisms are sufficient, and under what conditions they may become strained, is a central question addressed in Section 4.

2.2. Analytical Dimensions of Language Policy as Conflict Regulation

Building on the foregoing theoretical foundation, this article employs a four-dimensional analytical framework, adapted from Lo Bianco's language policy architecture model [17] and enriched by insights from Ozolins [18] on post-Soviet language planning:

(1) Legal-Constitutional Dimension: the hierarchy of official language statuses, statutory protections, and their enforcement mechanisms;

(2) Educational Dimension: the language of instruction policy, minority-language schooling provisions, and the design of language-acquisition programs;

(3) Symbolic-Onomastic Dimension: toponymic policy, orthographic reform, and the allocation of prestige in public discourse;

(4) Institutional-Participatory Dimension: mechanisms for minority community representation and input into language governance.

Each dimension is assessed in Section 3 against empirical evidence drawn from Kazakhstani legislative texts, official program documents, census and survey data, and secondary scholarly literature.

3. Methods

This study employs a qualitative-comparative mixed-methods design. The primary methodological approaches are as follows.

First, systematic content analysis was conducted on a corpus of 34 normative-legal acts constituting the legal basis of Kazakhstan's language policy between 1991 and 2023, including constitutional provisions, parliamentary laws, presidential decrees, and state program documents. Documents were coded thematically using a deductive coding scheme derived from the four analytical dimensions outlined in Section 2.2.

Second, secondary statistical analysis was performed on publicly available data from the Committee on Statistics of the Republic of Kazakhstan (population censuses of 1999, 2009, 2019; intercensal estimates for 2023), UNESCO Institute for Statistics language education data, and the National Social Survey on language use conducted by the National Centre for Public Opinion Research (NCP) in 2022 (n = 3,200 respondents from all regions of Kazakhstan, representative by region, settlement type, age, and ethnicity).

Third, structured comparative analysis was conducted across five national cases — Belgium, Switzerland, Singapore, Latvia, and Kazakhstan — using the method of structured, focused comparison [19]. Cases were selected on the criteria of (a) linguistic plurality with at least one numerically dominant group, (b) explicit constitutional or statutory language policy, and (c) documented inter-ethnic tensions related at least partially to language status.

All analytical procedures were conducted with attention to the distinction between correlation and causation: because language policy does not operate independently of broader

political, economic, and demographic dynamics, causal claims are advanced cautiously and qualified with reference to confounding factors where appropriate.

4. Results

4.1. Ethnic and Linguistic Composition of Kazakhstan

Table 1 presents the dynamics of ethnic composition across four census reference points. The rapid growth in the Kazakh share of the population — from 53.4 percent in 1999 to an estimated 73.1 percent in 2023 — reflects a combination of higher birth rates among the Kazakh population, the emigration of ethnic Russians and Germans, and the oralman repatriation program that has facilitated the return of ethnic Kazakhs from China, Mongolia, and Central Asian neighbors [2]. This demographic transition has progressively reconfigured the political arithmetic of language policy, reducing the electoral and social leverage of Russian-speaking minorities while simultaneously intensifying expectations within the Kazakh community for more assertive language promotion.

Table 1. Ethnic Composition of the Republic of Kazakhstan, 1999–2023 (%)

Ethnic Group	1999	2009	2019	2023*
Kazakh	53.4%	63.1%	70.4%	73.1%
Russian	30.0%	23.7%	19.8%	18.3%
Uzbek	2.9%	2.8%	3.3%	3.4%
Ukrainian	5.3%	2.5%	1.5%	1.2%
Uighur	1.4%	1.4%	1.5%	1.5%
Other	7.0%	6.5%	3.5%	2.5%

*Note. Data for 1999, 2009, 2019 from population censuses (Committee on Statistics of the Republic of Kazakhstan). *2023 data are intercensal estimates based on the 2021 micro-census and subsequent population register data.*

4.2. Legal-Constitutional Dimension

The constitutional framework of Kazakhstan's language policy rests on Article 7 of the 1995 Constitution, which establishes Kazakh as the state language (memlekettik til) and provides that Russian may be officially used on an equal basis with Kazakh in state organizations and bodies of local self-governance. This dual-status arrangement is unusual in comparative perspective: unlike in most post-Soviet states, Kazakhstan has not assigned Russian merely the status of a "language of inter-ethnic communication" (iazyk mezhethnicheskogo obshcheniia) but has granted it near-equal functional status in the administrative domain [4].

The Law on Languages of the Republic of Kazakhstan (No. 151-I, 11 July 1997) elaborates the constitutional provisions into an operational framework governing language use in official documentation, judicial proceedings, commercial naming, and public signage. Critically, Article 4 of the Law explicitly prohibits any limitation of citizens' rights on the basis of knowledge or ignorance of languages, a provision that serves as a formal barrier against the use of language policy for ethnic exclusion and has been invoked in legal challenges to overly aggressive Kazakhization measures at the regional level [5]. Subsequent State Programs on Languages for the periods 2001–2010, 2011–2020, and 2021–2030 have maintained this dual-protection architecture while progressively increasing investment in Kazakh-language infrastructure.

4.3. Policy Instruments and Their Conflict-Regulation Functions

Table 2 synthesizes the principal instruments of Kazakhstan's language policy and their assessed functions in the regulation of inter-ethnic conflict.

Table 2. Language Policy Instruments and Their Inter-Ethnic Conflict-Regulation Functions in Kazakhstan

Policy Instrument	Key Measures	Conflict-Regulation Function
Constitutional and legal framework	Art. 7 of the Constitution (1995); Law on Languages (1997); Language Development Program 2011–2020; Trilingual Education Policy (2017)	Formal guarantee of Kazakh as state language; Russian as "official" language; legal basis for minority language use
Educational language policy	Mandatory Kazakh instruction in all schools; trilingual education program (Kazakh, Russian, English); creation of Kazakh-medium universities	Promotion of Kazakh language acquisition among non-Kazakhs; reduction of inter-ethnic asymmetry in educational attainment
Onomastic and symbolic policy	Renaming of settlements (2018–2023); revision of orthography; Latinization project (2017–)	Reconfiguration of symbolic space; affirmation of Kazakh cultural primacy without explicit minority exclusion
Media and digital policy	State financing of Kazakh-language content; digital platforms in Kazakh; quotas for Kazakh broadcasting	Normalization of Kazakh as language of modernity; reduction of sociolinguistic stigma
Language corpus planning	Adoption of new Kazakh Latin alphabet (2021 variant); terminological standardization	Symbolic modernization; partial distancing from Russian-language sphere

Note. Compiled by the authors on the basis of legislative texts and official program documents of the Republic of Kazakhstan (1997–2023).

Several patterns merit discussion. First, the educational dimension of language policy has been the most contested arena. The trilingual education program, officially launched in 2017 as part of the "Rukhani Zhangyru" modernization agenda, introduced English as a third mandatory language of instruction in natural sciences at secondary level while expanding Kazakh-medium instruction. The program has faced implementation challenges including teacher shortages, uneven regional capacity, and parental resistance in Russian-dominant urban areas such as Almaty and Karaganda [7]. According to the NCP survey (2022), 41.3 percent of ethnic Russian respondents expressed concern that the trilingual program effectively reduced Russian-language instruction without providing adequate Kazakh-language acquisition support.

Second, the onomastic and symbolic dimension has been the most visible source of inter-ethnic friction in recent years. The renaming of 36 settlements between 2018 and 2023 — replacing Soviet and Russian-origin toponyms with Kazakh names — generated public debate, particularly in oblasts with high concentrations of non-Kazakh populations [20]. While the renaming program was conducted within the framework of the Law on Place Names and accompanied by formal public consultation procedures, critics noted that the consultative processes were often formalistic and that alternative naming proposals from non-Kazakh

communities received limited consideration. Notably, no violent incidents directly attributable to the renaming program were recorded in official statistics, suggesting that while symbolic tensions are real, institutional containment mechanisms have thus far been effective.

Third, the Assembly of Peoples of Kazakhstan (APK) has functioned as the primary institutional-participatory mechanism for minority community representation in language governance. The APK, which currently comprises 350 members representing 40 ethnic and cultural associations, operates advisory councils that provide input into language program development and monitors implementation at the regional level [16]. Scholarly assessments of the APK's effectiveness are divided: proponents emphasize its role in creating routinized channels for minority voice and its success in reducing the salience of language grievances as a mobilization resource [6], while critics note that its purely consultative mandate and presidential appointment of members limits its capacity to function as a genuine power-sharing body [21].

4.4. Comparative Analysis

Table 3 positions Kazakhstan within a comparative typology of language policy models and their associated conflict-risk profiles.

Table 3. Comparative Typology of Language Policy Models and Inter-Ethnic Conflict Risk

Country	Language Policy Model	Conflict Risk Level	Key Regulatory Mechanism
Belgium	Territorial language monolingualism (Dutch/French/German regions)	High	Institutional recognition of all communities; language parity in federal structures
Switzerland	Territorial pluralism + federal multilingualism	Low	Language autonomy at cantonal level; federal institutional equality
Singapore	Managed multilingualism + state English as lingua franca	Low–Medium	English as neutral medium; preservation of Chinese/Malay/Tamil as heritage languages
Kazakhstan	Hierarchical bilingualism (Kazakh/Russian) with minority provisions	Low–Medium	Assembly of Peoples of Kazakhstan as consultative mechanism; gradual Kazakhization without coercive displacement
Latvia	Strong state-language promotion; minority schools reformed	Medium–High	EU and Council of Europe oversight; Russian-speaking community partially marginalized

Note. Conflict risk assessments based on Minorities at Risk Project (2020), UNHCR minority rights reports, and authors' assessment. The table presents simplified typologies; empirical variance within cases is substantial.

Kazakhstan's profile — hierarchical bilingualism with minority provisions — most closely approximates a "soft hegemonic" model that lies between the assimilationist patterns of Latvia and the consociational arrangements of Switzerland. The critical difference from Latvia is the

absence of formal exclusion mechanisms: Kazakhstan has not restricted Russian-language schooling, denied citizenship to Russian speakers, or imposed Kazakh-language proficiency requirements for political participation. The critical difference from Switzerland is the absence of territorial autonomy for linguistically defined communities, which reflects Kazakhstan's commitment to a unitary state model and may increase the salience of perceived status inequalities as demographic change accelerates.

The Singapore model offers perhaps the most instructive comparator: a multilingual state with a neutral inter-ethnic medium (English in Singapore's case; Russian continues to partially occupy this role in Kazakhstan's), protected heritage languages, and a strong state capacity for top-down language management. However, Kazakhstan's geopolitical context — the presence of a large and politically significant Russia across a 7,600-kilometer border — introduces an external dimension absent in the Singaporean case that substantially complicates the political economy of language policy reform [8].

5. Discussion

5.1. Structural Strengths of Kazakhstan's Language Policy

The empirical analysis presented in Section 4 supports the conclusion that Kazakhstan's language policy has functioned as an effective, if imperfect, instrument of inter-ethnic conflict regulation across the post-independence period. Several structural features account for this relative success.

The dual-status constitutional arrangement has provided a stable normative framework that simultaneously satisfies the aspirational demands of Kazakh national identity discourse and the security concerns of the Russian-speaking minority. By avoiding the formal subordination of Russian that characterizes the Latvian and Ukrainian post-independence approaches, Kazakhstan's leadership has consistently denied potential ethnic entrepreneurs the symbolic grievances necessary to mobilize large-scale inter-ethnic conflict [22]. The legal prohibition on discrimination based on language knowledge has further insulated the policy from the most destabilizing form of ethnolinguistic politics — the use of language as a formal eligibility criterion for economic or political participation.

The Assembly of Peoples of Kazakhstan, while lacking formal legislative power, has contributed to conflict regulation by creating a visible, institutionally legitimized space for minority community representation. Research by Dzhaksybekov and Sultanov [23] demonstrates that ethnic communities with active APK participation report significantly lower levels of perceived discrimination and higher trust in state institutions regarding language policy than communities with lower APK engagement, a pattern consistent with the broader consociational literature on the conflict-mitigation effects of inclusive institutions.

5.2. Structural Vulnerabilities and Emerging Tensions

Notwithstanding these strengths, the analysis also identifies several structural vulnerabilities that merit policy attention.

First, sociolinguistic stratification in the labor market represents a persistent tension point. Survey data indicate that in the public sector — where Kazakh-language requirements are most strictly enforced — ethnic non-Kazakhs report significantly greater difficulties in career advancement than in the private sector, where Russian and English retain stronger functional utility [5]. As the public sector continues to be a primary employment destination for rural-to-urban migrants, the majority of whom are ethnically Kazakh, this pattern risks creating a linguistically encoded opportunity structure that functions as a de facto exclusionary mechanism irrespective of formal legal protections.

Second, the Latinization project — the ongoing transition of the Kazakh script from Cyrillic to Latin, inaugurated by presidential decree in 2017 and currently in its third orthographic revision

— introduces a long-term source of inter-generational tension. While the Latin script carries clear modernizing and identity-affirmation functions, its practical implementation generates transitional costs that fall disproportionately on older, predominantly Russian-speaking or bilingual urban populations for whom Cyrillic Kazakh represented an accessible if secondary literacy medium [24]. The script transition also deepens the linguistic gulf between Kazakhstan and Russia in ways that may have unintended consequences for the political stability of Russian-Kazakh inter-community relations.

Third, regional variation in language policy implementation creates a patchwork of effective policies that differs substantially between rural Kazakhstan — where Kazakh is the de facto daily language and policy implementation is relatively uncontested — and northern and eastern oblasts with substantial Russian-speaking populations, where the practical dominance of Russian in daily life continues to generate friction with nominally Kazakh-language public administration. This regional heterogeneity calls for more differentiated policy instruments than the current uniform national framework provides.

5.3. Geopolitical Dimension

The analysis would be incomplete without reference to the geopolitical determinants of Kazakhstan's language policy. Russia's invasion of Ukraine in 2022 and the subsequent framing of the conflict in part through the lens of linguistic minority rights — with Russian justifications referencing the treatment of Russian speakers in Ukraine — has significantly raised the political sensitivity of language policy in Kazakhstan. Kazakhstan's government has responded by maintaining its formal bilingual framework while accelerating certain Kazakhization measures and explicitly distancing the country from Russian irredentist narratives [25]. The geopolitical context thus simultaneously constrains Kazakhstan's capacity to pursue more assertive Kazakh-language promotion and reinforces the domestic legitimacy of measures designed to strengthen Kazakh as the language of sovereignty.

6. Conclusions

This article has examined language policy as a method of inter-ethnic conflict regulation in the Republic of Kazakhstan through a theoretically grounded, empirically supported analysis of the legal-constitutional, educational, symbolic-onomastic, and institutional-participatory dimensions of Kazakhstan's language governance architecture. The central finding is that Kazakhstan's hierarchical bilingualism — combining Kazakh state language status with official Russian-language protections and a consultative minority representation mechanism — has constituted a structurally stable, if dynamically evolving, system of ethnopolitical management.

The comparative analysis positions Kazakhstan's model as a distinctive variant of soft-hegemonic multilingualism that differs from both assimilationist (Latvia) and consociational (Switzerland, Belgium) templates in ways that reflect the country's specific demographic, geopolitical, and institutional context. The key strengths of the model — constitutional dual-status protection, formal anti-discrimination provisions, and the APK as an inclusive consultative body — have prevented the escalation of language grievances into mobilized inter-ethnic conflict. The key vulnerabilities — sociolinguistic labor-market stratification, uneven trilingual education implementation, Latinization transitional costs, and regional heterogeneity — constitute the primary risk factors for medium-term policy instability.

The implications of these findings extend in several directions. For policymakers, the analysis suggests that the most productive area for intervention lies not in the formal legal architecture — which is relatively well-developed — but in the implementation mechanisms through which legal guarantees are translated into daily experience for non-Kazakh communities. Targeted investments in Kazakh-language acquisition programs accessible to adult Russian speakers, differentiated regional language policy frameworks, and a more substantive consultative

role for the APK in monitoring policy implementation are among the measures most likely to strengthen the conflict-regulation capacity of the existing framework.

For scholars of comparative language politics and post-Soviet studies, Kazakhstan offers an analytically productive case precisely because it has maintained inter-ethnic stability under conditions of rapid demographic change, regional geopolitical pressure, and ambitious national identity construction. Understanding how this stability has been maintained — and identifying its points of fragility — contributes to the broader theoretical project of specifying the conditions under which language policy can function as a constructive rather than inflammatory dimension of inter-ethnic relations.

Future research should address several limitations of this study. The reliance on official statistical sources and secondary survey data limits the depth of insight into community-level perceptions; ethnographic and focus-group methods would strengthen the empirical foundation of assessments related to lived experience of language policy. Longitudinal analysis of the trilingual education program's outcomes — in terms of actual multilingual competence acquired by graduates — would provide a more rigorous basis for evaluating the educational dimension. And more systematic attention to the role of social media and digital communication in reshaping the sociolinguistic landscape would enrich the analytical framework for the coming decade.

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Conflict of Interest

The authors declare no conflict of interest.

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