**ІНСТИТУТ МАТЕМАТИКИ
МНО АЗЕРБАЙДЖАНСЬКОЇ РЕСПУБЛІКИ**

**НАЦІОНАЛЬНИЙ ТЕХНІЧНИЙ УНІВЕРСИТЕТ
"ХАРКІВСЬКИЙ ПОЛІТЕХНІЧНИЙ ІНСТИТУТ"**

**ХАРКІВСЬКИЙ НАЦІОНАЛЬНИЙ
УНІВЕРСИТЕТ РАДІОЕЛЕКТРОНІКИ**

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"ХАРКІВСЬКИЙ АВІАЦІЙНИЙ ІНСТИТУТ"**

УНІВЕРСИТЕТ МІСТА ЖИЛІНА

СУЧАСНІ НАПРЯМИ РОЗВИТКУ ІНФОРМАЦІЙНО-КОМУНІКАЦІЙНИХ ТЕХНОЛОГІЙ ТА ЗАСОБІВ УПРАВЛІННЯ

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У збірнику подано тези доповідей шістнадцятої міжнародної науково-технічної конференції "Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління". Розглянуті питання за такими напрямами: теоретичні та прикладні аспекти систем прийняття рішень, оптимізації та управління системами і процесами; комп'ютерні методи та засоби інформаційно-комунікаційних технологій та управління; безпека функціонування комп'ютерних систем та мереж; інформаційні технології у цивільній безпеці; сучасні інформаційно-вимірювальні системи; інформаційні технології у цивільній безпеці.

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CURRENT DIRECTIONS IN THE DEVELOPMENT OF INFORMATION AND COMMUNICATION TECHNOLOGIES AND CONTROL TOOLS

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Abstracts of reports of the 16-th international scientific and technical conference "Current directions of development of information and communication technologies and control tools" are presented in the collection. Considered issues in the following directions: theoretical and applied aspects of decision-making systems, optimization and control of systems and processes; computer methods and means of information and communication technologies and management; security of functioning of computer systems and networks; information technologies in civil security; modern information and measurement systems; information technologies in civil security.

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СЕКЦІЯ 6

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Підсекція 6.1. ІНФОРМАЦІЙНІ ТЕХНОЛОГІЇ У ЦИВІЛЬНІЙ БЕЗПЕЦІ

ЗАБЕЗПЕЧЕННЯ СТІЙКОСТІ МЕТАЛЕВИХ КОЛОН ПРОМИСЛОВИХ БУДІВЕЛЬ

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Забезпечення стійкості будівельних конструкцій (БК) є основною задачею забезпечення стійкості промислових будівель, з яких вони складаються. І це є основною задачею при проектуванні будівель і споруд. Згідно до вимог пожежної безпеки [1] до стійкості БК в залежності від місця хз експлуатації в об'ємно-планувальних рішеннях будівлі висуваються свої вимоги до межі вогнестійкості БК.

Відомо [2], що при впливі температури пожежі на будівельні конструкції виникає зниження міцності матеріалу, з якого виготовлена конструкція. Тому при експлуатації необхідно забезпечити БК вимогам відповідних норм

Метою доповіді є: визначення технологічних параметрів та властивостей вогнезахиского матеріалу виконаного на основі золи сміттєспалення та розрахунок межі вогнестійкості розробленого покриття. Відомо [3], що для забезпечення необхідної межі вогнестійкості використовуються три основні способи вогнезахисту: зміна (модифікація) речовини з метою підвищення температури її спалахування, горіння, уповільнення транспорту горючих компонентів до поверхні; перешкоджання потраплянню окислювача до горючої речовини; запобігання нагріванню поверхні.

В доповіді наведені основні досліджувані склади вогнезахисного матеріалу та стандартними методами визначені його основні властивості.

Встановлено, що для забезпечення надійного захисту металевих БК від впливу високих температур необхідно використовувати вогнезахисний матеріалі зі складом, в якому усі компоненти знаходяться у збалансованому стані і мають актуальні показники за необхідними параметрами такими як: міцність на стискання, середня щільність, загальна пористість та теплоємність.

Для забезпечення межі вогнестійкості металевої колони 3 години достатньо 50 мм покриття

Список літератури

1. ДБН В.1.1-7:2016 Пожежна безпека об'єктів будівництва. Загальні вимоги. Київ: Мінрегіонбуд України, 2017. 38 с.

2. Пушкаренко А. С., Васильченко О. В. Будівельні матеріали та їх поведінка в умовах високих температур. Харків : АПБУ, 2000. 146 с.

3. Пушкаренко А. С. та ін. Вогнезахисне обробляння будівельних матеріалів і конструкцій. Харків : НУЦЗУ, 2011. 176 с.

ІНФОРМАТИЗАЦІЯ УПРАВЛІННЯ ЯКІСТЮ ТА БЕЗПЕКОЮ ВИРОБНИЧИХ ПРОЦЕСІВ НА ОБ'ЄКТАХ ХАРЧУВАННЯ В КОНТЕКСТІ ЦИВІЛЬНОГО ЗАХИСТУ

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Сучасні виклики у сфері цивільного захисту та безпеки населення вимагають перегляду традиційних підходів до функціонування критичної інфраструктури. Заклади ресторанного господарства та об'єкти масового харчування, особливо ті, що залучені до забезпечення життєдіяльності соціальних установ (лікарень, шкіл, пунктів незламності), об'єктивно стають елементами цієї інфраструктури. Їх стабільна та безпечна робота безпосередньо впливає на здоров'я нації та соціальну стабільність. Забезпечення якості та безпеки виробничих процесів у цій галузі виходить за межі комерційного інтересу і стає питанням цивільної безпеки. Традиційні, паперові методи контролю, засновані на періодичних перевірках, демонструють недостатню оперативність та вразливість в умовах кризових ситуацій.

Метою доповіді є аналіз ролі та методів інформатизації систем управління якістю та безпекою харчових продуктів на об'єктах харчування як невід'ємної складової загальнодержавної системи цивільного захисту.

Проблематика захисту критичної інфраструктури активно досліджується, зокрема в контексті забезпечення продовольчої безпеки в умовах надзвичайних ситуацій [1].

Одночасно, світова практика демонструє стрімкий розвиток цифрових систем управління безпекою харчових продуктів, зокрема, впровадження цифрових платформ на основі стандартів HACCP (Hazard Analysis and Critical Control Points) та ISO 22000 у закладах громадського харчування [2].

Дослідники вивчають потенціал технологій Інтернету речей (IoT) для моніторингу критичних контрольних точок та використання блокчейн-технологій для забезпечення повної простежуваності ланцюгів постачання [3]. Проте, залишається недостатньо дослідженим питання інтеграції цих корпоративних IT-рішень у загальний контур цивільної безпеки та захисту населення від загроз, пов'язаних із харчуванням.

Зв'язок між безпекою харчових продуктів та цивільним захистом є багатогранним. Він охоплює не лише запобігання випадковим біологічним та хімічним забрудненням (спалахи сальмонельозу, ботулізму), але й протидію умисним загрозам, таким як "food defense" (захист продуктів від умисного зараження) та біотероризм. У кризових ситуаціях (воєнний стан, природні чи техногенні катастрофи) порушення у роботі систем водопостачання,

енергетики або логістики миттєво підвищують ризики на об'єктах харчування. Саме тут інформатизація стає інструментом превентивного захисту.

Основним напрямом є цифровізація процедур HACCP. Перехід від паперових журналів до цифрових систем дозволяє не лише фіксувати дані, але й автоматично аналізувати їх у режимі реального часу. Впровадження IoT-сенсорів для безперервного моніторингу критичних контрольних точок (ККТ), таких як температурні режими холодильного та теплового обладнання, параметри вологості та часу обробки, мінімізує людський фактор.

Це формує перший рівень цифрового захисту.

Другим рівнем є впровадження наскрізних систем простежуваності (traceability), що є критично важливим для цивільного захисту. Інформаційні системи, особливо ті, що базуються на технології блокчейн, дозволяють відстежити весь шлях продукту "від поля до столу" за лічені хвилини [4]. Це дає змогу миттєво локалізувати загрозу, інформувати відповідні служби цивільного захисту та запобігти масовим отруєнням чи поширенню небезпечних агентів.

Третій, найвищий рівень інформатизації, полягає в інтеграції даних з об'єктів харчування у єдиний державний моніторинговий центр цивільної безпеки. Агрегація знеособлених даних з тисяч закладів (наприклад, про часті відхилення температури у певних районах через перебої з енергопостачанням, або про надходження скарг на певний тип продукції) дозволяє за допомогою інструментів великих даних (Big Data) та штучного інтелекту виявляти приховані загрози, прогнозувати епідеміологічні ризики та координувати превентивні дії на регіональному чи національному рівні.

Разом з тим, інформатизація створює нові виклики, зокрема у сфері кібербезпеки. "Розумні" холодильники, сенсори та системи управління підключені до мережі, що робить їх потенційними цілями для кібератак. Злам такої системи може призвести до умисного псування продуктів у великих обсягах. Тому розробка та впровадження захищених протоколів передачі даних, систем автентифікації та регулярний аудит кібербезпеки мають стати невід'ємною частиною стратегії інформатизації управління якістю.

Список літератури

1. Крилов, Д. (2023). Проблеми забезпечення продовольчої безпеки України в сучасних умовах. Проблеми сучасних трансформацій. Серія: економіка та управління. 10.54929/2786-5738-2023-7-03-07.

2. Fernández-Segovia, Isabel & Pérez-Llácer, Ana & Peidro, Begoña & Fuentes, Ana. (2014). Implementation of a food safety management system according to ISO 22000 in the food supplement industry: A case study. Food Control. 43. 28–34. 10.1016/j.foodcont.2014.02.042.

3. Kamilaris A., Fonts A., Prenafeta-Boldú F. X. The rise of blockchain technology in agriculture and food supply chains. *Trends in Food Science & Technology*. 2019. Vol. 91. P. 640–652. DOI: https://doi.org/10.1016/j.tifs.2019.07.034

IMPLEMENTATION OF EU ECOLOGICAL STANDARDS (EU ECOLABEL, GREEN KEY) FOR INCREASING THE RESILIENCE OF HOSPITALITY FACILITIES AS ELEMENTS OF CIVIL SECURITY)

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In today’s conditions of hybrid threats, climate change, and socio-political instability, the traditional perception of hospitality and restaurant businesses solely as part of the tourism industry is incomplete. In crisis situations – during natural disasters, pandemics, technological accidents, or military actions – hotels, food establishments, and recreational complexes instantly transform into key elements of critical infrastructure. They become shelters for internally displaced persons, bases for rescue services, medical personnel, and volunteers, as well as hubs for providing the population's basic needs for food and sanitation [1]. Thus, their operational resilience – the ability to continue functioning despite the disruption of centralized systems – becomes a matter of civil security. However, the hospitality sector is extremely vulnerable due to its high dependence on stable supplies of energy, water, and food. The purpose of this report is to analyze leading EU environmental standards, particularly the EU Ecolabel and Green Key, as instrumental frameworks for enhancing the operational resilience of hospitality facilities, which directly enhances their role in the civil protection system.

Analysis of recent research. Research in the field of crisis management in the hotel business is increasingly focusing on the need to develop comprehensive emergency action plans [2]. Experts emphasize that resilience requires a proactive, rather than reactive, approach, including thorough risk assessment (from supply chain disruptions to cyberattacks) and the development of business continuity protocols [3]. In parallel, the academic community is actively studying mechanisms for sustainable development in tourism. However, in the Ukrainian context, as evidenced by the needs analysis of the "Green Hospitality" (GREEN-HOST) project, awareness of leading European environmental standards remains low. The link between "green" practices and operational resilience in the context of civil security remains an under-researched area. This report aims to partially fill this gap by arguing that environmental certification is a direct investment in security and resilience.

At first glance, environmental standards such as the EU Ecolabel and Green Key are aimed at reducing negative environmental impact. Their criteria focus on the rational use of resources, waste minimization, and the use of environmentally friendly substances. However, upon detailed analysis, these criteria prove to be powerful tools for building operational resilience, which is critically important for civil security objects.

First, this concerns energy resilience. The EU Ecolabel criteria require accommodation facilities to significantly reduce energy consumption, use energy-efficient lighting and equipment, and mandatorily use energy from renewable sources. Similarly, the Green Key standard encourages the installation of automatic energy consumption control systems and investment in own-generation (e.g., solar panels). For a civil protection system, this means that a certified hotel has a significantly lower dependence on the centralized power grid. In conditions of blackouts caused by military actions or natural disasters, such a facility can sustain life-supporting operations (heating, communication, kitchen equipment) for the needs of the population and rescue services for much longer.

Second is the resilience of water supply and sanitation. Both standards set strict requirements for reducing water consumption: installing aerators, low-flush systems, monitoring leaks, and, ideally, rainwater harvesting systems for technical needs. In a crisis situation where the centralized water supply is damaged, a facility with such systems can provide basic sanitary needs for much longer, preventing outbreaks of infectious diseases. This transforms it from a passive consumer into an autonomous hub for maintaining hygiene.

Third is the resilience of supply chains and waste management. Eco-standards encourage waste minimization (especially food waste) and cooperation with local suppliers to reduce the transport footprint. In conditions of disrupted national logistics, the ability to efficiently manage stocks, minimize losses, and rely on short, local supply chains is a decisive factor for food security. A facility that already has established ties with local farmers will be able to organize food for evacuees more promptly.

Thus, the implementation of EU Ecolabel and Green Key standards transforms the hotel's business model from vulnerable (high consumption, long supply chains) to resilient (efficiency, autonomy, localization). This transformation directly correlates with the requirements for critical infrastructure objects. That is why educational initiatives, such as the development of courses "Ecological Practices and Certification in Hospitality" and "Energy Efficiency and Sustainable Resource Management," are not just environmental projects, but also security projects. They equip future managers in the hospitality sector with the competencies needed to manage critical infrastructure facilities in emergency situations.

References

1. What are the best practices for hotel disaster preparedness? *International Hospitality Institute*. URL: https://www.internationalhospitalityinstitute.com/articles/what-are-the-best-practices-for-hotel-disaster-preparedness .

2. Crisis Preparedness: Emergency Response Strategies for Hotels. *Mise En Place*. 2025. 21 May. URL: https://traininghotels.com/2025/05/21/crisis-preparedness-emergency-response-strategies-for-hotels/ .

3. Williams S., B. Building hospitality resilience in an era of escalating natural disasters. *Hotel Business*. 2025. 11 Aug. URL: https://hotelbusiness.com/building-hospitality-resilience-in-an-era-of-escalating-natural-disasters/.

ОХОРОНА ПРАЦІ ТА СТІЙКІСТЬ РОБОТИ ПІДПРИЄМСТВ

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Забезпечення стійкості роботи об'єктів критичної інфраструктури є одним з основних факторів забезпечення безпеки держави.

Однак не можена забувати про те, шо на усіх підприємствах України основними силами виробництва є люди, забезпечення безпечних умов роботи яких є основою стікості виробничого процесу і виробнитва в цілому, тому створення безпечних умов роботи для працівників підприєства єневідємлімою задачею кожного роботодавця.

Відсутність професійних захворювань і травматизму на варобництві є запорукою стійкості роботи будь-якого підприємства, установи, закладу тощо.

Метою доповіді є визначення взаємозв'язку між охороною праці і стійкості роботи підприємства.

В доповіді наведені основні досліджувані параметри виробництва, що розглядається, шкідливі та небезпечні фактори, що впливають на працездатність та здоров'я людини під час виконання нею професійних обов'язків.

Так, в результаті аналізу умов праці були означені наступні шкідливі та небезпечні фактори:

мікроклімат, електричні поля й випромінювання,

високий рівень виробничих шумів,

недостатнє природне або штучне освітлення;

тяжкість роботи, яка представлена обсягом фізичних зусиль, навантаженням на опорно-руховий апарат;

інтенсивність праці, яка представлена навантаженням на центральну нервову систему, органи чуття, психологічний стан робочого [1, 2].

Встановлено, що для забезпечення стійкої роботи підприємства необхідно визначитися з такими умовами праці, які б відповідали вимогам нормативно-правових і нормативно-технічних документів, які дозволяють мінімізувати відхилення від діючих норм і створити нормальні умови праці для робітників.

Список літератури

1. Про затвердження Державних санітарних норм та правил "Гігієнічна класифікація праці за показниками шкідливості та небезпечності факторів виробничого середовища, важкості та напруженості трудового процесу". Наказ Міністерства охорони здоров'я України № 248 від 08.04.2014. URL:https://ips.ligazakon.net/document/RE25249. *Дата звернення 01.11.2025 р.)

2. Третьяков О. В., Доронін Є. В. Пономаренко Р. В., Безсонний В. Л. Основи охорони праці : Підручник. Харків :ТОВ “Пданета-Принт”, 2020. 588 с.

ПІДВИЩЕННЯ СТІЙКОСТІ ОБ'ЄКТІВ КРИТИЧНОЇ ІНФРАСТРУКТУРИ НАФТОПЕРЕРОБНОЇ ПРОМИСЛОВОСТІ ЗА РАХУНОК ПІДВИЩЕННЯ СТАНУ ПОЖЕЖНОЇ БЕЗПЕКИ

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Об'єкти нафтопереробної промисловості (НПЗ, термінали, резервуарні парки, трубопроводи) є критично важливими для енергетичної та економічної безпеки держави. Їхня стійкість визначає безперебійність роботи економіки та оборонного сектора. При цьому вони — високопожежонебезпечні через наявність горючих рідин, парів, високих температур процесів, тиску, відкритих джерел енергії [3]. Підвищення пожежної безпеки - підвищення загальної стійкості критичної інфраструктури, оскільки зменшується імовірність втрати функціональності навіть за екстремальних умов (НС, атаки, зношування).

Основні фактори, що знижують пожежну стійкість об'єктів НПЗ:

1. Горючі речовини: нафта, бензин, газ, легколеткі пари (зона вибухопожежа).
2. Високий тиск і температура у колонних установках.
3. Ефект доміно: загоряння одного блоку ініціює згорання сусідніх.
4. Зовнішні чинники: диверсії, обстріли, дрони, природні НС.
5. Зношеність обладнання, корозія, відсутність модернізації.
6. Людський фактор: порушення регламентів, помилки персоналу.
7. Механізм підвищення стійкості за рахунок пожежної безпеки.

Стійкість визначається як здатність об'єкта:

1) витримати негативний вплив (не загорітися / не вибухнути),

2) локалізувати подію (не допустити розповсюдження),

3) швидко відновити роботу [1].

Пожежно-технічні заходи працюють на всіх трьох етапах: усунення джерел займання; локалізація та ліквідація.

Конкретні заходи підвищення пожежної безпеки НПЗ:

Технічні:

- ✓ автоматичні системи пожежогасіння статичних і плаваючих резервуарів;
- ✓ пінні кільця, охолодження водяними завісами, інертні газові системи;
- ✓ вибухозахищене електрообладнання в вибухонебезпечних зонах;
- ✓ вогнезахисні покриття металоконструкцій;
- ✓ подвійні трубопроводи з сигналізацією витоків;
- розриви між об'єктами для запобігання ефекту доміно;
- протипожежні стіни, екрани, земляні вали;
- виведення із зон ризику АСУТП та пунктів керування;
- підземне розміщення критичних вузлів.

Організаційні:

- регламентні огляди, технічне обслуговування;

- аудит пожежної безпеки, ризик-аналіз (HAZOP, LOPA);
- план локалізації і ліквідації аварійних ситуацій (ПЛАС);
- навчання, тренування, пожежні формування та добровільні дружини.

Захист від цілеспрямованого ураження:

- захисні куполи над резервуарами високого ризику;
- системи детекції дронів і системи гасіння після атаки;
- дистанційно-керовані лафетні стволи без перебування людей у зоні вогню [2].

Очікуваний результат — що означає “підвищення стійкості” на практиці, зменшення імовірності загоряння (відмова сценарію на ранній фазі), зменшення масштабу події (обмеження в межах однієї секції), зменшення часу простою та збитків, підвищення живучості об’єкта в умовах обстрілів, забезпечення контролю над аварією без загибелі персоналу, збереження критичних технологічних вузлів.

Мета доповіді: показати та навести основні принципи захисту НПЗ в Україні під час військового стану та в мирний час. В доповіді викладені основні принципи підвищення пожежної безпеки на об'єктах нафтопереробної галузі та наведені пожежо-технічні заходи для захисту об’єктів НПЗ. До цих заходів відносяться: дотримання протипожежних розривів; обвалування ємностей з горючими рідинами; витримування технологічних параметрів зберігання та переробки нафтопродуктів; утримання в робочому стані систем оповіщення про пожежу та систем пожежогасінннґ тощо.

Список літератури

1. ДБН В.1.2-7:2021 "Основні вимоги до будівель і споруд. Пожежна безпека", [Чинний від 2022-09-1]. Київ : Мінрегіонбуд України, 2022 17 с.

2. Кодекс цивільного захисту України. URL:https://zakon.rada.gov.ua/laws/show/5403-17#Text. (Дата звернення 01.11.2025 .)

3. Безпека життєдіяльності: навч.посіб. / Демиденко Г.П. Київ : НТУУ «КПІ», 2018. 386 с.

ПРОГНОЗУВАННЯ РЕГЛАМЕНТОВАНИХ РАДІАЦІЙНИХ ПАРАМЕТРІВ НА ЯРУЖНИХ ХВОСТОСХОВИЩАХ

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Вступ. Експлуатація радіаційно-небезпечних об’єктів (РНО), до яких належать хвостосховища колишнього уранового виробництва ВО «Придніпровський хімічний завод» (ВО «ПХЗ»), є складним, технологічно насиченим і відповідальним процесом. Її проведення вимагає постійного

дотримання вимог чинних норм радіаційної безпеки [1]. Функціонування таких об'єктів неможливе без ефективної системи фізичного захисту та системи радіаційного спостереження, яка забезпечує систематичний моніторинг хвостосховищ та інших РНО і забезпечує регулярне спостереження за екологічним та радіаційним станом прилеглих територій [2]. Навіть у період стабільного функціонування подібні об'єкти створюють суттєві технічні, організаційні та екологічні виклики, адже залишкові продукти уранового циклу зберігають значну потенційну небезпеку [3]. Тому питання удосконалення методів контролю, аналітичного опрацювання даних і прогнозування радіаційної ситуації на таких територіях є особливо актуальними та науково значущими [4].

Мета і завдання дослідження. Метою цієї роботи є здійснення комплексного радіаційного моніторингу хвостосховищ колишнього уранового виробництва ВО «ПХЗ» і розроблення прогнозних моделей зміни основних радіаційних параметрів з оцінкою рівня радіаційної безпеки на п'ятирічну перспективу. Для досягнення поставленої мети було визначено такі основні завдання:

1. Провести систематичний збір експериментальних даних щодо основних радіаційних характеристик хвостосховищ.

2. Виконати аналітичне опрацювання результатів моніторингу та за допомогою методів математичної екстраполяції визначити прогнозовані значення параметрів на наступні п'ять років.

3. Провести порівняльний аналіз фактичних і розрахункових показників для перевірки достовірності прогнозу та оцінити рівень радіаційної безпеки персоналу РНО.

Матеріали та методи дослідження. Польові спостереження здійснювалися на хвостосховищах ядерно-паливного циклу України, зокрема на промислових майданчиках ВО «ПХЗ». Для дослідження використано комплекс методів [5], а саме:

- ✓ статистичну обробку результатів з метою побудови трендів і визначення прогнозних регламентованих радіаційних параметрів (РРП);
- ✓ математичне моделювання (метод трикутників, квадратів, кінцевих елементів, графів, матриць, дерево-подій);
- ✓ комп'ютерне моделювання із застосуванням програм ANSYS, PYTHON, MCNP, Geant4;
- ✓ польові вимірювання рівнів γ-випромінювання за допомогою дозиметрів або дозиметрів-радіометрів.

Результати дослідження. У результаті дослідження отримано розрахункові, прогнозовані та фактичні значення потужності експозиційної дози (ПЕД) та щільності потоку (ЩП) опромінення персоналу, що обслуговує яружні хвостосховища в період 2010÷2025 роки.

Для аналізу динаміки радіаційної ситуації опрацьовано результати натурних практичних вимірювань ПЕД γ-випромінювання, виконаних у 2010–2019 роках. Дослідження охопили три основні ділянки:

дамбу між секціями яружних хвостосховищ довжиною близько 1,5 км близько 20 точок вимірювань із кроком 45÷75 м);

маршрут навколо 1 секції яружного РНО протяжністю приблизно 7,5 км (80 замірів із кроком 75÷100 м).

маршрут навколо 2 секції яружного РНО протяжністю приблизно 8,3 км (100 замірів із кроком 75÷100 м).

Отримані експериментальні дані стали основою для створення прогнозних моделей на 2020–2025 роки з використанням методів екстраполяції та кінцевих елементів. Результати моделювання засвідчили тенденцію до поступового зниження рівнів ПЕД на більшості ділянок спостереження [6]. Це вказує як на ефективність заходів із забезпечення радіаційної безпеки, так і на природні процеси самоізоляції радіоактивних матеріалів у геологічному середовищі.

У свою чергу, визначивши регламентовані радіаційні параметри за якими здійснювався радіаційний контроль, можна визначити фактичну ефективну дозу опромінення (формула 1):

. (1)

Порівняння прогнозних і фактичних результатів продемонструвало високу збіжність даних — похибка не перевищує 3–5%, що узгоджується з точністю вимірювальної апаратури та допустимими статистичними відхиленнями.

Окрему увагу приділено оцінці РРП і розрахунку сумарної дози опромінення персоналу. За отриманими результатами, усі показники перебувають у межах допустимих значень, встановлених діючими санітарними нормами [1], а допустиме значення сумарної дози опромінення для різних категорій (формула 2) має свій ліміт на рік (мЗв/рік):

(2)

Розроблені аналітичні моделі дозволяють прогнозувати зміну рівнів забруднення територій і дози опромінення персоналу, що створює основу для подальшої оптимізації системи контролю та планування заходів безпеки.

Таким чином, на підставі комплексного аналізу інструментальних і теоретичних даних доведено можливість точного прогнозування потужності еквівалентної та поглиненої дози на території яружних хвостосховищ, що розташовані на промисловому майданчику «Сухачівське» за період 2010–2020 років. Прогнозні показники на 2020–2025 роки підтверджені експериментально з похибкою 3–5%. Аналіз даних дозволив оцінити сучасний стан радіаційного забруднення на території промислового майданчика, визначити фактичні та прогнозовані рівні ПЕД, ППД, ЩП, сумарну дозу

опромінення персоналу і ступінь забруднення прилеглих зон. Було виявлено стабілізацію рівнів ПЕД на ряді ділянок, особливо в холодний період року, що пояснюється сезонними коливаннями вологості й температури, які впливають на міграцію радіонуклідів.

Список літератури

1. Основні санітарні правила проти радіаційного захисту України / (ОСПУ) ДСП 6.074.120-01 – Київ: МОЗ. – 2001. - 135 с.

2. ICRP, 1991. 1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. Ann. ICRP 21 (1-3).

3. ICRP Publication 103 The 2007 Recommendations of the International Commission on Radiological Protection.

4. ICRP, 2022. Radiation detriment calculation methodology. ICRP Publication 152. Ann. ICRP 51(3).

5. The effect of external radiation exposure per person depending on his position and anthropometric indicators Pylypenko O., Shalomov V., Strezhekurov Y., Rudenko V., & Tymchenko P. International Scientific and Practical Conference Innovations in Construction and Smart Building Technologies for Comfortable, Energy Efficient and Sustainable Lifestyle (ICSBT 2024) 10 June 2024 E3S Web of Conferences Volume 534, 2024 – 01016. Режим доступа: https://doi.org/10.1051/e3sconf/202453401016.

6. Pylypenko, O., Zelensky, A., Rybalka, K., Kolokhov, V., & Nazha, P. (2025). Express method for determining power of equivalent dose in radiation-contaminated territories of radioactive tailings storage facilities. In Chemical engineering: Ecology and environmental technology. Technology Audit and Production Reserves, 3 (3 (83)), 48–55. https://doi.org/10.15587/2706-5448.2025.331755

ОРГАНІЗАЦІЯ ПОШУКУ ТА РЯТУВАННЯ ПІД ЧАС ЕКСПЛУАТАЦІЇ АВІАЦІЙНОЇ ТЕХНІКИ

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Пошуково-рятувальне забезпечення (ПРЗ) є невід’ємною складовою авіаційної безпеки та основою стійкості авіаперевезень у разі надзвичайних подій. Єдині підходи до побудови ПРЗ задають міжнародні акти — Додаток 12 до Конвенції ІКАО та керівництва IAMSAR: вони визначають повноваження і структури, а також підходи до планування пошуку й координації рятувальних дій [1; 2]. Стандартизація процедур дає змогу державним органам і операторам діяти злагоджено в повітрі, на суші та на воді.

Мета доповіді. Підсумувати прикладні принципи організації ПРЗ у цивільній авіації з урахуванням міжнародних норм і українського законодавства, а також показати, як сучасні технології та якісне управління даними скорочують час виявлення події та підвищують шанси на порятунок. Ключові процеси розглянуто крізь призму IAMSAR (насамперед Тому II «Координація місії»): оповіщення, вироблення рішень, планування пошуку, синхронізація сил і підсумковий розбір [2; 3].

Додаток 12 покладає на держави обов'язок створювати й підтримувати служби ПРЗ, окреслювати райони відповідальності (SRR), розподіляти ролі та забезпечувати регулярну підготовку персоналу [1]. Три томи IAMSAR деталізують архітектуру системи, управління місіями та дії безпосередньо в районі інциденту, формуючи спільну мову процедур для авіаційних і морських складових [2; 3]. Реагування зростає по трьох стандартних фазах: INCERFA (невизначеність), ALERFA (тривога) і DETRESFA (лихо). Перехід між фазами визначають за критеріями втрати зв'язку або спостереження, відхилення від плану польоту чи наявності підтверджених ознак лиха; для кожної фази передбачено канали оповіщення, списки розсилок і перелік першочергових дій підрозділів ОПР і ПРЗ [4; 5]. Центральним елементом є рятувально-координаційний центр (RCC/ARCC): він приймає повідомлення, оцінює обстановку, призначає координатора на місці (On-Scene Coordinator) і розподіляє ресурси. На морських подіях діють MRCC або об'єднані JRCC; узгодженість авіаційних і морських процедур забезпечує IAMSAR [2]. На аеродромах першу лінію реагування становлять аварійно-рятувальні та протипожежні підрозділи (RFFS) відповідно до вимог Додатка 14 ІКАО та спеціальних керівництв [6; 7]. Система сповіщення базується на аварійних маяках 406 МГц (ELT/EPIRB/PLB), інтегрованих у супутникову мережу COSPAS–SARSAT. Їх реєстрація в національних і/або міжнародній базах (NBRD/IBRD) надає координаторам контактні дані та технічні характеристики об'єкта, що зменшує кількість хибних спрацювань і пришвидшує залучення відповідних центрів. Вибір зон і патернів пошуку (expanding square, sector search, creeping line тощо) визначається останньою відомою точкою, метеоумовами, характером місцевості/акваторії та ймовірнісними моделями дрейфу. Координатор формує комбіноване угруповання (повітря/земля/вода), задає частоти та протоколи зв'язку, правила розподілу висот і секторів, а також ліміти безпеки. У Томі II IAMSAR наведено алгоритми для оцінки ймовірності виявлення й насиченості пошуку [3].

Ефективність ПРЗ забезпечує єдина оперативна картина, що об'єднує плани польоту, останні радіо- та ADS-B/MLAT-треки, метеодані, NOTAM, довідники можливих майданчиків і записи про реєстрацію ELT/EPIRB. Стандартизовані повідомлення (у т.ч. за фазами INCERFA/ALERFA/DETRESFA) пришвидшують узгодження між ОПР, RCC/ARCC і залученими силами; резервні канали та дублювання критичних вузлів підвищують надійність у пікові періоди [5].

До висування проводять динамічну оцінку ризику: метеомінімум, можливості типів ПС та оснащення, актуальні загрози (обстріли, мінні небезпеки, небезпечні речовини), наявність майданчиків для посадки й евакуації. Обмеження тривалості роботи екіпажів, альтернативні маршрути, процедура припинення («abort») і взаємне резервування підрозділів зменшують ризик вторинних інцидентів. Для аеродромів обов'язкове дотримання вимог щодо RFFS (категорія, тактика доступу/гасіння, взаємодія з медслужбами) [6; 7].

Додаток 12 наголошує на постійній підготовці персоналу ПРЗ і регулярних навчаннях, зокрема міжвідомчих та міжнародних — це критично для інцидентів у прикордонних зонах між сусідніми SRR [1]. Командно-штабні й тактико-спеціальні тренування за участі RFFS, поліції, медицини катастроф, оборонних і морських структур відпрацьовують канали зв'язку, передачу координації та сумісність обладнання.

Сучасні RCC/ARCC застосовують ГІС-платформи для картографування і журналювання пошуку, інтегрують ADS-B/MLAT, реєстри маяків і погодні сервіси. Аналітичні модулі допомагають оцінювати ймовірність виявлення з урахуванням рельєфу, погоди та видимості; після місії формуються таймлайни і «уроки», що лягають в основу оновлення SOP та навчальних матеріалів. Усі рішення мають відповідати IAMSAR і національним правилам збереження та розкриття даних [2; 3].

Стаття 114 Повітряного кодексу України визначає засади організації пошуку та рятування, порядок залучення сил, компенсацію витрат і правила евакуації повітряних суден із місця події [8]. Постанова КМУ № 1037 від 14.11.2012 встановлює порядок залучення сил і засобів ПРЗ під час авіаційних подій і надзвичайних ситуацій, регламентуючи координацію та логістику взаємодії [9]. Інші авіаційні правила узгоджуються з Чиказькою конвенцією та її Додатками.

Після завершення робіт проводять дебрифінг: порівнюють запланований пошук із фактичним виконанням, розбирають причини затримок в оповіщенні/розгортанні, оцінюють взаємодію з RFFS та сусідніми SRR. Висновки документують та використовують для коригування планів ПРЗ, програм підготовки і процедур інформування родин і ЗМІ.

Системний обмін досвідом між відомствами підвищує загальну готовність [1; 2].

Висновки. Ефективність ПРЗ визначається не стільки масштабом наявних сил, скільки якістю координації, налаштованістю інформаційних процесів і рівнем підготовки персоналу. Дотримання вимог ІКАО (Annex 12) та IAMSAR, упровадження сучасних технологій (маяки 406 МГц, реєстри, ГІС), міжвідомча злагодженість і чітка національна нормативна база формують систему, здатну оперативно знаходити постраждалих і рятувати життя навіть у складних умовах.

Список літератури

1. ICAO Annex 12: Search and Rescue — міжнародні вимоги до створення та функціонування служб ПРЗ.

2. IAMSAR Manual (Vol. I–III) — узгоджені авіаційно-морські настанови з організації та забезпечення ПРЗ.

3. IAMSAR Manual, Volume II: Mission Coordination (9-те вид., 2022) — практики планування та координації місій.

4. ICAO Emergency Phases — визначення INCERFA/ALERFA/DETRESFA та принципи їх застосування.

5. FAA ATC: Oceanic Emergency Procedures — структура повідомлень і порядок ескалації фаз.

6. Rescue and Fire Fighting Services (RFFS) — роль і вимоги до RFFS згідно з Annex 14, Vol. I.

7. ICAO Annex 14, Volume I — Aerodrome Design and Operations — SARPs для аеродромів і дотичні керівництва.

8. Повітряний кодекс України, ст. 114 — організація пошуку і рятування та залучення сил.

9.Постанова КМУ № 1037 від 14.11.2012 — порядок залучення сил і засобів до робіт з ПРЗ.

ІНТЕГРОВАНЕ УПРАВЛІННЯ РИЗИКАМИ ЯК ЧИННИК ПІДВИЩЕННЯ СТІЙКОСТІ КРИТИЧНОЇ ІНФРАСТРУКТУРИ

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У сучасних умовах підвищеної невизначеності питання інтеграції систем управління ризиками набуває особливого значення. Класичні підходи, що ґрунтуються на роздільному функціонуванні фінансових, технічних та організаційних систем безпеки, не забезпечують належного рівня стійкості об’єктів критичної інфраструктури.

Метою доповіді є розроблення та впровадження інтегрованої моделі управління ризиками, яка сприяє підвищенню ефективності прийняття рішень, зменшенню ймовірності кризових ситуацій, забезпеченню конкурентоспроможності та сталого розвитку підприємств і критичної інфраструктури.

Інтегровані системи управління ризиками дозволяють поєднати стратегічне, операційне та технічне управління у єдину платформу [1]. Основними підходами до інтеграції виступають процесний, системний, стандартний та інноваційний.

Процесний підхід передбачає, що кожен етап діяльності організації супроводжується ідентифікацією ризиків, їх кількісною та якісною оцінкою, визначенням заходів реагування. Це дозволяє інтегрувати управління ризиками у повсякденну діяльність та забезпечувати безперервність виробничих процесів.

Системний підхід розглядає організацію як цілісну систему, де ризики взаємопов’язані а загрози в одному сегменті можуть спричинити каскадні ефекти в інших (наприклад, відмова енергопостачання призводить до збоїв у транспортній або медичній сфері).

Реалізація цього підходу потребує побудови комплексної моделі взаємодії між підрозділами, створення єдиних інформаційних платформ та застосування методів сценарного аналізу та прогнозування [2].

Стандартний підхід базується на використанні міжнародних норм і рекомендацій, зокрема ISO 31000:2018 «Менеджмент ризиків.

Принципи й керівні вказівки» та ISO 27005:2018 «Менеджмент ризику інформаційної безпеки», що дозволяє гармонізувати внутрішні процеси з міжнародною практикою, підвищити довіру партнерів та інвесторів.

Інноваційний підхід використовує сучасні технології у процесі індентифікації та моніторингу ризиків - Big Data, штучний інтелект, системи прогнозної аналітики. Це забезпечує раннє виявлення загроз, автоматизацію процесів оцінювання та моделювання сценаріїв надзвичайних ситуацій.

Для України питання інтегрованого управління ризиками є особливо актуальним у зв'язку з необхідністю підвищення стійкості критичної інфраструктури (енергетика, транспорт, водопостачання, газові об'єкти). Системна інтеграція сприятиме зменшенню уразливості інфраструктури до зовнішніх та внутрішніх загроз, підвищенню ефективності реагування на кризові ситуації та створенню основи для побудови державної політики безпеки відповідно до європейських стандартів.

Інтеграція систем управління ризиками є необхідною умовою підвищення безпеки та конкурентоспроможності підприємств і держави загалом [3]. Найбільш ефективним є поєднання процесного, системного, стандартного та інноваційного підходів у межах єдиної адаптивної моделі управління ризиками, яка буде здатна своєчасно реагувати на нові виклики та загрози.

Запропонована модель базується на поєднанні кількісних і якісних методів оцінювання ризиків, зокрема моделювання на основі нечітких множин, графових структур та системних показників стійкості [4].

Впровадження інтегрованої моделі дає змогу виявляти взаємозалежності між ризиками, прогнозувати каскадні ефекти та формувати адаптивні сценарії реагування.

Її практичне застосування дозволяє оптимізувати управлінські процеси, мінімізувати втрати від надзвичайних ситуацій і забезпечити безперервність функціонування критично важливих об'єктів у мінливих умовах зовнішніх і внутрішніх загроз.

Список літератури

1. Методи, моделі та інформаційні технології оцінювання станів складних об'єктів: монографія / Є. І. Кучеренко, В. Є. Кучеренко, І. С. Глушенкова, І. С. Творошенко. Х.: ХНАМГ, ХНУРЕ, 2012. 278 с.

2. Тарасова К.І. Методологічні засади кількісної оцінки ризиків / К. І. Тарасова // Наукові записки [Національного університету "Острозька академія"]. Економіка. 2013. Вип. 23. С. 367 – 372.

3. Zio, E. Challenges in the vulnerability and risk analysis of critical infrastructures, Reliability Engineering and System Safety, 152, 2016. pp. 137-150.

4. Кічата Н.М., Третьяков О.В., Федина В.П., Доронін Є.В. Методологічний підхід до підвищення безпеки та стійкості об'єктів критичної інфраструктури. Науково-технічний журнал «Техногенно-екологічна безпека», №16 (2/2024). 2024. С.3 – 10. DOI: 10.52363/2522-1892.2024.2.1

СТАН ВОДНИХ РЕСУРСІВ УКРАЇНИ В УМОВАХ ВІЙНИ: ОЦІНКА ВИКОНАННЯ ОСНОВНИХ ЗАСАД ДЕРЖАВНОЇ ЕКОЛОГІЧНОЇ ПОЛІТИКИ

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Збройна агресія рф проти України спричинила суттєве погіршення стану водних ресурсів України. Серед основних наслідків бойових дій, що створюють загрозу екологічній безпеці водного середовища, виокремлюють три ключові [1]:

– порушення функціонування очисних споруд, які забезпечують очищення міських стічних вод;

– перебої у водопостачанні населення та промислових підприємств, особливо у великих містах;

– пряме механічне й хімічне забруднення поверхневих і підземних вод унаслідок бойових дій.

Варто зазначити, що проблема ефективного управління водними ресурсами в Україні існувала й до початку широкомасштабного вторгнення. Значна частина очисних споруд перебуває у незадовільному технічному стані, обладнання є застарілим і потребує кваліфікованого обслуговування. У період з лютого по вересень 2022 року російські війська неодноразово порушували роботу очисних систем, що призвело до ще більшого загострення екологічної ситуації у сфері водокористування [1].

Згідно з даними Екозагрози збитки, які завдані водним об’єктам внаслідок збройної агресії проти України становлять 117,75 млдр грн., зокрема внаслідок забруднення водних об’єктів – 64,99 млрд. грн., а маса забруднюючих речовин, що потрапили у водні об'єкти складає 47 940 тонн. Шкода внаслідок забруднення морських вод – 8,03 млрд. грн., а маса забруднюючих речовин, що потрапили у морські води 66 802 кг [2].

У зв'язку з вищенаведеним доцільно дослідити вплив збройної агресії рф на ефективність виконання Закону України «Про Основні засади (стратегію) державної екологічної політики України на період до 2030 року» (далі – Закон) з метою перевірки його виконання та розроблення рекомендацій щодо внесення змін до Закону з урахуванням наслідків збройної агресії рф.

Оцінка ефективності виконання Закону здійснюється за 30 показниками, з яких через відсутність даних наразі неможливо провести оцінку для 6-ти показників.

Для решти показників були побудовані графіки їх часової динаміки, визначено тенденції зміни їх значень та здійснена оцінка значущості тенденцій, що спостерігаються.

Визначення тенденцій та оцінка їх значущості здійснювалися методом лінійного регресійного аналізу. У доповіді наведено оцінку для показників, що характеризують забруднення водного середовища.

Метою доповіді є проведення оцінки ефективності виконання «Основних засад (стратегій) державної екологічної політики України на період до 2030 року» за попередні періоди, яка здійснювалася за показниками «скиди забруднених стічних вод у водні об'єкти» та «скиди забруднених стічних вод до морського середовища».

Для проведення аналізу динаміки цих показників використано дані статистики досягнення Цілей Сталого розвитку з 2015 по 2023 рік, які представлено на офіційному сайті Sustainable Development Goals для України [3–4]. На рисунках 1 – 2 наведено результати динаміки показників та їх цільові значення для 2025 та 2030 років. У порівнянні з 2015 роком у 2023 році об'єм стічних вод зменшився на 4,64%. За 2024 рік дані наразі відсутні. Окремо розподіл на комунальні, промислові та зворотні води публічно не оприлюднюються.

Цільове значення скидів забруднених стічних вод у водні об'єкти для 2025 року становить 10%, а для 2030 року – 5%. Згідно зі значеннями тренду у 2024 році було досягнуто цільове значення за 2025 рік, проте підтвердити це наразі неможливо у зв'язку з відсутністю даних, а значення за 2030 рік буде досягнуто у 2031 році, якщо у подальшому збережеться тенденція.

Скиди забруднених стічних вод до морського середовища з 2015 року до 2023 року зменшилися на 28,07%. Дані державного обліку водокористування за 2022–2023 роки надаються з урахуванням подання звітності відповідно до норм Закону України «Про захист інтересів суб'єктів подання звітності та інших документів у період дії воєнного стану або стану війни», а також без водокористувачів тимчасово окупованої рф території України. Дані за 2024 рік наразі відсутні.

Цільове значення для 2025 року становить 9%, а для 2030 року – 5%. Наявні дані свідчать, що ці величини вже досягнуто, оскільки з 2019 по 2023 роки скиди забруднення стічних вод до морського середовища становили 0,61 – 1,56%.

Тенденція до зменшення скидання зворотних вод обумовлена різким скороченням витрат стічних вод у 2019 р. Проте згідно з відомостями екологічних паспортів Донецької області з 2019 року підприємства-забруднювачі ПрАТ «Металургійний комбінат «Азовсталь»» та ПрАТ «Маріупольський металургійний комбінат імені Ілліча» не надають звітність про скиди стічних вод до морського середовища. Це може бути однією з причин такого стрімкого зниження значень скидання.

У зв'язку зі збройною агресією та окупаційними діями рф в Україні частина даних відсутні у відкритому доступі чи взагалі, що, у свою чергу, ускладнює чи унеможливлює здійснити оцінку ефективності виконання основних засад (стратегії) державної екологічної політики за попередні періоди.

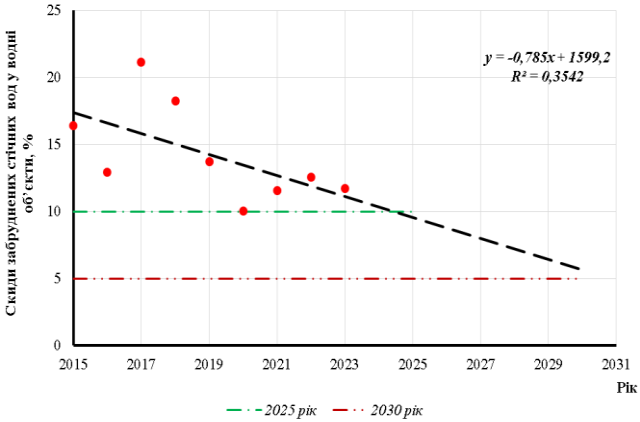

Рисунок 1 – Скиди забруднених стічних вод у водні об’єкти

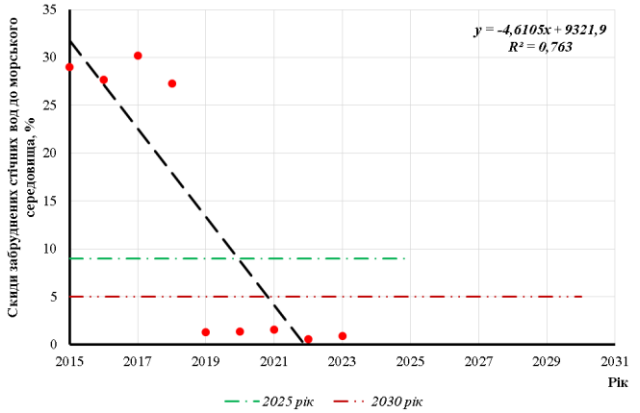

Рисунок 2 – Скиди забруднених стічних вод до морського середовища

Список літератури

1. Наслідки для довкілля війни росії проти України / О. Ангурець та ін. Електронне науково-популярне видання. 2023, с. 84. URL: https://cleanair.org.ua/wp-content/uploads/2023/03/cleanair.org.ua-war-damages-ua-version-04-low-res.pdf

2. Екозагроза. Офіційний ресурс Міністерства захисту довкілля та природних ресурсів України. URL: https://ecozagroza.gov.ua/damage/water

3. Показник 6.3.2. Частка скидів забруднених (забруднених без очистки та недостатньо очищених) стічних вод у водні об’єкти у загальному обсязі скидів, % (за даними офіційної статистики Sustainable Development Goals для України). URL: https://sdg.ukrstat.gov.ua/uk/6-3-2/

4. Показник 14.1.1.Частка скидів забруднених стічних вод у загальному обсязі скидів до морського середовища, % (за даними офіційної статистики Sustainable Development Goals для України). URL: https://sdg.ukrstat.gov.ua/uk/14-1-1/

ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ ДЛЯ ПРОГНОЗУВАННЯ РОЗВИТКУ НАДЗВИЧАЙНИХ СИТУАЦІЙ

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Зростання кількості та масштабів надзвичайних ситуацій (НС) потребує впровадження інтелектуальних технологій для підвищення ефективності систем прогнозування та моніторингу. Традиційні методи аналізу не завжди забезпечують достатню точність через складність динамічних процесів та велику кількість взаємозалежних факторів.

Метою доповіді є розроблення та дослідження моделей прогнозування розвитку надзвичайних ситуацій із використанням технологій штучного інтелекту, що дозволяє підвищити достовірність оцінки ризиків, оптимізувати процес прийняття рішень та скоротити час реагування на потенційні загрози.

У роботі представлено результати моделювання із застосуванням нейронних мереж глибокого навчання для аналізу часових та просторових даних.

Розроблена модель здійснює багатофакторний аналіз — поєднуючи метеорологічні, геопросторові та техногенні параметри — і формує прогноз розвитку подій у реальному часі [1].

Отримані результати свідчать, що застосування алгоритмів штучного інтелекту дає змогу значно підвищити якість прогнозів і скоротити похибку порівняно з класичними методами статистичного аналізу. Розроблений підхід придатний для інтеграції в інформаційно-аналітичні системи моніторингу й може бути використаний для побудови інструментів підтримки прийняття рішень на різних рівнях.

Модель демонструє гнучкість, здатність адаптуватися до нових умов і може використовуватися як основа для створення автоматизованих систем підтримки прийняття рішень у сфері безпеки, екології та управління ризиками [2].

Подальший розвиток дослідження передбачає вдосконалення архітектури моделі, розширення наборів даних та підвищення рівня автономності системи для її використання у різних галузях, де важливе своєчасне виявлення потенційних загроз.

Список літератури

1. Даник Ю. О. Кіріченко Д. О. Застосування систем штучного інтелекту для вирішення проблем пожежної безпеки. Механіка та математичні методи. VII/1/2025. С. 152–172. URL: http://mmm-journal.com.ua/journals/13/13.pdf.

2. Деркач К. Ю. Використання штучного інтелекту для прогнозування і попередження надзвичайних ситуацій, Безпека людини у сучасних умовах : зб. доп. 16-ї Міжнар. наук.-метод. конф., 6-7 грудня 2024 р.; Нац. техн. ун-т "Харків. політехн. ін-т" [та ін.], 2024. – С. 119-120.

ОПЕРАТИВНИЙ КОНТРОЛЬ ТЕХНОЛОГІЧНИХ ПРОЦЕСІВ В УМОВАХ ЕКСПЛУАТАЦІЇ

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Різноманітність технологічних об`єктів стратегічного призначення визначає специфіку умов вимірювання температури, як основного параметра багатьох технологічних процесів. У більшості випадків у процесі вимірювань відбувається втручання в умови теплообміну, які існували в об`єкті перед цим втручанням, тому для забезпечення необхідної прецизійності необхідно мінімізувати наслідки такого втручання.

Забезпечення оперативного контролю теплофізичних параметрів технологічних установок, а саме вимірювання температури на об’єктах підвищеного ступеня ризику здійснюється автоматизованими системами термоконтролю.

Під час експлуатації існуючих термодатчиків, розташованих у важкодосяжних місцях, наприклад, на АЕС або об’єктах металургії можливе виникнення незворотних змін індивідуальних номінальних статичних характеристик первинних перетворювачів (ПВП), які ставлять під сумнів вірогідність температурних вимірювань [1, 2]. Результати вимірів зумовлюються не лише властивостями реєструвального приладу, але і тим наскільки вдається наблизити температуру датчика до температури вимірюваного середовища. Різниця при цьому і складає помилку вимірів.

Метою доповіді є визначення особливостей вимірювання температури газових потоків та забезпеченню правильного вибору місця установлення відповідних датчиків вимірювання теплофізичних параметрів.

В доповіді наводяться результати вимірювань теплофізичних параметрів в реакторах установок каталітичного риформінгу і гідроочищення нафтопродуктів, які здійснюють за допомогою здійснюють за допомогою перетворювачів термоелектричних типу ТХК-2988 класу допуску 2 та типу ТХА-706-02, класу допуску 2, які застосовують для контролю температури колоснікового і периферійного газів доменного виробництва. Проаналізовані переваги та недоліки методів контактної термометрії при вимірюванні температури газових потоків в умовах експлуатації.

Список літератури

1. Озгович, А. Методи і засоби вимірювання розподілу темератури / А. Озгович, О. Панчук // Вимірювальна техніка та метрологія. – 2017. – № 78. – С. 34-41.

2. Поліщук, Є.С. Метрологія та вимірювальна техніка : підручник / Є.С. Поліщук, М.М. Дорожовець, В.О. Яцук, В.М. Ванько, Т.Г. Бойко ; за ред. проф.. Є.С. Поліщука. – Львів : Видавництво «Бескид Біт», 2003. – 544 с.

ЗАХИСТ ОБ'ЄКТІВ АВІАЦІЙНОЇ ІНФРАСТРУКТУРИ ВІД ТЕРОРИСТИЧНИХ АТАК

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Оцінювання ризиків терористичних загроз для аеропортів є одним із ключових напрямів у забезпеченні авіаційної безпеки, адже авіаційна інфраструктура належить до об'єктів підвищеної небезпеки.

З огляду на зростання кількості терористичних актів у світі та появу новітніх технологій, які можуть бути використані зловмисниками, виникає необхідність у постійному вдосконаленні системи захисту цивільної авіації.

Аеропорти являють собою складні технічні комплекси, що обслуговують значну кількість пасажирів і вантажів, тому навіть незначний недолік у системі безпеки може призвести до серйозних наслідків.

Метою доповіді є вивчення систем відеоспостереження як елементів системи безпеки і стійкості підприємств авіаційної інфраструктури.

Ризик у сфері авіаційної безпеки розглядається як поєднання ймовірності виникнення терористичної події та можливих наслідків від її реалізації. За даними Міжнародної організації цивільної авіації (ICAO), підхід, що базується на ризиках (risk-based approach), є ключовим принципом побудови сучасної системи авіаційної безпеки.

Він передбачає аналіз загроз, виявлення уразливостей об'єктів та визначення ефективних заходів реагування [1].

Однак, як свідчить практика, важливу роль відіграє і людський фактор – рівень підготовленості персоналу, його вміння діяти в надзвичайних ситуаціях та швидко оцінювати потенційні ризики.

В Україні питання оцінки ризиків терористичних загроз у сфері цивільної авіації врегульовані Законом України «Про державну програму авіаційної безпеки цивільної авіації». Цей документ визначає правові, організаційні та технічні основи запобігання актам незаконного втручання, у тому числі терористичним актам [2].

Кожен аеропорт повинен розробляти та впроваджувати власну систему управління ризиками, що враховує його географічне розташування, обсяг пасажиропотоку, рівень технічного оснащення та можливі загрози.

Такі системи мають бути гнучкими й постійно оновлюватися відповідно до актуальних викликів і сучасних тенденцій у сфері протидії тероризму.

Методи оцінювання ризиків у цивільній авіації поділяються на якісні та кількісні.

Якісне оцінювання ґрунтується на експертних висновках і застосуванні матриць ризику, у межах яких кожна потенційна загроза аналізується за ймовірністю виникнення та серйозністю можливих наслідків.

Кількісні методи, своєю чергою, передбачають використання математичних моделей, що дозволяють визначити рівень небезпеки на основі статистичних даних про попередні події чи інциденти.

Дослідження Європейського агентства авіаційної безпеки (EASA) показують, що комбінування обох методів дозволяє створювати більш точні прогнози ризиків і ефективніше розподіляти ресурси безпеки [3].

Однією з найважливіших складових сучасної системи оцінки ризиків є використання цифрових технологій.

Аналітичні системи з елементами штучного інтелекту дозволяють автоматично обробляти великі масиви даних — від відеоспостереження до перевірок багажу та інформації про пасажирів.

Це дає змогу не лише виявляти підозрілі дії, а й прогнозувати потенційні загрози.

Водночас, як зазначає Державіус О. В., важливо, щоб цифрові рішення не замінювали людський контроль, а лише посилювали його ефективність [4].

Слід наголосити, що оцінка ризиків не може бути одноразовим заходом. Це безперервний процес, який включає постійний моніторинг, аналіз, оновлення інформаційних баз і адаптацію до нових умов.

Ефективне функціонування системи управління ризиками можливе лише за умови тісної співпраці між авіаційними службами, правоохоронними органами та міжнародними структурами.

Важливе значення має також професійна підготовка персоналу – фахівців із безпеки, які володіють сучасними методами аналізу ризиків і мають практичний досвід реагування на надзвичайні ситуації.

Таким чином, ефективна оцінка ризиків терористичних загроз в аеропортах є багатогранним процесом, що поєднує правові, технічні, організаційні та аналітичні складові.

Удосконалення національної нормативної бази, впровадження інноваційних інформаційних технологій і підвищення професійної компетентності працівників сприятимуть зменшенню рівня терористичних загроз і забезпеченню стабільного функціонування авіаційної інфраструктури України.

Список літератури

1. International Civil Aviation Organization (ICAO). Aviation Security Manual (Doc 8973). — Montreal, 2022.

2. Закон України «Про державну програму авіаційної безпеки цивільної авіації» від 21.03.2017 р. № 1965-VIII.

3. European Union Aviation Safety Agency (EASA). Risk Management in Aviation Security. — Cologne, 2021.

4. Державіус О. В. Сучасні підходи до оцінювання ризиків у системі авіаційної безпеки // Вісник НАУ. — 2023. — № 2. — С. 47–54.

ІНТЕЛЕКТУАЛІЗАЦІЯ СИСТЕМИ ПОЖЕЖНОЇ БЕЗПЕКИ ПІДПРИЄМСТВ ЕНЕРГЕТИЧНОГО КОМПЛЕКСУ

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Сучасна енергетична інфраструктура України є складною сукупністю технічних систем, що функціонують у режимі підвищених навантажень і характеризуються значною концентрацією пожежонебезпечного обладнання. Підвищення рівня технологічної інтеграції об'єктів енергетики, зокрема електропідстанцій, супроводжується зростанням ризиків займання та аварійних ситуацій. За таких умов традиційні системи протипожежного захисту, побудовані на принципах пасивного контролю, втрачають ефективність, що обумовлює потребу у впровадженні інтелектуальних підходів до управління пожежною безпекою. [1, 2]

Метою дослідження є розроблення концептуальних засад інтелектуалізації системи пожежної безпеки на підприємствах енергетичного комплексу, зокрема на електропідстанціях, для підвищення її адаптивності, надійності та швидкодії реагування на загрози займання.

Інтелектуалізація систем пожежної безпеки передбачає інтеграцію технологій Інтернету речей, штучного інтелекту, машинного навчання та аналітики великих даних у процеси моніторингу та управління.

У межах електропідстанцій така система може включати сенсори диму, температури, струму, газів і вібрацій, які формують єдину інформаційну мережу з безперервною передачею даних у центр управління безпекою. [3]

На основі зібраних даних штучний інтелект здійснює прогнозування можливих осередків займання за допомогою алгоритмів виявлення відхилень у роботі електрообладнання. У разі виявлення потенційної небезпеки система може автоматично активувати локальні засоби пожежогасіння, ініціювати аварійне відключення обладнання або сповістити персонал через інтегровану диспетчерську мережу.

Ключовою перевагою інтелектуальних систем є перехід від реактивного підходу (реагування на вже виявлену пожежу) до прогностичного управління ризиками. Такий підхід дозволяє мінімізувати людський фактор, зменшити час реагування та запобігти ескалації аварійних процесів. Крім того, аналітичні модулі дають змогу оцінювати ефективність застосованих заходів, адаптувати алгоритми до конкретних технологічних умов і створювати базу знань для подальшого удосконалення системи.

Розроблення інтелектуалізованих систем пожежної безпеки на електропідстанціях передбачає врахування особливостей технологічних процесів енергетичних підприємств, а також вимог чинних нормативних документів у сфері пожежної безпеки.

Важливою складовою є формування інформаційно-аналітичної платформи, що забезпечує взаємодію між технічними засобами контролю,

автоматизованими системами управління технологічними процесами та службами цивільного захисту.

Запровадження таких систем створює передумови для формування єдиного цифрового контуру безпеки енергетичної галузі, де пожежна безпека стає частиною загальної стратегії цифрової трансформації критичної інфраструктури.

У перспективі розвиток інтелектуалізованих систем пожежного захисту може стати базою для побудови національної платформи моніторингу техногенної безпеки.

Інтелектуалізація систем пожежної безпеки є стратегічним напрямом підвищення надійності енергетичних підприємств. Використання сучасних інформаційних технологій забезпечує підвищення рівня прогнозування пожежонебезпечних ситуацій, оперативності реагування та мінімізацію збитків.

Подальші дослідження мають бути спрямовані на математичне моделювання процесів займання, створення адаптивних алгоритмів управління пожежогасінням та інтеграцію систем моніторингу у структуру національної енергетичної безпеки.

Запровадження інтелектуалізованої системи на електропідстанції доцільно виконувати як багаторівневу архітектуру: польовий рівень (багатодатчикові пожежні сповіщувачі, тепловізійний контроль шин і силових трансформаторів, газоаналіз у розподільних установках та в обладнанні з масляними діелектриками), рівень периферійних обчислень для попереднього аналізу сигналів і відсіювання завад у реальному часі та центральний рівень з обчислювальним центром, програмними засобами аналізу даних і підсистемою підтримки прийняття рішень.

Така побудова забезпечує стійкість до відмов, зменшення затримок передавання даних і сумісність з автоматизованими системами управління технологічними процесами, дозволяє реалізувати сценарії автоматизованого реагування (селективне відключення секцій, локалізація осередку загоряння, запуск модулів автоматичного пожежогасіння) та вимагає періодичних випробувань і калібрування датчиків, резервування електроживлення і каналів зв’язку, а також захисту інформаційних каналів між підсистемами моніторингу і диспетчерськими пунктами.

Список літератури

1. NFPA 850: Recommended Practice for Fire Protection for Electric Generating Plants and High Voltage Direct Current Converter Stations. National Fire Protection Association, 2020.

2. Гаврилюк В. О., Кузик М. П. Системи протипожежного захисту на енергетичних підприємствах: сучасний стан та тенденції розвитку. Журнал Пожежна безпека, 2022, с. 15–21.

3. ISO 7240-29:2017. Fire detection and alarm systems — Multi-sensor fire detectors.

ЗАБЕЗПЕЧЕННЯ СТІЙКОСТІ ОБ'ЄКТІВ КРИТИЧНОЇ ІНФРАСТРУКТУРИ З ВИКОРИСТАННЯМ АЛЬТЕРНАТИВНИХ ДЖЕРЕЛ ЕНЕРГОПОСТАЧАННЯ

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Забезпечення стійкості об’єктів критичної інфраструктури передбачає впровадження надійних систем резервного та альтернативного енергопостачання, що дозволяють підтримувати безперебійну роботу у разі надзвичайних ситуацій або відключень централізованих мереж. Одним із ефективних рішень є використання альтернативних джерел енергії — таких як сонячні, вітрові установки, біоенергетичні системи та когенераційні установки (CHP), які одночасно виробляють електроенергію та теплову енергію з високим коефіцієнтом корисної дії. Когенерація дозволяє значно підвищити енергоефективність і зменшити залежність від зовнішніх постачальників, забезпечуючи локальне енергопостачання для лікарень, водоканалів, комунікаційних вузлів, об’єктів оборони та інших критично важливих структур. Поєднання когенераційних систем з відновлюваними джерелами енергії створює гібридні енергокомплекси, здатні забезпечити енергетичну автономність, надійність та екологічну безпечність [1]. Забезпечення стійкості об’єктів критичної інфраструктури є одним із ключових завдань національної безпеки та енергетичної незалежності держави. До таких об’єктів належать енергетичні, транспортні, комунальні, медичні, інформаційно-комунікаційні, водопостачальні та інші системи, безперервна робота яких є життєво важливою для суспільства та економіки [2б 3].

В умовах зростання загроз — як техногенних, так і воєнних — особливої актуальності набуває створення стійких систем енергопостачання, здатних функціонувати автономно під час аварій, відключень або руйнування центральних енергетичних мереж. Одним із ефективних напрямів є використання альтернативних джерел енергопостачання та когенераційних технологій [3]. До альтернативних джерел енергопостачання належать:

- ✓ Сонячні електростанції (СЕС), забезпечують виробництво електроенергії з енергії сонця;
- ✓ Вітрові електростанції (ВЕС), ефективні в регіонах із достатнім рівнем вітрової активності;
- ✓ Біоенергетичні установки, використовують біомасу або біогаз для отримання електроенергії й тепла;
- ✓ Малі гідроелектростанції, забезпечують стабільне локальне енергопостачання;
- ✓ Акумулюючі системи (батарейні та гібридні), дозволяють зберігати енергію та використовувати її при пікових навантаженнях або відключеннях [4].

Використання цих джерел сприяє підвищенню енергетичної автономності, зменшенню викидів парникових газів і диверсифікації енергобалансу, що підвищує загальну стійкість інфраструктури.

Когенерація (CHP – Combined Heat and Power) — це технологія одночасного виробництва електричної та теплової енергії з одного виду палива (природний газ, біогаз, дизель, відходи виробництва тощо) [4]. Когенераційні установки можуть працювати як автономно, так і у складі гібридних енергетичних систем, поєднуючись із сонячними, вітровими або біоенергетичними джерелами. Це забезпечує створення малої локальної енергосистеми (мікромережі), здатної підтримувати роботу об'єкта в ізольованому режимі [1].

Мета доповіді: доповісти про використання альтернативних джерел енергопостачання у поєднанні з когенераційними установками, що є стратегічно важливим напрямом підвищення стійкості, надійності та ефективності функціонування об'єктів критичної інфраструктури. Такий підхід дозволяє створити гнучкі та автономні енергетичні системи, здатні працювати в умовах будь-яких зовнішніх впливів і забезпечувати безперебійне постачання енергії для життєво важливих сфер суспільства.

Список літератури

1. Когенерація. URL : https://www.kts-eng.com/solutions/kogeneraciya/

2. Закон України "Про критичну інфраструктуру" URL: https://zakon.rada.gov.ua/laws/show/1882-20#Text

3. Деякі питання об'єктів критичної інфраструктури. Постанова Кабінету Міністрів України № 1109 від 09.10.2020 р. URL: https://zakon.rada.gov.ua/laws/show/1109-2020-%D0%BF#Text/

4. Альтернативна енергетика/ Малишев В. В. та ін: конспект лекцій. Київ:Університет Україна. 2020. 60 с.

ОЦІНКА Й РАНЖУВАННЯ НЕБЕЗПЕК ПРИ ГАСІННІ ПОЖЕЖ СЛУЖБОВЦЯМИ ПОЖЕЖНО-РЯТУВАЛЬНОЇ ЧАСТИНИ НА ОСНОВІ МАТРИЧНОГО РИЗИК-ОРІЄНТОВАНОГО МЕТОДУ

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За даними «Міжнародної асоціації пожежників» професія пожежного за ступенем шкідливого впливу факторів робочої зони на організм та рівнем небезпеки займає одне з перших місць серед інших професій. особливістю роботи пожежних під час гасіння пожеж є наявність екстремальних умов праці при виконанні завдань. При цьому екстремальність проявляється в негативній дії комплексу наступних основних негативних виробничих факторів [4]:

- потужні теплові потоки, тобто підвищена температура повітря й підвищений рівень випромінювання теплової енергії;
- висока задимленість повітря, значні концентрації шкідливих хімічних речовин (чадний газ CO, продукти горіння різних матеріалів, тверді пиловидні частинки);

- підвищені рівні шуму й вібрації, що надходять від працюючих пожежних машин і обладнання;

- високий рівень нервово-психічного напруження, пов'язаного зі значним ступенем відповідальності за прийняті тактичні рішення й кінцевий результат завдання з гасіння пожежі [1].

Очевидно, що так як рівень впливу перерахованих вище *тільки основних* негативних факторів є високим, тому такі умови праці можуть бути причиною формування професійних захворювань різного типу. До основних, найбільш поширених захворювань відносяться [5, 6]: - хронічні захворювання серцево-судинної системи; - захворювання органів дихання; – захворювання кістково-м'язової системи; – гострі нервово-психічні розлади внаслідок значного нервового перенапруження; – онкологічні захворювання, що обумовлюється канцерогенною дією таких речовин як фосген, діоксин, бенз-а-пірен. При цьому, в наслідок дії небезпечних факторів при таких пожежах загинуло 1 309 осіб і 1 612 отримали травми. Порівняно з 2023 р. кількість загиблих за 11 міс. 2024 р. збільшилася на 4,6%, а кількість травмованих на пожежах - на 16,7 %.

Матричний ризик-орієнтований метод є поширеним у розрізі вирішення прикладних задач, стосовно оцінювання ризиків травмування, профзахворювання працівників на установах, підприємствах, організаціях [14, 15]. Він заснований на кількісній оцінці (визначенні) рівня ризику ушкодження здоров'я працівника через такі основні два параметри: ймовірність виникнення (P); тяжкість наслідків (S). В таблиці представлена матриця й ранжування небезпек, діючих на пожежних при гасінні пожежі.

Таблиця — ранжування небезпек, діючих на пожежних при гасінні пожежі

№ з/п	Небезпечний чи шкідливий виробничий фактор	P	S	Вплив (E)	Ризик (R)
1	Висока концентрація диму, токсичних продуктів горіння в повітрі робочої зони, контакт з технологічними речовинами	5	5	5	125
2	Висока температура повітря робочої зони, ІЧ- випромінювання	5	5	4	100
3	Психоемоційні перевантаження. Посттравматичний стрес	5	5	4	100
4	Підвищена напруга в електричному ланцюзі	3	5	4	60
5	Підвищений рівень шуму та вібрації від обладнання	5	3	3	45

Список літератури

1. Гігієнічна оцінка умов праці пожежних. – Режим доступу: https://oppb.com.ua/articles/gigiyenichna-ocinka-umov-praci-pozhezhnyh

2. Drew E Gonzalez, Sarah N Lanham, Steven E Martin , Richard E Cleveland, Thad E Wilson, Emily L Langford, Mark G Abel "Firefighter Health: A Review of Occupational Hazards and Countermeasures» / Healthcare. 12(4) :44008.02.2024. Basel. – Access mode: DOI: 10.3390/healthcare12040440

3. Woo-Ri Lee, Haejong Lee, Eun Woo Nam, Jin-Won Noh, Jin-Ha Yoon, Ki-Bong Yoo «Comparison of the risks of occupational diseases, avoidable hospitalization, and all-cause deaths between firefighters and non-firefighters: A cohort study using national health insurance claims data» / Front Public Health, 2023, Jan 16;10. – Access mode: DOI:: 10.3389/fpubh.2022.1070023

4. Sara Alves, Josiana Vaz, Adília Fernandes «Occupational health of firefighters: a systematic review» / International Symposium on Occupational Safety and Hygiene (SHO'23), pp. 56-66. – Access mode: doi.org/10.24840/978-989-54863-4-2_0056-0066

УПРАВЛІННЯ РИЗИКАМИ ВНУТРІШНІХ ЗАГРОЗ ОБ'ЄКТІВ КРИТИЧНОЇ ІНФРАСТРУКТУРИ

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Ризик визначається як можливість навмисного або ненавмисного заподіяння шкоди організації шляхом неналежного використання її ресурсів особою, яка має до них авторизований доступ. Під доступом мається на увазі як фізичний, так і віртуальний доступ, а ресурси включають інформацію, процеси, системи та обладнання [1].

Метою доповіді є розроблення підходу до оцінки ризику внутрішніх загроз та можливих шляхів управління ними задля підвищення безпеки і стійкості об'єктів критичної інфраструктури.

У роботі проаналізовани інциденти з безпекою з наявним наміром заподіяти шкоду, спричинені інсайдерами, які можуть виникати різними способами: насильство або загрозу насильства інших працівників; саботаж (умисне пошкодження обладнання або розкриття конфіденційної інформації); крадіжка ресурсів, конфіденційних даних або інтелектуальної власності організації задля отримання особистої вигоди; промислове шпигунство; шахрайські дії з метою отримання особистої вигоди [2].

У доповіді наведено основні індикатори виявлення внутрішніх ризиків, в яких відіграють роль як люди, так і технології. Ключова умова – визначити межі норми поведінки, що дозволить легше виявляти незвичні дії. До основних індикаторів віднесено:

1) зміни в діях користувача (колеги, керівники та партнери здатні помітити зміни в поведінці схильного до ризику інсайдера, який має на меті спричинити інцидент із безпекою даних);
2) послідовність пов'язаних ризикованих дій з конфеденційними даними, матеріалами тощо;
3) аномальний доступ до системи (потенційні внутрішні ризики можуть починатися з того, що користувачі отримують доступ до ресурсів, які зазвичай не потрібні їм для роботи);
4) перевищення повноважень доступу без чіткого ділового обґрунтування;

5) аномальна ексфільтрація даних (користувач раптово ділиться незвично великим обсягом конфіденційних даних або завантажує його);

6) ексфільтрація даних, яка зростає разом зі звільненнями та може бути як навмисною, так і ненавмисною;

7) погрози, переслідування або дискримінації співробітників.

Цілісна програма керування внутрішніми ризиками, яка визначає пріоритетність відносин між працівниками та роботодавцем та інтегрує елементи керування конфіденційністю, може зменшити кількість потенційних внутрішніх інцидентів із безпекою, і прискорити їх виявлення.

Нещодавнє дослідження, проведене корпорацією Майкрософт, виявило, що компанії з цілісною програмою керування внутрішніми ризиками на 33% частіше швидко виявляють ризики витоку інсайдерської інформації, та на 16% частіше швидко усувають такі ризики, ніж компанії з більш фрагментарним підходом.

Організації можуть цілісно підходити до боротьби із внутрішніми ризиками, зосереджуючи увагу на процесах, людях, інструментах та освіті.

Створення довіри серед працівників починається з визначення їхньої конфіденційності пріоритетом. необхідно впровадити багаторівневий процес затвердження для ініціювання внутрішніх розслідувань, щоб сприяти створенню відчуття комфорту за допомогою програми керування внутрішніми ризиками.

Важливо перевіряти дії тих, хто проводить розслідування, щоб переконатися, що вони не перевищують свої повноваження. Збереженню конфіденційності також сприятиме упровадження елементів керування доступом на основі ролей для обмеження кількості членів команди безпеки, які можуть отримати доступ до даних розслідування. Знеособлення імен користувачів під час розслідувань може додатково захистити конфіденційність працівників.

ІТ-відділи та відділи безпеки повинні нести основну відповідальність за керування внутрішніми ризиками, але важливо залучати до цих зусиль усіх працівників компанії. Відділи кадрів, юридичні відділи відіграють важливу роль у визначенні політик, спілкуванні із зацікавленими сторонами та прийнятті рішень під час розслідування. Щоб розробити більш комплексну та ефективну програму керування внутрішніми ризиками, організаціям слід залучити до цього процесу співробітників, що представляють усі напрямки діяльності компанії.

Працівники відіграють важливу роль у запобіганні інцидентів із безпекою, що робить їх першою лінією захисту. Щоб захистити ресурси компанії, потрібна підтримка всіх працівників, що, у свою чергу, підвищує безпеку організації в цілому. Одним із найефективніших способів забезпечення підтримки всіх працівників є навчання. Навчаючи працівників, можна зменшити кількість ненавмисних інцидентів внутрішніх ризиків. Важливо роз'яснювати, як інциденти внутрішньої безпеки можуть вплинути на компанію, та її працівників.

Крім того, дуже важливо обговорювати політики захисту даних і навчати працівників уникати потенційного витоку даних.

Позитивні стримувальні фактори, такі як події, спрямовані на підвищення морального стану працівників, ретельний інструктаж, постійне навчання та тренування з безпеки даних, ефективний зворотний зв'язок та програми з балансу роботи та особистого життя можуть зменшити ймовірність внутрішніх ризиків.

Залучаючи працівників у ефективний і проактивний спосіб, позитивні стримувальні фактори усувають джерела ризику та сприяють розвитку культури безпеки в організації.

Ефективний захист організації від внутрішніх ризиків вимагає не лише впровадження найкращих інструментів безпеки; але й інтегрованих рішень, які забезпечують видимість і захист на рівні підприємства. Інтегровані рішення з керування безпекою даних, ідентичністю та доступом, розширеного виявлення та реагування (XDR), а також керування захистом інформації (SIEM) дозволяють командам безпеки ефективно виявляти та попереджати інциденти внутрішньої безпеки.

Для сучасного робочого місця характерними є динамічні ризики безпеки з різними факторами, що постійно змінюються. Це ускладнює виявлення й реагування на них.

Втім, організації можуть миттєво виявляти та зменшувати внутрішні ризики завдяки використанню машинного навчання та штучного інтелекту, забезпечуючи адаптивну та орієнтовану на людей безпеку.

Ця передова технологія допомагає організаціям зрозуміти, як користувачі взаємодіють із даними, обчислюють і призначають рівні ризиків, а також автоматично налаштовують відповідні елементи керування безпекою. За допомогою цих інструментів організації можуть оптимізувати процес виявлення потенційних ризиків і визначити пріоритети використання своїх обмежених ресурсів для запобігання діям з внутрішніми ризиками високого ступеню. Це заощаджує цінний час для команд безпеки та посилює безпеку даних.

Захиститися від внутрішніх загроз може бути складно, оскільки природно довіряти тим, хто працює в організації та разом з нею.

Швидка ідентифікація найкритичніших внутрішніх ризиків та визначення пріоритетів використання ресурсів для розслідування та усунення цих ризиків вкрай важливі для зменшення впливу потенційних інцидентів і порушень безпеки.

Список літератури

1. Герасименко О. М. Моделювання системи забезпечення кадрової безпеки суб'єкта господарювання. *Актуальні проблеми економіки*. 2012. № 2. С. 118–124.

2. Панченко В. А. Схематика дій інсайдерів у системі кадрової безпеки суб'єктів господарювання. *Підприємництво і торгівля*. 2018. Вип. 22. С. 101-107.

ЛЮДСЬКИЙ ФАКТОР ЯК ЕЛЕМЕНТ СТІЙКОСТІ КРИТИЧНОЇ ІНФРАСТРУКТУРИ В УМОВАХ ВОЄННОГО СТАНУ

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Стійкість критичної інфраструктури України, зокрема залізничного транспорту, є однією з фундаментальних умов обороноздатності та життєздатності держави в умовах повномасштабної війни. Якщо технічні аспекти захисту інфраструктури активно досліджуються, то роль "людської ланки" часто залишається недооціненою, хоча саме від ефективності та надійності персоналу залежить реальне функціонування систем. Працівники залізниці діють під впливом екстремальних факторів: пряма фізична загроза життю під час виконання службових обов'язків на об’єктах, що є потенційними цілями ударів; хронічне психологічне виснаження через постійні повітряні тривоги, обстріли та втрати; а також значна інтенсифікація робочих процесів через необхідність забезпечення військової логістики, масових евакуаційних рейсів та оперативної адаптації до зруйнованих маршрутів [1]. Ці умови перетворюють персонал на потенційно вразливий елемент системи, де помилки, викликані втомою, стресом чи недостатньою підготовкою до нових викликів, можуть мати каскадні негативні наслідки. Наслідки таких помилок, зумовлених людським фактором, не є абстрактними. Це конкретні операційні збої: помилкові дії диспетчера через когнітивне перенавантаження можуть призвести до збою графіків руху або аварійних ситуацій; порушення протоколів безпеки ремонтною бригадою через стрес може спричинити технічну відмову інфраструктури; неправильне управління натовпом з боку персоналу вокзалу в стані паніки може призвести до давки та травмування пасажирів в укриттях.

Метою доповіді є підкреслення критичної важливості людського фактору в загальній системі стійкості критичної інфраструктури та представлення методичного підходу до його системної оцінки для превентивного управління відповідними ризиками в кризових умовах.

Забезпечення стійкості критичної інфраструктури вимагає комплексного, системного підходу, що інтегрує технічні, організаційні та людські аспекти [2]. Недооцінка останнього може нівелювати ефективність значних інвестицій у фізичний захист чи кібербезпеку.

Тому пропонується методика оцінки вразливості, пов’язаної саме з персоналом, на основі набору ключових індикаторів, які можна згрупувати за напрямками: кадрове забезпечення, професійна, психосоціальна стійкість, та організаційна взаємодія.

Запропонована методика передбачає використання стандартизованої шкали для експертного оцінювання цих індикаторів (з можливим залученням як внутрішніх фахівців, так і зовнішніх експертів з безпеки та психології праці) та їх подальшу агрегацію у зважений показник. Такий підхід дозволяє отримати об'єктивну кількісну міру вразливості, зумовлену саме станом

людського капіталу, та відстежувати її динаміку. Обґрунтування вибору цих груп індикаторів є критичним. "Кадрове забезпечення" аналізується через ризики дефіциту унікальних фахівців (диспетчерів, машиністів), що виникає внаслідок мобілізації та міграції. "Професійна стійкість" оцінює не лише базову кваліфікацію, але й готовність персоналу до специфічних воєнних сценаріїв, до яких стандартні інструкції їх не готували. "Психосоціальна стійкість" є ключовою, оскільки хронічний стрес напряму погіршує когнітивні функції та швидкість реакції. "Організаційна взаємодія" є життєво важливою, оскільки чіткі протоколи комунікації та координації першими руйнуються в умовах хаосу, призводячи до неправильних дій.

Аналіз функціонування транспортної системи під час війни [3] та загальні принципи управління людським фактором [1] свідчать, що високий рівень стресу, мобілізація частини персоналу та вимушена міграція кваліфікованих кадрів створюють значні ризики для операційної стійкості. Ймовірність помилок в ухваленні рішень диспетчерами, порушення правил безпеки ремонтними бригадами, зниження уваги машиністами – все це може зростати, а час реагування на інциденти – збільшуватись. Тому управління ризиками, пов'язаними з людським фактором, потребує проактивних, а не лише реактивних заходів. До них належать:

створення багаторівневої системи психологічної підтримки (від груп самодопомоги до професійних консультацій) та програм посттравматичної реабілітації;

регулярне проведення максимально реалістичних тренувань, що моделюють специфічні для війни сценарії (наприклад, робота під час обстрілу, дії при пошкодженні інфраструктури);

впровадження гнучких та адаптивних графіків роботи з обов’язковими періодами відновлення; активне формування кадрового резерву через програми прискореної підготовки та наставництва, можливо, із залученням ветеранів.

Комплексна робота з персоналом є невід'ємною частиною стратегії забезпечення безперервності функціонування критичної інфраструктури [4] та підвищення загальної обороноздатності держави.

Список літератури

1. Human Factors in Safety-Critical Systems / Ed. by T. Kontogiannis, C. Malakis. CRC Press, 2021. 384 p.

2. Закон України «Про критичну інфраструктуру» від 16.11.2021 № 1882-IX // Відомості Верховної Ради України. – 2022. № 2. ст. 11.

3. Ukraine: Rapid Damage and Needs Assessment. World Bank Group, Government of Ukraine, European Commission, United Nations. February 2023. – P. 136-141.

4. ISO 22301:2019. Security and resilience — Business continuity management systems, Requirements. International Organization for Standardization. – 2019.

ЗАХОДИ ІЗ ЗАБЕЗПЕЧЕННЯ СТІЙКОСТІ ЕНЕРГЕТИЧНОЇ ІНФРАСТРУКТУРИ

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Енергетична інфраструктура є надзвичайно критичною для забезпечення життєво важливих функцій у будь якій державі. У той же час цей сектор є дуже вразливим до впливів природного, техногенного та військового характеру. Особливо наглядно це спостерігається в Україні після вторгнення російських військ в лютому 2022 р.

Порушення функціонування критичної енергетичної інфраструктури може безпосередньо вплинути на безпеку та стійкість інших секторів критичної інфраструктури, громадську безпеку, функціонування економіки та на національну безпеку загалом [1].

Метою доповіді є аналіз досвіду забезпечення стійкості енергетичної інфраструктури на законодавчому та організаційному рівнях у таких країнах як США, Велика Британія та країнах Євросоюзу.

Базуючись на досвіді найбільш розвинених країн світу в Україні формується своя законодавча база для забезпечення стійкості об'єктів критичної інфраструктури в цілому і об'єктів енергетичної інфраструктури окремо [2].

Досвід фахівців енергетичної інфраструктури, які ліквідовують наслідки атак на об'єкти КІ, у створенні форм координації діяльності на випадок кризової ситуації дав можливість створити у 2023 р. загальнодержавний Координаційний штаб оперативного реагування з метою сприяння координації діяльності центральних та місцевих органів виконавчої влади, а також інших державних органів, органів місцевого самоврядування, суб'єктів господарювання всіх форм власності (за згодою) з питань оперативного реагування та забезпечення створення нормальних умов життєдіяльності населення під час обмеження та/або припинення постачання електричної енергії, та доручив місцевим органам виконавчої влади створити подібні штаби на місцевому рівні [1].

Список літератури

1. Суходоля О. М. Стійкість критичної енергетичної інфраструктури та життєдіяльності громад : аналіт. доп. Київ : НІСД, 2024. 160 с. – https://doi.org/10.53679/NISS-analytrep.2024.04

2. Резнікова О. О. Національна стійкість в умовах мінливого безпекового середовища : монографія. Київ : НІСД, 2022. 532 с.

ПІДВИЩЕННЯ БЕЗПЕКИ ЕНЕРГЕТИЧНИХ ОБ'ЄКТІВ ШЛЯХОМ УПРАВЛІННЯ РИЗИКАМИ ПРОЯВУ НЕБЕЗПЕЧНИХ ПОДІЙ

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Стійке функціонування енергетичної інфраструктури є одним із головних чинників національної безпеки держави. Порушення роботи енергетичних об'єктів призводить до збоїв у системах життєзабезпечення, транспорту, зв'язку та оборони. В умовах зростання техногенних ризиків, кібератак, екстремальних погодних явищ і воєнних загроз актуальним є створення ефективних механізмів оцінки та управління ризиками небезпечних подій для енергетичних систем.

Метою доповіді є розроблення підходу до підвищення безпеки енергетичних об'єктів на основі системної оцінки ризику та управління ризиками потенційних загроз, що враховує технічні, організаційні й інформаційні аспекти стійкості інфраструктури.

У роботі проаналізовано чинники, які впливають на зниження надійності функціонування енергетичних систем, зокрема: фізичні ушкодження обладнання, порушення ланцюгів постачання, несанкціоновані втручання, а також зовнішні природні фактори.

Для визначення ступеня небезпеки запропоновано використовувати ризик-орієнтований підхід, що базується на методах кількісного оцінювання ймовірності реалізації загроз та прогнозування їх наслідків [1].

У доповіді наведено результати аналізу вразливості окремих елементів енергетичної інфраструктури з використанням сучасних цифрових технологій моніторингу та ранжування ризиків відповідно до їх визначених рівнів. Отримані результати свідчать, що впровадження комплексної системи управління ризиками дозволяє підвищити рівень захищеності енергетичних об'єктів, скоротити час відновлення після аварійних подій і забезпечити безперервність енергопостачання критичних споживачів [2].

Такий підхід може бути застосований для розроблення місцевих і секторальних програм підвищення безпеки і стійкості об'єктів критичної інфраструктури.

Список літератури

1. Визначення та класифікація загроз енергетичній безпеці України в сучасних умовах військових викликів / Y. Kliat та ін. Journal of Scientific Papers «Social Development and Security». 2024. Т. 14, № 2. С. 272–285. URL: https://doi.org/10.33445/sds.2024.14.2.22

2. Khomik M., Matsko P. Системні передумови оцінювання загроз для об'єктів критичної енергетичної інфраструктури в умовах збройного протистояння в Україні. Journal of Scientific Papers «Social Development and Security». 2024. Т. 14, № 5. С. 191–201. URL: https://doi.org/10.33445/sds.2024.14.5.19

СТІЙКІСТЬ ОБ'ЄКТІВ ТРАНСПОРТНОЇ ІНФРАСТРУКТУРИ. Повітряний транспорт

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Транспортна інфраструктура України достатньо складна й розгалужена. Воеа складається з низки транспортних систем: наземної, водної, повітряної, газонафтотранспортної, енергетичної.

Кожен підвид транспортної системи має безліч об'єктів, які впливають на стійкість роботи кожної з систем. Вихід з ладу одного з елементів системи здатен суттєво вплинути на роботу системи в цілому. Так, пошкодження злітної смуги або вихід з ладу її обладнання здатні перешкодити нормальній роботі аеропорту.

Тому забезпечення штатної роботи об'єктів транспортної інфраструктури є актуальною задачею, особливо в умовах сьогодення.

Мета і завдання дослідження. Метою даної роботи є визначення слабких сторін в роботі повітряної транспортної системи та розробка заходів, які дозволять підвищити ступінь її захисту та забезпечити стійку роботу усіх об'єктів.

В доповіді викладені основні структурні елементи аеропортів: аеровокзал, злітна смуга та її обладнання, диспетчерські служби, ремонтні служби, склади авіаційного палива, об'єкти протипожежної служби: депо, місця розміщення чергових караулів тощо.

В плані правового поля безпека роботи повітряного транспорту забезпечена Повітряним кодексом України [1], національною транспортною стратегією України на період до 2030 р [2] тощо.

До початку повномасштабного розвитку не приділялося в достатній мірі уваги до стійкої роботи об'єстів повітряної транспортної системи.

На жаль, вона на даний час не працює в належному режимі і потребує значного переосмислення до її захисту й безпеки, що дозволить підвищити її стійкість.

Визначені при вивченні слабкі елементи структури повітряної транспортноїсистеми дозволяють таким чином перейти до розробки конкретних заходів, що дозволять підвищити стійкість об'єктів транспортної інфраструктури, забезпечивши таким чином їх безпеку і безпеку України в цілому

Список літератури

1. Повітряний кодекс України. URL:https://zakon.rada.gov.ua/laws/show/3393-17#Text

2. Національна транспортна стратегія України на період до 2030 року. URL: https://zakon.rada.gov.ua/laws/show/430-2018-%D1%80#Text

ОРГАНІЗАЦІЯ НЕВІДКЛАДНИХ РОБІТ ІЗ ЕВАКУАЦІЇ ПОСТРАЖДАЛИХ ПРИ ЛІКВІДАЦІЇ НАСЛІДКІВ НАДЗВИЧАЙНИХ СИТУАЦІЙ У ВОЄННИЙ ЧАС

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Актуальність теми. Проблема організації невідкладних евакуаційних робіт набула критичної, безпрецедентної актуальності в умовах широкомасштабної збройної агресії.

Надзвичайні ситуації воєнного часу (комплексні руйнування критичної інфраструктури, хімічні та радіаційні загрози, масові жертви, спричинені застосуванням високоточної зброї) вимагають розробки та імплементації якісно нових, адаптованих до бойових умов, організаційно-управлінських рішень.

Необхідність мінімізації санітарних та безповоротних втрат серед цивільного населення та особового складу екстрених служб у "червоних зонах" обумовлює нагальну потребу в оптимізації процесів пошуку, тріажу та транспортування.

Це є основою для визначення мети дослідження: розробка науково обґрунтованих організаційно-методичних рекомендацій та моделей щодо підвищення оперативності, безпеки та ефективності евакуаційних заходів у воєнний час [1].

Метою доповіді є детальне вивчення понятійно-категоріального апарату "НС воєнного часу" та "медицина катастроф" з урахуванням сучасних викликів. Проведено комплексний аналіз нормативно-правової бази України (Закони, Постанови КМУ) та положень Міжнародного гуманітарного права (МГП), що регулюють захист медичної місії, персоналу та евакуаційних шляхів під час конфлікту.

Особлива увага приділена науковому обґрунтуванню необхідності адаптації фундаментальних медичних принципів надання допомоги, зокрема концепцій "золотої години" та "платинової хвилини", до умов, що характеризуються високим рівнем безпекових загроз, обмеженням доступу та необхідністю застосування броньованої техніки.

Також розглянуто світові моделі медичного сортування (наприклад, START, SALT) для застосування в умовах масового надходження постраждалих у зоні бойових дій.

В роботі проведено аналіз існуючої системи організації невідкладних евакуаційних заходів в умовах повномасштабного воєнного стану в Україні. Дослідження виявило системні проблеми міжвідомчої взаємодії між ключовими суб'єктами (ДСНС, ЗСУ, ТРО, Національна поліція, екстрена медична допомога), що проявляються у відсутності єдиних стандартизованих протоколів та фрагментації командування. Ідентифіковано та класифіковано критичні ризики:

✓ **логістичні** (руйнування транспортної інфраструктури, що ускладнює прохідність),

✓ **безпекові** (мінна небезпека та висока ймовірність вторинних обстрілів),

✓ **технічні** (гострий дефіцит спеціалізованого броньованого евакуаційного транспорту та обладнання для дистанційної розвідки) [2].

У результаті досліджень розроблені та обґрунтувані три взаємопов'язані ключові елементи, які спрямовані на підвищення життєздатності системи евакуації:

- **Уніфікований алгоритм дій та управління:** Створення ієрархічної, єдиної схеми дій служб цивільного захисту, що включає чіткі етапи від моменту отримання сигналу (верифікація, первинний тріаж) до доставки постраждалого до медичного закладу. Алгоритм передбачає інтеграцію військових та цивільних протоколів.
- **Модель ресурсно-технічного забезпечення:** Обґрунтування тактико-технічних вимог до багатофункціонального броньованого евакуаційного транспорту (БЕТ), здатного працювати в умовах високої воєнної небезпеки, та створення мобільних резервів медичного обладнання.
- **Оптимізація маршрутів та логістика:** Запропоновано методологію використання сучасних інформаційних технологій (Геоінформаційних систем – ГІС – та безпілотних літальних апаратів – БПЛА) для оперативного моніторингу, моделювання та розрахунку найбезпечніших та найшвидших евакуаційних маршрутів (з урахуванням чинників часу, безпеки та прохідності) [3,4].

Висновки

Досягнення мети дослідження підтверджується розробкою конкретних практичних інструментів, алгоритмів та моделей. Перспективи подальших досліджень пов'язані з деталізацією системи підготовки та тренування персоналу на основі розробленого уніфікованого алгоритму та апробацією моделі БЕТ.

Список літератури

1. Організація та ведення рятувальних та інших невідкладних робіт. Навчальний посібник / За заг. ред. Іванова С.П. Київ: ДСНС України, 2023.

2. Оцінка безпекових ризиків під час проведення евакуаційних робіт у прифронтовій зоні. / Савчук М. М. // Безпека життєдіяльності. 2024. № 1.

3. Звіт ДСНС України «Про результати ліквідації наслідків надзвичайних ситуацій, спричинених воєнними діями» (Офіційний сайт ДСНС).

4. Вимоги до тактико-технічних характеристик броньованого евакуаційного транспорту. / Лисенко Д. А. // Журнал транспортних технологій. 2023. № 2.

МОДЕЛЮВАННЯ СТРАТЕГІЙ ПЛАНУВАННЯ АТАКУЮЧИХ МІСІЙ З ВИКОРИСТАННЯМ УДАРНИХ ДРОНІВ

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Сучасна гібридна війна – це боротьба технологічних інновацій. Поява різних, за призначенням БПЛА (дронів), призвела до необхідності формування нових стратегій використання сучасного озброєння на полі бою [1]. Тому, актуальна тема запропонованої доповіді, в якій представлені результати дослідження щодо аналізу можливих стратегій планування масованих атак, з використанням рою ударних дронів [2].

Метою доповіді є представлення результатів дослідження зі створення моделей для аналізу та обґрунтування стратегій військових місій з використанням дронів.

Проаналізована послідовність дій щодо планування та проведення військової місії, з використанням різних дронів. У сучасній повітряній атаці використовується розвідувальні дрони, дрони-імітатори, дрони з цілевказівкою, ударні дрони.

Особливу увагу приділено можливості їх використання при формуванні стратегії військової місії. Проведено моделювання формування рою дронів, розподілу рою на групи, політ групи до множини відокремлених цілей противника.

Створена оптимізаційна модель щодо пошуку актуальних цілей, які необхідно, у першу чергу, уразити. Розроблено алгоритм формування маршруту польоту рою (групи) дронів, в умовах впливу протидії противника (РЕБ, дрони-перехоплювачі, тощо). Можлива зміна обставин на полі бою впливає на необхідність оперативного перепланування польоту рою дронів. Створена агентна імітаційна модель, яка дозволяє аналізувати різні сценарії та стратегії проведення повітряної атаки, з використанням рою дронів.

В доповіді наводяться результати дослідження стратегій формування повітряних атак, за допомогою рою ударних дронів, що дозволяє підвищити ефективність атакуючої місії та допомогти військовим на полі бою.

Список літератури

1. Modeling waves of a strike drones swarm for a massive attack on enemy targets / O. Fedorovich, D. Krytskyi, O. Leshchenko, O. Yashina, Yu. Malieieva / Radioelectronic and Computer Systems, 2024, no. 2, P. 203-212

2. Lv, Huan & Liu, Fang & Yuan, NaiChang. (2021). Drone Presence Detection by the Drone's RF Communication. Journal of Physics: Conference Series. 1738. 012044. 10.1088/1742-6596/1738/1/012044.

МОДЕЛЮВАННЯ ЗАХИСТУ ОБ'ЄКТІВ КРИТИЧНОЇ ІНФРАСТРУКТУРИ ВІД ВПЛИВУ ВІЙСЬКОВИХ ДІЙ

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Для стійкого функціонування об'єктів критичної інфраструктури (промисловість, енергопостачання, тощо), потрібно сформувати систему захисту від атакуючих дій противника [1]. Тому, актуальна тема доповіді, в якій представлені результати досліджень зі створення захисту об'єктів критичної інфраструктури в особливому стані країни.

Метою доповіді є створення моделей, які дозволяють виділити найбільш актуальні об'єкти критичної інфраструктури для захисту та провести моделювання захисних дій від атак противника [2].

Проведено системний аналіз та виявлення критичних об'єктів для створення системи захисту від впливу військових загроз.

Сформовані дії зі створення системи захисту у вигляді пасивного та активного способів захисту. Досліджено створення пасивного захисту у вигляді інженерних конструкцій, бетонних споруд, тощо, в умовах обмеженості ресурсів. Далі, проведено дослідження зі створення та моделювання активного захисту у вигляді використання засобів РЕБ, множини дронів-перехоплювачів, зенітних дронів, тощо.

Розроблена оптимізаційна модель щодо пошуку найкращого варіанту захисту у вигляді комбінованої системи, з використанням як пасивного, так і активного способів захисту. Створена агентна імітаційна модель щодо дослідження послідовності дій зі створення захисту критичних об'єктів. Використано математичні методи: системний аналіз, лексикографічне впорядковування варіантів, багатокритеріальна оптимізація, агентне та імітаційне моделювання. Створена прикладна інформаційна технологія для моделювання формування системи захисту критичних об'єктів.

В доповіді наводяться результати досліджень зі створення захисту критичних об'єктів, що дозволяє підвищити обороноздатність країни від впливу військових загроз.

Список літератури

1. Fedorovich, O., & Pronchakov, Y. Risk-oriented simulation of the long logistics supply chains in developing enterprises. Авіаційно-космічна техніка і технологія, 2021, (3), 84-90.

2. Наконечний, О. Аналіз умов та факторів, що впливають на ефективність функціонування системи логістики сил оборони держави [Text] / О. Наконечний // Системи управління, навігації та зв'язку. Збірник наукових праць. – 2019. – Т. 3, №. 55. – С. 48-57. DOI: 10.26906/SUNZ.2019.3.048.

МОДЕЛЮВАННЯ ДОВГИХ ЛАНЦЮГІВ ПЕРЕВЕЗЕНЬ В УМОВАХ ВПЛИВУ ЗАГРОЗ

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Сучасне зовнішнє середовище має множину негативних факторів, які впливають на логістику постачання високотехнологічних виробництв [1]. Поширення негативних факторів призводить до необхідності пошуку відносно безпечних маршрутів перевезень комплектуючих, що особливо важливо для планової роботи підприємств. Тому, актуальна тема запропонованої доповіді, в якій розглядається моделювання та пошук раціональних маршрутів перевезень, в умовах впливу загроз [2].

Метою доповіді є представлення результатів дослідження щодо створення відносно безпечних маршрутів для постачання комплектуючих, в умовах впливу загроз.

Аналізуються можливі загрози, які впливають на планування транспортних мультимодальних перевезень в різнорідному транспортному середовищі (залізничний ,автомобільний, морський та інші види транспорту). Довгі ланцюги перевезень збільшують ризики постачання комплектуючих для виробництва високотехнологічних виробів (авіабудування, автомобілебудування, суднобудування, тощо). Тому, були створенні моделі, які дозволяють аналізувати та формувати раціональні маршрути перевезень, з урахуванням можливих загроз (політико-економічні, терористичні, кліматичні, військові, тощо). Створена оптимізаційна модель щодо обґрунтування складу логістичних компонент, які потрібні для налагодження планових перевезень комплектуючих (транспортні магістралі, розподільчі центри, проміжне складування, тощо). Створені алгоритми імітаційного моделювання для формування маршрутів перевезень, в умовах загроз. Оцінюються показники часу, вартості та ризиків перевезень.

В доповіді наводяться результати досліджень для аналізу довгих ланцюгів перевезень, в умовах загроз та проводиться пошук відносно безпечних шляхів постачання комплектуючих для виробництва високотехнологічних виробів.

Список літератури

1. Федорович, О., Прончаков, Ю., Рибка, К., & Лещенко, Ю. Вибір постачальників для виробництва високотехнологічної продукції з урахуванням довгих логістичних ланцюгів постачання вантажів. Авіаційно-космічна техніка і технологія, 2021, (5), 75-81.

2. Pecina, M. Application of the new NATO logistics system [Text] / M. Pecina, J. Husak // Land Forces Academy Review. – 2018. – Vol. 23, No. 2. – P. 121-127. DOI: 10.2478/raft-2018-0014.

МОДЕЛЮВАННЯ ЗАБЕЗПЕЧЕННЯ СТІЙКОСТІ КРИТИЧНИХ ОБ'ЄКТІВ В УМОВАХ ОСОБЛИВОГО СТАНУ

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Сучасний стан країни пов'язаний з функціонуванням складних систем (об'єкти критичної інфраструктури, промисловість, транспортна логістика, тощо), в умовах впливу великої кількості загроз (політико-економічні, воєнні, кліматичні, тощо) [1]. Прийняття дій та проведення заходів щодо забезпечення стійкості критичних об'єктів є актуальним завданням, яке розглядається та вирішується у пропонованому дослідженні. **Метою доповіді** є розробка комплексу моделей, які дозволяють аналізувати та виявляти вразливості об'єктів критичної інфраструктури, для планування заходів щодо підвищення стійкості від впливу негативних факторів зовнішнього середовища. В дослідженні сформовані результати, що дозволяють забезпечити виявлення найбільш вразливих об'єктів критичної інфраструктури для планування та проведення превентивних заходів щодо забезпечення стійкості, в умовах обмежених ресурсів (витрати, час) [2]. Створена модель, яка дозволяє, з використанням оцінок експертів та методу ієрархій, сформувати пріоритетний ряд критичних об'єктів щодо підвищення їх стійкості. Враховуються старіння об'єктів (деградація), яка збільшує кількість вразливостей та призводить до їх використання в якості цілей противника для проведення масованих атак. Моделюються можливості щодо підвищення стійкості, з урахуванням виділених ресурсів та часу проведення проєктів. Проведена оцінка ризиків щодо підвищення стійкості. Створена оптимізаційна модель, за допомогою якої формується підмножина актуальних вразливостей для їх подальшого зменшення, або нейтралізації. Використано лексикографічне впорядковування варіантів для вибору раціонального, для проведення дій щодо підвищення стійкості критичних об'єктів. Проведена багатокритеріальна оптимізація для пошуку раціональних варіантів по підвищенню стійкості, в умовах обмежених ресурсів. Створена мультиагентна модель для аналізу послідовності дій щодо підвищення стійкості критичних об'єктів. **В доповіді** наводяться результати досліджень щодо виявлення та нейтралізації вразливостей критичних об'єктів та підвищення їх стійкості.

Список літератури

1. Fedorovich, O., & Pronchakov, Y. Risk-oriented simulation of the long logistics supply chains in developing enterprises. Авіаційно-космічна техніка і технологія, 2021, (3), 84-90.

2. Barbu M. L. et al. Theoretical considerations concerning the setting of the capability requirements specific to combat engineers' structures supporting management acrivities from the airfield //Journal of Defense Resources Management (JoDRM). – 2019. – Vol. 10. – №. 2. – P. 188-196.

КОНЦЕПТУАЛЬНІ ЗАСАДИ ПОСИЛЕННЯ ЦИФРОВОЇ РЕЗИЛЬЄНТНОСТІ ДЕРЖАВНИХ ІНФОРМАЦІЙНИХ СИСТЕМ НА ОСНОВІ ВІДМОВОСТІЙКИХ МОДУЛЬНИХ КОДІВ

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Забезпечення стійкого цифрового розвитку України у 2026 році вимагає створення цілісної системи протидії кіберзагрозам на національному рівні. Особливої актуальності набуває питання цифрової резильєнтності (стійкості) критичної інфраструктури та державних інформаційних систем до атак на цілісність даних. Традиційні методи захисту часто мають надмірні часові затримки, що є критичним для систем реального часу. Ефективним рішенням є впровадження модульних кодів, які дозволяють інтегрувати функції контролю та виправлення помилок безпосередньо в арифметико-логічний базис системи для забезпечення економічної стійкості телекомунікаційних мереж [1, 2].

Метою доповіді є розробка практичних рекомендацій щодо посилення цифрової стійкості інформаційних систем держави через впровадження високопродуктивних засобів діагностування даних у модульних кодах.

У межах розробки концептуальної моделі цілісної системи протидії кіберзагрозам запропоновано використовувати внутрішні властивості модульних кодів для побудови самокоригувальних обчислювальних структур. Такий підхід дозволяє реалізувати механізм активного захисту на рівні протоколів автентифікації та виявлення гомології шкідливого програмного забезпечення [3, 4].

Основними рекомендаціями щодо посилення резильєнтності економічних суб'єктів та державних структур є:

1. Впровадження паралельних методів діагностування, а саме використання властивостей модульних кодів дозволяє поєднати в часі процеси обчислень та аналізу контрольних ознак (проекцій) чисел. Це забезпечує виявлення помилок (спричинених як збоями обладнання, так і навмисними спотвореннями) у реальному часі [2].

2. Динамічне керування надмірністю в структурі обчислювальних засобів. Концептуальна модель передбачає можливість адаптивної зміни кількості контрольних основ у модульних кодах залежно від рівня кіберзагрози. Це дозволяє підтримувати стабільність функціонування критичних вузлів навіть в умовах інтенсивних атак [3, 4].

Запропонована логічна організація відмовостійких вузлів обробки інформації на базі модульних кодів виступає як ефективний механізм управління в публічних організаціях з високим рівнем безпеки [5], дозволяючи державним інформаційним системам зберігати функціональність при відмові окремих обчислювальних каналів, що є фундаментом національної цифрової резильєнтності.

Реалізація запропонованих рекомендацій дозволить сформувати стійке цифрове середовище, де захищеність інформаційних систем держави базується на внутрішній стійкості модульних кодів.

Список літератури

1. Yanko A., Mychailichenko O., Hlushko A. Modern methods for protecting and storing data in computer systems to ensure their fault tolerance. *Theoretical and Applied Cyber Security*. 2024. Vol. 6, No. 1. P. 72–81. DOI: https://doi.org/10.20535/tacs.2664-29132024.1.315086

2. Янко А. С., Маслій О. А. Математична модель економічної стійкості телекомунікаційних систем з урахуванням показників відмовостійкості. *Цифрова економіка та економічна безпека*. 2025. № 4 (19). С. 461–468. DOI: https://doi.org/10.32782/dees.19-66

3. Sun H., Shu H., Kang F., Guang Y. ModDiff: Modularity Similarity-Based Malware Homologation Detection. *Electronics*. 2023. Vol. 12, No. 10. 2258. DOI: https://doi.org/10.3390/electronics12102258

4. Kalmykov I. A., Olenev A. A., Kononova N. V. et al. Improvement of the Cybersecurity of the Satellite Internet of Vehicles through the Application of an Authentication Protocol Based on a Modular Error-Correction Code. *World Electric Vehicle Journal*. 2024. Vol. 15, No. 7. 278. DOI: https://doi.org/10.3390/wevj15070278

5. Plevnik M. Communication and Information Systems User Support as a Governance Mechanism in a High-Security Public Organization. *Systems*. 2026. Vol. 14, No. 3. 288. DOI: https://doi.org/10.3390/systems14030288

SOFTWARE AND HARDWARE COMPLEX FOR AUTOMATED MONITORING OF IoT DEVICES OF A FIRE SAFETY SYSTEM

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The steady growth in the number of fires at residential, public and industrial facilities makes automated fire safety monitoring one of the most critical tasks of modern civil protection [1]. Traditional fire alarm systems based on stand-alone detectors have limited diagnostic capabilities, do not allow remote assessment of the technical state of the equipment, and in most cases react only to already developed hazardous factors of a fire. The rapid spread of the Internet of Things (IoT) paradigm opens new opportunities for building distributed monitoring systems capable of collecting, transmitting and analysing heterogeneous data from a large number of sensor nodes in real time [2].

The aim of the work is to develop a software and hardware complex for the automated monitoring of IoT devices of a fire safety system that provides continuous control over the operability of the sensor nodes, early detection of pre-emergency states and prompt notification of the responsible personnel.

The proposed complex has a three-tier architecture in accordance with the IoT reference model. The lower (perception) tier includes smoke, temperature, carbon monoxide and flame sensors connected to microcontroller nodes based on ESP32 modules with Wi-Fi and BLE interfaces. The middle (network) tier is built on an

MQTT broker, which ensures reliable delivery of telemetry messages with a configurable quality of service and minimal overhead, which is especially important for battery-powered nodes [3]. The upper (application) tier is implemented as a web service that stores time-series data in an InfluxDB database and visualises the state of the monitored objects through a Grafana dashboard.

To detect anomalies in the sensor readings and signs of device malfunctions, the complex uses a combined approach. Simple threshold rules, defined in accordance with current fire safety standards, are complemented by statistical control of the rate of change of the monitored parameters and by a lightweight machine-learning model based on an isolation forest algorithm, which is able to identify atypical combinations of readings that do not exceed individual thresholds but indicate a developing hazardous situation [4]. The health of each IoT node is additionally controlled by periodic heartbeat messages; the absence of a heartbeat for a configurable period is interpreted as a loss of the node and triggers a separate notification channel.

An experimental prototype of the complex was deployed in a laboratory environment on a network of eight sensor nodes. The measurements show that the average end-to-end latency from the moment of an event at the sensor to its visualisation on the dashboard does not exceed 1.2 s at an MQTT QoS level of 1, while the share of correctly detected pre-emergency situations reaches 96 % with a false-positive rate of less than 3 %. The obtained results confirm the feasibility of the proposed architecture and show that the combination of rule-based and data-driven methods allows a considerable increase in the reliability of fire safety monitoring compared with classical threshold systems [5].

The novelty of this development lies in the further development of methods for automated monitoring of IoT devices of the fire safety system by jointly using self-diagnosis of sensor nodes and detecting anomalies using their telemetry, which allows not only to register fire factors, but also to detect degradation of the monitoring equipment itself in advance.

References

1. Ray P. P. A survey on Internet of Things architectures. Journal of King Saud University – Computer and Information Sciences. 2018. Vol. 30, No. 3. P. 291–319. DOI: https://doi.org/10.1016/j.jksuci.2016.10.003

2. Atzori L., Iera A., Morabito G. The Internet of Things: A survey. Computer Networks. 2010. Vol. 54, No. 15. P. 2787–2805. DOI: https://doi.org/10.1016/ j.comnet.2010.05.010.

3. Light R. A. Mosquitto: server and client implementation of the MQTT protocol. Journal of Open Source Software. 2017. Vol. 2, No. 13. P. 265. DOI: https://doi.org/10.21105/joss.00265.

4. Liu F. T., Ting K. M., Zhou Z.-H. Isolation-based anomaly detection. ACM Transactions on Knowledge Discovery from Data. 2012. Vol. 6, No. 1. P. 1–39. DOI: https://doi.org/10.1145/2133360.2133363.

5. Sarwar B., Bajwa I. S., Ramzan S. Design and application of fuzzy logic based fire monitoring and warning systems for smart buildings. Symmetry. 2018. Vol. 10, No. 11. P. 615. DOI: https://doi.org/10.3390/sym10110615.

Підсекція 6.2. ІНФОРМАЦІЙНО-КОМУНІКАЦІЙНІ ТЕХНОЛОГІЇ ТА ЗАСОБИ УПРАВЛІННЯ У ЗАХИСТІ ЦИВІЛЬНОЇ ІНФРАСТРУКТУРИ

OPERATIONS RESEARCH IN MILITARY EDUCATION: THEORETICAL FOUNDATIONS AND PRACTICAL TEACHING OPPORTUNITIES

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In the modern system of military education, the quality of officer training is determined not only by the transfer of theoretical knowledge, but also by the ability to make well-grounded decisions in complex situations, allocate limited resources optimally, assess uncertainty, and compare alternative courses of action. In this regard, operations research occupies a particularly important place in military education. This discipline contributes to the scientific foundations of decision-making through mathematical modeling, optimization, probability analysis, network approaches, game-based reasoning, queueing systems, and simulation methods. For this reason, operations research in professional military education should be considered not merely as an auxiliary computational tool, but also as an essential instrument for the formation of analytical thinking, systematic assessment of situations, and managerial culture.

The main purpose of this material is to generalize, within a unified conceptual framework, the theoretical essence and practical possibilities of the topics included in operations research for military education. Within this objective, the content of the discipline has been structured, its main thematic directions have been identified, the military application potential of these directions has been explained, and didactic approaches suitable for the teaching process have been systematized. The analysis shows that operations research in military education should not be limited to the teaching of isolated mathematical techniques. On the contrary, it should be taught as an integrative scientific field that enables the study of military decisions through the interrelated categories of objective, constraint, risk, time, resource, and outcome.

The study is based on a systems approach, content analysis, comparative interpretation, and didactic generalization. Through the systems approach, the individual topics of operations research have been examined within a unified decision-making logic. Content analysis made it possible to classify the discipline into several functional topic groups. These include optimization problems, probability and risk analysis, network and routing problems, queueing and service systems, game-theoretic situations, simulation modeling, and multicriteria choice approaches. Comparative interpretation helped reveal the degree to which these topics are connected with military planning, staff activity, logistics, force protection, maneuver, resource allocation, and operational situation assessment. Didactic generalization was used to identify teaching formats that can ensure more effective comprehension of these topics by cadets and trainees.

The results indicate that the theoretical potential of operations research lies in its ability to generalize multilevel decision processes. In military activity, decisions are often made not under conditions of complete information, but within limited time, changing circumstances, multiple risks, and several alternative options. Under such conditions, intuition-based decisions alone are insufficient. Scientifically grounded choice requires modeling, comparison, quantitative evaluation, and outcome forecasting. Operations research provides precisely this theoretical basis. The optimization methods included in the discipline show how resources can be allocated in the most appropriate way. Probability and risk analysis allow the expected outcomes of different alternatives to be compared. Network and routing models support the efficient design of movement, supply, and communication systems. Queueing models help assess workload level, waiting time, and throughput in supply and service processes. The analysis of game situations supports the justification of strategies by considering possible actions of the opposing side. Simulation modeling, in turn, makes it possible to test the consequences of decisions on scenarios close to real conditions.

Another important result of the study is that the practical possibilities of operations research create broad opportunities for teaching through applied tasks in military education. The theoretical topics of this discipline produce stronger didactic outcomes when they are linked to real or conditionally modeled military situations. For example, the optimal distribution of limited fuel and ammunition among different units, the selection of a movement route taking into account threat level and distance, the deployment of surveillance and protection assets, the planning of patrol routes, the calculation of reserve storage norms, and the selection of the most appropriate response option under several possible enemy behaviors clearly demonstrate the military application potential of operations research. Such tasks do not merely develop the ability to use formulas. They also encourage cadets to understand the logic of decisions, compare the advantages and weaknesses of alternatives, justify results, and make choices on the basis of structured reasoning.

It has also been established that a scenario-based approach is of particular importance in teaching this discipline. Operations research is not simply a field of mathematical transformations, but an intellectual platform for the formation of decision culture. If the teaching process is built only around formal mathematical procedures, cadets may perceive the subject as detached from practical reality. However, when each theoretical tool is accompanied by a specific military scenario, its practical value becomes immediately visible. For this reason, a staged teaching approach appears appropriate. At the first stage, key concepts and principles of model construction should be introduced. At the second stage, typical computational examples should be studied. At the third stage, comparative decision selection should be carried out on the basis of multivariable and multi-option situations. Such a didactic sequence creates an effective bridge between theoretical knowledge and practical skill.

The findings also show that operations research can strengthen interdisciplinary integration in military education institutions. This discipline can be

organically connected with tactics, logistics, management, communications, support, security, staff work, and information analysis. As a result, cadets begin to understand that knowledge acquired in different subjects is not fragmented, but serves a unified logic of decision-making. This creates systemic thinking within professional military cognition. This quality is particularly important in the modern operational environment, because real-world decisions are made not in isolated disciplinary categories, but in conditions of interaction among multiple functional domains.

At the same time, the study has identified several methodological difficulties. First, the successful comprehension of several sections of operations research requires an adequate mathematical foundation. Second, the preparation of practical tasks is itself a demanding issue. Such tasks must be theoretically correct and, at the same time, relevant to military reality. Third, the effective teaching of this discipline increasingly depends on the use of modern software tools, computational platforms, and visual modeling instruments. However, these difficulties do not reduce the significance of the discipline. On the contrary, they indicate that the effective teaching of operations research requires a richer methodological base, teaching materials prepared in a staged form, and a bank of tasks adapted to the level of cadet preparation.

In general, it can be concluded that operations research is a strategically important academic field in military education, possessing substantial theoretical depth and wide practical applicability. Its teaching contributes to the development of analytical thinking, evidence-based decision-making, choice under uncertainty, and efficient use of resources among future officers. Therefore, it appears appropriate to restructure the content of this discipline in military curricula by thematic groups, enrich theoretical material with applied examples, increase the number of scenario-based and computational exercises, and integrate digital modeling capabilities into the teaching process. Such an approach would allow operations research to be realized not merely as a theoretical domain of knowledge, but as a key intellectual foundation of military management and professional officer training.

References

1.Scala, N. M., & Howard, J. P., II (Eds.). (2020). *Handbook of Military and Defense Operations Research*. Boca Raton, FL: Chapman and Hall/CRC.

2.Brown, G. G., DeGrange, W. C., Dell, R. F., & Fricker, R. D., Jr. (2015). ASP, Art and Science of Practice: Educating Military Operations Research Practitioners. *Interfaces, 45*(2), 175-186. https://doi.org/10.1287/inte.2014.0780

3.Armacost, A., Lowe, J., Pietz, J., Martin, K., Wilck, J., & Ives, D. (2018). Developing Operations Research Practitioners: United States Air Force Academy Operations Research Program. *Interfaces, 48*(6), 500-509. https://doi.org/10.1287/inte.2018.0968

4.Radovanović M. et al. Application of the new hybrid model LMAW-G-EDAS multi-criteria decision-making when choosing an assault rifle for the needs of the army //Journal of decision analytics and intelligent computing. – 2024. – Т. 4. – №. 1. – С. 16-31.

5.Dadashov A. (2023). Designing military engineering training based on the model of didactic justification. Journal of defense resources management . 2023 №14:2 (281), p.87-96.

6. Dadashov A. (2024). Applying didactic teaching princples to professional engineering in military higher education institutions. Journal of defense resources management. 2024 № 15:2 (237), p. 152-163.

7.Agayev, S.O., et al. Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*. 2016.

8. Piriyev, H.K., et al. Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, 2014, (4), 3-9.

9. Piriyev, H.K., et al. Provide interactive training methods. Methodological materials. *Baku: Military publishing house*. 2016

10. Tahirov, R. K. et al. Environmental aspects of information technology implementation. In *Problems of Informatization*. 2024, (Vol. 3, pp. 138–139).

11. Tahirov R. K., Hashimov E. G. Professional military education and the development of strategic human capital. – 2025.

12. İbrahimov R.İ. et al. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

13. Piriyev, H.K. et al. (2016). Modelling of the battle operations. *Monografiya, Herbi Nashriat", Baku.–2017*.

14. Ibrahimov B. G. Special purpose machine learning and data mining methods. *In* Current directions of development of information and communication technologies and control tools. 2025, Volume 2: sections 2. p.90

15. Hasanov A. H. et al. Strategic reforms and digital innovation in military educational management. *In* Current directions of development of information and communication technologies and control tools. 2025, Volume 4: sections 6. p.62

16. Hasanov A.H., Hashimov E.G. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. 2025, Volume 4: sections 6. p.39

17. Piriyev H.K. et al. Some aspects of optimization of control. *In* Current directions of development of information and communication technologies and control tools. 2024, Vol.1. p.18-19.

18. Talibov, A. M. et al. (2025). Training military personnel in radiation and chemical threat protection methods. *Proceedings of the 15th International Scientific and Technical Conference* (Vol. 4, p. 94–95).

19. Piriyev, H.K. et al. Model for assessing the functionality of systems in the structure of the armed forces. *İn* Problems of informatization. Proceedings of 11-th International Scientific and Technical Conference. 2023, Vol. 3. p.14-15.

20. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.

21. Johnes, J. (2015). Operational research in education. *European Journal of Operational Research, 243*(3), 683-696. https://doi.org/10.1016/j.ejor.2014.10.043

22. Armacost, A. P., & Lowe, J. K. (2003). Operations Research Capstone Course: A Project-Based Process of Discovery and Application. *INFORMS Transactions on Education, 3*(2), 1-25.

23. Meerveld, H., & Lindelauf, R. (2025). Data Science in Military Decision-Making: Foci and Gaps. *Global Society, 39*(2), 103-129. https://doi.org/10.1080/13600826.2024.2353657

DIDACTIC AND METHODOLOGICAL FEATURES OF INFORMATIZATION IN MILITARY ENGINEERING TRAINING

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The article deals with the study of the didactic and methodological features of the informatization process in the modern military education system that affect the quality of training of engineering personnel. The study analyzes the integration of a new didactic model based on COLE (Computational, Organizational, Learning, and Experiential) technologies into the military engineering academic program. Special attention is paid to the formation of competencies in accordance with the standards of the NATO DEEP program, digital simulations, artificial intelligence-based adaptive learning systems, and the development of digital simulations. The results show that informatization is one of the most important decisive factors in military engineering training, accelerating the transition from classical theory to practice and increasing operational effectiveness.

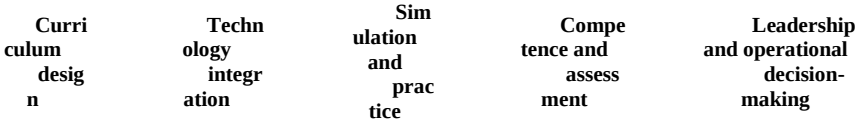
The dynamics of the modern battlefield, the introduction of high-tech weapon systems and cyber-platforms necessitate a fundamental restructuring of the military engineering training system. The requirements of the information society require military higher education institutions to train specialists who not only have technical knowledge, but also can make operational decisions in complex digital ecosystems. In this context, informatization in military education is not just the application of technical means, but also a digital transformation of the content, form, and methodology of teaching. In the process of didactic design of military engineering training, under the influence of informatization, the educational paradigm is shifting from a "knowledge-oriented" model to a "competence and result-oriented" model [1]. This transformation becomes more effective, especially with the introduction of COLE (Computational, Organizational, Training and Experimental) technologies into teaching. The aim of the article is to analyze the role of informatization in military engineering training from a scientific and pedagogical aspect and to substantiate the effectiveness of the new didactic models applied.

Methodology. The methodological basis of the study is a systematic analysis of military-pedagogical literature indexed in international scientific databases (web of science, scopus), a comparative analysis of the standards established within the framework of the NATO Defense education enhancement program (DEEP), and empirical observation of COLE technologies applied in military institutions. The methodology is also based on the "gap analysis" method between traditional curricula and modern digital engineering disciplines through the analysis of the academic program.

Informatization and COLE technologies in didactic design.

The most important feature of informatization in military engineering training is the individualization and interactivity of the didactic process. Unlike traditional

lecture-based education, COLE technologies play a central role in the modern model. These technologies combine multimedia tools, mission games, role-playing simulations, and AI-based auxiliary systems [2].



Informatization expands didactic functions, allowing for the digital visualization of "invisible" technical processes in the mastery of engineering disciplines. This provides cadets with a deeper understanding of complex engineering systems (for example, control algorithms for unmanned aerial vehicles or cyber-defense architecture) [3]. The Dadashov, A. (2024). highlights that this approach transforms military engineers from passive recipients of information into active, skilled professionals [4].

Artificial intelligence and adaptive learning models.

Since the mid-2020s, the role of artificial intelligence (AI) in military education has changed from an auxiliary tool to a driving engine. AI-based platforms analyze the performance of each cadet in real time and build individual learning trajectories. This is especially evident in the development of mathematical modeling and programming skills, which are critical in the training of engineers [5-7]. The application of AI is a decisive factor in the preparation of officers who will serve in "intellectual units". Through these systems, the optimization of engineering solutions for various combat scenarios is taught. Data analytics identifies the weaknesses of trainees and provides automatic adaptation of didactic material.

Simulation centers and digital experimental training.

Another important feature of informatization is the transfer of military engineering tests to digital laboratories. Simulation, Virtual reality (VR) and Augmented reality (AR) technologies allow trainees to perform complex engineering tasks (e.g., optimal preparation of obstacle crossings, explosion impact analysis, endurance testing of bridge structures) without real risk and resource expenditure [8]. In this approach model, the cadet has the "right to make mistakes". Mistakes made in the digital environment stimulate the engineer's creative thinking and sharpen the ability to find optimal solutions under stress.

International standards and NATO. Integration NATO's DEEP standards play an important role in the modernization of the military education system of Azerbaijan. Informatization is the main tool that ensures the "interoperability" required by these standards. The level of digital literacy of engineering personnel expands their opportunities to participate in international military operations and joint exercises [9,10]. Within the framework of the integrated didactic model, access to international educational resources through digital platforms and distance learning modules increase transparency and quality in engineering training. This process

forms a "strategic engineering" view in engineers, which means the coordination of technical knowledge with operational-tactical goals.

Discussion. The impact of informatization on military engineering training can be directly expressed by the formula "educational efficiency". However, along with digitalization, it is also important to preserve the fundamentals of military engineering (physical engineering instincts). COLE technologies play a role of a bridge between these two poles. Studies show that although informatized didactics increases the speed of solving complex engineering tasks by 40% for cadets, this requires high digital competence of the teaching staff [11-14]. The integration of artificial intelligence into teaching should be carried out in parallel with ethical responsibility and awareness of cybersecurity. Informatization in military engineering training should answer not only the question of "how" (technological application), but also the question of "why" (strategic goal).

Conclusion. Informatization in military education is a dynamic process that fundamentally changes the quality parameter of modern engineering training. The results of the study show that didactic design based on COLE technologies and AI adapts the level of training of engineering personnel to the requirements of the modern battlefield.

The engineer profile formed under the influence of informatization has both high technical skills and the ability to make operational decisions. It is recommended that future research focus on a deeper exploration of the didactic foundations of cyber-defense engineering in military education.

References

1. Dadashov, A. S. (2023). Designing military engineering training based on the model of didactic justification. Journal of Defense Resources Management, 14(2), 87-96.

2. Dadaşov, A. S. (2024). Hərbi ali təhsildə mütəxəssis hazırlığı: təlim prosesinə müasir texnologiyaların tətbiqi imkanları. Milli Müdafiə Universitetinin Hərbi Elmi Tədqiqat İnstitutu - Respublika elmi praktik konfransının materialları, 98-101.

3.Wang Xiao-shuang, Zhao Jing, and Zhao Hai-yan. 2019. Informatization of education in military academies: Logical Connotation and Development Path. In Proceedings of the 2019 4th International Conference on Distance Education and Learning (ICDEL '19). Association for Computing Machinery, New York, NY, USA, 189–193.

4. Dadashov, A. (2024). Applying didactic teaching principles to professional engineering education in military higher education institutions. Journal of Defense Resources Management, 15(2), 152–163. https://doi.org/10.64404/jodrm.2024.2.10

5. Campbell, K. C., & Wang, S. (2023). Military instructors' perspectives on interactive multimedia application in military classrooms. Journal of Military Learning, 46-61.

6. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

7. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

8.Barreiros dos Santos, L. A., Loureiro, N. A. R. S., do Vale Lima, J. M. M., de Sousa Silveira, J. A. & da Silva Grilo, R. J. (2019). Military higher education teaching and learning methodologies: An approach to the introduction of technologies in the classroom. Security and Defence Quarterly, 24(2), 123–154. https://doi.org/10.35467/sdq/108668

9. NATO Defence Education Enhancement Programme (DEEP). (2022). Faculty development curriculum guide. NATO.
https://www.nato.int/cps/en/natohq/topics_139182.html

10. Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.

11. Stănciulescu, R., & Beldiman, E. (2017). Didactics of the Military Specialty – Pedagogic process with major implications in the curricular architecture of military leaders' training. International Conference Knowledge-Based Organization, 23(1), 292-297.

12. Dadashov A. S. Integration of new technologies into the teaching methods of engineering education in military institutions //Modern directions of development of information and communication technologies and management tools. 14th International Scientific and Technical Conference. – 2024. – T. 2. – C. 3-6.

13. Dadashov A. S. Some results of the study on the didactic design of engineering training in military higher education. – 2025.

14. Dadashov A. S. Possibilities of applying information technologies in the formation of the didactic design model of military engineer training. – 2024.

ALARM OVERLOAD AND PRIORITIZATION POLICIES FOR AVIATION SECURITY OPERATIONS CENTERS

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Introduction

Aviation security operations centers (SOCs) supporting airbases and airfields operate in a uniquely high-noise environment where dense legitimate activity continuously generates alarms, alerts, and anomalous patterns. In surge periods, during large-scale flight operations, or under deliberate diversionary tactics, the SOC may face alarm overload that degrades validation speed, decision quality, and dispatch timeliness. The operational consequence is a loss of sufficiency in the detection–decision–response chain: the defender may fail not because sensors or response forces are absent, but because the SOC cannot triage, validate, and prioritize events fast enough to protect critical elements. The purpose of this thesis is to justify a structured approach to alarm overload management and prioritization policies tailored to aviation facilities, with measurable acceptance targets and evidence pathways.

Methodology

The methodology combines scenario-oriented analysis with queueing logic and time-budget decomposition of SOC decision processes. Representative aviation scenarios are defined, including false-alarm surges, diversion plus main attack, parallel alarms across multiple zones, insider-assisted anomalies that resemble routine access, and communications degradation that increases confirmation time. The SOC workflow is decomposed into measurable components: detection indication time, operator acknowledgement, validation and fusion time, classification and prioritization decision time, escalation/authorization latency, and dispatch initiation. Workload is represented through alert arrival rate, queue length,

and service capacity of operators and analytic pipelines. Acceptance is defined through bounded latency targets under load and stability criteria indicating that alarm queues remain controlled rather than diverging during stress windows. Evidence is specified through instrumented drills, alarm-injection stress tests, log-based measurement, and simulation or hybrid validation for rare multi-event conditions.

Main Part

The key argument is that alarm overload is not merely an efficiency issue but a structural vulnerability that can be exploited deliberately. In aviation environments, the SOC must distinguish threat-relevant signals from routine activity under time pressure, and it must do so while preserving the time margin required for interruption. When alarm volume exceeds processing capacity, the system enters a queueing regime where validation time increases nonlinearly, prioritization becomes unstable, and operators rely on heuristics that may down-rank the true main event. Diversionary tactics amplify this effect by creating attention sinks and by forcing reallocations of response resources, which further delays confirmation and dispatch for the primary threat. Therefore, prioritization policy must be treated as an engineered control mechanism rather than a procedural guideline.

A central concept is that prioritization must be scenario-conditioned and asset-driven. Aviation facilities contain heterogeneous critical elements whose consequence profiles differ sharply: aircraft on aprons, fuel farms, ammunition nodes, command-and-control and ATC infrastructure, and power/communications backbones. Prioritization rules should incorporate both consequence and time sensitivity, not only nominal alarm severity. In practice, this implies multi-criteria triage that combines threat likelihood cues (signature strength, correlation across sources), consequence weighting (critical element proximity), and time-to-impact estimates (trajectory proximity and expected adversary time-to-target). The method emphasizes that prioritization is effective only when it is coupled to validation workflow design; otherwise, the SOC can be correct in ranking but still too slow in confirming and escalating the highest-priority event.

The thesis proposes a layered alarm management model. First, the alarm stream is structured into classes: safety-critical, security-critical, informational, and nuisance, with explicit definitions tied to facility operating states. Second, correlation rules are used to reduce false alarms without delaying true events, by fusing access-control anomalies, sensor triggers, video analytics, and patrol reports into a single event hypothesis. Third, queue governance is introduced: when workload indicators exceed thresholds, the SOC switches into a stress mode with simplified validation pathways, tighter escalation rules, and pre-authorized response actions for predefined high-risk patterns. This prevents the system from collapsing into slow, manual confirmation loops precisely when speed is most needed.

Measurable acceptance targets are essential. Under defined overload conditions, the SOC must meet bounded validation-plus-decision latency for high-priority event classes, maintain communications availability for dispatch, and preserve correct prioritization rates for critical-element scenarios. Queue stability is treated as an acceptance-relevant property: if queue length grows without recovery

during a stress window, the SOC cannot guarantee timely handling of the main event. Evidence is defined through timed multi-event drills, controlled alarm injections that emulate surge conditions, and log-based measurement to confirm that performance holds during real operations. Where concurrency combinations are rare or unsafe to reproduce, simulation is used as a supporting tool only when calibrated with measured service times and validated against historical alarm streams.

Results and Conclusions

The thesis develops a defensible framework for managing alarm overload and prioritization in aviation SOCs as a sufficiency-preserving control problem rather than an administrative procedure. The analysis supports the hypothesis that the dominant mechanism of sufficiency loss under multi-event aviation stress is the nonlinear growth of validation and decision latency caused by overload, compounded by diversionary actions and communications friction. Practical significance lies in providing structured prioritization rules, stress-mode governance logic, workload indicators, and acceptance evidence pathways that can be incorporated into SOC requirements, training, and testing programs. The approach enables earlier detection of overload-induced vulnerability, more rational allocation of analytic and human resources, and improved resilience of aviation facilities to concurrent incidents and diversionary tactics.

References

1. Hashimov, E. et al. (2026). Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*, *10*(1), 66-71.

2. Elshan, H. et al. (2026). *Constrained optimization of an integral security indicator for adaptive management of hazardous facilities*. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

3. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // *International scientific journal «Grail of Science»*. 2026. № 62. С. 873–889.

4. Akhundov, R. et al. (2026). *Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities*. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

5. Akhundov, R., Hashimov, E. G., & Islamov, I. (2026). *Adaptive modeling of multi-layer protection systems under time-constrained threat scenarios*. Grail of Science, (63), 410–422. https://doi.org/10.36074/grail-of-science.18.03.2026.072

6. Akhundov, R., Hashimov, E. G., & Islamov, I. (2026). Methodological framework for adaptive risk-based zoning in multi-layer physical protection systems. Grail of Science, (62), 515–526. https://doi.org/10.36074/grail-of-science.20.02.2026.094

7. Akhundov, R., & Hashimov, E. (2026). *Enhancing the physical protection of critical facilities through the integration of physical process models and machine learning*. Grail of Science, (61), 722–731. https://doi.org/10.36074/grail-of-science.23.01.2026.083

8. Hashimov, E., et al. (2026). Decision support for physical protection systems using route-level metrics and simulation-based evaluation. *Grail of Science*, (63), 531–542. https://doi.org/10.36074/grail-of-science.06.03.2026.059

9. Akhundov, R., Hashimov, E. G., & Islamov, I. (2026). Scenario oriented sufficiency criteria for physical protection systems provide a traceable path from threat classes to design requirements. *International Scientific Journal «Grail of Science»*, (63), 687–699. https://doi.org/10.36074/grail-of-science.06.03.2026.074

ARTIFICIAL INTELLIGENCE AND ITS IMPACT ON MILITARY DECISION-MAKING

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Artificial intelligence is becoming one of the most influential technological factors in the transformation of modern military management and command processes. In contemporary operational environments, military decision-making takes place under conditions of high uncertainty, limited time, large volumes of heterogeneous information, dynamic threat evolution, and the need to compare several courses of action simultaneously. Under such conditions, traditional decision-support approaches often face limitations in processing speed, analytical depth, and predictive capability. Against this background, artificial intelligence emerges as a powerful instrument for enhancing situational awareness, accelerating information processing, supporting scenario analysis, and improving the quality of command decisions. At the same time, its growing role raises serious questions related to reliability, explainability, bias, legal responsibility, cyber vulnerability, and the preservation of meaningful human control. Therefore, the study of artificial intelligence in military decision-making must address not only technological efficiency, but also organizational, doctrinal, ethical, and governance dimensions.

The purpose of this material is to examine the influence of artificial intelligence on military decision-making from both theoretical and applied perspectives and to identify its main opportunities, limitations, and integration requirements. The analysis proceeds from the assumption that artificial intelligence should not be understood as a substitute for the military commander, but rather as an advanced analytical and decision-support layer that strengthens the ability of command structures to process information, evaluate alternatives, and anticipate operational developments. Its value lies less in autonomous decision replacement and more in improving the quality, speed, and structure of human-centered decision processes.

The study is based on systems analysis, comparative interpretation, conceptual modeling, and content generalization. A systems approach makes it possible to examine military decision-making as a sequence of interconnected stages rather than as a single isolated act. Within this sequence, artificial intelligence may influence information collection, filtering, recognition of significant patterns, forecasting, scenario generation, comparison of alternatives, and post-decision evaluation. Comparative interpretation is used to relate scientific arguments to broader institutional approaches that emphasize responsible, reliable, and controllable application of artificial intelligence in the military domain. Conceptual modeling helps structure the mechanism through which artificial intelligence affects command processes, while content generalization allows recurring themes in academic and policy discussions to be synthesized into a coherent analytical framework.

Figure illustrates the conceptual structure of artificial intelligence influence on the military decision-making process, including information sources, analytical

processing, command-level interpretation, oversight mechanisms, and operational outcomes.

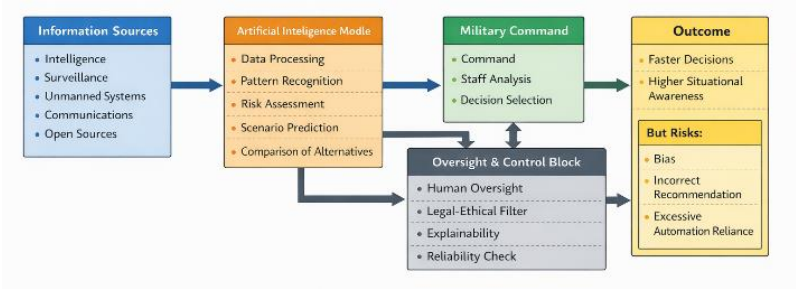

Figure. Conceptual model of artificial intelligence's impact on the military decision-making process

The results of the analysis indicate that the first major contribution of artificial intelligence to military decision-making lies in the enhancement of situational awareness. Modern command structures must process large flows of information from surveillance systems, reconnaissance assets, communications networks, open sources, reports from subordinate units, and technical monitoring devices. Human analysts are often unable to handle such volumes with the required operational speed. Artificial intelligence improves this process by rapidly sorting, classifying, correlating, and prioritizing information streams. Through pattern recognition, anomaly detection, and data fusion, it can identify signals of operational significance that might remain unnoticed in a purely manual process. As a result, commanders receive a more structured and timely picture of the operational environment.

A second important effect concerns support for alternative evaluation. Military decision-making rarely involves only one possible course of action. In most cases, command authorities must compare several alternatives under different assumptions about enemy behavior, resource availability, terrain, timing, and mission priorities. Artificial intelligence can support this process by simulating possible consequences, ranking alternatives according to selected criteria, and highlighting trade-offs between speed, risk, force protection, and mission effectiveness. This makes the decision process more transparent and analytically grounded, especially in situations where many variables must be evaluated simultaneously.

A third contribution concerns forecasting and anticipatory analysis. Military management increasingly depends not only on understanding the present situation, but also on anticipating likely developments. Artificial intelligence systems can assist in estimating probable adversary actions, identifying escalation trajectories, detecting logistical overload patterns, and revealing emerging risk zones before they fully materialize. However, this capability depends on the quality and relevance of the underlying data. A system trained on incomplete or biased datasets may produce distorted predictions, especially when the operational context changes rapidly. Thus, predictive value is always conditional upon rigorous data governance and continuous validation.

Despite these advantages, the analysis also demonstrates that the use of artificial intelligence in military decision-making introduces substantial risks. One of the most serious is the problem of explainability. If an artificial intelligence system recommends a specific course of action but the decision-maker cannot understand the basis of that recommendation, the command process may suffer from blind trust or total rejection. Blind trust weakens critical judgment and may lead to overreliance on machine-generated outputs. Total rejection, by contrast, prevents the effective use of analytical capabilities that could improve command performance. Therefore, explainable outputs, traceable logic, and auditable reasoning are essential requirements for military decision-support systems based on artificial intelligence.

Another critical issue is algorithmic bias and model fragility. Artificial intelligence systems are shaped by the data on which they are trained and the assumptions embedded in their design. If training data reflect incomplete threat representations or narrow operational assumptions, the resulting outputs may systematically misinterpret new conditions. In the military sphere, such errors may influence threat prioritization, route selection, target classification, and force allocation. The consequences of biased outputs are especially severe because military decisions operate under high-stakes conditions. This makes testing, verification, validation, and continuous recalibration indispensable elements of responsible implementation.

The question of human control also remains central. As artificial intelligence accelerates decision cycles, there is a risk that human participation may become nominal rather than substantive. In highly dynamic environments, commanders may be pressured to approve machine-generated recommendations without sufficient reflection simply because the operational tempo leaves little room for manual assessment. Under such conditions, human oversight may persist formally while weakening in practice. Meaningful human control must therefore be preserved not merely as a declarative principle, but as an operationally real capability supported by training, interface design, procedural safeguards, and escalation thresholds for human intervention.

The findings further suggest that successful integration of artificial intelligence into military decision-making requires more than technological acquisition. It depends on the development of an institutional ecosystem in which organizational procedures, operator competence, data standards, cybersecurity measures, and legal-ethical frameworks evolve together. Artificial intelligence is not simply software added to an existing command structure. Its integration transforms workflows, redistributes analytical tasks, changes the nature of staff work, and alters the relationship between information, judgment, and responsibility.

In general, the study confirms that artificial intelligence has substantial potential to strengthen military decision-making by improving situational awareness, accelerating analysis, supporting multi-option comparison, and enabling anticipatory assessment of operational developments. At the same time, its use introduces serious challenges related to explainability, reliability, bias, cyber resilience, and the preservation of meaningful human responsibility. Accordingly,

artificial intelligence should be understood not as an autonomous replacement for command judgment, but as a high-capacity analytical framework that supports, structures, and strengthens human decision-making under conditions of complexity and uncertainty. Only under these conditions can artificial intelligence become a source of operational advantage without undermining legal responsibility, ethical standards, and command integrity.

References

1.Radovanović M. et al. Application of the new hybrid model LMAW-G-EDAS multi-criteria decision-making when choosing an assault rifle for the needs of the army //Journal of decision analytics and intelligent computing. – 2024. – Т. 4. – №. 1. – С. 16-31.

2.Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.

3.İskhandarov, K. et al. (2025). Artificial intelligence in logistics operations. In *Topical issues of science development: Proceedings of the VI International Scientific Conference* (pp. 433–442). https://doi.org/10.62731/mcnd-31.10.2025

4.Rustamov, A. (2025). Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.

5.Krikun, V.L., et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7.p.120-121

6.Valehov S.A., et al. AI-based efficiency model in university governance. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.26-28.

7.Dergachov K., et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.75-78

8.Bayramov A.A. Application SMART for small unmanned aircraft system of systems // Handbook of Research on Artificial Intelligence Applications in the Aviation and Aerospace Industries. – IGI Global Scientific Publishing, 2020. – С. 193-213.

9. Hashimov E., Khaligov G. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – Т. 8. – №. 3. – С. 53-58.

10. İbrahimov, Ramil, et al. "Artificial Intelligence Applications in Higher Education: Prospects for Personalized Learning AND Governance Efficiency." *Grail of Science*, no. 55, 22 Aug. 2025, pp. 601-614, doi:10.36074/grail-of-science.22.08.2025.071.

11. İbrahimov B.G. Special purpose machine learning and data mining methods. *In* Current directions of development of information and communication technologies and control tools. 2025. Volume 2: sections 2. p.90

12. Maharramov, R. Application of C4ISR systems in military and security operations. *Матеріали конференцій МЦНД*, (15.08.2025; Харків, Україна), 125–134.

13. Hashimov E.Q., Talibov A. M., Gasanov A. G. Mathematical modeling of military systems. Lesson and routine //Baku: Military Publishing House. – 2018.

14. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.102-103

15. Jabrayilov A., et al. Digital technologies and artificial intelligence in the management of environmental safety in the army //Current directions of development of information and communication technologies and control tools. Proc. of 15-th International Scientific and Technical Conference. – 2025. – Т. 1. – С. 110-111.

FEATURES OF THE APPLICATION OF DIGITAL TECHNOLOGIES IN MILITARY EDUCATION

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The article systematically analyzes the functional role of digital technologies in the process of training military personnel in modern times, their impact on the quality indicators of education and the specific features of their application. In particular, the new pedagogical opportunities and practical advantages formed by simulation technologies and artificial intelligence-based training systems in the military educational environment are scientifically investigated. At the same time, the issues of digitalization of the modern educational process, integration of information technologies (IT) and application of innovative educational platforms are studied. The impact of digital platforms, simulation systems and local software on the efficiency of military personnel training, the formation of operational decision-making skills and the development of professional competencies is comprehensively analyzed. The article also analyzes modern digital technologies applied in the training process in higher military educational institutions and their pedagogical capabilities. It is noted that new technologies make it possible to create simulation environments suitable for real combat conditions, and to apply interactive and personalized learning methods. This approach serves not only to form and improve theoretical knowledge, but also practical skills. Artificial intelligence-based adaptive learning platforms offer curricula tailored to the individual knowledge level of learners, which allows for the individualization and increase in efficiency of the training process.

Currently, the changing nature of battlefields and the emergence of the concept of network-centric warfare necessitate fundamental reforms in the military education system. Classical teaching methods are no longer sufficient for the training of modern officers using high-tech weapons. The integration of digital technologies into the teaching of military subjects accelerates the assimilation of theoretical knowledge and creates conditions for the formation of practical skills without risk [1]. In the modern era, the optimization of military education is conditioned by the dynamically changing international security environment and technological challenges. In this context, the training of highly qualified personnel, increasing the state's defense capability and the adoption of innovative military technologies, the improvement of teaching methodology through digital tools is of strategic importance. According to the study, the role of innovative technologies, simulations and digital resources in the application of didactic principles for the training of military engineers is particularly emphasized. The study justifies the need to build a bridge between theory and practice through digital tools and blended learning methods in engineer training. [2]. The application of modern technologies in higher military educational institutions not only increases the effectiveness of training, but also allows students to acquire skills appropriate to real combat conditions. Virtual

reality and augmented reality occupy a special place among the currently widely used technologies. Through virtual reality technologies, students gain experience in environments that simulate real combat conditions. These systems allow for testing various combat strategies and studying different operational scenarios. Augmented reality, on the other hand, forms a deeper and more visualized learning environment by adding digital elements to the real environment. Augmented reality technologies are widely used, especially in teaching technical subjects and explaining the principles of operation of weapons and military equipment. Simulation and modeling systems play an important role in modern military exercises [3]. Computer-based combat simulators allow for the creation of various combat conditions and develop the decision-making skills of students. Simulators designed for pilots and tank crews are used as an effective tool in the training of aviation and armored vehicle units. The created simulators play an important role in teaching management and combat tactics. These systems provide the formation of practical knowledge and skills in a safe environment without involvement in real operations. Electronic learning systems and digital learning platforms are widely used in modern higher military educational institutions. Electronic resources provide cadets with access to a rich information base and expand the application of interactive teaching methods. Artificial intelligence and big data analysis create conditions for the application of innovative approaches in the military education system. Artificial intelligence-based systems analyze the level of knowledge of students, individualize the training process and automate assessment. At the same time, these technologies are used in the analysis of combat strategies and the planning of modern military operations. Operational processing of large volumes of data allows for optimal decision-making [4].

During the application of this type of digital training methods, a number of technical and psychological difficulties are observed, the names of which are listed below:

- instability of network connection and technical shortcomings of hardware.
- the need to protect confidential military information.
- a feeling of social isolation among cadets and low motivation due to the lack of direct communication.
- the inability of digital methods to completely replace field training in some cases.

The above shows that the rapid development of technologies has had a significant impact on the military education system and has updated the content of traditional teaching methods. The application of innovative technologies such as augmented reality, simulation and modeling systems, artificial intelligence, big data analysis and robotics in military educational institutions not only improves the quality of the educational process, but also allows cadets to be prepared for real combat conditions at a higher level. According to the study, the integration of augmented reality, simulation systems and artificial intelligence into teaching in higher military educational institutions significantly increases the quality of military engineering training. This innovative approach accelerates the mastery of complex

engineering tasks by cadets and allows them to develop skills close to real combat conditions [5-11].

The digitalization of military training has changed the educational paradigm from traditional methods to visual and interactive models. Although information technologies increase the efficiency of training, this transition must necessarily be accompanied by the preservation of information security and methodological balance.

These technologies ensure more effective mastery of theoretical knowledge, the development of practical skills, and the testing of complex combat scenarios in safe conditions.

As a result, the integration of digital technologies into the military education system, in addition to increasing the knowledge and skills of cadets, also allows for positive results in the areas of decision-making, teamwork, and operational training. These innovative approaches create the basis for future officers to reach a high level of professionalism and make flexible and effective decisions in accordance with the requirements of modern military operations.

References

1. Cummings, M. L. Artificial Intelligence and the Future of Warfare. Chatham House, International Security Department, 2017.

2.Dadashov A. (2024). Applying didactic teaching princples to professional engineering in military higher education institutions. Journal of defense resources management. 2024 № 15:2 (237), səh. 152-163. https://doi.org/10.64404/jodrm.2024.2.10

3.Doicariu, D. H. Digital transformation of military education in nato using e-learning. https://www.armyacademy.ro/reviste/rev4_2025/Doicariu_RAFT_4_2025.pdf

4.Mammadov, Z M. Applıcatıon possıbılıtıes of modern ınformatıon technologıes ın mılıtary educatıon. 2025. https://repository.kpi.kharkov.ua/handle/KhPI-Press/93218

5.Dadashov A. S. Integration of new technologies into the teaching methods of engineering education in military institutions // Modern directions of development of information and communication technologies and management tools. 14-th International Scientific and Technical Conference, Vol. 2: section 3-6. – Kharkiv, 2024. P. 92-93.

6.Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.

7.Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.

8.Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

9.İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

10. Piriyev H.K. et al. Some aspects of optimization of control / Current directions of development of information and communication technologies and control tools. Proceedings of 14-th International Scientific and Technical Conference. Volume 1. 2024. -pp.18-19.

11. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.

IMPROVEMENT OF NIGHT COMBAT TRAINING OF SPECIAL FORCES UNITS AND FORMATIONS BASED ON THE APPLICATION OF MODERN TECHNOLOGIES

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Analysis of the current global armed conflicts shows that special operations conducted at night and in low visibility conditions play an important role in the activities of special forces units and formations. The effectiveness of special operations conducted in such conditions is determined by the ability to obtain information continuously and make quick decisions, as well as the skillful and purposeful use of modern technological advancements.

The study examines the theoretical foundations of preparations for night combat operations, the application of modern technical means and their impact on the planning and execution of special operations. In particular, the role of various combat-oriented Unmanned Aerial Vehicles (UAVs) and drones, night vision and thermal surveillance, navigation and guidance, camouflage, radio-electronic warfare (REW), recognition (identification) of our own troops, artificial intelligence and digital command and control systems was studied. The study found that the systematic and purposeful application of modern and advanced technologies increases the combat capability of special forces units and formations, accelerates the decision-making process and increases the effectiveness of the operation. The study presents solutions and proposals that allow special forces units and formations to gain an advantage during special operations conducted at night and in low-visibility conditions.

The scientific novelty of this study is the systematic impact analysis of the complex use of modern technological tools, unmanned systems, sensor fusion technology, REW tools and artificial intelligence-based decision-making systems on the effectiveness of special operations conducted by special forces at night and in low-visibility conditions.

The nature of wars and armed conflicts has significantly changed in the modern era, particularly in the last few years. The rapid technological advancement, the development of high-precision weapons and the use of artificial intelligence in planning and controlling operations have radically changed the forms and methods of conducting combat operations. These changes are especially evident during operations conducted at night and in low-visibility conditions.

In particular, the Russia-Ukraine war, military confrontations between Israel, the USA and Iran, as well as anti-terrorism operations carried out across the globe show that special operations conducted at night allow gaining the initiative, disrupting enemy forces and completing out the operation with minimum casualties [1].

The planning and execution of modern combat operations are closely related to the application of modern information and advanced technologies. The application

of artificial intelligence and information technologies, unmanned systems, observation and sensor means, recognition (identification) devices, radio-electronic warfare (REW), anti-drone (jammer, drone hunter, anti-drone radar) systems has significantly changed the forms and methods of conducting all types of modern military operations. In particular, the use of these technologies during the planning, management and execution of special operations increases the effectiveness of operations [2]. In the contemporary military operations, UAVs and various drone systems are particularly important. Real-time intelligence gathering, adversary position determination and ongoing control and intervention during the operation are all made feasible by these systems. In particular, the analysis of the Russia-Ukraine war shows that the widespread use of UAVs performing reconnaissance and strike functions has drastically changed the tactics of combat operations and enabled the "reconnaissance - strike" period to be shortened [3]. In particular, unmanned strike systems of the “loitering munition” type (switchblade, luncet, harop) have become one of the important tools that increase the effectiveness of night combat operations.

Night vision and thermal observation systems also play a major role in gaining an advantage in night combat operations, detecting enemy manpower, firepower and combat equipment. Sensor-fusion technology applied in modern armies provides the collection of data obtained from night vision and thermal means, enabling the collection, analysis and quick decision-making of more accurate and useful data regarding the combat operations area [4].

Navigation and guidance systems are also crucial in ensuring effectiveness in night combat operations. Thus, satellite navigation systems, digital map technologies, command and control systems provide precise control of units, facilitate the planning of directions of action in the operational area and strengthen the interaction between units [5].

The application of technological means in modern armed conflicts has led to the widespread use of REW systems.

These systems were previously used to disable the enemy’s communication and control systems. But in modern warfare, it aims to limit the activities of UAVs and other technological systems. The experience of the Second Garabagh War and the Russia-Ukraine war demonstrates that the application of REW systems directly affects the operation of UAVs and other devices and can significantly influence the outcome of combat operations [6].

Developed countries, along with all sectors, widely apply artificial intelligence and digital command and control systems in their armies. Through artificial intelligence technologies, large volumes of data are processed and analyzed quickly, which allows the command staff to more accurately assess the operational situation and make quick decisions [7]. At the same time, the “blue force tracking” technology applied in command and control systems ensures continuous real-time tracking and recognition of our own troops on the battlefield, reducing the risk of misidentification.

Digital command and control systems accelerate the exchange of information between units and ensure coordination of operations. By increasing information flow

about the battlefield situation and significantly reducing the decision-making time, these systems have become one of the main factors improving the effectiveness of combat operations.

As a result of the research, it is considered appropriate to carry out the following measures in order to significantly increase the effectiveness of special operations carried out by special forces units and formations at night and in low visibility condition through the systematic application of modern technologies [8-16].

1. Expanding the integration of various UAVs and drone systems into the combat training process of special forces units, for this purpose, increasing the readiness of personnel to obtain intelligence information, identify targets, and strike various targets in various situations and conditions. Creating realistic combat scenarios in the training process and enhancing the proficiency of all unit personnel by gradually increasing their difficulty.

2. Ensuring the integration of night vision and thermal surveillance equipment with sensor-fusion technologies, creating mechanisms for real-time processing of information obtained from all surveillance equipment in the field of combat operations and transmitting it to command and control centers, thereby increasing the ability of the command to quickly obtain information about the real situation in the operational area and intervene the situation.

3. Implementing digital command and control systems at all control points, ensuring rapid information exchange and interaction between all subordinate units and formations through these systems, and more effective coordination of operations.

4. Providing special-purpose units with portable REW equipment, improving their proficiency in using the equipment, as well as increasing the resistance of all communication, navigation and control equipment used by the unit against the enemy REW effects. Developing anti-drone systems in order to increase the capabilities of combating enemy's UAVs and drones.

5. Widespread use of artificial intelligence technologies in the operational analysis of information obtained during night operations of all branches of the Armed Forces, as well as special forces units and formations, in ensuring identification security in the area of combat operations and in implementing the command and control process more quickly and sustainably, as well as training specialists in this field.

Analysis of current global and regional conflicts indicates that the force that achieves superiority in night operations typically possesses a technological edge through continuous reconnaissance, widespread deployment of various unmanned systems, and accelerated decision-making. At the same time, studies have shown that the effectiveness of operations in night conditions directly depends not only on technical capabilities, but also on the level of specialized training of individual personnel.

In this regard, improving night combat training serves to increase the general combat readiness of units, reduce losses, and more accurate and effective execution

of combat missions. Developing skills such as systematic observation, covert and silent maneuvering, and decision-making during operations is of particular importance.

At the same time, it is crucial to enhance personnel's practical training for the effective use of modern night vision devices, thermal observation devices, and digital communication systems. Studies show that training and exercises conducted at night enhance personnel's morale and psychological resilience, as well as strengthen inter-unit coordination and collaboration.

References

1. 1.Watling, J., Danylyuk, O. V., & Reynolds, N. (2024, July 18). Preliminary lessons from Ukraine's offensive operations, 2022–23. Royal United Services Institute.

2. NATO Special Operations Headquarters. (2020, December). Comprehensive defence handbook (Vol. 1).

3. 3 Watling, J., & Reynolds, N. (2025, February 14). Tactical developments during the third year of the Russo-Ukrainian War. Royal United Services Institute.

4. Marine Corps Systems Command. (2024). *Next generation night vision systems*. U.S. Marine Corps Systems Command. https://www.marcorsyscom.marines.mil

5. Department of the Army. (2024, January). Infantry rifle platoon and squad (ATP 3-21.8).

6. Allied Command Transformation. (2020). *NATO C2 of EW overview and Q&A*. North Atlantic Treaty Organization.

7. 7.Scharre, P. (2023). Four battlegrounds: Power in the age of artificial *intelligence*. W. W. Norton & Company.

8. Office of the Secretary of Defense. (2018, June). Unmanned systems integrated roadmap 2017–2042. U.S. Department of Defense.

9. Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.

10. Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.

11. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

12. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

13. Dadashov A. S. Integration of new technologies into the teaching methods of engineering education in military institutions //Modern directions of development of information and communication technologies and management tools. 14th International Scientific and Technical Conference. – 2024. – T. 2. – C. 3-6.

14. Dadashov A. S. Some results of the study on the didactic design of engineering training in military higher education. – 2025.

15. Dadashov A. S. Possibilities of applying information technologies in the formation of the didactic design model of military engineer training. – 2024.

16. Piriyev H.K. et al. Some aspects of optimization of control / Current directions of development of information and communication technologies and control tools. Proceedings of 14-th International Scientific and Technical Conference. Volume 1. 2024. -pp.18-19.

THE IMPACT OF UNMANNED SYSTEMS ON THE COMBAT READINESS OF SPECIAL UNITS

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The role of unmanned systems in the main concept of conflicts that have occurred in the second decade of the 21st century and are still ongoing has significantly increased and changed the form of conducting combat operations. In particular, unmanned aerial vehicles (UAVs), loitering munitions (switchblade, luncet, harpoon-type loitering munitions) and robotic vehicles are no longer just auxiliary tools, but also one of the main elements of combat. These changes have had a serious impact on the activities of special forces units and necessitated the reformulation of combat readiness [1].

Although combat readiness has traditionally been based mainly on tactical, fire and other preparations, in modern times, conducting real-time reconnaissance, obtaining accurate and timely information, using technology in all areas and integrating it into combat elements have become the main factors that directly affect and determine the results of combat operations. In the military doctrines of the US and NATO countries, the use of UAV systems in active combat operations is considered a “force multiplier” (a factor that increases power).

The ongoing war between Ukraine and Russia has practically confirmed this trend. The widespread use of unmanned systems in combat operations, both offensive and defensive, has changed the dynamics of combat and reduced the effectiveness of classical tactics, creating a new combat model [2].

Therefore, the combat training of special forces units in the new combat conditions cannot continue in the old way. Knowledge and skills related to the use and management of unmanned systems, technological adaptation, activities in the digital sphere, as well as the use of artificial intelligence have become a key part of combat training.

The purpose of this study is to comprehensively analyze the impact of unmanned systems on the combat training of special forces units and to develop new scientific approaches in this direction.

The role of unmanned systems has been widely studied in many modern military literature. US military analysts note that unmanned systems fundamentally change the decision-making process by creating “persistent surveillance” capabilities in the area of combat operations [3].

NATO doctrine documents highlight the importance of reconnaissance, surveillance and target designation functions as one of the main elements of special combat operations [4].

The use of “Bayraktar TB2”, “ANKA” and other unmanned systems, produced by the military industry of the Republic of Turkey and widely used by many countries, has proven how effective and important unmanned technologies are in modern armed conflicts .

The experience of using unmanned systems during the 2020 and 2023 operations of the Azerbaijani Armed Forces to liberate the territories of Karabakh and surrounding regions occupied by Armenia showed that these technologies can affect the outcome of combat operations not only at the tactical, but also at the operational-strategic level [5].

Nevertheless, the impact of unmanned systems on combat readiness has not been fully systematically investigated in the existing modern literature. Most research materials have focused only on technical or limited operational aspects, but their impact on the combat readiness process has not been comprehensively analyzed.

The impact of unmanned systems on the combat readiness of special forces units is manifested in several areas.

The information obtained through unmanned systems allows for real-time monitoring of the area of combat operations.

This increases the speed of decision-making by special forces unit and formation commanders at command and control points, as well as all levels of command staff directly on the battlefield, and reduces the risks of identification (mutual recognition) [4].

During the planning stage of the operation, information obtained through UAVs allows for more accurate and realistic decision-making [3].

The introduction of modern technology is radically changing the combat readiness process of special forces units. Now, members of special forces units must have not only physical and tactical training, but also technological and analytical skills [1].

Unmanned systems are divided into different categories and have different effects on the combat readiness of special forces units.

Reconnaissance and surveillance UAVs are one of the main technological support tools for special forces. Through these systems, special forces operating both from command posts and directly on the battlefield conduct continuous observation day and night and monitor the real situation on the battlefield [6].

In the US Army, MQ-9 Reaper and RQ-7 Shadow systems have made the planning of special operations as efficient as possible by transmitting intelligence information in real time [6].

The widespread use of small-sized drones in the Ukrainian-Russian war has shown that even low-cost systems and means can achieve a significant advantage on the battlefield [3].

Strike UAVs and drones, which are other types of unmanned systems, are capable of not only observing, but also striking targets. These various types of unmanned systems reduce the risk level during special combat operations of special forces units and allow them to strike enemy forces from a long distance [5].

The Turkish-made “Bayraktar TB2” and “ANKA-s” unmanned systems have been successfully used in many conflict zones, proving the superiority of strike UAVs. These systems have made it possible to detect and destroy targets in the area of combat operations in a timely and accurate manner [4].

At the same time, the extensive use of these systems by the Azerbaijani Army during the military operations in Karabakh clearly demonstrated how effective unmanned technologies are at the operational-strategic level [2].

One of the most effective and dangerous types of modern unmanned systems is loitering munitions. These systems stay in the air for a long time, track the target, and immediately destroy it if necessary.

The Turkish-made "Kargu" and the Israeli-made "Harop" have been widely used in recent wars and have demonstrated high efficiency [1].

These modern technologies, which are widely used in the combat training of special forces units, not only strengthen the concept of "precision strikes", but also allow achieving maximum results with minimal resources.

Recently, especially in the war between Ukraine and Russia, FRV (first person view) drones have been widely used.

These drones are controlled directly by operators and detect and destroy targets with high accuracy [3]. In general, the Ukrainian army has formed a new model of using unmanned systems in combat.

The most effective of these is the massive use of drones, which has recently allowed it to gain an advantage over the Russian army.

The advantage of these drones is that they are cheap, fast to deploy, and can hit targets with high accuracy.

The use of these types of drones has led to the emergence of new tactical methods in the combat training of special forces units.

Although unmanned systems are as effective in the air as ground-based robotic systems are, they are also successfully deployed in ground conditions. They are mainly widely used in the field of mine detection, reconnaissance, and inspection of dangerous areas [6].

The deployment of these systems reduces personnel losses during special operations and is actively used by modern armies.

The study found that the use of unmanned systems has led to fundamental changes in the combat readiness of special forces units.

Thus, during the operational planning of special forces units and formations, it has become possible to obtain accurate intelligence information in real time, personnel losses have been minimized, and the decision-making process has become more accurate, faster and more flexible [7-12].

The new scientific approaches put forward in this study are as follows:

1. The combat training of special forces units should be based not only on technology, but also on people. New modern technology should not replace people, but should further strengthen them.

2. Modern technological means should be integrated with each other and the battlefield should be kept under continuous control.

3. Decisions from all categories should be made not only from command and control levels, but also directly on the battlefield using available systems.

The training of special forces units should not be organized without unmanned systems.

Therefore, the application of unmanned systems during combat training planning should be included in the entire training process and further improved over time.

Since technological superiority also gives an advantage in the battlefield, it requires a revision of classical military theories.

Considering that mass unmanned systems will become the main strike tool in future combat operations, it is necessary to update the entire combat training system.

As a result, it is considered appropriate to conduct work on the following areas in future research: the use of artificial intelligence-based unmanned aerial vehicles; the use of mass (swarm) drones in combat; development of anti-drone systems, Integration of REM tools into unmanned systems.

References

1.Carapau, R. S., Rodrigues, A. V., Marques, M. M., & Lobo, V. (2017). Unmanned aerial systems in military environments: The benefits of interoperability. Scientific Bulletin of Naval Academy, 20(1).

2. Fitzgerald, B. (2017). Operational surveillance and reconnaissance battalion. Military Review.

3. Gargalakos, M. (2024). The role of unmanned aerial vehicles in military communications: Application scenarios, current trends, and beyond. The Journal of Defense Modeling and Simulation, 21(3), 313–321.

4. Scott, B. (2021). Army Counter-UAS 2021–2028. Military Review, 101(2), 65–80.

5. Edmonds, J. A., & Bendett, S. (2023). Russia's use of uncrewed systems in Ukraine. CNA.

6. Konaev, M. (2023). Tomorrow's technology in today's war: The use of AI and autonomous technologies in the war in Ukraine and implications for strategic stability. CNA.

7. Mahmoud Zadeh, S., Yazdani, A., Kalantari, Y., Ciftler, B., Aidarus, F., & Al Kadri, M. O. (2024). Holistic review of UAV-centric situational awareness: Applications, limitations, and algorithmic challenges. Robotics, 13(8), 117.

8.Muradov S., et al. Determining the location of the UAV equipped with a homing device based on radio beacons //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 54-56.

9. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.

10. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116

11. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

12. Bayramov A.A. Application SMART for small unmanned aircraft system of systems //Handbook of Research on Artificial Intelligence Applications in the Aviation and Aerospace Industries. – IGI Global Scientific Publishing, 2020. – С. 193-213.

MORAL VALUE FACTOR IN THE DEVELOPMENT OF THE STUDENT'S PERSONALITY

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In modern times, one of the main tasks facing the military education system is not only to prepare personnel with professional knowledge and skills, but also to form a patriotic, responsible and socially mature personality with high moral qualities [1]. The behavioral model, decision-making mechanism and leadership characteristics of a cadet working in military collectives are directly related to his system of moral and ethical values.

Moral values are a set of norms and principles that regulate a person's behavior and determine his position in the system of social relations. In the military environment, these values have a more serious and systematic character, since responsibility, discipline, loyalty and service to the homeland are accepted as the highest principles here [2].

The issues of moral education and value-oriented development have occupied a wide place in classical and modern pedagogical thought. The ancient philosopher Aristotle considered morality as the main criterion in the formation of human character and noted that virtues arise as a result of repeated correct behavior. His principle of “the mean” is also important in terms of balanced and responsible decision-making in a military environment [3].

In Eastern philosophical thought, Nasir al-Din Tusi, in his work “Akhlaqi-Nasiri”, presents morality as a path leading to human perfection and emphasizes the role of family, society and state factors in the upbringing process. This approach justifies the importance of collective and institutional influence in the modern military education system [4].

In modern psychological theories, moral development is interpreted as a staged process. In particular, Lawrence Kohlberg explained the mechanism of an individual’s assimilation of social norms and their transformation into internal principles, showing that moral development consists of six stages [5]. The transition of cadets from the initial stage of normative obedience to the stage of principled responsibility is one of the main goals of military pedagogy.

In military educational institutions, moral values are formed not only through theoretical training, but also through daily rules of discipline, collective relations and leadership examples [6]. This process is characterized by the following features: Collective responsibility – the impact of individual behavior on collective results; leadership model – moral influence through the personal example of the teaching and officer staff; patriotism and statehood values – strengthening national-spiritual identity [7].

The military doctrine of the Republic of Azerbaijan and the concept of national security also emphasize the importance of moral-spiritual preparation. Along with professional preparation, moral-psychological preparation has been identified as a

priority direction within the framework of the reforms carried out in the system of the Armed Forces of the Republic of Azerbaijan [8].

The cadet personality has a multi-component structure and its main elements include the intellectual component, the emotional-volitional component, the social-communicative component, and the moral-spiritual components. The moral component plays the role of a regulatory mechanism that determines the direction of action of other components [9]. For example, high intellectual potential, if not accompanied by moral responsibility, can lead to unconstructive decisions. In this regard, moral values ensure the safe and legitimate nature of the cadet's professional activity [10-12]. The formation of moral qualities in the personality of a cadet requires a systematic pedagogical approach. These mechanisms can be implemented through the analysis of ethical issues in the content of humanitarian and military disciplines, discussion of real situations, and ethical assessment of decision-making models.

In addition, the development of moral values can be achieved through collective events, swearing-in ceremonies, respect for state attributes and the promotion of historical examples of heroism, strengthening the internal motivation of cadets, developing self-analysis and self-control skills, and the personal example and individual approach of officer-teaching staff, which accelerate the internalization of moral values.

References

1.Huseynov, R., Cahangirov, V. (2018). Ali hərbi təhsil müəssisələrində kursantların bilik və bacarıqlara yiyələnməsində keçirilən məsləhət saatlarının əhəmiyyəti. H.Əliyev adına AAHM-in Elmi əsərlər məcmuəsi. Bakı

2.Aristotel. Nikomax etikası. Bakı: Şərq-Qərb, 2008.

3.Əlizadə, Ə. (2019). Hərbi pedaqogikanın əsasları. Bakı: Elm və Təhsil.

4.Tusi, N. Əxlaqi-Nasiri. Bakı: Lider nəşriyyatı, 2005.

5.Kohlberg, L. (1984). Essays on Moral Development. Vol. II. San Francisco: Harper & Row.

6.Huseynov, R., Cahangirov, V. (2018). Ordunun peşəkarlığının artırılmasında gənc zabitlərin şəxsiyyətyönümlü inkişafının əhəmiyyəti. "Heydər Əliyev və Azərbaycan Ordusu" elmi-praktik konfransı. Bakı

7.Huseynov, R. (2017). İdarəetmə və liderlik fenomeni. H.Əliyev adına AAHM-in Elmi əsərlər məcmuəsi. Bakı

8.Huseynov, R. (2018). Təhsilalanların şəxsiyyətyönümlü inkişafında müasir təhsil texnologiyalarının üstünlüyü. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU

9. Huseynov, R., Zəkəryəyev, Z., Əliyeva, V. (2023). İnsan resurslarının idarə edilməsinin zəruriliyi və inkişaf effektivliyi. "Azərbaycanın inkişaf strategiyası: potensial imkanlar və yeni çağırışlar" respublika elmi-praktik konfransı, Bakı, Hərbi İnstitut

10. Həsənov, A. (2022). Milli təhlükəsizlik və hərbi-strateji inkişaf. Bakı: Elm.

11. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

12. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

THE IMPACT OF TRADITIONAL PRINCIPLES ON THE MODERN EDUCATION SYSTEM

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The education system is one of the main pillars of the socio-cultural development of society. In modern times, globalization, the rapid development of information technologies and the changing demands of the labor market have necessitated reforms in the education system.

However, the classical principles formed on the basis of pedagogical science remain relevant.

Historically, the traditional education model was formed as a teacher-centered approach based on the systematic and consistent transfer of knowledge. The theoretical foundations of this model were reflected in the didactic principles developed by Jan Amos Komenski, in particular. Komenski's principles of systematicity, conformity to nature and clarity had a strong influence on the development of subsequent pedagogical theories [1].

Thus, the traditional didactic system is based on various principles, some of which we can mention:

– the principle of scientificity - the basis of educational material on scientific grounds;

– systematicity and consistency - the gradual and logical transfer of knowledge;

– awareness and activity - the active participation of students in the learning process;

– clarity - the use of visual and concrete means; reinforcement - the consolidation of knowledge through repetition and application.

These principles formed the basis of classical pedagogy and were later developed by educators such as Johann Heinrich Pestalozzi and Konstantin Ushinsky [2].

In the traditional model, the teacher acts as the main source of knowledge, and the student is positioned as the recipient of this knowledge. This approach has had a positive impact on the formation of discipline, responsibility, and academic discipline.

However, in the modern education system, the principles are changing. In this system, the teacher is more of a guide and guide. At the same time, the teacher also plays the role of a judge in the discussion between students, trying to explain what is right [3; 4].

In a broader sense, we can show the characteristics of the modern education system as follows: student-centeredness, individualized learning, competency-based approach, integration of digital technologies, development of critical and creative thinking.

The theoretical foundations of modern pedagogical approaches are based on the philosophy of constructivism. In this direction, the ideas of scientists such as Jean Piaget and Lev Vygotsky are of particular importance [5]. According to their

theories, knowledge is not passively received, but is constructed in the process of social and cognitive activity.

Thus, the modern model promotes an interactive and collaborative learning environment, unlike the traditional transmission mechanism. Also, despite the widespread use of digital platforms, the principle of systematicity remains the basis for the development of curricula. Electronic textbooks and LMS platforms are built on the basis of such logical sequence [6].

Traditional methods of repetition are implemented in a modern format through online tests, project-based tasks and portfolios. This ensures continuous monitoring of knowledge [7]. In the traditional model, the teacher, who is the transmitter of knowledge, plays the role of a facilitator and mentor in the modern system. However, in terms of pedagogical leadership and organization of the process, the authority of the classical teacher is still significant.

It is not possible and advisable to completely abandon tradition in the modern education system. On the contrary, an effective model should be based on the following synthesis. This can be illustrated by the following formula: classical systematicity + digital flexibility, discipline + creative freedom, theoretical basis + practical application, teacher leadership + student initiative [8-11].

References

1.Jan Amos Komenski (1957). Didactica Magna (The Great Didactic). London: Adam & Charles Black.

2.Konstantin Uşinski (1948). Man as the Subject of. Moscow: Academy of Pedagogical Sciences of RSFSR.

3.Huseynov, R., Cahangirov, V. (2018). Ordunun peşəkarlığının artırılmasında gənc zabitlərin şəxsiyyətyönümlü inkişafının əhəmiyyəti. "Heydər Əliyev və Azərbaycan Ordusu" elmi-praktik konfransı. Bakı

4.Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. "Müasir ali təhsil və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

5.Lev Vygotsky (1978). Mind in Society: The Development of Higher Psychological Processes. Cambridge, MA: Harvard University Press.

6.Huseynov, R. (2023). İnsan resurslarının idarə edilməsinin zəruriliyi və inkişaf effektivliyi. "Azərbaycanın inkişaf strategiyası: potensial imkanlar və yeni çağırışlar" respublika elmi-praktik konfransı, Bakı, Hərbi İnstitut

7.Huseynov, R. (2021). Daxili işlər orqanlarının fəaliyyətində yeni yanaşmanın tətbiqı: kadrların hazırlanmasında keyfiyyətin artırılması. Beynəlxalq elmi-praktik konfrans. Bakı, Polis Akademiyası.

8.Azərbaycan Respublikası Təhsil Nazirliyi (2006). Azərbaycan Respublikasında ümumi təhsilin Konsepsiyası (Milli Kurikulum). Bakı: Təhsil Nazirliyi nəşri.

9.Huseynov, R., Cahangirov, V. (2018). Təhsilalanların şəxsiyyətyönümlü inkişafında müasir təhsil texnologiyalarının üstünlüyü. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU

10. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

11. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

PATRIOTISM FACTOR IN ACHIEVING VICTORY IN MODERN WARS

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In the modern era, the nature and methods of waging wars are changing rapidly. Technological development, the use of high-precision weapons, information warfare and cyber operations have become the main features of military conflicts [1; 2]. At the same time, history shows that one of the main factors determining the fate of wars is the human factor. In this context, the feeling of patriotism - that is, devotion to the homeland, loyalty to national values and selflessness for the defense of the state - plays an important role in achieving victory in modern wars.

Patriotism is not only an emotional attitude, but also an important ideological and psychological component of the national security system. It strengthens the fighting spirit of the military, ensures the mobilization of society in war conditions and serves to strengthen the defense potential of the state. Therefore, victory in modern wars depends not only on technical and tactical advantages, but also on moral and psychological factors such as patriotism.

Wars of the 21st century are multifaceted and complex. In modern wars, not only military forces, but also information, economics, diplomacy and ideological means of influence play an important role [3]. In this regard, war is no longer considered only an armed conflict on the front line, but a large-scale process in which the entire society participates.

One of the main features of modern wars is the rapid development of technology [4]. Unmanned aerial vehicles, artificial intelligence systems, cyber operations and high-precision weapons have changed the nature of battles. However, the development of technology has not reduced the importance of the human factor. On the contrary, the effective use of modern technologies requires the presence of highly trained, motivated and patriotic personnel.

It has been proven in military science that an army with a high fighting spirit can operate effectively even in the most difficult conditions. Along with combat training, the moral and psychological state of personnel also directly affects the results of military operations. In this sense, patriotism is considered one of the main ideological pillars in the formation of the army's combat capability [5; 6]. Because patriotism combines values such as love for the homeland, attachment to national identity, and self-sacrifice in order to protect the interests of the state. This feeling is closely connected with a person's sense of responsibility towards his people, history, culture, and state, which is most evident during combat.

Sociological and pedagogical studies show that patriotism is not only an individual trait, but also a value system formed under the influence of the social environment. Family, educational institutions, state ideology, and national culture play an important role in this process. Patriotic education, especially in military educational institutions, acts as one of the important directions in the formation of the personality of cadets.

Patriotic feelings increase the motivation of military personnel on the battlefield, strengthen collective solidarity, and ensure endurance in difficult situations. These characteristics are considered to be important conditions for achieving victory in modern wars [7].

That is, the combat capability of the army is not limited only to technical equipment and tactical training. One of the important components of combat capability is the moral and psychological preparation of personnel, and patriotism acts as one of the main elements of this preparation.

When we pay attention to the nature of modern wars, we see that no matter how much technological capabilities prevail, we must not forget that a soldier with a high sense of patriotism performs combat missions more responsibly. He is more tolerant of difficulties and carries out the commander's orders with greater confidence. In addition, patriotism helps to form mutual trust and solidarity in the military collective [8-12].

Historical experience shows that armies with a high patriotic spirit have been able to achieve successful results even against a stronger and better equipped enemy. This fact once again confirms the importance of the moral factor in modern wars.

References

13. Huseynov, R. (2016). Beynəlxalq geosiyasi proseslər və Azərbaycan Respublikasının Milli Təhlükəsizlik Konsepsiyası. Milli təhlükəsizlik və hərbi elmlər. Bakı.

14. Freedman L. (2017). The future of war: a history. PublicAffairs

15. Huseynov, R. (2018). Milli təhlükəsizliyinin əsası kimi hərbi təhlükəsizliyin təmin olunması. "Azərbaycanda ordu quruculuğu və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı, SQ Hərbi Akademiyası

16. Kerimov, D. (2016). Gənclərin vətənpərvərlik tərbiyəsində əsas istiqamətlər. Bakı Qızlar Universitetinin "Elmi əsərlər" jurnalı.

17. Huseynov, R. (2019). Milli təhlükəsizliyin təmin olunmasında dövlətin güc amillərindən düzgün və səmərəli istifadənin vacibliyi. Hərbi bilik jurnalı. Bakı

18. Gray C. (1999). Modern strategy. Oxford University Press

19. Huseynov, R. (2016). Multikultural təhlükəsizlik: dünya reallıqları və Azərbaycan modeli. "Azərbaycan multikulturalizmi: din və dil siyasətinin inkişaf perspektivləri" beynəlxalq elmi konfransın materialları, Bakı

20. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

21. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

22. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614.

23. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

24. Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. "Müasir ali təhsil və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

THE ROLE OF SPEECH SKILLS IN THE DEVELOPMENT OF AN OFFICER'S PERSONALITY

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Speech skills are of great importance in terms of effective leadership in the military, clear issuing of orders, motivation of personnel and psychological preparation. Research shows that one of the important components of an officer's professional training is communicative competence and high speech culture [1].

In modern times, the training of military personnel is not limited to the acquisition of tactical and technical knowledge only. Psychological, ethical and communicative skills also play an important role in the formation of an officer as a personality [2]. In this regard, speech skills are considered an integral part of an officer's professional activity.

An officer who performs a leadership function in a military collective also acts as a teacher, organizer and educator. The successful implementation of these functions is closely related to the clarity, logic, impact and compliance with ethical norms of his speech. Speech skills have a significant impact on the formation of an officer's personal reputation, the creation of a healthy psychological environment in the team, and the effective execution of tasks [3].

It should be borne in mind that since military activity is collective in nature, effective communication acts as one of the main conditions for officer activity [4]. Because an officer gives orders [5], monitors the execution of tasks, provides explanations and instructions in the process of daily communication with personnel. In this process, it is of particular importance that the speech is clear and logical.

A leader with poor speech skills can create misunderstandings in the execution of tasks, which negatively affects the efficiency of military activity [6]. On the contrary, an officer with clear and systematic speech creates conditions for personnel to correctly perceive tasks and execute them promptly.

In addition, an officer's speech also plays an important role in the formation of his leadership qualities. Effective communication increases the officer's reputation, strengthens the trust of personnel in him, and helps to strengthen discipline in the team [7].

Speech culture includes not only the rules of correct speech, but also adherence to ethical norms, emotional stability and a style of expression appropriate to the situation. Compliance with speech culture in the military collective plays an important role in the formation of an officer's professional image.

In a generalized form, we can show the importance of speech skills in the development of an officer's personality in the following issues: the importance of accuracy and clarity for the correct understanding of orders and instructions; logic ensures the consistent and systematic expression of ideas; laconicism and concreteness help in making operational decisions in military conditions; effectiveness increases the motivation and fighting spirit of personnel; ethical compliance serves to form mutual respect in the collective [8].

It should not be forgotten that a modern professional officer is not only a leader who gives orders, but also an ideological and moral leader of the collective.

The role of speech skills in the formation of leadership qualities is of particular importance.

That is, an officer with effective speaking skills has the ability to motivate personnel, form a common goal and idea in the team, ensure psychological stability in complex situations, and create an atmosphere of trust and confidence

History shows that most prominent military leaders had strong oratory skills. Their speech not only conveyed information, but also served to influence and inspire people.

The formation of speech skills should be one of the important directions in the process of professional training of officers [9-11]. For this purpose, the following forms of activity can be used in military educational institutions: organizing special trainings on oratory and communication, debate and discussion sessions, preparation of presentations and speeches, pedagogical and psychological training courses, practical leadership sessions.

These methods can have a positive effect on the development of both communicative and leadership skills of cadets.

References

1. NATO (2021). Military leadership and communication. Brussels: NATO Publications

2. Huseynov, R., Cahangirov, V. (2018). Ordunun peşəkarlığının artırılmasında gənc zabitlərin şəxsiyyətyönümlü inkişafının əhəmiyyəti. "Heydər Əliyev və Azərbaycan Ordusu" elmi-praktik konfransı. Bakı

3. Kerimova, D. (2020). Müasir texnologiyanın inkişafı şəraitində nitq mədəniyyətinin aktuallığı, H.Əliyevin 97-ci ildönümünə həsr edilmiş "Gənc tədqiqatçıların IV Beynəlxalq elmi konfransının" materialları Bakı, BMU

4. Huseynov, R. (2017). İdarəetmə və liderlik fenomeni. H.Əliyev adına AAHM-in Elmi əsərlər məcmuəsi. Bakı

5. Huseynov, R. (2018). Təhsilalanların şəxsiyyətyönümlü inkişafında müasir təhsil texnologiyalarının üstünlüyü. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU

6. Kerimova, D. (2019). Natiqlik bacarığının inkişafında zəruri olan amillər. H.Əliyev adına AAHM-in "Elmi əsərlər məcmuəsi" jurnalı. № 2(33)

7. Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. "Müasir ali təhsil və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

8. Əliyev R. (2018). Liderlik və idarəetmə psixologiyası. Bakı: Elm nəşriyyatı

9. Huseynov, R. Nəsirov, E. (2024). Zabit kadrlarının hazırlanmasında innovativ texnologiyalardan istifadənin vacibliyi və əhəmiyyəti. Heydər Əliyev adına Hərbi İnstitutun Elmi Əsələr jurnalı.

10. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

11. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

THE TECHNOLOGICAL SUPERIORITY OF THE AZERBAIJANI ARMY IN THE SECOND KARABAKH WAR

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The Second Karabakh War, which took place in 2020, is considered one of the conflicts in which technology played a decisive role in the history of modern warfare. During this war, the Azerbaijani Army made extensive use of high-tech capabilities, especially unmanned aerial vehicles (UAVs) [1,2], high-precision weapon systems, and modern intelligence and information technologies. The article scientifically analyzes the main directions of the technological superiority of the Azerbaijani Army, the impact of this superiority on the course of combat operations, and the innovations it brings to modern military strategy.

Wars of the 21st century differ sharply from the classical model of military confrontation. In the modern era, the outcome of military operations is determined not only by manpower and traditional weapons systems, but also by high technologies. Information technologies, artificial intelligence elements, unmanned systems, and high-precision weapons have changed the nature of wars and led to the formation of new military strategies [3].

The Second Karabakh War, which took place from September 27 to November 10, 2020, also went down in history as one of the military conflicts in which modern technologies were effectively applied in this regard. The Azerbaijani Army gained a significant advantage in this war by using new tactics and strategies based on modern technologies [4]. Technological superiority allowed the Azerbaijani Armed Forces to conduct combat operations more efficiently, accurately and effectively.

In modern military strategy, technological superiority is considered one of the main indicators of the military power of states [5]. As a result of the development of technology, the methods of waging wars have changed, and information superiority and high-precision strike capabilities on the battlefield have gained special importance.

As is known, the main components of technological superiority include unmanned aerial vehicles and robotic systems, high-precision missile and artillery systems, electronic warfare means, satellite and reconnaissance technologies, information and communication systems.

These technologies allow for efficiency and accuracy in planning and executing combat operations. Thus, one of the most important features of the Second Karabakh War was the significant advantage of the Azerbaijani Army on the battlefield by using various types of reconnaissance and strike UAVs [6].

Thus, the application of UAVs has yielded effective results in the following areas: detection of enemy military equipment, increasing the accuracy of artillery strikes, destruction of armored vehicles, neutralization of manpower, real-time observation of the battlefield. In other words, these systems have made it possible to detect enemy defensive positions and destroy them in a short time.

High-precision weapon systems used during the war have also been one of the main factors ensuring the technological superiority of the Azerbaijani Army [7-10]. These weapons have allowed for the effective destruction of enemy strategic facilities and military equipment, the elimination of defense systems, as well as the acceleration of military operations and the minimization of manpower losses.

One of the means of creating technological superiority in war has been electronic warfare [11]. During the Second Karabakh War, electronic warfare equipment had a serious impact on the operation of the enemy's communication and control systems. The enemy's communication systems were weakened, the activity of unmanned aerial vehicles was limited, and command and control systems were disrupted.

Thus, the Second Karabakh War occupies an important place in modern military history in terms of the effective application of the high-tech capabilities of the Azerbaijani Army. The war showed that technological superiority is one of the main factors that directly affects the outcome of combat operations.

References

1.Guliyev, U., Huseynov, R. (2025). The solution of the Karabakh problem: military-political factors that necessitated the war and conditioned Azerbaijan's victory. Proceedings of Science of the Military Institute named after Heydar Aliyev

2.Piriyev H. K., Hashimov E.G. The Second Karabakh War: military-political and military-technical aspects //Scientific Works. – 2023. – T. 1. – №. 21. – C. 7-16.

3.Kofman M., Edmonds J. (2021). Drone warfare and the future of armed conflict. Military Review Journal

4.Huseynov, R., Pasha, E. (2023). Geopolitical situation in the South Caucasus after the Second Karabakh War: Russia's military-political behavior. “Foundations and Trends in Modern Learning” International scientific and practical online conference, Berlin, Germany

5.Huseynov, R. (2022). The impact of globalization on diplomacy: historical traditions and modern approaches. Sciences of Europe journal, (Praha, Czech Republic) № 104 (1)

6.Kasapoğlu C., Ozkan S. (2021). Drone Warfare in the Nagorno-Karabakh Conflict. Istanbul: EDAM Report

7.Huseynov, R. (2022). Information security and Cyber wars: the role of the states and the rational behavior of society. “Information security: problems and prospects” International conference, Baku, AU

8.Hashimov E. GIS technology and terrain orthophotomap making for military application //Journal of Defense Resources Management. – 2017. – T. 8. – №. 2. – C. 81-90.

9.Bayramov A. Seismic location station for detection of unobserved moving military machineries //Journal of Management and Information Science. – 2016. T.4. №. 2. C 61-66.

10. Hashimov E.G. Terrain orthophotomap making and combat control //Proceeding of Internatonal Conf.“Modern Call of Security and Defence”. I-st. – 2016. – T. 19. – C. 68-71.

11. Huseynov, R. (2021). The impact of geopolitical conflicts to globalization: changing the world order. Igdir international social sciences congress, Abstract book, Igdır University. 14-15 Aprel,

SECURITY IN THE SOUTH CAUCASUS IN THE POST-WAR PERIOD CURRENT THREATS TO PEACE

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The South Caucasus region has occupied a special place in the system of international relations since the end of the 20th century as a place where geopolitical competition, ethnic conflicts, and the struggle over energy routes have intensified. The Second Karabakh War that broke out in 2020 has radically changed the political map and security architecture of the region [1; 2]. Despite the formal ceasefire regime in the post-war stage, the establishment of a lasting and institutional peace has not yet been fully ensured. In other words, although post-war realities have created new communication opportunities and prospects for regional cooperation on the one hand, there are numerous threats that affect peace-oriented processes on the other [3].

After 2020, the balance of power in the region has changed, and the military-political balance has been formed on the basis of new realities. The issue of restoring the territorial integrity of the Republic of Azerbaijan and opening new transport and communication lines in the region is gradually becoming a reality. However, despite this, institutional gaps and an atmosphere of mutual distrust remain in the security system.

The failure to sign a lasting peace agreement maintains a state of "neither war nor complete peace" in the region. The incomplete completion of the process of delimitation and demarcation of state borders increases the risk of local incidents, which deepens the security dilemma and may lead to a resurgence of military rhetoric. The interest of institutions such as the European Union, NATO, and the Collective Security Treaty Organization in the region affects the security balance. Increased competition between major powers may limit the foreign policy maneuvering opportunities of the regional states and increase the risk of blockade [4].

In the post-war phase, the parties' increased defense spending and acquisition of new weapons systems exacerbate the security dilemma [5]. When this process occurs against the background of mutual distrust, it may also lead to the actualization of preventive strike doctrines. The traumas caused by war, forced displacement, the problem of missing persons, and the threat of mines seriously affect the peacebuilding process [6]. The weakness of peace and reintegration mechanisms between societies poses a risk to long-term stability.

The lack of full realization of economic cooperation opportunities in the region and the delay in the development of transport corridors due to political disputes create uncertainty in terms of economic security [7,8]. The opening of communication lines may stimulate peace, but it is also possible that this may become a tool of geopolitical manipulation.

In order to ensure lasting peace in the post-war period, the signing of a peace treaty and the formation of a legal framework, as well as the normalization of interstate relations based on the principles of international law should be a priority. In particular, a sustainable security model requires a synthesis of these three approaches: balance of power, economic integration and socio-cultural peace should be developed in parallel [9].

The security environment of the South Caucasus in the post-war period is in a transformational stage [9-14]. The cessation of military operations does not automatically mean the provision of lasting peace. Political and legal uncertainty, geopolitical competition, armament trends, humanitarian problems and economic risks remain the main threats to stability in the region.

References

1. European Council on Foreign Relations. (2022–2023). Armenia, Azerbaijan and the EU Mediation Efforts (policy reports).

2. Hüseynov, R., & Paşa, E. (2025). TÜRKİYE VE RUSYA'NIN JEOPOLİTİK DAVRANIŞI BAĞLAMINDA GÜNEY KAFKASYA'NIN YENİ YAPILANMASI. Güvenlik Bilimleri Dergisi, 14(1), 139-160.

3. European Union Institute for Security Studies. (2021). The South Caucasus After the 2020 War: Challenges and Opportunities for the EU. Paris.

4. Hüseynov, R., & Aslanlı, A. (2019). Milli təhlükəsizliyin təmin olunması sahəsində Azərbaycanın Rusiya və NATO ilə əməkdaşlığı. Qərbi Kaspi Universitetinin Elmi xəbərlər jurnalı. Bakı: Humanitar elmlər seriası, 4, 89-98

5. Chatham House. (2021). The Nagorno-Karabakh Ceasefire and the Future of the South Caucasus. London.

6. Huseynov, R. (2021). Rusya'nın Jeopolitik Çıkarları Bağlamında Güney Kafkasya'nın Güvenliği. Rus Dış Politikasında Orta Asya ve Kafkasya (223-248). Ankara: Nobel Bilimsel Yayıncılık.

7. German Institute for International and Security Affairs. (2022). The South Caucasus Between War and Peace. Berlin.

8. Hashimov E. et al. The Socioeconomic Impact of the Zangezur Corridor on the South Caucasus Region //Social Development and Security. 2025. Т.15. №.4. С.1-18.

9. Huseynov, R., Pasha, E. (2023). Geopolitical situation in the South Caucasus after the Second Karabakh War: Russia's military-political behavior.

10. Huseynov, R. S., & Asgerov, G. R. (2024). Factors preventing the achievement of peace between Armenia and Azerbaijan.

11. Guliyev, U., Huseynov, R. (2025). The solutıon of the Karabakh problem: mılıtary-polıtıcal factors that necessıtated the war and condıtıoned Azerbaıjan's vıctory. Proceedings of Science of the Military Institute named after Heydar Aliyev

12. Garayev, M. (2025). The development of renewable energy sources and its impact on Azerbaijan's energy security. *Матеріали конференцій МЦНД*, (25.07.2025; Запоріжжя, Україна), 53–62.

13. Giyas E. H., Ibrahim K. I., Saleh S. S. The role the Armed Forces likely to play in future conflicts //Civitas et Lex. – 2019. – №. 1 (21). – С. 25-35.

14. Piriyev H. K., Hashimov E.G. The Second Karabakh War: military-political and military-technical aspects //Scientific Works. – 2023. – Т. 1. – №. 21. – С. 7-16.

THE FACTOR OF MILITARY READINESS IN ENSURING MILITARY SECURITY

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The transformations taking place in the system of international relations in the 21st century have expanded the content of the concept of security [1]. Along with traditional military threats, information warfare, cyberattacks, terrorism and unconventional forms of conflict have created new risks [2]. In these conditions, the defense capability of states is determined not only by technical armament, but also by the presence of professional and highly trained military personnel.

The Armed Forces of the Republic of Azerbaijan act as the institutional base for ensuring military security in the Republic of Azerbaijan [3]. Strengthening the personnel potential is one of the priority directions in the structural and functional development of the army.

However, it should not be forgotten that the modern officer corps should not be satisfied with only tactical knowledge, but should have strategic thinking, decision-making skills and the ability to react promptly in crisis situations [4]. In addition, leadership qualities, which have become an important factor in military management in recent years, play a decisive role in the formation of discipline and fighting spirit in the military collective.

It should be borne in mind that the most commonly used means of information pressure and psychological influence in modern wars are widely used. Therefore, the stress resistance, emotional intelligence and commitment to moral and ethical values of military personnel are important conditions for security. At the same time, since digitalization - unmanned aerial vehicles, artificial intelligence and cyber systems - are an integral part of modern warfare, interoperability and technological knowledge in accordance with international standards are of particular importance in this sense [5; 6].

Taking into account all these important factors, it should be noted that officer training in the Republic of Azerbaijan is carried out systematically and in stages. In this direction, the National Defense University and its main component, the Heydar Aliyev Military Institute, act as the main educational platforms.

The educational programs in these institutions, along with theoretical knowledge, include practical tactical exercises, field exercises and international cooperation programs. Also, the operational experience gained in the post-conflict period has given impetus to the renewal of military education programs and their adaptation to real combat conditions. This process has led to the flexible and adaptive nature of personnel training [7].

Because we must not forget that for the sustainability of military security, continuous education and professional development programs are absolutely essential - regular updating of officers' knowledge and skills; international training and experience exchange - adaptation to modern military standards; strengthening

military-scientific-research activities - development of military science; ethical and patriotic education - strengthening national-moral values [8-17].

The analysis shows that the training of military personnel is a fundamental and system-forming factor in ensuring military security. In the modern security environment, technological superiority gives effective results only when synthesized with professional and highly qualified human resources. The military education reforms and institutional development process implemented in the Republic of Azerbaijan serve to strengthen the defense capabilities of the army.

References

1.Huntington, S. P. The Soldier and the State. Harvard University Press.

2.Huseynov, R. (2018). Milli təhlükəsizliyinin əsası kimi hərbi təhlükəsizliyin təmin olunması. Elmi-praktik konfransın materialları. Bakı, SQ Hərbi Akademiyası

3.Azərbaycan Respublikasının Hərbi Doktrinası. Bakı, 2010.

4.Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. "Müasir ali təhsil və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

5.Huseynov, R, Aslanlı, A., Gülərli, G., Əliyeva, T. (2019). Обеспечение военной безопасности как приоритет внешней политики государства. The army in the era of globalization. II international scientific conference, Tbilisi

6.Baylis, J., Wirtz, J., Gray, C. Strategy in the Contemporary World. Oxford University Press, 2020.

7.Hüseynov, R., & Aslanlı, A. (2019). Milli təhlükəsizliyin təmin olunması sahəsində Azərbaycanın Rusiya və NATO ilə əməkdaşlığı. Qərbi Kaspi Universitetinin Elmi xəbərlər jurnalı. Bakı: Humanitar elmlər seriası, 4, 89-98

8.Huseynov, R., Paşa, E. (2019). Milli təhlükəsizliyin təmin olunmasında dövlətin güc amillərindən düzgün və səmərəli istifadənin vacibliyi. Hərbi bilik jurnalı. Bakı

9.NATO. Professional Military Education Reference Curriculum. Brussels, 2021.

10. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

11. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

12. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614.

13. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

14. Piriyev, H.K. et al. (2016). Modelling of the battle operations. *Monografiya, Herbi Nashriat", Baku.–2017*.

15. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. 2025. T.4: section 6. C. 39.

16. Hasanov A.H. Online education platforms in higher education: opportunities, challenges, and future directions. *İn* "New technologies - for the protection of air space". – Kh.: KhNUPS named after I. Kozheduba, 2025. - p.752-753

17. Piriyev H.K. et al. Some aspects of optimization of control. *In* Current directions of development of information and communication technologies and control tools. 2024. Volume 1. 18-19

MODERN PEDAGOGICAL FOUNDATIONS OF CADET TRAINING IN THE CONTEXT OF THE CHARACTERISTICS OF GENERATION Z

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The transformations taking place in the education system in the 21st century are conditioned by socio-cultural changes and the rapid development of digital technologies. In particular, the entry of Generation Z into the educational environment has necessitated a review of pedagogical approaches. Representatives of this generation have been formed in conditions of information abundance, rapid communication and visual culture [1].

Trainee training is a complex process that includes both intellectual, physical and psychological preparation [2]. In this regard, considering the characteristics of Generation Z is one of the main factors that increase the effectiveness of training.

Undoubtedly, before studying the pedagogical foundations for personnel training of this generation, it is necessary to determine the psychological and pedagogical characteristics of Generation Z. Thus, the main characteristics of this generation are mainly digital nativeness - since they grew up with the Internet and mobile technologies, they perceive information mainly in a visual and concise format [3]; Multitasking ability - the ability to monitor several sources of information at the same time, but the attention span is relatively short; Practical orientation - giving preference to practical application over theoretical information; Individuality and independence - the tendency to freely express their own opinion and make decisions; Social responsibility and the need for security - they are sensitive to social justice, ethical values, and security issues.

Only by taking the above-mentioned characteristics into account can cadet training be carried out. In other words, it is important to select and apply training methods based on the above-mentioned characteristics [4]. In this case, this approach to cadet training can be applied in the following forms: situational tasks, problem-based learning, simulations, and tactical games [5; 6].

It should also be considered that these methods meet the active and interactive learning needs of Generation Z.

At the same time, we should not forget that the interest of this generation is not only to acquire knowledge, but also to master skills.

Therefore, the competency approach involves the formation of skills and values, along with knowledge, in which key competencies such as leadership, teamwork, stress resistance, critical and strategic thinking are developed in trainee training [7]. For Generation Z, technology is not only a tool, but also a learning environment. We should introduce virtual simulators, online platforms, digital assessment systems, augmented and virtual reality technologies as important factors in modern trainee training.

The motivation model of Generation Z is based on intrinsic interest, goal clarity and feedback mechanisms.

Regular and constructive feedback in trainee training, visualization of achievements, team-based competition, psychological support programs, increase the effectiveness of training.

In general, it can be concluded that the characteristics of this generation necessitate a transformation of pedagogical approaches in training students. A constructivist, competency-based, and technology-integrated model should be applied to effectively train this generation, which has been formed in a digital environment [8-15].

References

1.Prensky, M. (2001). Digital Natives, Digital Immigrants. On the Horizon, 9(5), 1–6.

2.Huseynov, R. (2022). Advantage of Modern Educational Technologies in Personality Formation of Officers. თავდაცვა და მეცნიერება, (1), 25-28.

3.Huseynov, R. Nəsirov, E. (2024). Zabit kadrlarının hazırlanmasında innovativ texnologiyalardan istifadənin vacibliyi və əhəmiyyəti. Heydər Əliyev adına Hərbi İnstitutun Elmi Əsələr jurnalı.

4.Başirova, G. (2024). Müəllim və kursantlar arasında qarşılıqlı pedaqoji münasibətlərdə sistemlilik əsas prinsip kimi. Heydər Əliyev adına Hərbi İnstitutun "Elmi Əsərlər" jurnalı.

5.Huseynov, R. (2018). Ali hərbi təhsil müəssisələrində kursantların şəxsiyyətyönümlü formalaşmasının vacibliyi. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU

6.Huseynov, R. (2021). Daxili işlər orqanlarının fəaliyyətində yeni yanaşmanın tətbiqı: kadrların hazırlanmasında keyfiyyətin artırılması. Beynəlxalq elmi-praktik konfrans. Bakı, Polis Akademiyası.

7.OECD (2018). The Future of Education and Skills 2030. Paris: OECD Publishing.

8.Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

9.Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

10. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614.

11. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

12. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.

13. Hasanov A.H. Online education platforms in higher education: opportunities, challenges, and future directions. *İn* "New technologies - for the protection of air space". – Kh.: KhNUPS named after I. Kozheduba, 2025. - p.752-753

14. Piriyev H.K. et al. Some aspects of optimization of control / Current directions of development of information and communication technologies and control tools. Proceedings of 14-th International Scientific and Technical Conference. Volume 1. 2024. -pp.18-19.

15. Huseynov, R. (2023). İnsan resurslarının idarə edilməsinin zəruriliyi və inkişaf effektivliyi. "Azərbaycanın inkişaf strategiyası: potensial imkanlar və yeni çağırışlar" respublika elmi-praktik konfransı, Bakı, Hərbi İnstitut

SPECIFIC ASPECTS OF TEACHER-STUDENT RELATIONSHIPS

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Teacher-cadet relations are a special form of pedagogical interaction, differing from the traditional teacher-student model in terms of structure-discipline, professional orientation and the severity of regulatory requirements. Especially in military and law enforcement educational institutions, these relations are one of the main factors determining both the effectiveness of the training process and the quality of future professional activity [1; 2].

In the modern education system, the relations between the teacher and the learner are not limited only to the transfer of knowledge, but also serve the formation of personality, the development of social skills and the establishment of professional identity. In this regard, teacher-cadet relations have a specific character.

Relations in special-purpose higher education institutions have both an academic and service-hierarchical character and are regulated by regulatory documents.

Thus, teacher-cadet relations, unlike other higher education models, are regulated not only within the pedagogical framework, but also by internal regulations and service rules. Here, the teacher is not only a person who gives knowledge, but also an example of discipline and professional ethics [3; 4].

Specific aspects of the relationship can be listed as follows:

The presence of a hierarchical structure - interaction is based on a certain division of rank and authority; Normative-disciplinary framework - relations are strictly regulated by internal rules; Professional orientation - the training process is directed towards specific practical and operational activities.

One of the important factors in relationships is psychological characteristics, in which case relationships should be based on a balance of mutual respect, demandingness and trust from a psychological point of view [5; 6].

In order to be effective and efficient, a teacher working in these institutions is required to pay attention to many points: demonstrate emotional stability, conduct fair assessments, and take an objective and principled position.

In addition, since the motivation of trainees is mainly related to professional responsibility and future service activities, the role of the teacher is also to strengthen this motivation and provide psychological support for the formation of internal discipline [7].

The effectiveness of relationships is closely related to the quality of pedagogical communication. In this context, communication: should be clear and specific; orders and tasks should be expressed briefly and accurately; an official-business style should be maintained.

Here, the teacher's speech culture is of particular importance. Because harsh or unethical communication can lead to a decrease in motivation and psychological tension.

Preservation and development of ethical and moral aspects in the process of education and upbringing can lead to a better level of relationships. To this end, the teacher must respect the dignity of the trainee; not allow discrimination; act transparently and objectively.

It should be borne in mind that violation of ethical principles in relationships can lead to both psychological trauma and disruption of the collective environment [8-14].

References

1. Bashirova, G. (2025). The role of the proper organization of teacher-student relations in ensuring the cognitive activity of students in the pedagogical process. “Research Retrieval and Academic Letters” (January 30-31, 2025). Warsaw, Poland

2. Huseynov, R. (2022). Advantage of Modern Educational Technologies in Personality Formation of Officers. თავდაცვა და მეცნიერება, (1), 25-28.

3. Başirova, G. (2024). Müəllim və kursantlar arasında qarşılıqlı pedaqoji münasibətlərdə sistemlilik əsas prinsip kimi. Heydər Əliyev adına Hərbi İnstitutun “Elmi Əsərlər” jurnalı.

4. Huseynov, R. Nəsirov, E. (2024). Zabit kadrlarının hazırlanmasında innovativ texnologiyalardan istifadənin vacibliyi və əhəmiyyəti. Heydər Əliyev adına Hərbi İnstitutun Elmi Əsələr jurnalı.

5. Qasımov, Ə. (2014). Təlim nəzəriyyəsi və metodikası. Bakı: Adiloğlu.

6. Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. “Müasir ali təhsil və hərb elmi” mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

7. Huseynov, R. (2018). Ali hərbi təhsil müəssisələrində kursantların şəxsiyyətyönümlü formalaşmasının vacibliyi. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU

8. Abbasov, A. N. (2010). Pedaqoji psixologiya. Bakı: Mütərcim.

9. Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.

10. Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.

11. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

12. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

13. Piriyev H.K. et al. Some aspects of optimization of control / Current directions of development of information and communication technologies and control tools. Proceedings of 14-th International Scientific and Technical Conference. Volume 1. 2024. -pp.18-19.

14. Huseynov, R. (2021). Daxili işlər orqanlarının fəaliyyətində yeni yanaşmanın tətbiqi: kadrların hazırlanmasında keyfiyyətin artırılması. Beynəlxalq elmi-praktik konfrans. Bakı, Polis Akademiyası.

INNOVATIVE MODELS OF FORMING MILITARY QUALITIES IN CADETS

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In the modern era, the military education system is not only satisfied with providing theoretical knowledge, but also prioritizes developing leadership, strategic thinking, operational decision-making and command skills of future officers [1]. Especially in recent years, the complexity of the security environment in modern times, the rapid development of technologies and changes in warfare methods require the renewal of the military education system. In this regard, the application of innovative training models for the formation of military qualities of future officers in military educational institutions is of particular importance [2]. The application of active and interactive training methods in military educational institutions has a significant impact on the development of creative abilities and practical skills of cadets.

The modernization of the military education system also necessitates the application of digital technologies, simulation tools and innovative pedagogical methods [3].

This process allows for the training of future officers in an environment closer to combat conditions.

It should be noted that in order to form military qualities in cadets who are future officers, it is first necessary to study the theoretical foundations of the issue. Thus, military qualities are understood as a set of professional and moral characteristics that characterize the personality of an officer, such as leadership and command skills, responsibility and discipline, operational and strategic thinking, psychological stability, ability to work in a team, patriotism and moral values, and other factors.

In special-purpose higher education institutions, various fields of science and educational disciplines are used to form the mentioned qualities. Each of them is of great importance in itself.

The formation of these qualities is carried out not only through theoretical lessons, but also through practical activities, tactical exercises and trainings close to real situations [4].

It should also be noted that in the modern military education system, innovative models are aimed at increasing the effectiveness of the training process and developing the practical skills of cadets.

The main feature of these models is that they ensure the active participation of cadets and prepare them in accordance with real operational conditions. Studies show that the application of innovative pedagogical approaches improves the quality of military education and increases the level of professional training of officers [5].

Proceeding from this, the following are examples of the main innovative models used in the modern military education system:

– Simulation and virtual reality-based training model: simulation technologies are widely used in the military education system. This method allows cadets to undergo training in an environment close to real combat conditions.

– Problem-based learning model: problem-based learning is an innovative pedagogical approach that develops analytical thinking and independent decision-making skills of cadets. In this model, cadets are presented with real military problems and they develop various strategies to solve these problems [6].

– Module and competency-based training model: the modular training system ensures the gradual acquisition of knowledge and skills in military education. In this model, the educational process consists of various modules, and each module focuses on the formation of a specific skill.

– Digital and artificial intelligence-based training model: in recent years, the application of artificial intelligence and big data technologies in the military education system has been expanding. Through these technologies: tactical scenarios are automatically created, decision-making processes are modeled, and cadets' activities are analyzed [7-10].

In general, the application of these models allows cadets to acquire not only theoretical knowledge, but also to develop practical skills. As a result, future officers acquire the skills of making operational decisions in complex combat conditions, acting collectively, and effectively using modern technologies.

References

1. Sotvoldiyev A., Salimov J. Principles of modular technology and their integration with military education training. International Journal of Artificial Intelligence, 2025.
2. Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. “Müasir ali təhsil və hərb elmi” mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM
3. Huseynov, R. (2021). Daxili işlər orqanlarının fəaliyyətində yeni yanaşmanın tətbiqı: kadrların hazırlanmasında keyfiyyətin artırılması. Beynəlxalq elmi-praktik konfrans. Bakı, Polis Akademiyası.
4. Pampukha I., Vovkotecha O., Kubiavka M. (2024). Innovative teaching methods in higher military education institutions. Bulletin of T.Shevchenko National University, 2024.
5. Huseynov, R. (2018). Təhsilalanların şəxsiyyətyönümlü inkişafında müasir təhsil texnologiyalarının üstünlüyü. II INTERNATIONAL SCIENTIFIC CONFERENCE OF YOUNG RESEARCHERS. Baku, BEU
6. Huseynov, R. Nəsirov, E. (2024). Zabit kadrlarının hazırlanmasında innovativ texnologiyalardan istifadənin vacibliyi və əhəmiyyəti. Heydər Əliyev adına Hərbi İnstitutun Elmi Əsələr jurnalı.
7. Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.
8. Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.
9. Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.
10. Huseynov, R. (2022). Advantage of Modern Educational Technologies in Personality Formation of Officers. თავდაცვა და მეცნიერება, (1), 25-28.

THE EFFECTS OF RUSSIA'S WAR AGAINST UKRAINE ON RUSSIA'S POSITION IN THE SOUTH CAUCASUS

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The South Caucasus region has historically been a geopolitical arena of great powers.

The strategic location of the region, its energy resources and transport corridors have led to a clash of interests between various states [1]. After the collapse of the Soviet Union, Russia has sought to maintain its influence in the South Caucasus and has played an important role in the security and political processes of the countries of the region [2].

However, the large-scale military operations launched by Russia against Ukraine in 2022 have led to serious geopolitical changes in the system of international relations.

This war has affected not only the European security system, but also the balance of power in the post-Soviet space. In particular, the South Caucasus region, as one of Russia's traditional spheres of influence, has been directly affected by this process.

It should be noted that the war against Ukraine has changed Moscow's foreign policy priorities and the distribution of its resources [3].

In other words, the South Caucasus policy, which is of great strategic importance, has been greatly affected.

In the new international environment, the countries of the region have begun to pursue a more independent and multi-vector policy, which has led to a transformation of Russia's positions.

However, Russia, as one of the main centers of power in the South Caucasus in the post-Soviet period, has always tried to maintain its position, using both political, military and economic means for this [4].

It should also be noted that Russia has used the Armenian card more to maintain its geopolitical position in the region.

Proceeding from this, it has tried to control the process by creating the Armenia-Azerbaijan war [5]. It has put pressure on Azerbaijan by using military-political circles in Armenia for indirect purposes and has implemented a policy of occupation.

It is true that the issue of the war between Armenia and Azerbaijan has been resolved. Both states are at the stage of concluding a peace treaty. However, despite this, Russia is still trying to prevent this with every effort. It can influence the situation by using forces close to it in Armenia, as well as the 102nd military base located in this country.

However, the war with Ukraine since 2022, which has diverted most of Russia's military-political resources, has also created conditions for a number of changes in the South Caucasus [6; 7]:

The fact that most of Russia's military potential was directed towards the Ukrainian front has led to a certain weakening of its military capabilities in the region [8]. This has accelerated the orientation of the countries of the region towards alternative partners in their security policy.

The countries of the region have begun to pursue a more independent foreign policy, which has allowed them to implement a balanced policy in the system of international relations [9].

The role of new power centers in the region has increased. In particular, Turkey's influence in the South Caucasus has strengthened further. The strategic partnership between Turkey and Azerbaijan has influenced the formation of a new security model in the region.

The European Union and the United States have increased their diplomatic activity and have begun to pay more attention to the South Caucasus in terms of energy security and regional stability in the region.

In the future, how Russia's balance of power in the region will be shaped will depend both on the results of the Ukrainian war and the policies of regional states.

References

1.Huseynov, R. (2021). Rusya'nın Jeopolitik Çıkarları Bağlamında Güney Kafkasya'nın Güvenliği. Rus Dış Politikasında Orta Asya ve Kafkasya (223-248). Ankara: Nobel Bilimsel Yayıncılık.

2.Hüseynov, R. (2022). Türkiyənin Cənubi Qafqazda geosiyasi üstünlüyünü genişləndirməsi: Rusiyanın mane olmaq cəhdləri. Respublika elmi-praktik konfransı, Bakı, AAHM

3.Allison, R. (2023). Russia, the west, and military intervention. Oxford University Press

4.Cornell S., Starr S. (2022). The new geopolitics of the South Caucasus. Johns Hopkins University Press

5.Huseynov, R., Pasha, E. (2023). Geopolitical situation in the South Caucasus after the Second Karabakh War: Russia's military-political behavior. "Foundations and Trends in Modern Learning" International scientific and practical online conference, Berlin, Germany

6.Galeotti, M. (2023). Russia's war in Ukraine and its strategic consequences. Routledge, London

7.Huseynov, R. S., Asgerov, G. R., & Esedov, F. M. (2024). The impact of the war against Ukraine on Russia's international image. Proceedings of 14-th International Scientific and Technical Conference, Kharkov

8.Hüseynov, R., & Paşa, E. (2025). TÜRKİYE VE RUSYA'NIN JEOPOLİTİK DAVRANIŞI BAĞLAMINDA GÜNEY KAFKASYA'NIN YENİ YAPILANMASI. Güvenlik Bilimleri Dergisi, 14(1), 139-160.

9.Huseynov, R. (2024). Socio-political stability in the context of ensuring national security. Problems of İnformatization: Proceedings of 12-th International Scientific and Technical Conference, Kharkov

THE IMPACT OF THE RUSSIA-UKRAINE WAR ON THE INTERNATIONAL SECURITY SYSTEM

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The international security system is a set of institutions, mechanisms and legal norms established to protect the sovereignty of states, prevent conflicts and ensure global stability [1]. The main elements of this system are international organizations, collective security mechanisms, international legal norms and diplomatic relations.

The international security system formed after the Second World War was mainly built on the United Nations, regional security institutions and the principles of international law. However, the regional conflicts and competition between great powers that occurred in the 21st century have tested the effectiveness of this system to some extent [2].

The processes taking place in the system of international relations in the 21st century mainly show that the global security environment is changing dynamically. In particular, the large-scale military intervention of the Russian Federation against Ukraine in 2022 is considered the beginning of a new stage in international relations [3].

This event had a serious impact on the international security system formed after the Second World War and created new realities in the global balance of power. This war was not only a regional conflict, but also affected the global security architecture, the application of international law, collective security mechanisms and the change in the geopolitical balance.

Thus, the Russia-Ukraine war has brought the issues of the application of international law, the sovereignty of states, territorial integrity and the effectiveness of collective security mechanisms back to the agenda [4]. The war has affected the global system not only in the military-political sphere, but also in terms of economic, energy and information security.

On the other hand, the war has led to a change in the global geopolitical balance, increased competition between great powers and the strengthening of new geopolitical bloc tendencies.

On the one hand, Western states have supported Ukraine politically, economically and militarily, while on the other hand, Russia has faced international sanctions and political pressure [5]. This process has led to the formation of a new line of confrontation in international relations.

At the same time, the war has led to a reassessment of security issues in the post-Soviet space. A number of states have reconsidered their security strategies and made changes to their defense policies [6].

The war has led to an increase in NATO's role in the international security system. The increase in defense spending and strengthening of collective defense mechanisms by the Alliance member states is considered one of the main results of this conflict [7].

In addition, the decision of Finland and Sweden to join NATO has created significant changes in the security architecture of Europe. This process has led to the expansion of NATO and the reshaping of the European security system. In addition, the increase in NATO's military presence in Eastern Europe has had a direct impact on the security balance in the region [8; 9].

In addition to the above, the Russia-Ukraine war has had a serious impact on the global energy market [10-13]. The attempts of European countries to reduce their dependence on Russian energy resources have led to the formation of new energy strategies, and this issue has become one of the main components of the international security system.

Many states have accelerated the transition to alternative energy sources and expanded their activities towards the creation of new energy routes.

References

1. Huseynov, R. (2021). The impact of geopolitical conflicts to globalization: changing the world order. Igdir international social sciences congress, Abstract book, Igdır University

2. Huseynov, R. (2018). The impact of modern conflicts on states' national security systems. Hərbi bilik jurnalı. (1) Bakı

3. Freedman, L. (2023). The Russo-Ukrainian war: The return of history. London: Polity Press.

4. Huseynov, R. (2021). Rusya'nın Jeopolitik Çıkarları Bağlamında Güney Kafkasya'nın Güvenliği. Rus Dış Politikasında Orta Asya ve Kafkasya (223-248). Ankara: Nobel Bilimsel Yayıncılık.

5. Mearsheimer, J. (2023). The Causes and consequences of the Ukraine war. Chicago: University of Chicago Press.

6. Huseynov, R. (2024). Socio-political stability in the context of ensuring national security. Problems of Informatization: Proceedings of 12-th International Scientific and Technical Conference, Kharkov

7. Huseynov, R. (2025). Balanslı və çoxvektorlu xarici siyasət təhlükəsizliyin təmin olunması kontekstində: Azərbaycan təcrübəsi. "Azərbaycan Respublikasının inkişaf strategiyası: potensial imkanlar və yeni çağırışlar" respublika elmi-praktik konfransı, Bakı

8. Kofman, M., & Lee, R. (2022). Not Built for Purpose: The Russian military's Ill-fated force design. Washington: Center for Naval Analyses.

9. Huseynov, R., Pasha, E. (2023). Geopolitical situation in the South Caucasus after the Second Karabakh War: Russia's military-political behavior. "Foundations and Trends in Modern Learning" International scientific and practical online conference, Berlin, Germany

10. Smith, H. (2024). European security after the Ukraine war. London: Routledge.

11. Mammadov B. Key duties of a country's economy related to national defense in critical times //journal of defense resources management. – 2017. – Т. 8. – №. 1.

12. Giyas E. H., Ibrahim K. I., Saleh S. S. The role the Armed Forces likely to play in future conflicts //Civitas et Lex. – 2019. – №. 1 (21). – С. 25-35.

13. Hashimov E., Talibov A., Iskandarov K. The Socioeconomic Impact of the Zangezur Corridor on the South Caucasus Region //Social Development and Security. – 2025. – Т. 15. – №. 4. – С. 1-18.

THE NEED FOR A NEW APPROACH TO THE MILITARY EDUCATION SYSTEM AFTER THE SECOND KARABAKH WAR

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The changing nature of modern wars, the application of high technologies, information warfare and the widespread use of unmanned aerial vehicles (UAVs) necessitate the application of new approaches in military personnel training [1]. In modern times, the international security environment is changing rapidly, and these changes directly affect the functioning of military systems [2]. Wars in the 21st century in particular show that modern weapons systems, information technologies and high-tech operations have fundamentally changed the nature of military operations. In this context, the Second Karabakh War that took place in 2020 is considered an event of great importance not only from a regional but also a global military-strategic perspective. Thus, this war also demonstrated the effectiveness of the application of modern technologies in combat operations [3,4]. In particular, the widespread use of unmanned aerial vehicles, the integration of intelligence and strike systems, a network-centric control system and the activities of highly maneuverable military units have revealed the main features of modern warfare.

In addition, the wars that have taken place in recent years show that the methods of conducting military operations have changed significantly. Thus, current wars are characterized by information warfare, cyber attacks, the use of unmanned aerial vehicles and high-precision weapons [5]. These observed requirements undoubtedly necessitate the application of new approaches in the form and content of the military education system.

For example, the Second Karabakh War demonstrated a completely new model of modern warfare. The tactics chosen to solve extremely important tasks in a short time frame and with fewer losses required high professionalism. In this regard, the participation of professional soldiers, the application of modern military management principles, the use of modern military technology, weapons, as well as the acquisition of real-time intelligence information and coordinated strike operations yielded positive results. In particular, the advantages provided by the use of unmanned aerial vehicles and drones greatly distinguished this war from previous ones.

The results of the Second Karabakh War showed that technological superiority plays a decisive role in modern combat operations. The introduction of unmanned aerial vehicles, high-precision missile systems and electronic warfare means had a serious impact on the course of combat operations [6]. This experience also formed a number of new requirements in the training of military personnel. It revealed the importance of a modern officer not only having tactical knowledge, but also having a high level of analytical thinking, technological knowledge and the ability to make quick decisions.

Proceeding from this, an important component of army building is undoubtedly the improvement of the military education system and its integration into advanced

systems [7; 8]. For this, it is an important condition to carry out work in the following areas:

– development of educational programs based on high technologies; – teaching modern combat tactics; – development of analytical and strategic thinking skills;

– – increasing knowledge in the field of information and cyber security. Also, strengthening technological training: development of special educational programs on the management of unmanned systems, cyber security and information technologies in military educational institutions. Application of simulation and virtual training systems, development of tactical and strategic thinking, study of international experience [9].

In addition, one of the important directions of modernization of the military education system is the participation of cadets in training appropriate to real combat conditions, increasing leadership and psychological training, and developing scientific and research activities.

References

1.Kaldor M. (2021). New and Old Wars: Organized Violence in a Global Era. Stanford University Press.

2.NATO Defense College.. Military education and modern warfare. Rome, 2021.

3.Guliyev, U., Huseynov, R. (2025). The solution of the karabakh problem: military-political factors that necessitated the war and conditioned Azerbaijan's victory. Proceedings of Science of the Military Institute named after Heydar Aliyev

4. Piriyev H. K., Hashimov E.G. The Second Karabakh War: military-political and military-technical aspects //Scientific Works. – 2023. – T. 1. – №. 21. – C. 7-16.

5. Freedman L. (2020). The Future of War: A History. London: Penguin Books.

6.Bayramov, A. (2023). Müasir hərbi texnologiyalar və müharibənin transformasiyası. Bakı: Elm və Təhsil,

7.Huseynov, R. (2016). Müasir peşəkar zabit kadrlarının formalaşmasında hərbi təhsil müəssisələrinin rolu. "Müasir ali təhsil və hərb elmi" mövzusunda elmi-praktik konfransın materialları. Bakı: H.Əliyev adına AAHM

8.Huseynov, R. Nəsirov, E. (2024). Zabit kadrlarının hazırlanmasında innovativ texnologiyalardan istifadənin vacibliyi və əhəmiyyəti. Heydər Əliyev adına Hərbi İnstitutun Elmi Əsələr jurnalı.

9.Huseynov, R. (2021). Daxili işlər orqanlarının fəaliyyətində yeni yanaşmanın tətbiqı: kadrların hazırlanmasında keyfiyyətin artırılması. Beynəlxalq elmi-praktik konfrans. Bakı, Polis Akademiyası.

10. Piriyev H. K. et al. Some issues of pedagogical staff training for special-purpose higher education institutions //Military knowledge, (4). – 2014. – C. 3-9.

11. Agayev S.O. et al. Modern pedagogical technologies in military education. Textbook. Part I //Baku: Military Publishing House. – 2016.

12. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614.

13. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.

THE TECHNOLOGICAL SUPERIORITY OF THE AZERBAIJANI ARMY IN THE SECOND KARABAKH WAR

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The Second Karabakh War, which took place in 2020, is considered one of the conflicts in which technology played a decisive role in the history of modern warfare. During this war, the Azerbaijani Army made extensive use of high-tech capabilities, especially unmanned aerial vehicles (UAVs) [1,2], high-precision weapon systems, and modern intelligence and information technologies. The article scientifically analyzes the main directions of the technological superiority of the Azerbaijani Army, the impact of this superiority on the course of combat operations, and the innovations it brings to modern military strategy.

Wars of the 21st century differ sharply from the classical model of military confrontation. In the modern era, the outcome of military operations is determined not only by manpower and traditional weapons systems, but also by high technologies. Information technologies, artificial intelligence elements, unmanned systems, and high-precision weapons have changed the nature of wars and led to the formation of new military strategies [3].

The Second Karabakh War, which took place from September 27 to November 10, 2020, also went down in history as one of the military conflicts in which modern technologies were effectively applied in this regard. The Azerbaijani Army gained a significant advantage in this war by using new tactics and strategies based on modern technologies [4].

Technological superiority allowed the Azerbaijani Armed Forces to conduct combat operations more efficiently, accurately and effectively.

In modern military strategy, technological superiority is considered one of the main indicators of the military power of states [5]. As a result of the development of technology, the methods of waging wars have changed, and information superiority and high-precision strike capabilities on the battlefield have gained special importance.

As is known, the main components of technological superiority include unmanned aerial vehicles and robotic systems, high-precision missile and artillery systems, electronic warfare means, satellite and reconnaissance technologies, information and communication systems.

These technologies allow for efficiency and accuracy in planning and executing combat operations. Thus, one of the most important features of the Second Karabakh War was the significant advantage of the Azerbaijani Army on the battlefield by using various types of reconnaissance and strike UAVs [6].

Thus, the application of UAVs has yielded effective results in the following areas: detection of enemy military equipment, increasing the accuracy of artillery strikes, destruction of armored vehicles, neutralization of manpower, real-time observation of the battlefield. In other words, these systems have made it possible to detect enemy defensive positions and destroy them in a short time.

High-precision weapon systems used during the war have also been one of the main factors ensuring the technological superiority of the Azerbaijani Army [7-10].

These weapons have allowed for the effective destruction of enemy strategic facilities and military equipment, the elimination of defense systems, as well as the acceleration of military operations and the minimization of manpower losses.

One of the means of creating technological superiority in war has been electronic warfare [11].

During the Second Karabakh War, electronic warfare equipment had a serious impact on the operation of the enemy's communication and control systems. The enemy's communication systems were weakened, the activity of unmanned aerial vehicles was limited, and command and control systems were disrupted.

Thus, the Second Karabakh War occupies an important place in modern military history in terms of the effective application of the high-tech capabilities of the Azerbaijani Army.

The war showed that technological superiority is one of the main factors that directly affects the outcome of combat operations.

References

1.Guliyev, U., Huseynov, R. (2025). The solution of the Karabakh problem: military-political factors that necessitated the war and conditioned Azerbaijan's victory. Proceedings of Science of the Military Institute named after Heydar Aliyev

2.Piriyev H. K., Hashimov E.G. The Second Karabakh War: military-political and military-technical aspects //Scientific Works. – 2023. – T. 1. – №. 21. – C. 7-16.

3.Kofman M., Edmonds J. (2021). Drone warfare and the future of armed conflict. Military Review Journal

4.Huseynov, R., Pasha, E. (2023). Geopolitical situation in the South Caucasus after the Second Karabakh War: Russia's military-political behavior. “Foundations and Trends in Modern Learning” International scientific and practical online conference, Berlin, Germany

5.Huseynov, R. (2022). The impact of globalization on diplomacy: historical traditions and modern approaches. Sciences of Europe journal, (Praha, Czech Republic) № 104 (1)

6.Kasapoğlu C., Ozkan S. (2021). Drone Warfare in the Nagorno-Karabakh Conflict. Istanbul: EDAM Report

7.Huseynov, R. (2022). Information security and Cyber wars: the role of the states and the rational behavior of society. “Information security: problems and prospects” International conference, Baku, AU

8.Hashimov E. GIS technology and terrain orthophotomap making for military application //Journal of Defense Resources Management. – 2017. – T. 8. – №. 2. – C. 81-90.

9.Bayramov A. Seismic location station for detection of unobserved moving military machineries //Journal of Management and Information Science. – 2016. T.4. №. 2. C 61-66.

10. Hashimov E.G. Terrain orthophotomap making and combat control //Proceeding of Internatonal Conf.“Modern Call of Security and Defence”. I-st. – 2016. – T. 19. – C. 68-71.

11. Huseynov, R. (2021). The impact of geopolitical conflicts to globalization: changing the world order. Igdir international social sciences congress, Abstract book, Igdır University. 14-15 Aprel,

SPACE TECHNOLOGIES FOR DEFENSE: RESILIENCE OF ORBITAL INFRASTRUCTURE AND PROTECTION OF SPACE SERVICES

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Introduction

Space technologies have become a critical enabler of modern defense because military operations increasingly depend on satellite-based communications, positioning, navigation and timing, missile warning, environmental monitoring, and persistent surveillance.

NATO states that reliable access to space services is necessary to support all-domain operations, and its 2025 Commercial Space Strategy explicitly frames commercial space cooperation as a means to increase complementary capabilities, capacity, and resilience for the Alliance. At the same time, the U.S. Department of Defense has formally articulated an approach to protecting and defending space systems and to protecting the Joint Force from hostile use of space, which indicates that the issue is no longer limited to technical modernization, but has become an operational security problem. The aim of this study is to determine how space technologies support defense missions, what makes orbital infrastructure resilient, and how space-enabled services can be protected under contemporary threat conditions.

Methodology

The research is based on a systems approach, structural-functional analysis, and scenario-based assessment of military dependence on space-enabled services. The analytical framework includes four interconnected functions: satellite communications, positioning, navigation and timing, space-based surveillance and warning, and space domain awareness. Orbital infrastructure is treated as a layered architecture that includes satellites, ground segments, communication links, command systems, and data services. The study compares vulnerable centralized models with more resilient approaches based on distribution, redundancy, rapid reconstitution, diversified providers, and protected service continuity.

The working hypothesis states that defense resilience in the space domain increases when orbital systems and the services they provide are designed as adaptive, distributed, and recoverable operational architectures rather than as isolated high-value assets. This interpretation is consistent with NATO's resilient space operations priorities and with current U.S. Space Force doctrine defining secure and resilient SATCOM as a core space service.

Main part

The first argument of the study is that the military value of space technologies lies primarily in the services they provide to joint operations rather than in the mere existence of satellites in orbit. Modern defense depends on space-based

communications for secure connectivity, on positioning and timing for synchronization and navigation, and on space-based surveillance for early warning and battlespace awareness. NATO's current public materials emphasize that space capabilities support navigation, communications, and intelligence, while the Alliance Persistent Surveillance from Space programme was established to enhance space-based surveillance and intelligence for NATO. This means that the disruption of space services can immediately degrade operations on land, at sea, in the air, in cyberspace, and across command networks, even if no direct attack occurs against terrestrial forces.

The second argument is that resilience of orbital infrastructure requires a shift from concentration toward distribution and diversification. Traditional architectures often relied on a limited number of strategically important satellites, which created acute vulnerabilities to hostile action, technical failure, and service interruption. By contrast, recent U.S. Space Force and Space Systems Command efforts emphasize resilient constellations and proliferated architectures. In March 2026, the U.S. Space Force reported progress toward a ten-satellite MEO constellation intended to provide resilient space-based missile warning and tracking, while recent U.S. budget and acquisition materials continue to support proliferated low Earth orbit architectures and broader space-based system investment. This indicates that resilience is increasingly being pursued through constellation design, redundancy, and architectural dispersion rather than through reliance on a small number of exquisite platforms.

The third argument concerns the protection of space-enabled services rather than only physical protection of satellites. The 2023 DoD report on the protection of satellites explicitly addresses both the protection and defense of space systems and the protection of the Joint Force from adversary hostile use of space.

This distinction is important because a military user experiences disruption at the service level. A unit may lose reliable timing, missile warning data, or secure communications without needing to know whether the root cause is kinetic attack, cyber compromise, signal interference, or degradation in the supporting architecture. Consequently, resilient defense planning must focus on assured service continuity through protected SATCOM, alternative PNT pathways, diversified sources of data, and operational procedures that account for partial or complete loss of access to space services. NATO's overarching Space Policy already stressed that exercises should include scenarios involving partial or complete loss of space services, which underlines the operational significance of service denial.

The fourth argument is that commercial space capabilities are becoming part of defense resilience rather than merely supplementary assets. NATO's 2025 Commercial Space Strategy was endorsed specifically to improve cooperation with the commercial space sector and to create increased resilience for the Alliance, while NATO public reporting in 2025 described this strategy as a decisive change in how the Alliance integrates commercial providers. The U.S. Space Force Commercial Space Strategy likewise states that commercial PNT capabilities are being sought to enable operational resilience across the Joint Force and allies. The practical

implication is that resilience now depends not only on national military constellations, but also on hybrid architectures that combine military, allied, and commercial services to preserve continuity under stress.

The fifth argument is that protection of orbital infrastructure increasingly depends on space domain awareness and adaptive control. Recent U.S. Space Force reporting on ATLAS described a new operational capability for modern space domain awareness, while NATO DIANA's resilient space operations challenge highlights the requirement for persistent domain awareness, reliable access to space services, and the ability to reposition or repair satellites when threats emerge. This suggests that future defense use of space will rely not only on passive endurance, but also on active monitoring, maneuver planning, anomaly assessment, and responsive operational decision-making.

Orbital resilience therefore includes the ability to understand what is happening in space, to distinguish threat from normal activity, and to adapt the architecture before local degradation becomes systemic failure.

At the same time, the analysis identifies important limitations. Orbital infrastructure remains exposed to kinetic threats, cyber intrusion, electronic interference, congestion, and dependency on vulnerable ground segments. Hybrid architectures with commercial participation may improve resilience, but they also create governance, interoperability, and security challenges.

Official NATO and U.S. materials therefore suggest that the most realistic model is not invulnerability, but layered resilience based on distribution, redundancy, commercial integration, protected services, and planning for degraded operations.

Results and conclusions

The study supports the hypothesis that defense effectiveness in the space domain depends less on possession of individual satellites than on the resilience of the services those systems provide.

Orbital infrastructure becomes militarily valuable when it sustains secure communications, positioning and timing, surveillance, warning, and space domain awareness under conditions of disruption, interference, or hostile pressure. The strongest resilience is achieved through distributed constellations, diversified providers, adaptive control, and protected service continuity.

The main conclusion is that space technologies should be treated as a foundational defense support layer whose protection requires both resilient orbital infrastructure and deliberate safeguarding of space-enabled services.

The practical significance of the study lies in its applicability to defense planning, SATCOM and PNT resilience, space-based surveillance, protection of command networks, and the design of hybrid military-commercial space architectures for multidomain operations.

References

1. Muradov, S. A. et al. (2025). System-level methods for enhancing UAV flight safety and resource efficiency. *In* Problems of informatization. 2025. Vol. 2., section 3,7.. p.124-126

2. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

3. Dergachov, K. et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 75-78.

4. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.102-103

5. Hashimov, E. et al. Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*. 2026. 10(1), 66-71.

6. Kovalev V.A, et al. AI assisted control model for strike UAV swarms *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.108-109

7. Piriyev, H. et al. Optimizing intelligence, surveillance, and assessment in urban environments. Матеріали конференцій МЦНД, (07.11. 2025; Дніпро, Україна), 246-256.

8. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 72-74

9. Krikun, V. L. et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.120-121

10. Kartashov, O. S. et al. (2025). Hybrid acoustic seismic approach for the identification of moving targets. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.118-119

11. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.116-117

12. Talibov, A. A. et al. (2025). Game theory enabled multi-level logistics planning. *In* Problems of Informatization. 2025. (Vol. 4, sections 5 and 6, pp. 105–107).

13. Huseynov, B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.132-134

14. Petrovski, A. A. et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts. In Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 97-100).

15. Rustamov, A. R. et al. A systems approach to urban operations for the protection of critical infrastructure and the management of civilian risks. In *Problems of Informatization.* 2025. Vol. 4, pp. 80-82.

16. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.

17. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

18. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

19. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

NEW APPROACHES TO THE PROTECTION OF CRITICAL MILITARY INFRASTRUCTURE THROUGH INTELLIGENT MONITORING SYSTEMS

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Introduction

The protection of critical military infrastructure is becoming more complex because military installations and supporting defense assets are exposed not only to direct physical attack, but also to sabotage, unmanned threats, cyber intrusion, and hybrid disruption of the services on which readiness depends. NATO's recent resilience work states that Allies must be able to withstand shocks such as failure of critical infrastructure or hybrid and armed attack, while NATO's 2025 IAMD policy also stresses that passive measures are necessary to minimize the vulnerability of critical infrastructure and assets. The objective of this study is to determine how intelligent monitoring systems can strengthen the protection of critical military infrastructure by improving early detection, situational awareness, and response coordination under contemporary threat conditions.

Methodology

The research is based on a systems approach, structural-functional analysis, and scenario-based assessment of military infrastructure protection tasks. Intelligent monitoring is treated as an integrated operational architecture that combines distributed sensors, video surveillance, anomaly detection, data fusion, automated alert prioritization, and operator decision support. The analytical framework evaluates the system through four functions: continuous observation, threat recognition, event correlation, and response support. The working hypothesis states that infrastructure protection becomes more effective when monitoring is organized as a unified intelligent environment rather than as a set of disconnected security devices. This logic is consistent with recent U.S. Army installation-security demonstrations, where AI-enabled systems were used to enhance existing electronic security infrastructure by identifying intruders, weapons, behavior anomalies, smoke, and fire while supporting broader modernization of security across industrial-base facilities.

The first argument of the study is that critical military infrastructure can no longer be protected effectively through static perimeter security alone. Contemporary threats are multidomain and often develop gradually through weak signals, abnormal behavior, or coordinated interference rather than through a single visible breach. NATO's resilience reporting emphasizes that critical infrastructure failure and hybrid attack are major resilience challenges, while NATO's recent actions on critical undersea infrastructure show that the Alliance is expanding cooperation specifically to strengthen vigilance and protection of vital infrastructure.

This indicates that infrastructure security must increasingly rely on persistent monitoring and early recognition of anomalies rather than only on fixed barriers and conventional guard functions.

The second argument is that the main operational value of intelligent monitoring lies in the transformation of raw surveillance streams into actionable security understanding. In many conventional protection systems, cameras, alarms, access-control logs, and technical sensors produce large volumes of unconnected data that overload operators and delay correct interpretation. By contrast, the U.S. Army's recent AI-propelled security work reports that intelligent video analytics can transform existing electronic security infrastructure so that it identifies objects, intruders, weapons, behavior anomalies, and other significant events. This means that intelligent monitoring systems do not simply collect more data. Their real value lies in filtering, classifying, and prioritizing events so that personnel receive a clearer and more usable picture of emerging threats.

The third argument is that intelligent monitoring improves protection because it supports correlation across multiple technical channels. A military installation may face simultaneous indicators from video feeds, access-control events, intrusion sensors, perimeter radars, communication anomalies, or fire and safety systems. When these signals remain isolated, the defender often reacts to symptoms rather than to the underlying event. When they are fused, a weak indicator in one subsystem can gain significance through confirmation from another. This approach aligns with broader NATO thinking on resilience and infrastructure monitoring, including NATO Science for Peace and Security priorities that explicitly include monitoring and protection of critical infrastructure and threat detection technologies for infrastructure environments. The implication is that intelligent monitoring should be structured as a correlation and fusion layer, not merely as an upgraded surveillance camera network.

The fourth argument concerns the role of AI. Artificial intelligence increases the practical value of monitoring systems because it helps security personnel recognize suspicious patterns in real time, reduce nuisance alarms, and focus attention on probable threats. At the same time, official guidance also points to the need for secure and trustworthy implementation of AI. NATO's AI strategy notes that AI can affect critical infrastructure and create exploitable vulnerabilities, while recent CISA guidance on AI in operational technology stresses that AI integration must be approached with risk reduction and secure data practices. Therefore, the use of AI in infrastructure monitoring should be understood as a force multiplier for detection and assessment, but only when accompanied by cybersecurity, validation, and human supervision.

The fifth argument is that protection of critical military infrastructure now depends not only on the infrastructure itself, but also on the civilian and digital systems that sustain military readiness. Recent analysis on critical infrastructure serving domestic military installations argues that military readiness platforms rely heavily on contractor-owned and civilian-operated services such as electricity, gas, water, and wastewater systems. This expands the meaning of intelligent monitoring.

It should cover not only gates, perimeters, and local intrusion alarms, but also indicators of disruption in cyber-physical and utility support systems whose failure can degrade military readiness without a direct physical assault on the installation. As a result, infrastructure protection must increasingly combine physical security monitoring with cyber resilience, service continuity awareness, and interdependence mapping.

At the same time, the study identifies important limitations. Intelligent monitoring systems depend on sensor quality, communications reliability, data integrity, calibrated analytics, and effective operator interfaces. Poorly integrated systems may generate more alerts without producing better security. In addition, AI-enabled monitoring introduces cybersecurity and data-governance demands, especially when deployed in operational technology or infrastructure-control contexts. Recent CISA materials on industrial control systems and AI integration highlight that owners and operators should reduce risk while integrating AI into such environments. Therefore, the greatest practical value of intelligent monitoring is achieved when sensing, analytics, cyber protection, and operator procedures are designed as one resilient security architecture.

Results and conclusions

The study supports the hypothesis that critical military infrastructure can be protected more effectively when intelligent monitoring systems provide continuous observation, anomaly recognition, event correlation, and response support within a unified architecture. Their main practical value lies in earlier threat detection, improved situational awareness, reduced false alarms, and better coordination of protective actions across complex military sites and supporting infrastructure systems.

The main conclusion is that future protection of critical military infrastructure should be based on intelligent, integrated, and cyber-aware monitoring architectures rather than on isolated surveillance elements. The practical significance of the study lies in its applicability to military bases, depots, logistics hubs, command sites, industrial-base facilities, and other infrastructure whose disruption would directly affect operational readiness and defense resilience.

References

1. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

2. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

3. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

4. Dergachov, K. et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 75-78

5. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.102-103

6. Hashimov, E. et al. Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*. 2026. 10(1), 66-71.

7. Piriyev, H. et al. Optimizing intelligence, surveillance, and assessment in urban environments. Матеріали конференцій МЦНД, (07.11. 2025; Дніпро, Україна), 246-256.

8. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

9. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 72-74

10. Krikun, V. L. et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.120-121

11. Maharramov, R. R. et al. Impact of high-frequency electromagnetic fields on UAV swarms and countermeasures. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.122-123

12. Kartashov, O. S. et al. (2025). Hybrid acoustic seismic approach for the identification of moving targets. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.118-119

13. Muradov, S. A. et al. (2025). System-level methods for enhancing UAV flight safety and resource efficiency. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.124-126

14. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.116-117

15. Talibov, A. A. et al. (2025). Game theory enabled multi-level logistics planning. *In* Problems of Informatization. 2025. (Vol. 4, sections 5 and 6, pp. 105–107).

16. Huseynov, B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.132-134

17. Bakhshali, V. I. et al. Hybrid energy systems in Azerbaijan: Resilience metrics and spatial constraints. *In* Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 94-96).

18. Sadiqli, A. B. et al. GIS-based evaluation of road traffic emissions and substantiation of control measures. *In* Problems of Informatization. 2025. (Vol. 4, pp. 101-104).

19. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.

20. Mashaev E.T. et al. System of systems at war: UAV enabled sensing and strike integration. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.112-113

21. Petrovski, A. A. et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts. In Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 97-100).

22. Rustamov, A. R. et al. A systems approach to urban operations for the protection of critical infrastructure and the management of civilian risks. In *Problems of Informatization.* 2025. Vol. 4, pp. 80-82.

BIG DATA APPLICATIONS FOR THREAT FORECASTING IN THE MILITARY AND DEFENSE-INDUSTRIAL SPHERE

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Introduction

The contemporary security environment is characterized by high uncertainty, multidomain threats, rapid information turnover, and the growing interdependence of military, industrial, cyber, and logistical systems. Under such conditions, threat assessment can no longer rely only on isolated intelligence reports or retrospective analysis. The U.S. Department of Defense states in its 2023 Data, Analytics, and Artificial Intelligence Adoption Strategy that high-quality data, advanced analytics, and AI are essential for enabling rapid, well-informed decisions and enduring decision advantage. NATO's science and technology reporting likewise notes that AI supports strategic planning, tactical decision-making, ISR enhancement, and cyber monitoring, while NATO technical work has specifically examined decision-making in the age of big data and hybrid threats. The purpose of this study is to determine how big data can be used for forecasting threats in the military and defense-industrial sphere and to identify the conditions under which predictive analytics produces operationally useful results rather than fragmented information overload.

Methodology

The research is based on a systems approach, structural-functional analysis, and scenario-based assessment of defense forecasting tasks. Big data is interpreted not simply as a large volume of information, but as a dynamic environment in which heterogeneous streams from intelligence, logistics, communications, cyber monitoring, industrial production, open sources, and operational reporting are aggregated and analyzed. The analytical framework includes four functions: data integration, anomaly detection, predictive modeling, and decision support. The study compares reactive threat assessment with predictive models capable of identifying precursors, weak signals, and emerging patterns before they develop into operationally significant threats. The working hypothesis states that threat forecasting becomes more effective when diverse data sources are connected through analytics and model-driven interpretation rather than processed in isolated organizational or technical silos. This approach is consistent with DoD strategy, which focuses on accelerating adoption of data, analytics, and AI across the enterprise, and with Army analytical work that frames predictive analytics as a tool for anticipating risks in contested environments.

The first argument of the study is that big data changes the logic of military threat analysis from episodic assessment to continuous forecasting. In traditional practice, threat recognition often depends on separate intelligence products, manually interpreted indicators, or localized reporting chains. This model is too slow for an environment where cyber activity, force posture changes, supply-chain anomalies, disinformation signals, and operational indicators may evolve simultaneously. DoD's adoption strategy explicitly frames data, analytics, and AI as

the basis for rapid and well-informed decisions, while NATO materials describe big data and AI as tools that can increase the speed and quality of the decision cycle. In practical terms, this means that predictive systems can identify risk accumulation earlier than conventional reporting mechanisms by detecting change across multiple data layers at once.

The second argument is that the value of big data lies not in scale alone, but in the integration of heterogeneous indicators into a common analytical picture. Military and defense-industrial threats rarely emerge from one channel only. They may be preceded by changes in logistics demand, unusual network activity, anomalies in procurement or maintenance flows, movement patterns, industrial disruption, or shifts in the information environment. The Army's recent analytical work on predictive logistics and contested environments emphasizes that predictive analytics provides planners with foresight needed to mitigate disruptions, while real-time data analysis can optimize routes and adapt sustainment under changing threats. Although this example is framed through logistics, the underlying logic is broader: threat forecasting improves when operational, industrial, and support data are interpreted together rather than separately.

The third argument is that predictive analytics is especially important for defense-industrial security because the defense-industrial sphere is both a support base and a target. Threats in this domain include supply-chain disruption, production delays, cyber compromise, dependency on vulnerable suppliers, and cascading degradation of readiness. Recent DoD acquisition strategy materials note that predictive analytics can be used to anticipate emerging threats and technology trends, while DARPA budget materials reference predictive analytics for supply-chain risk management. This indicates that defense institutions increasingly regard predictive analysis as a practical instrument for identifying vulnerabilities before they become strategic constraints. In this sense, big data analytics supports not only battlefield awareness but also industrial resilience and readiness assurance.

The fourth argument concerns cyber and hybrid threats. NATO continues to emphasize the relevance of hybrid threats to allied decision-making, and its technology strategy highlights rapid detection and recovery from evolving malicious cyber activities.

In a data-rich environment, predictive models can use network telemetry, behavioral anomalies, access irregularities, and cross-domain indicators to identify elevated threat conditions before full-scale disruption occurs. This does not eliminate uncertainty, but it creates earlier warning and improves prioritization. The significance of this capability increases when cyber activity is synchronized with disinformation, economic pressure, or operational maneuver, because isolated monitoring may fail to recognize a coordinated campaign.

The fifth argument is that the operational usefulness of big data depends on data quality, governance, and interpretability.

A predictive system may produce misleading outputs if source data are incomplete, incompatible, manipulated, or contextually misunderstood. DoD guidance on data and AI adoption therefore focuses not only on analytic ambition

but on organizational conditions for repeatable and scalable use. Recent defense discussion of AI-enabled decision support also emphasizes that analytics can rapidly assess feasibility and risks only when relevant variables are properly integrated. Consequently, big data forecasting should be treated as a disciplined decision-support function, not as an automatic substitute for human judgment. Its greatest value arises when analytical outputs are transparent enough to support review, prioritization, and command decision-making under uncertainty.

At the same time, the study identifies important limitations. Large-scale data environments may generate noise, false correlations, and overconfidence in model outputs.

Organizational fragmentation, access barriers, classification constraints, and uneven data standards can reduce predictive quality. In addition, adversaries may deliberately manipulate observable indicators in order to mislead analytical systems. For this reason, big data forecasting in the military sphere must combine robust data governance, model validation, cross-source verification, and expert supervision. Only under such conditions can predictive analytics support operational anticipation rather than produce algorithmic illusion.

Results and conclusions

The study supports the hypothesis that big data can significantly improve threat forecasting in the military and defense-industrial sphere when diverse information streams are fused into a unified analytical environment and interpreted through predictive models. Its main practical value lies in earlier recognition of weak signals, better identification of emerging risk patterns, improved anticipation of hybrid and cyber threats, and stronger readiness planning across operational and industrial domains.

The main conclusion is that big data should be treated as a strategic forecasting resource rather than merely a technical accumulation of information. Its effective military use requires integrated data architectures, predictive analytics, disciplined governance, and human-supervised interpretation.

The practical significance of the study lies in its applicability to intelligence support, cyber defense, logistics resilience, defense-industrial monitoring, and the broader anticipation of multidomain threats affecting military effectiveness and national defense readiness.

References

1. Islamov, I., et al. Big data analytics and machine learning for predicting radiation and chemical threats in the military sphere. *Collection of Scientific Papers «SCIENTIA»*, (September 26, 2025; Kraków, Poland), 30–38.

2. Hashimov, E. et al. Research of the efficiency multiservice networks using MIMO technology. Advanced Information Systems. 2026. 10(1), 66-71.

3. Rustamov, A. R. et al. A systems approach to urban operations for the protection of critical infrastructure and the management of civilian risks. In *Problems of Informatization.* 2025. Vol. 4, pp. 80-82.

4. Petrovski, A. A. et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts. In Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 97-100).

5. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

6. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014.

7. Dergachov, K. et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 75-78

8. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.102-103

9. Kovalev V.A, et al. AI assisted control model for strike UAV swarms *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.108-109

10. Piriyev, H. et al. Optimizing intelligence, surveillance, and assessment in urban environments. Матеріали конференцій МЦНД, (07.11. 2025; Дніпро, Україна), 246-256.

11. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

12. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 72-74

13. Krikun, V. L. et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.120-121

14. Maharramov, R. R. et al. Impact of high-frequency electromagnetic fields on UAV swarms and countermeasures. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.122-123

15. Kartashov, O. S. et al. (2025). Hybrid acoustic seismic approach for the identification of moving targets. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.118-119

16. Muradov, S. A. et al. (2025). System-level methods for enhancing UAV flight safety and resource efficiency. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.124-126

17. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.116-117

18. Talibov, A. A. et al. (2025). Game theory enabled multi-level logistics planning. *In* Problems of Informatization. 2025. (Vol. 4, sections 5 and 6, pp. 105–107).

19. Huseynov, B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.132-134

20. Bakhshali, V. I. et al. Hybrid energy systems in Azerbaijan: Resilience metrics and spatial constraints. *In* Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 94-96).

21. Mashaev E.T. et al. System of systems at war: UAV enabled sensing and strike integration. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.112-113

22. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

ROBOTIC GROUND PLATFORMS FOR SECURITY AND LOGISTICS SUPPORT

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Introduction

Robotic ground platforms are becoming an increasingly important component of modern military capability because they can extend observation, support security tasks, and reduce personnel exposure in hazardous operational environments. Recent U.S. Army materials describe robotic systems as transformative instruments for reconnaissance and sustainment, identifying the robotic dog as a platform for enhanced reconnaissance and situational awareness, and the Small Multipurpose Equipment Transport system as a “robotic mule” for combat, combat support, and combat service support operations. At the same time, the Army’s 2026 xTech|Edge Strike: Ground competition explicitly seeks innovative autonomous ground systems and launched effects for experimentation with soldiers and NATO end users, which indicates growing institutional demand for ground robotics in operational settings. The purpose of this study is to determine how robotic ground platforms can enhance reconnaissance, security, and logistics support in military operations and to identify the conditions under which their deployment becomes tactically effective and operationally justified.

Methodology

The research is based on a systems approach, structural-functional analysis, and scenario-based assessment of military tasks performed by robotic ground platforms. The analytical framework includes three principal functions: reconnaissance and surveillance, local security and force protection, and logistics support in contested or hazardous environments. A robotic ground platform is treated as an integrated system combining mobility, sensing, communication, mission management, and human-machine control. The study compares manned execution of selected tasks with mixed human-robot models in which robotic platforms perform forward observation, route screening, perimeter patrol, load carriage, or resupply support under operator supervision. The working hypothesis states that robotic ground platforms produce the greatest military effect when they are integrated into combined operational architectures, reducing soldier exposure and workload while preserving human command over mission-critical decisions. This interpretation is consistent with recent Army discussions of robotization and with the increasing integration of unmanned technologies into NATO’s emerging surveillance and control systems.

The first argument of the study is that the military value of robotic ground platforms lies in risk redistribution. In conventional operations, reconnaissance, route security, and forward resupply frequently require soldiers to enter areas exposed to observation, fire, mines, improvised explosive devices, or chemical and

environmental hazards. Robotic ground systems allow part of this burden to be transferred from personnel to platforms. The U.S. Army's recent discussion of transformative robotization explicitly identifies robotic dogs as tools for enhanced reconnaissance and situational awareness and describes transport robots as enabling combat and support operations. This means that robotic ground platforms are relevant not merely as technical novelties, but as instruments for reducing tactical exposure and preserving human effectiveness in dangerous zones.

The second argument is that robotic ground platforms are especially valuable for reconnaissance and local security because they expand sensing reach without demanding continuous human presence in the most exposed sectors. A robot operating ahead of a patrol, along an access route, or around a defended installation can extend observation, confirm anomalies, and support sector monitoring before soldiers physically enter the space. Recent U.S. Army discussions of reconnaissance reform and future battlefield adaptation emphasize the continued importance of reconnaissance and security under increasingly dangerous multidomain conditions, while ground robotic research is being tied to AI, autonomy, and battle damage assessment. In practical terms, a robotic ground platform contributes to reconnaissance not only by moving a sensor forward, but by enabling a more distributed observation architecture in which local detection and confirmation can occur with less direct soldier exposure.

The third argument is that robotic platforms are increasingly important for logistics support. A large share of battlefield effort is consumed not by direct engagement, but by movement of ammunition, water, batteries, medical equipment, engineering loads, and other mission-essential supplies. When resupply must take place in contested terrain, the burden on personnel becomes a direct vulnerability. Army materials describe the Small Multipurpose Equipment Transport as a robotic mule able to support combat, combat support, and combat service support operations, which illustrates the institutional view that ground robotics can relieve soldiers of repetitive and physically demanding sustainment tasks. The operational significance of this capability lies in reducing fatigue, increasing unit endurance, and supporting dispersed operations in which human carriers alone cannot sustain the required tempo.

The fourth argument concerns the command model. The tactical usefulness of robotic ground systems depends not simply on mobility and sensors, but on the relationship between autonomy and supervision. The Army's 2026 xTech|Edge Strike: Ground competition focuses on autonomous ground systems in direct interaction with end users, which indicates that the key issue is no longer only remote control, but practical military autonomy under safety and mission constraints. However, full independence remains problematic in cluttered terrain, under hostile deception, and in rapidly changing combat conditions. For this reason, the most effective model is a human-supervised architecture in which the operator defines mission intent and boundaries, while the platform performs route following, local navigation, obstacle avoidance, or load transport autonomously within defined limits.

The fifth argument is that robotic ground platforms should be treated as part of a broader system of systems rather than as isolated devices. NATO's future surveillance capability will integrate legacy and new assets, including unmanned technologies, into a federated surveillance and control architecture, while NATO's renewed surveillance initiatives emphasize multi-domain integration. Although such efforts are broader than ground robotics alone, they confirm the general military trend toward connected unmanned assets that contribute to ISR and control in a distributed architecture. Therefore, the real value of robotic ground systems is highest when they are linked with aerial unmanned systems, command networks, local ISR, and force-protection structures rather than deployed as stand-alone platforms.

At the same time, the analysis identifies major constraints. Robotic ground systems remain sensitive to terrain complexity, mobility restrictions, battery limitations, communication vulnerability, and the difficulty of perception in mud, rubble, vegetation, urban clutter, and degraded visibility.

Their operational value may also decline if units are not trained to integrate them into planning and maneuver.

Army materials on experimentation and robotization suggest that effective adoption depends not only on platform maturity, but also on doctrine, user feedback, and realistic field testing. Consequently, robotic platforms should be viewed as force multipliers that require disciplined integration rather than as direct substitutes for soldiers.

Results and conclusions

The study supports the hypothesis that robotic ground platforms can significantly improve military effectiveness in reconnaissance, local security, and logistics support when they are integrated into human-supervised operational architectures. Their principal value lies in extending sensing reach, reducing soldier exposure, supporting perimeter and route security, and carrying mission-essential loads under hazardous conditions.

The strongest practical effect is achieved when these systems operate as part of a broader reconnaissance, sustainment, and command network rather than as isolated technical tools.

The main conclusion is that robotic ground platforms should be treated as an important direction of military modernization, especially for missions where risk, fatigue, and exposure constrain human performance.

Their practical significance lies in forward reconnaissance, facility and route security, last-mile resupply, and distributed support of maneuver forces in contested environments. Future effectiveness will depend on autonomy within controlled limits, rugged mobility, secure communications, and doctrinal integration into combined operations.

References

1. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // Grail of Science. 2026. № 62. С. 873–889.

2. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608.

3. Valehov, S. A. et al. AI-based efficiency model in university governance. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.26-28.

4. Dergachov, K. et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 75-78

5. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.102-103

6. Hashimov, E. et al. Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*. 2026. 10(1), 66-71.

7. Kovalev V.A, et al. AI assisted control model for strike UAV swarms *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.108-109

8. Piriyev, H. et al. Optimizing intelligence, surveillance, and assessment in urban environments. Матеріали конференцій МЦНД, (07.11. 2025; Дніпро, Україна), 246-256.

9. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

10. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 72-74

11. Krikun, V. L. et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.120-121

12. Maharramov, R. R. et al. Impact of high-frequency electromagnetic fields on UAV swarms and countermeasures. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.122-123

13. Kartashov, O. S. et al. (2025). Hybrid acoustic seismic approach for the identification of moving targets. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.118-119

14. Muradov, S. A. et al. (2025). System-level methods for enhancing UAV flight safety and resource efficiency. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.124-126

15. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.116-117

16. Talibov, A. A. et al. (2025). Game theory enabled multi-level logistics planning. *In* Problems of Informatization. 2025. (Vol. 4, sections 5 and 6, pp. 105–107).

17. Huseynov, B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.132-134

18. Petrovski, A. A. et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts. In Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 97-100).

19. Rustamov, A. R. et al. A systems approach to urban operations for the protection of critical infrastructure and the management of civilian risks. In *Problems of Informatization.* 2025. Vol. 4, pp. 80-82.

20. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

BIOTECHNOLOGIES AND HUMAN PERFORMANCE ENHANCEMENT TECHNOLOGIES FOR INCREASING THE FUNCTIONAL RESILIENCE OF MILITARY PERSONNEL IN EXTREME CONDITIONS

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Introduction

The human element remains the decisive factor of military effectiveness even as defense systems become more automated, networked, and data-driven. At the same time, combat and support operations increasingly place personnel in environments characterized by heat, cold, hypoxia, fatigue, sleep disruption, toxic exposure, cognitive overload, and prolonged physical strain. NATO's 2024 Biotechnology and Human Enhancement Technologies Strategy states that biotechnology and human enhancement technologies will transform security and defense and identifies defense-relevant opportunities in human protection, human performance, advanced biosensors, and biological materials. NATO's long-range science and technology trends report likewise notes that, in the Alliance context, biotechnology includes both bio-engineered materials and human enhancement technologies, while DARPA's Biological Technologies Office explicitly links its work to warfighter performance, protection, recovery, diagnostics, and medical countermeasures.

The purpose of this study is to determine how biotechnologies and human performance enhancement technologies can improve the functional resilience of military personnel in extreme conditions and to identify the requirements that distinguish operationally useful enhancement from speculative or ethically uncontrolled intervention.

Methodology

In this research, biotechnology and human performance enhancement are treated as a coordinated defense capability space rather than as isolated medical or laboratory innovations.

The analytical framework combines structural-functional analysis with scenario-based assessment and considers four interrelated application areas: physiological resilience, cognitive stability, biosensing and condition monitoring, and protection against chemical and biological stressors. The study compares conventional approaches based on training, acclimatization, and standard medical support with technology-enabled models that incorporate advanced biosensors, targeted biological interventions, improved protective systems, and enhanced recovery measures. The working hypothesis states that functional resilience rises when biotechnologies are integrated into a controlled system of monitoring, prevention, support, and recovery instead of being viewed only as post-exposure medical treatment. This interpretation is consistent with DARPA's emphasis on warfighter performance and protection, NATO's official biotechnology strategy, and the NATO Science and Technology Organization's 2025 collaborative programme

of work, which includes both biotechnology for defense innovation and aircrew human performance optimization.

A key reason this topic has become central to defense planning is that extreme environments quickly expose the limits of conventional human adaptation.

Even well-trained personnel experience reduced endurance, impaired vigilance, slower recovery, and cognitive decline under heat stress, hypoxia, fatigue, toxic exposure, and prolonged physical strain. NATO's 2024 Biotechnology and Human Enhancement Technologies Strategy identifies defense-relevant opportunities in human protection, human performance, biosensors, and related technologies.

This shows that biotechnology in defense is no longer limited to treatment after degradation has already occurred.

Its growing significance lies in preserving acceptable performance before physiological decline becomes mission-critical.

One of the most important directions is real-time biosensing and physiological monitoring. In extreme conditions, early detection of dehydration, metabolic overload, abnormal fatigue, or toxic exposure can improve command decisions and the timing of medical intervention. NATO strategy documents refer to biodata and biosensors as part of the broader biotechnology landscape, while DARPA's Biological Technologies Office links its research to diagnostics, assessment, protection, and warfighter performance.

In military terms, such tools are valuable because they allow earlier warning, individualized load management, and more rational rotation or extraction decisions.

Another important issue is physiological enhancement and protection. Biotechnology in defense includes not only biomedical treatment, but also improved protective solutions, regenerative approaches, and targeted methods for increasing tolerance to environmental and operational stress. NATO's biotechnology strategy and related defense programs indicate that future military applications may focus on improving stress tolerance, recovery speed, and survivability in conditions where natural adaptation is too slow or insufficient.

This is especially relevant for personnel operating in heat, cold, altitude, contamination risk, or prolonged overload.

The cognitive dimension is equally significant. Extreme conditions affect not only physical output but also attention, judgment, and speed of response. For this reason, human resilience must be understood as a combined physical and cognitive capability. Recent NATO research planning on human performance optimization suggests that technologies supporting alertness, cognitive stability, and faster neurophysiological recovery may be as important as those aimed at pure physical endurance.

At the same time, defense use of enhancement technologies raises strict operational and governance constraints. NATO's official strategy emphasizes ethical, legal, and social implications as a core part of the issue. This means that any military application must be reliable, medically safe, controllable, and subject to disciplined oversight.

The most realistic model is therefore not unrestricted human enhancement, but carefully governed integration of biosensors, protective biotechnologies, targeted support tools, and recovery systems into military human-performance management.

Results and conclusions

The analysis supports the hypothesis that biotechnologies and human performance enhancement technologies can improve the functional resilience of military personnel in extreme conditions when they are incorporated into a structured system of monitoring, protection, support, and recovery.

Their main practical value lies in earlier detection of physiological decline, improved tolerance to stress, stronger protection against hazardous exposure, and faster restoration of performance after intensive operational loads.

The principal conclusion is that biotechnology in the military sphere should be treated as a controlled resilience-enhancing capability rather than as a narrow medical supplement or an unrestricted enhancement agenda. Its practical significance lies in supporting personnel exposed to heat, cold, hypoxia, fatigue, and contamination risk, where mission success depends on preserving both physical and cognitive function.

The most effective path forward is phased and ethically governed integration into the broader architecture of military human-performance support.

References

1. Rustamli B., et al. Prospects and challenges of bio-nano remediation of military-contaminated lands //Матеріали конференцій МЦНД. – 2025. – №. 24.10. 2025; Житомир, Україна. – С. 227-237.

2. Valehov, S. A. et al. AI-based efficiency model in university governance. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.26-28.

3. Dergachov, K. et al. AI based physical and cyber defense for energy grids and transportation systems. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 75-78

4. Hashimov E. G. Destruction of enemy combat power in indeterminacy condition //Proc. of Vth International Scientific Technical conference “Modern development directions of data communication technology and control means. – 2015. – С. 23-24.

5. Hashimov, E. et al. Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*. 2026. 10(1), 66-71.

6. Kovalev V.A, et al. AI assisted control model for strike UAV swarms *In* Problems of informatization. 2025. Vol. 1., section 1,2. p.108-109

7. Piriyev, H. et al. Optimizing intelligence, surveillance, and assessment in urban environments. Матеріали конференцій МЦНД, (07.11. 2025; Дніпро, Україна), 246-256.

8. Islamov, I., et al. Prospects for the use of robotic complexes in eliminating the consequences of environmental accidents at military facilities. *Матеріали конференцій МЦНД*, (07.11.2025; Дніпро, Україна), 301–311.

9. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025. Vol. 1., section 1,2. p. 72-74

10. Krikun, V. L. et al. Accelerating decision making and operational efficiency through C4ISR architecture. *In* Problems of informatization. 2025. Vol. 2., section 3,7. .p.120-121

11. Maharramov, R. R. et al. Impact of high-frequency electromagnetic fields on UAV swarms and countermeasures. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.122-123

12. Kartashov, O. S. et al. (2025). Hybrid acoustic seismic approach for the identification of moving targets. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.118-119

13. Muradov, S. A. et al. (2025). System-level methods for enhancing UAV flight safety and resource efficiency. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.124-126

14. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.116-117

15. Talibov, A. A. et al. (2025). Game theory enabled multi-level logistics planning. *In* Problems of Informatization. 2025. (Vol. 4, sections 5 and 6, pp. 105–107).

16. Huseynov, B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. *In* Problems of informatization. 2025. Vol. 2., section 3,7..p.132-134

17. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.

18. Sadiqli, A. B. et al. GIS-based evaluation of road traffic emissions and substantiation of control measures. *In* Problems of Informatization. 2025. (Vol. 4, pp. 101-104).

19. Mashaev E.T. et al. System of systems at war: UAV enabled sensing and strike integration. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.112-113

20. Petrovski, A. A. et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts. In Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. 2025. (Vol. 4, pp. 97-100).

21. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.

22. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

23. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

24. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

25. Muradova E.E., et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems // Актуальні питання розвитку галузей науки: збірник науковихпраць з матеріаламиVIМіжнародної наукової конференції. 2025. p.351-360

26. Rustamov, A. R. et al. A systems approach to urban operations for the protection of critical infrastructure and the management of civilian risks. In *Problems of Informatization.* 2025. Vol. 4, pp. 80-82.

EVIDENCE-BASED ACCEPTANCE OF PHYSICAL PROTECTION EFFECTIVENESS UNDER MULTI-EVENT STRESS

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Introduction

This thesis addresses the problem of evidence-based acceptance of physical protection effectiveness for high-consequence facilities under multi-event stress conditions. The issue is operationally relevant because concurrent incidents such as diversionary actions, false-alarm surges, degraded communications, and simultaneous intrusion attempts can erode sufficiency even when a system is formally compliant with prescriptive requirements. In such regimes, failure is rarely caused by a single technical component; it emerges from the coupled information-and-control loop that links detection to validation, decision-making, dispatch, and response. When this loop is slowed by workload and resource contention, the defender may lose the time reserve required to interrupt the adversary before the critical element is reached. The goal of the study is to propose an acceptance approach in which sufficiency is demonstrated through measurable, scenario-conditioned criteria and predefined evidence channels rather than through documentation closure or isolated subsystem checks.

Methodology

The methodology combines scenario-oriented analysis with time-budget decomposition of the defender chain. A bounded stress-scenario library is defined to represent multi-event regimes, including diversion plus main attack, parallel alarms across zones, false-alarm bursts, command-and-control degradation, and limited response staffing. For each scenario, the defender timeline is decomposed into measurable components: detection latency, validation time, decision and authorization latency, dispatch time, travel time, and effective engagement time. Workload variables are also introduced, including alarm arrival rate, queue length, and response-force occupancy. Acceptance conditions are formulated as verifiable time-based constraints requiring intervention before adversary completion, with an explicit margin; for multi-event regimes, a probabilistic form may be used to capture tail risk under concurrency. Evidence is defined a priori and combines instrumented timed drills, log-based measurement from SOC and C2 systems, stress tests with alarm injection and communications degradation, and simulation or hybrid evidence for rare multi-event combinations.

The central argument is that conventional acceptance practices, which emphasize documentation closure and isolated subsystem checks, systematically under-represent the dominant degradation mechanisms that appear under multi-event stress. In many facilities, acceptance is reduced to verifying that sensors exist, barriers meet nominal delay ratings, procedures are documented, and response forces are staffed. These checks are necessary but not sufficient because they do not test whether the integrated system remains timely and coherent when multiple incidents compete for attention, communications, and response resources. Multi-event

regimes expose a different class of failure mechanisms: queueing and overload in alarm processing, ambiguity-driven expansion of validation time, decision latency under competing priorities, dispatch contention, and degraded communications that fragment situational awareness. In such conditions, sufficiency is lost not because the system is absent, but because the system cannot transform signals into action within the available time window. A crucial observation is that multi-event stress collapses the assumption of independence between incidents. A diversionary event changes the effective defender timeline for the main event by consuming operator capacity and response resources, increasing the time required for validation and decision-making and delaying dispatch. Even when the physical layer provides adequate nominal delay, the usable time reserve can be eliminated if $t_{val}+t_{dec}+t_{dispt}$ grows due to workload and contention. This is the operational reason why "compliant but insufficient" configurations persist: the facility is protected in a component sense, but not in a time-coupled system sense. Therefore, acceptance must evaluate the system in the same operational regime in which it is expected to work, including concurrency, uncertainty, and degraded modes.

The proposed acceptance concept begins by fixing a bounded stress-scenario set that is explicitly designed to reveal distinct failure mechanisms. A minimal library includes: (i) diversion plus main attack, where response is intentionally saturated; (ii) parallel alarms across zones, creating ambiguity and prioritization conflict; (iii) false-alarm bursts, which generate operator overload and alarm fatigue; (iv) command-and-control degradation, including intermittent communications loss; and (v) limited response availability due to parallel tasks or staffing constraints. Each scenario is parameterized by a defined operating state and a specified critical element, ensuring that acceptance targets are linked to concrete operational objectives rather than general "security posture" claims. Within each stress scenario, the acceptance approach requires instrumentation of the end-to-end defender chain. The key is to measure not only the initial sensor trigger but also the post-detection processing that frequently dominates total time to action. This includes timestamps for alarm acknowledgement, validation completion, decision authorization, dispatch initiation, and arrival at the engagement point, plus indicators of communications delivery and operator workload. The acceptance logic focuses on two coupled outcomes. The first is timeliness: whether intervention occurs before the adversary could plausibly reach the critical element, with an explicit margin that accounts for uncertainty. The second is stability: whether the system maintains controlled performance under load, meaning that alarm queues do not diverge and that prioritization does not collapse critical coverage. In practice, this shifts acceptance from a binary "pass/fail by checklist" to an operational evaluation of whether time-to-intervention remains within limits across stressed conditions.

To make this operationally usable, the method organizes evidence around a minimal metric set that is both measurable and directly linked to sufficiency. The core metrics include total time to effective intervention, the combined validation-plus-decision latency under load, dispatch delay under resource contention, communications availability and delivery latency in degraded mode, and the

classification/prioritization performance that determines whether the main event is handled as critical even during a diversion. Workload indicators such as alarm arrival rate and processing queue length are treated as acceptance-relevant because they explain why latency grows and whether the system is approaching a tipping point. This is essential in aviation and defense contexts where surge operations are common and where adversaries may intentionally manipulate workload through diversionary tactics. A defining element of the approach is that acceptance evidence is specified before testing, not after. Timed drills are appropriate for dispatch and travel components, but they must be instrumented and repeated under controlled variations to capture variability rather than a single nominal value. Log-based measurement is required to validate that performance holds in real operations and to detect drift over time. Stress tests with injected alarms are necessary because nominal conditions cannot reveal queue instability or alarm fatigue effects. Degraded-communications tests are required because the time-to-action chain is often sensitive to message loss and retransmission delays. Finally, simulation or hybrid evidence is used to address regimes that are rare or unsafe to reproduce at full scale, such as high-concurrency multi-point incidents; however, simulation is treated as evidence only when its assumptions are transparent and calibrated against observed timings.

The practical benefit of this acceptance approach is that it makes failure explainable and correctable. When acceptance is scenario-conditioned and instrumented, a failure can be attributed to a specific bottleneck, such as excessive validation time under ambiguity, decision delays due to authorization hierarchy, dispatch contention caused by resource allocation rules, or communications delivery failures in degraded mode. This attribution supports targeted corrective actions: redesign of validation workflows, improved alarm management and prioritization logic, delegation of decision authority, redundancy in communications paths, or adjustments to staffing and readiness posture during surge periods. In contrast, checklist-based acceptance often produces non-actionable outcomes, because it does not reveal where and why the time reserve was lost. In summary, the main claim is that evidence-based acceptance under multi-event stress must be defined as a system-level, time-coupled demonstration of sufficiency, supported by measurable criteria and scenario-driven evidence. This approach aligns acceptance with the operational reality of deliberate adversaries and high-tempo environments by testing the very mechanisms that are most likely to fail: validation, decision-making, dispatch under contention, and communications under degradation.

Results and conclusions

The study formulates an evidence-based acceptance approach for physical protection effectiveness under multi-event stress, grounded in scenario-conditioned, measurable criteria and predefined evidence channels. The analysis supports the hypothesis that “compliant but operationally insufficient” outcomes are primarily driven by latency growth and workload-induced degradation in the information-and-control loop rather than by the mere absence of technical measures. The practical value is that the proposed acceptance scheme can be used to justify requirements, design acceptance tests, and support lifecycle revalidation using operational data. It

enables early identification of critical bottlenecks, more rational prioritization of modernization resources, and improved resilience to diversionary actions and concurrent incident regimes.

References

1. Hashimov, E.G. et al. (2026). Research of the efficiency multiservice networks using MIMO technology. *Advanced Information Systems*, *10*(1), 66-71.

2. Elshan, H. et al. (2026). *Constrained optimization of an integral security indicator for adaptive management of hazardous facilities*. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

3. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // *International scientific journal «Grail of Science»*. 2026. № 62. С. 873–889.

4. Akhundov, R. et al. (2026). *Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities*. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

5. Akhundov, R., Hashimov, E.G., & Islamov, I. (2026). *Adaptive modeling of multi-layer protection systems under time-constrained threat scenarios*. Grail of Science, (63), 410–422. https://doi.org/10.36074/grail-of-science.18.03.2026.072

6. Akhundov, R., Hashimov, E. G., & Islamov, I. (2026). Methodological framework for adaptive risk-based zoning in multi-layer physical protection systems. Grail of Science, (62), 515–526. https://doi.org/10.36074/grail-of-science.20.02.2026.094

7. Akhundov, R., & Hashimov, E. (2026). *Enhancing the physical protection of critical facilities through the integration of physical process models and machine learning*. Grail of Science, (61), 722–731. https://doi.org/10.36074/grail-of-science.23.01.2026.083

8. Hashimov, E.G., Akhundov, R., Talibov, A., & Islamov, I. (2026). Decision support for physical protection systems using route-level metrics and simulation-based evaluation. *Grail of Science*, (63), 531–542. https://doi.org/10.36074/grail-of-science.06.03.2026.059

9. İsmayil, İsmayil (2025). Security and protection of Azerbaijan's oil and gas pipelines: cybersecurity and risk management approaches. *Матеріали конференцій МЦНД*, (11.07.2025; Львів, Україна), 136–144.

10. Akhundov, R., Hashimov, E.G., & Islamov, I. (2026). Scenario oriented sufficiency criteria for physical protection systems provide a traceable path from threat classes to design requirements. *International Scientific Journal «Grail of Science»*, (63), 687–699. https://doi.org/10.36074/grail-of-science.06.03.2026.074

FORMATION OF NATIONAL AND MORAL VALUES IN MILITARY LYCEUMS IN THE REPUBLIC OF AZERBAIJAN: MODERN APPROACHES AND PERSPECTIVES

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In the context of contemporary global transformations, the sustainable development of societies depends not only on economic and technological factors, but also on the preservation and transmission of national-spiritual values to future generations. In this regard, the education system, particularly specialized institutions

such as military lyceums in the Republic of Azerbaijan, plays a leading role in shaping the value orientations of young people.

The educational process in military lyceums extends beyond academic knowledge. It purposefully focuses on forming cadets' personalities, strengthening their national identity, and fostering a sense of attachment to the homeland. Characterized by high discipline, collective responsibility, and established social norms, this environment provides a strong foundation for the systematic instillation of national-spiritual values. Modern pedagogical approaches require combining traditional methods with innovative technologies, expanding interactive learning, and considering cadets' individual characteristics. Thus, the formation of national-spiritual values becomes an integrative process based on the interaction of instruction, upbringing, and the social environment [3]. In the school and military education environment, national-spiritual values are developed through the following main components:

1. National identity and cultural belonging – the formation of a sense of respect for language, history, and culture.
2. Patriotism – the values of loyalty to the state and readiness to defend the homeland.
3. Moral responsibility – the alignment of personal and social behavior with ethical standards.
4. Social norms – the development of appropriate behavioral skills in peer and collective environments.

The formation of these values in military lyceums is not based solely on the teaching process; it is also complemented by extracurricular activities, practical exercises, and historical-patriotic events [4].

The primary objective of education in Azerbaijani military lyceums is to train cadets as professional military officers and to shape their personalities based on the philosophy of life grounded in national-spiritual values, national identity, and patriotism. In these educational institutions, the teaching process is not devoted solely to general education and military knowledge; at the same time, aspects of cadets' leadership, collective responsibility, physical training, and moral development are structured in parallel [5, pp.24]. To achieve these goals, the instructional and educational programs are harmonized with each other and supported by extracurricular activities.Currently, two main military lyceums operate in the territory of the Republic of Azerbaijan:

Jamshid Nakhchivanski Military Lyceum is one of the oldest military educational institutions established in the Republic of Azerbaijan in 1971. The school is named after Jamshid Nakhchivanski, a prominent Azerbaijani officer and national hero. Since its establishment in 1971, the lyceum has maintained long-standing traditions in the training of officer personnel in the republic and continues to play a significant role in the formation of the country's armed forces to this day. Cadets studying at the lyceum receive both general secondary education and specialized military-pedagogical training. The structure of the curriculum includes, alongside academic subjects, programs in military training, physical education, and

moral-ethical upbringing. Graduates of the lyceum subsequently enter higher military educational institutions and professional military service. The educational environment of the school strengthens cadets' self-confidence, discipline, and sense of patriotism, preparing them for future service in the defense of the State. The lyceum's activities continue intensively in the modern period and are highly valued by the republic's leadership [1]. Heydar Aliyev Military Lyceum (Nakhchivan and Baku) is a strategically important educational institution located in the Nakhchivan Autonomous Republic. It traces its history back to 1998. Initially operating as a branch of the Jamshid Nakhchivanski Military Lyceum in Nakhchivan, it later gained independent status and was named after Heydar Aliyev. In addition to general education programs, the lyceum offers specialized training programs in military sciences and physical preparation for its cadets. The lyceum's cadets participate in various military parades and events, demonstrating their practical skills, which in turn enhances their level of social adaptation and leadership. The activities of this institution are officially confirmed on the portal of the Ministry of Defense of the Republic of Azerbaijan, where detailed information is provided regarding the purpose and structure of the educational process, as well as aspects of cadet life [2].

Thus, the activities of Azerbaijani military lyceums hold both strategic and practical significance in terms of training young people as professional patriotic officers in the future.

Based on the research findings, the following recommendations can be made:

1. Further integration of national-spiritual values into the curriculum – a more systematic application of historical and cultural knowledge in lessons and classes can strengthen cadets' sense of national identity.
2. Implementation of innovative teaching and upbringing methods – interactive learning, simulations, and project-based activities can enhance cadets' practical skills and moral upbringing.
3. Expansion of extracurricular activities – military-patriotic events, excursions, and social projects can more effectively develop cadets' leadership and collective work skills.
4. Strengthening the individualized approach and mentorship system – personalizing training and upbringing programs by taking into account cadets' individual needs and interests can increase their motivation and moral development.
5. Utilization of modern technologies – the use of digital platforms and interactive tools can enable national-spiritual values to reach a wider audience.

These recommendations will not only increase the effectiveness of the instructional and educational activities in military lyceums but will also support the training of cadets as professional citizens and patriotic officers in the future.

References

1. Azərbaycan Respublikası Müdafiə Nazirliyi. (2026). Cəmşid Naxçıvanski və Heydər Əliyev adına hərbi lisey haqqında məlumat. https://mod.gov.az/az/cemsid-naxcivanski-ve-heyder-eliyev-adina-herbi-lisey-200/
2. Azərbaycan Respublikası Müdafiə Nazirliyi. (2026). Heydər Əliyev adına hərbi lisey haqqında məlumat. https://mod.gov.az/az/pre/25965.html

3. Məmmədzadə, M. (2025). Hərbi təhsil müəssisələrində tədris prosesinin idarə olunması. *Polis Akademiyasının Elmi Xəbərləri, 1*(43), 173–177.

4. Naghizade, A. (2025). Formation of national and spiritual values among cadets of Azerbaijani military lyceums: Opportunities and approaches. *Akademik Tarih ve Düşünce Dergisi, 12*(Özel Sayı 2025-1), 133–144. https://doi.org/10.46868/atdd.2025.1027

5. Nuriyev, S., Əliyev, N., & Həsənov, A. (2016). *Təlim psixologiyası, təlimin metodları və funksiyaları. Problemli hərbi təlim metodları*. Hərbi Nəşriyyat.

NUROTROPHİN PATHWAYS AND STRESS RESİLİENCE İN MİLİTARY-RELATED POST-TRAUMATİC STRESS DİSORDER

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Post-Traumatic Stress Disorder (PTSD) is one of the most prevalent and serious mental health conditions affecting military personnel worldwide [1]. Epidemiological studies indicate that the prevalence of PTSD in general population is approximately 3-4%, whereas this rate significantly increases in military populations, reaching 10-20% depending on combat exposure. In some high-risk groups, such as veterans who have participated in active combat operations, the prevalence may exceed 25% [2]. Continuous exposure to traumatic events, including combat, explosions, physical violence, severe injury, and dangerous situations makes military personnel particularly vulnerable to long-term psychological and neurobiological consequences [3]. In addition to symptoms such as, anxiety, intrusive memories, hyperarousal, and emotional dysregulation, PTSD is associated with structural and functional alterations in the brain. Chronic stress disrupts neuronal plasticity, synaptic communication, and adaptive stress response mechanisms, which are essential for cognitive and emotional functioning [4].

Recent neurobiological studies have demonstrated that stress-related disorders are closely linked to disturbances in neurotrophic signaling pathways, which regulate neuronal survival, synaptic strength, and brain adaptability. Among these pathways, brain-derives neurotrophic factor (BDNF) plays a central role in maintaining synaptic plasticity, learning, memory, and emotional regulation [5]. Alterations in BDNF signaling are associated with impaired fear extinction and long-term consolidation of traumatic memories, which are key characteristics of PTSD [6]. In military environments, repeated and prolonged exposure to trauma may lead to dysregulation of BDNF-mediated mechanisms, increasing vulnerability to chronic stress and psychological disorder [5].

The aim of the present study was to investigate the role of the BDNF-centered neurotrophin signaling system in the neurobiological mechanisms of PTSD in military personnel. The study focused on identifying functional interactions between BDNF and related proteins and evaluating their contribution to stress adaptation, neuronal plasticity, and emotional memory. Understanding these molecular mechanisms may provide new perspectives for personalized and targeted therapeutic

strategies, particularly in individuals exposed to prolonged and severe trauma in military settings.

A bioinformatic approach was applied to analyze molecular interactions and biological pathways associated with BDNF. In this context, BDNF and its main receptors were selected as the primary research material. A protein-protein interaction network was constructed using the STRING database to identify the functional relationships between BDNF and interacting proteins. This approach enabled visualization of complex molecular interactions and confirmed the central regulatory role of BDNF in neurotrophin signaling system. In addition, enrichment analysis based on GO Biological Process was performed using the Enrichr platform to determine the main biological processes associated with these proteins.

Pathway mapping was also performed using the KEGG database to visualize the intracellular signaling cascades activated after interaction of BDNF with Trk receptors. The neurotrophin signaling pathway map allowed identification of key molecular mechanisms related to neuronal survival, synaptic plasticity, and emotional memory regulation. This analysis provided a clearer understanding of how chronic stress and trauma in military environments may influence BDNF-mediated signaling and contribute to the development and persistence of PTSD.

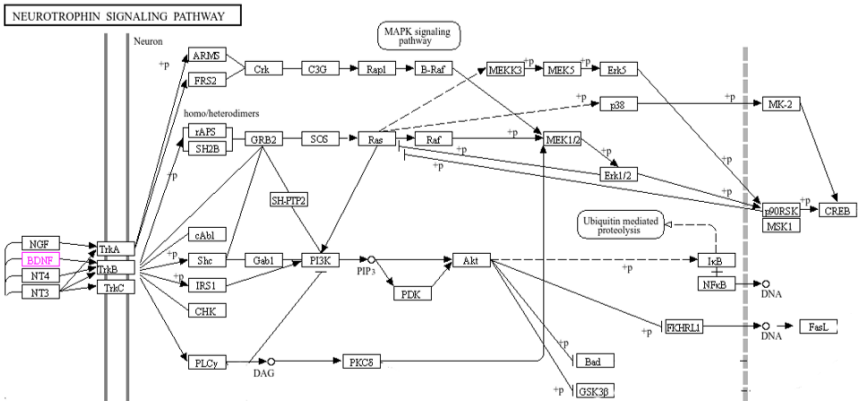

Figure 1. The basic molecular mechanism and intracellular cascades of the BDNF-based neurotrophin signaling pathway

The obtained findings demonstrated that BDNF functions as a central hub within the neurotrophin signaling network and interacts with multiple proteins involved in neuronal survival, synaptic plasticity, and stress response. The analyses revealed that BDNF-TrK receptor axis is associated with key signaling pathways regulating neuronal apoptosis, synaptic strengthening, and emotional memory formation. These pathways are essential for maintaining neuronal adaptability and resilience under chronic stress conditions. Enrichment results confirmed that the selected proteins are mainly involved in cellular response to neurotrophin stimuli, receptor tyrosine kinase signaling, and regulation of neuronal survival.

In the military context, repeated exposure to traumatic stress may disrupt these signaling mechanism and weaken neuronal adaptive capacity. Dysregulation of BDNF signaling may increase sensitivity to stress, impair emotional regulation, and promote the persistence of fear memory. This may explain the chronic and recurrent nature of PTSD and the difficulty in extinguishing traumatic memories in affected individuals. Reduced neuronal plasticity may also limit recover and increase the risk of comorbid psychiatric conditions. Overall, the results highlight the importance of the BDNF-centered neurotrophin system in understanding the neurobiological basis of PTSD in military populations. Integration of protein interaction, pathway, and enrichment analyses provides a comprehensive perspective on molecular mechanisms underlying stress-related disorders. These findings suggest that targeting the BDNF signaling network may offer new opportunities for biomolecular diagnostics and personalized therapeutic strategies aimed at improving resilience and recovery in individuals exposed to severe trauma.

In conclusion, this study demonstrates that bioinformatic approaches can significantly contribute to understanding molecular mechanisms associated with PTSD. The BDNF-Trk signaling system plays a critical role in neuronal adaptation, emotional memory, and stress regulation. Investigation of this system in military populations is particularly important due to their high exposure to traumatic stress. Future research focusing on this pathway may support the development of early diagnostic tools and targeted treatment strategies to improve mental health outcomes in military personnel and other high-risk groups.

References

1. Barbara L. Pitts, Jukia M. Whealin, Ilan Harpaz-Rotem, Ronald S. Duman, John H.Krystal, Steven M. Southwick et al. BDNF Val66Met polymorphism and post-traumatic stress syptoms in U.S military veterans: Protective effect of physical exercise. Psychoneuroendocrinology Vol. 100, 2019, https://doi.org/10.1016/j.psyneuen.2018.10.011

2. Elzinga, B. M., & Bremner, J. D. (2002). *Are the neural substrates of memory the final common pathway in posttraumatic stress disorder (PTSD)?* Journal of Affective Disorders, 70(1), 1–17. https://doi.org/10.1016/S0165-0327(01)00351-2

3. Wampold, B. E., Imel, Z. E., Laska, K. M., Benish, S. G., Miller, S. D., Flückiger, C., Del Re, A. C., Baardseth, T. P., & Budge, S. L. (2010). *Determining what works in the treatment of PTSD*. Clinical Psychology Review, 30(8), 923–933. https://doi.org/10.1016/j.cpr.2010.06.005

4. American Psychiatric Association**.** (2013). *Diagnostic and statistical manual of mental disorders* (5th ed. pp. 87–122). American Psychiatric Publishing. https://doi.org/10.1176/appi.books.9780890425596

5. Chen, Z. Y., Patel, P. D., Sant, G., Meng, C. X., Teng, K. K., Hempstead, B. L., & Lee, F. S. (2004). *Variant brain-derived neurotrophic factor (BDNF Val66Met) alters activity-dependent secretion of BDNF and affects neuronal plasticity.* Journal of Neuroscience, 24(18), 4401–4411. https://doi.org/10.1523/JNEUROSCI.0348-04.2004

6. Egan, M. F., Kojima, M., Callicott, J. H., Goldberg, T. E., Kolachana, B. S., Bertolino, A., … Weinberger, D. R. (2003). *The BDNF Val66Met polymorphism affects activity-dependent secretion of BDNF and human memory and hippocampal function.* Cell, 112(2), 257–269. https://doi.org/10.1016/S0092-8674(03)00035-7

THE POSSIBLE ROLE OF BDNF IN POST-TRAUMATIC STRESS DISORDER IN MILITARY PERSONNEL

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Post-Traumatic Stress Disorder (PTSD) is a multifaceted and chronic psychiatric disorder that develops in certain individuals following exposure to severe traumatic experiences, particularly within military environments characterized by combat operations, life-threatening situations, explosions, and prolonged psychological stress. According to DSM-V diagnostic criteria [1,2], PTSD manifests through four principal symptom clusters: intrusive recollections, persistent avoidance of trauma-related stimuli, negative alterations in cognition and mood, and sustained hyperarousal. These symptoms substantially impair functional adaptation, operational performance, and long-term psychological resilience among military personnel [3]. The variability in individual vulnerability to PTSD suggests that, beyond environmental exposure, biological and genetic determinants significantly contribute to disease susceptibility.

At the neurobiological level, PTSD is strongly associated with dysregulation of fear memory consolidation, impaired extinction learning, and alterations in synaptic plasticity within key brain regions involved in emotional processing. In this context, the BDNF (Brain-Derived Neurotrophic Factor) gene represents a critical molecular component due to its central role in neuronal survival, synaptic modulation, neuroplasticity, and stress adaptation mechanisms [4]. Variations within this gene may therefore influence individual differences in trauma processing and stress responsiveness.

The Val66Met (rs6265) single nucleotide polymorphism (SNP) of the BDNF gene has been widely recognized as a potential genetic risk factor for stress-related psychiatric disorders [5]. The substitution of valine with methionine at codon 66 affects intracellular trafficking and activity-dependent secretion of the BDNF protein [6]. Empirical evidence indicates that carriers of the 66Met allele exhibit increased sensitivity to stress and a higher probability of developing PTSD symptoms compared to individuals carrying the Val/Val genotype [7]. These findings position the rs6265 polymorphism as an important candidate genetic factor contributing to neurobiological vulnerability in military populations exposed to trauma.

The present study aimed to evaluate the structural and functional consequences of the Val66Met polymorphism using integrated in silico and quantum mechanical approaches. Molecular-level analyses demonstrated significant differences between valine and methionine in terms of electronic structure, energetic stability, and physicochemical properties [8]. The sulfur-containing side chain of methionine was shown to alter the local electronic environment of the BDNF protein, potentially affecting its conformational stability, intermolecular interactions, and biological activity [9, 10]. These molecular distinctions provide a mechanistic explanation for

previously reported functional and statistical associations between the rs6265 polymorphism and PTSS risk.

By combining computational modeling with quantum mechanical analysis, this study advances existing knowledge beyond correlation-based findings and offers a theoretical framework that links genetic variation to molecular structural alterations and, subsequently, to neurobiological mechanisms of stress adaptation. The results suggest that the Val66Met substitution may influence synaptic plasticity and fear-memory regulation processes that are central to PTSD pathophysiology. In this regard, the polymorphism may contribute to altered neural circuit dynamics involved in emotional regulation, threat perception, and trauma-related memory persistence.

Importantly, while the findings support the role of the Val66Met polymorphism as a biologically plausible risk factor, PTSD remains a complex, multifactorial disorder shaped by interactions between genetic predisposition, environmental exposure, psychosocial context, and individual coping mechanisms. Therefore, the rs6265 variant should be considered a contributing element within a broader integrative risk model rather than a deterministic predictor.

In conclusion, this study establishes a comprehensive molecular and theoretical basis for understanding how the Val66Met (rs6265) polymorphism of the BDNF gene may modulate structural protein properties and influence neurobiological susceptibility to PTSD in military personnel. The integration of in silico modeling and quantum mechanical methods strengthens the biological plausibility of genotype-phenotype associations and lays the groundwork for future experimental validation. Further large-scale, multidisciplinary investigations are required to confirm these findings and explore the potential application of genetic markers in personalized risk assessment, early intervention strategies, and precision-based mental health care within military settings.

References

1. American Psychiatric Association**.** (2013). *Diagnostic and statistical manual of mental disorders* (5th ed. pp. 87–122). American Psychiatric Publishing. https://doi.org/10.1176/appi.books.9780890425596

2. Rustamli, B. (2025). *Genetic variations in the bdnf gene in combat-exposed individuals with Post-Traumatic Stress Disorder*. In Proceedings of the 13th International Scientific and Technical Conference “Problems of Informatization” (Vol.4, Section 5-6). Baku-Kharkiv-Biesko-Biala

3. Chen, Z. Y., Patel, P. D., Sant, G., Meng, C. X., Teng, K. K., Hempstead, B. L., & Lee, F. S. (2004). *Variant brain-derived neurotrophic factor (BDNF Val66Met) alters activity-dependent secretion of BDNF and affects neuronal plasticity.* Journal of Neuroscience, 24(18), 4401–4411. https://doi.org/10.1523/JNEUROSCI.0348-04.2004

4. Egan, M. F., Kojima, M., Callicott, J. H., Goldberg, T. E., Kolachana, B. S., Bertolino, A., Weinberger, D. R. (2003). *The BDNF Val66Met polymorphism affects activity-dependent secretion of BDNF and human memory and hippocampal function.* Cell, 112(2), 257–269. https://doi.org/10.1016/S0092-8674(03)00035-7

5. Notaras, M., Hill, R., & van den Buuse, M. (2015). *The BDNF gene Val66Met polymorphism as a modifier of psychiatric disorder susceptibility: Progress and controversy.* Molecular Psychiatry, 20, 916–930. https://doi.org/10.1038/mp.2015.27

6. Rippey, C. S., Pietrzak, R. H., Maruff, P., *et al.* (2022). *Interactive effects of the BDNF Val66Met polymorphism and posttraumatic stress disorder on cognition*. Psychoneuroendocrinology, 142, 105820. https://doi.org/10.1016/j.psyneuen.2022.105820

7. Rustamli, B. (2025). *"CpG Methylation in the 1F Promoter of the NR3C1 Gene and Its Biomarker Potential in Post-Traumatic Stress Disorder."* Asian Journal of Biochemistry, Genetics and Molecular Biology17 (12):13-21. https://doi.org/10.9734/ajbgmb/2025/v17i12507.

8. Ramazanov, M.A., Pashaev, F.G., Gasanov, A.G., Maharramov, A. Mahmood, A.T. (2014). The quantum mechanical study of cadmium sulfur nanoparticles in basis of STO's. Chalcogenide Letters, Vol. 11, No. 7, pp.359-364.

9. Maharramov, A. M., Aliyeva, R. A., Aliyev, I. A., Pashaev, F. H., Gasanov, A. G., Azimova, S. I., ... & Mahmudov, K. T. (2010). Quantum-chemical calculations, tautomeric, thermodynamic, spectroscopic and X-ray studies of 3-(4-fluorophenylhydrazone) pentane-2, 4-dione. *Dyes and Pigments*, *85*(1-2), 1-6.

10. Alieva, R. A., Pashaev, F. G., Gasanov, A. G., & Mahmudov, K. T. (2009). Quantum-chemical calculations of the tautomeric forms of azo derivatives of acetylacetone and determination of the stability constants of their complexes with rare-earth metals. *Russian Journal of Coordination Chemistry*, *35*(4), 241-246.

MEASUREMENT OF RADON EMISSION FOR PREDİCTİNG EARTHQUAKES

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The study of seismic activity and its relationship with geophysical and geochemical parameters measured at the Earth's surface remains one of the most important tasks of modern seismology. Over recent decades, considerable efforts have been directed toward the development of reliable methods for earthquake prediction. In this context, particular attention has been paid to the identification of short-term and medium-term precursors that may reflect changes in the stress-strain state of the Earth's crust. Among the most promising indicators, radon anomalies in groundwater and fluctuations of the local magnetic field are considered especially significant.

At the same time, advances in computing power, digital monitoring, and artificial intelligence methods create new opportunities for processing complex, multifactorial datasets and for identifying hidden patterns associated with seismic preparation processes.

In the present study, radon gas analysis was carried out in groundwater within the Absheron seismic zone at the "Shikhov-2" and "Surakhani" observation facilities of the "Bibi-Heybat" geochemical station. Water samples were collected on a regular basis once a day, five days a week, which provided a systematic time series for monitoring temporal changes in radon concentration. Measurements were performed using the "Alpharad plus" radiometer, which is included in the official state register

of measuring devices under database number 49013-12. The instrument is characterized by a relative error limit of ±30%, which should be taken into account when interpreting variations in observed radon levels.

The monitoring program covered two hydrogeologically distinct wells. The first, "Shamakhi No. 8," has a depth of 100 to 200 m and is characterized by layered, hydrosulfide, cold, and low-mineralized water with a temperature of 13 to 14°C. The second, "Chukhuryurd No. 49," also has a depth of 100 to 200 m, but contains fractured, hydrosulfide, subthermal water with a temperature range of 16 to 24°C. The comparison of these wells is of interest because differences in geological structure, hydrogeological regime, and physicochemical water properties may influence radon transport and release mechanisms.

The purpose of the report is to investigate radon emission using geochemical monitoring technology at specialized stations located in the territory of the Republic of Azerbaijan and to assess its potential significance as a precursor of seismic activity.

The obtained results may contribute to the development of an integrated geodynamic monitoring approach in which radon observations, together with other geophysical indicators, can be used to improve the scientific basis for earthquake forecasting in seismically active regions.

References

1.Hashimov, E. G. Detection unobserved moving armored vehicles by seismic method // E.G.Hashimov, A.A.Bayramov / - Baku: National Security and Military Sciences. – 2015. – Т. 1. – №. 1. – С. 128-132.

2.A.Bayramov, S.Suleymanov, F.Abdullayev and R.Muradov AI-Based Complex for Measurement and Control Using the Machine Learning Method. Journal of Electrical Engineering. vol. 10 is. 12. 2025. pp. 116-128.

3.Bayramov A., Hashimov E. Seismic location station for detection of unobserved moving military machineries //Journal of Management and Information Science. – 2016. – Т. 4. – №. 2. – С. 61-66.

4.Huseynov, M., et al. Application of modern multi-sensor technologies for ground target detection. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 172–182.

5.Гашимов Э. Г. и др. Сейсмолокационная станция //-Баку: Военное обозрение. – 2016. – Т. 1. – №. 01. – С. 30-41.

6.Hashimov E. G. et al. Detection of Unobserved Ground Targets by Use of Seismic Location Stations //Advances in Military Technology. – 2019. – Т. 14. – №. 1. – С. 133-139.

7.Гашимов Э. Г., Байрамов А. А. Обнаружение передвижения ненаблюдаемой бронетехники противника сейсмолокационным методом //Национальная безопасность и военные науки. – 2015. – Т. 1. – №. 1. – С. 128-132.

8.Hashimov E.G., Bayramov A.A. Application of GIS and seismic location method for detection of invisible military objects. Monograph //Baku: Military publishing house. – 2017.

9.Hashimov E. G., Bayramov A. A., Sabziev E. N. Determination of the bearing angle of unobserved ground targets by use of seismic location cells //2017 International Conference on Military Technologies (ICMT). – IEEE, 2017. – С. 185-188.

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MODERN TECHNOLOGICAL SOLUTIONS FOR THE EFFECTIVE ORGANIZATION OF BORDER PROTECTION

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This article examines the adaptive model of border protection based on new technologies in the context of the growing complexity of the modern security environment. Contemporary border protection is no longer limited to the physical safeguarding of border lines, but increasingly functions as a multi-layer, data-driven, and dynamically managed system integrating surveillance, detection, identification, risk assessment, and operational response. The relevance of the study is determined by the increasing intensity of irregular migration, transnational crime, smuggling, document fraud, misuse of unmanned systems, and mass mobility flows, all of which require a transition from conventional border control mechanisms to technologically integrated and analytically supported protection models.

The purpose of the article is to substantiate an adaptive approach to border protection based on the integrated application of modern technologies and to determine their functional roles within a multi-layer security architecture. The study is based on systems analysis, functional comparison, and risk-based assessment. Border protection is conceptualized as a sequence of five interrelated stages: surveillance, initial detection, identification and classification, dynamic risk assessment, and response. Within this framework, technologies are grouped into three main categories: surveillance and data collection technologies, identification and border crossing control technologies, and analytical and management technologies. The proposed methodological approach also includes a comparative model for evaluating the implementation advantage of technological solutions through such parameters as surveillance coverage, detection accuracy, identification reliability, impact on response speed, and implementation complexity.

The results show that the effectiveness of modern border protection is achieved not through isolated technological tools, but through their integrated use within a unified operational chain. Unmanned aerial platforms improve surveillance coverage in geographically difficult and weakly monitored border sectors, while biometric identification and automated control systems increase accuracy and throughput at border crossing points. At the same time, digital identity solutions and entry-exit platforms strengthen pre-arrival risk assessment, whereas artificial intelligence-based analytics support anomaly detection, profiling, and decision support.

However, the study also demonstrates that the benefits of technological modernization depend on interoperability, standardization, cyber resilience, legal legitimacy, and data protection.

It is concluded that the adaptive model of border protection should be built on the principles of multi-layer surveillance, risk-based allocation of resources, integrated situational awareness, biometric and digital identity support, and human-

supervised intelligent analytics. Such an approach makes it possible to transform border protection from a linear control model into a flexible, adaptive, and technologically coordinated security system capable of responding more effectively to contemporary border threats.

References

1. Javadov, J. M. et al. (2025). Integrating UAV imagery with GIS-based spatial analytics to forecast border risks.
2. Javadov J.M. (2025) Application of UAV in the protection of state borders: GIS integration and risk management. *İn* Інноваційні тенденції сьогодення в сфері природничих, гуманітарних та точних наук. (15.08.2025; Харків, Україна). p.115-124. DOI https://doi.org/10.62731/mcnd-15.08.2025.003
3. Dergachov, K. et al. (2025). AI based physical and cyber defense for energy grids and transportation systems.
4. Ibrahimov B.G. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system //Advanced Information Systems. – 2024. – Т. 8. – №. 2. – С. 58-64.
5. Radovanović M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
6. Nasibov Y.A. et al. Modelling of the rationally deployment of observing systems //Advanced İnformation Systems. – 2019. – Т. 3. – №. 2. – С. 10-13.
7. Hashimov E. et al. Mathematical aspects of determining the motion parameters of a target by UAV //Advanced Information Systems. – 2023. – Т. 7. – №. 1. – С. 18-22.
8. Zulfugarov B. et al. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.
9. Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment // Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.
10. Bayramov A.A. Seismic location station for detection of unobserved moving military machineries //Journal of Management and Information Science. – 2016. – Т. 4. – №. 2. – С. 61-66.
11. Hashimov E.G., et al. Terrain orthophotomap making and combat control //Proceeding of Internatonal Conf."Modern Call of Security and Defence". 2016. T.19. c. 68-71.
12. Hashimov E.G. et al. GIS technology and terrain orthophotomap making for military application //Journal of Defense Resources Management. 2017. T.8. №. 2. c. 81-90.
13. Garayev M. F. Analysis of the possibilities of the photogrammetry method in object detection. *In* Проблеми інформатизації. 2024. Т.2. С.6.
14. Hashimov E. G., Bayramov A. A. Investigation of the observation conditions on the terrain of war operation using GIS technology //Сучасні інформаційні системи. – 2017. – №. 1,№ 1. – С. 65-69.
15. Bayramov A.A. et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

RAPID WATER SURFACE RECONSTRUCTION FOR DIGITAL WATERSHED ENVIRONMENTS

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The article examines the problem of three-dimensional reconstruction of water regions based on UAV-driven oblique photogrammetry data from the perspective of national water resource management, environmental monitoring, the development of digital twin watershed environments, and decision-support information systems [1-8]. The relevance of the study is justified by the growing need for operational, accurate, and visually reliable three-dimensional models of reservoirs, lakes, riparian areas, irrigation and drainage systems, and local basins under the conditions of Azerbaijan. However, in conventional real-scene models generated by unmanned aerial vehicles, the accurate reconstruction of water surfaces is complicated by wind, waves, shoreline reflections, and the weak stability of corresponding points across multiview images [9-14]. As a result, gaps, irregular surfaces, and texture distortions appear in the model. The purpose of the article is to substantiate a rapid and practical approach for overcoming this problem through the automatic extraction of water-region boundaries, surface reconstruction based on a triangulated irregular network, and texture mapping through intelligent image selection.

From a methodological perspective, the proposed approach is based on several sequential stages. Initially, the three-dimensional model generated from oblique and nadir images collected by a UAV is converted into a point cloud, after which interfering points are removed through adaptive filtering according to elevation and point-density criteria. At the next stage, the area is divided into grids, and an eight-neighborhood traversal algorithm is applied to separate the water-land boundary. This algorithm identifies boundary points by comparing differences in point density and the proximity of mean elevation between adjacent grids. Then, additional points are generated within the extracted boundary, and a triangulated model of the water surface is constructed using the Delaunay method. At the texture-selection stage, the nadir-view image whose coordinates are closest to the center of the water region is selected; when necessary, it is merged with neighboring images to create a mosaic, and only the fragment corresponding to the water region is clipped and mapped onto the surface. This sequence constitutes the principal scientific novelty of the article.

The results show that the proposed approach makes it possible to identify the boundaries of water regions with high accuracy, eliminate gaps in the initial three-dimensional models, and preserve important features such as water color, turbidity characteristics, the near-shore visual environment, and surface texture. According to the indicators presented in the article, the mean error, root mean square error, and standard deviation remained low, while the area error stayed within an acceptable

range; at the same time, the processing time was sufficiently short for practical application. This suggests that the approach can be effectively used in Azerbaijan for the technical monitoring of reservoirs, environmental control, visual tracking of pollution risks, digital support of hydraulic engineering facilities, and area-based management. Overall, the proposed method provides a systematic solution to the reconstruction of water regions in UAV-based real-scene modeling and creates a promising basis for the development of digital monitoring solutions in Azerbaijan's water sector.

References

1. Mammadov R., & Teymurov M. Assessment of water resources and risk of water losses due to climate changes and human activities. The Scientific Heritage. 2019,34-3, 3-11.
2. Makhmudov, R. et al. Regional climate changes in Azerbaijan and assessment of their impact on water resources with a new method. *Reliability: Theory &Applications*. 2024, 19(SI 6 (81)), 830-837.
3. Mammadov, G.S. et al. Climate change effects on soil fertility and moisture in the Nakhchivanchay River Basin, Azerbaijan. *International Journal of Agriculture and Biosciences*. 2026, 15(1), 77-86.
4. Teymurov, M.A. Assessment of soil-vegetation cover and water resources on the basis of modern scientific innovation. Scientific advances and innovative approaches. In *III International Scientific Conference*. 2023, (pp. 28-32).
5. Teymurov, M.A. Estimation of rivers' current water resources and prediction in the period until 2050. Materials of the international Scientific-Practical Conference. *Water resources, hydraulic facilities and environment*, 2017. 15.
6. Makhmudov, R. et al. Assessment of the water balance of the territory and rivers water resources using a new operational-interactive method. *Reliability: Theory & Applications*. 2023, 18(SI 5 (75)), 500-509.
7. Teymurov M.A. et al. Integated assessment of water resources in Azerbaijan from quantitative and qualitative perspectives // Технології, інструменти та стратегії реалізації наукових досліджень: збірник наукових праць з матеріалами XI Міжнародної наукової конференції. 2026. с. 109-120
8. Teymurov M. et al. Integrated approaches to water resource optimization in Azerbaijan. Scientific Forum: Theory and Practice of Research. Collection of Scientific Papers «SCIENTIA» 2026. p.189-198
9. Hashimov, E.G. The flight dynamics of drones. *National security and military sciences*. 2016, 2(3), 11-16.
10. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
11. Hashimov E.G. et al. Assessment of the natural regulation level of rivers and their runoff during intensive irrigation period. Norwegian Journal of development of the International Science No 175/2026/ p. 6-11. https://doi.org/10.5281/zenodo.18840564
12. Hashimov, E.G. About some aspects of using a flock of UAVs. *İn* Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023, 1, 4-5.
13. Nasibov, Y.A. et al. Modelling of the rationally deployment of observing systems. *Сучасні інформаційні системи*, 2019. (3,№ 2), 10-13.

UAV-BASED OPERATIONAL MONITORING OF ENVIRONMENTAL RISKS AT MILITARY FACILITIES

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This study develops a conceptual model for the operational monitoring of environmental risks at military facilities based on unmanned aerial vehicles. The relevance of the topic is determined by the growing strategic importance of environmental security in military infrastructure exposed to radioactive, chemical, and technogenic hazards. The storage and transportation of military-purpose materials, the operation of fuels and lubricants, the functioning of energy supply systems, and maintenance processes create objective preconditions for harmful environmental impacts. Under such conditions, conventional stationary monitoring systems are often insufficient because their fixed measurement positions limit spatial coverage, reduce adaptability to dynamic risk scenarios, and do not always provide the responsiveness required for timely decision-making. In contrast, UAVs offer a flexible and mobile platform for rapid data collection, near real-time assessment, and operational mapping of hazardous zones while also reducing direct personnel exposure to dangerous areas.

The purpose of the article is to formalize a concept-based model for UAV-supported environmental risk monitoring at military facilities, to substantiate its functional blocks, and to explain the logic of decision-making adapted to operational scenarios. The literature review shows that UAVs are already widely used in environmental observation, emergency monitoring, and risk assessment because of their mobility, maneuverability, sensor-carrying capacity, and ability to transmit data rapidly. However, most existing studies focus on civilian applications, whereas the specific hazard sources, regime constraints, confidentiality requirements, and time-sensitive operational conditions of military facilities remain insufficiently systematized in a dedicated methodological framework. This creates a need for an integrated model that combines data acquisition, quality control, threshold comparison, risk stratification, and response selection within a unified decision sequence.

Methodologically, the study is based on a sequential operational logic that accounts for the spatial and temporal variability of risk. At the initial stage, environmental hazard sources characteristic of military facilities are identified, and radioactive, chemical, and technogenic factors are classified by risk groups. This serves as the basis for selecting UAV-mounted measurement instruments and planning adaptive flight routes according to monitoring priorities. During the measurement stage, collected indicators are filtered and checked for reliability in order to reduce random errors and background variability. The processed data are then compared with regulatory thresholds, and the detected conditions are stratified into low, medium, and high risk levels. An important element of the model is spatial visualization through UAV-based risk mapping, which improves interpretability for

decision-makers and supports the timely selection of response measures. Depending on the assessed level of risk, the model предусматривает routine monitoring, increased monitoring intensity, additional measurements, alert activation, and immediate protective action.

The study concludes that the proposed UAV-based conceptual model provides a methodologically substantiated and application-oriented framework for ensuring environmental security at military facilities. Its main advantages include broader spatial coverage, safer observation processes, more accurate stratification of environmental threats, and stronger information support for management decisions. At the same time, the model remains subject to practical limitations related to flight endurance, meteorological dependence, and sensor calibration requirements. Overall, the proposed approach may serve as a promising basis for future mathematical formalization, scenario-based simulation, and quantitative evaluation of monitoring effectiveness and response measures.

References

1. Islamov, I., et al. The use of unmanned systems and artificial intelligence to enhance radiation and chemical safety in military ecology. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 183–192.

2. Islamov I., et al. Innovative approaches to environmental recovery in conflict-affected areas //Матеріали конференцій МЦНД. – 2025. – №. 24.10. 2025; Житомир, Україна. – С. 180-190.

3. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116

4. Islamov, I., et al. Prospects for the use of robotic complexes in eliminating the consequences of environmental accidents at military facilities. *Матеріали конференцій МЦНД*, (07.11.2025; Дніпро, Україна), 301–311.

5. Rustamli B. et al. Prospects and challenges of bio-nano remediation of military-contaminated lands //Матеріали конференцій МЦНД. – 2025. – №. 24.10. 2025; Житомир, Україна. – С. 227-237.

6. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.

7. Rustamov, A., et al. Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.

8. Hashimov E. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – Т. 8. – №. 3. – С. 53-58.

9. Akhundov R., Hashimov E. Enhancing the efficiency of the military environmental security system through the implementation of advanced technical means //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2025. – №. 8. – С. 348-352.

10. Garayev, M.F. (2025). Balancing innovation and sustainability: the ecological risks of modern technologies. *Collection of Scientific Papers «SCIENTIA»*, (September 12, 2025; Sydney, Australia), 52–59.

ASSESSMENT OF RIVER NATURAL REGULATION FOR INTENSIVE IRRIGATION ON THE SOUTHERN SLOPE OF THE GREATER CAUCASUS

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This study examines the natural regulation level of rivers and the seasonal distribution of runoff during the intensive irrigation period on the southern slope of the Greater Caucasus, one of the most water-rich regions of Azerbaijan. The relevance of the topic is determined by the increasingly acute contradiction between declining water availability and growing water demand in a country located in an arid and semi-arid climatic setting. In Azerbaijan, river waters constitute the main part of freshwater resources, yet a substantial share of these resources is formed outside national borders. At the same time, both transboundary inflow and locally generated runoff have been declining under the combined influence of climate change and increasing upstream water withdrawal. This situation significantly reduces the reliability of water supply and intensifies the need for a more precise hydrological assessment of how river runoff is distributed within the year. In practical terms, annual runoff volume alone is not sufficient for evaluating the usefulness of river waters. For irrigation-dependent economies, the decisive factor is the extent to which runoff is naturally distributed in a favorable way during the summer months, when agricultural demand reaches its maximum.

The article is based on the premise that the natural regulation of river runoff should be understood as the degree of evenness in its intra-annual distribution. In the hydrological conditions of Azerbaijan, this issue is especially important because most rivers have a pronounced high-water regime in spring and autumn, whereas summer and winter are characterized by low flow. Consequently, a significant part of the annual runoff occurs during periods when water demand is relatively low, while the irrigation season coincides with the driest hydrological phase. This disproportion creates serious limitations for the effective use of river water and objectively strengthens the need for artificial regulation through reservoirs and other storage solutions. The study therefore does not restrict itself to a descriptive characterization of seasonal runoff, but instead evaluates the suitability of spring and summer runoff structure for irrigation use. The southern slope of the Greater Caucasus was selected as the study area because it contains some of the most important right-bank tributaries of the Kura River and represents the most favorable natural zone in Azerbaijan in terms of river water formation.

Methodologically, the research integrates hydrometeorological observations, basin characteristics, and spatial analytical tools. The primary empirical basis consists of runoff, precipitation, and air temperature data obtained from official national observation sources. Supplementary information on basin elevation, slope,

landscape structure, and other runoff-forming factors was derived from satellite materials. Missing or incomplete observation series were restored using analogy and interpolation methods, while the homogeneity of the series and the reliability of the results were verified by Fisher and Student criteria. In addition, the resulting data were refined using GIS-based procedures in ArcGIS in order to obtain basin-specific estimates for spring and summer hydrometeorological conditions. The analysis also established a strong inverse correlation between mean multi-annual air temperature and station elevation across the study area, with a reported correlation coefficient of $R = 0.96$. In contrast, the precipitation-elevation relationship was modeled separately for two hydrologically different subregions due to weaker overall coverage and spatial heterogeneity.

The central analytical indicator of the article is the ratio of summer runoff to spring runoff, expressed as Q_{sm}/Q_{sp}. This ratio is used to classify the level of natural regulation of rivers. A value greater than 1 is interpreted as a very high level of regulation, because summer runoff exceeds spring runoff. Values between 0.90 and 1.00 indicate high regulation, values between 0.75 and 0.90 indicate average regulation, values between 0.50 and 0.75 indicate low regulation, and values below 0.50 indicate very low regulation. This classification makes it possible to assess not merely how much runoff is generated, but how well it is distributed relative to seasonal irrigation requirements. The basin-scale data show pronounced differences among rivers in both hydrometeorological characteristics and runoff structure. For example, several rivers in the western part of the study region exhibit high perennial runoff and relatively balanced spring and summer runoff values, whereas some eastern rivers are characterized by very limited runoff and sharp seasonal decline during summer.

The results reveal a clear spatial regularity. Rivers located in the western sector of the study area, between the Mazym and Dashagıl basins, generally demonstrate higher levels of natural regulation. In most of these rivers, regulation falls into the high or very high category. The main explanation offered in the article is the relatively large role of groundwater in their feeding regime, which contributes to a more gradual and even seasonal release of water and allows substantial discharge to continue into the summer months. In addition, these western rivers tend to have higher average multi-year runoff volumes, which further improves their practical suitability for rational water use. Examples such as Katekh, Tala, Mukhakh, Kurmukh, and Dashagıl illustrate this more favorable hydrological structure.

By contrast, rivers located in the eastern sector, between Dashagıl and Sumqayıt, display lower natural regulation and greater vulnerability during the intensive irrigation period. In these basins, the greater role of rainwater in runoff formation causes a stronger concentration of flow during spring rainfall events, followed by a marked summer decline. Combined with lower annual runoff, this leads to weak or very weak regulation in several rivers. The most unfavorable conditions were identified in Jeyrankechmez and Sumqayıt, where the Qsm/Qsp ratio falls into the very low class. As a result, these basins experience acute summer

water shortages and have limited capacity to satisfy irrigation demand without artificial regulation measures.

Overall, the study concludes that the evaluation of river water resources for irrigation planning should not be based solely on annual runoff totals. The natural regulation level of runoff is a decisive hydrological characteristic because it determines the degree to which water availability is synchronized with the period of maximum demand. The findings show that the western rivers of the southern slope of the Greater Caucasus have a more favorable hydrological regime, whereas eastern rivers are markedly less reliable under summer irrigation conditions. This creates a strong scientific basis for differentiating river basins in water management policy and for prioritizing artificial regulation, seasonal storage, and conservation measures where natural regulation is insufficient.

References

1. Teymurov M.A. et al. Integated assessment of water resources in Azerbaijan from quantitative and qualitative perspectives // Технології, інструменти та стратегії реалізації наукових досліджень: збірник наукових праць з матеріалами XI Міжнародної наукової конференції. 2026. с. 109-120

2. Teymurov M. et al. Integrated approaches to water resource optimization in Azerbaijan. Scientific Forum: Theory and Practice of Research. Collection of Scientific Papers «SCIENTIA» 2026. p.189-198

3. Mammadov R., & Teymurov M. Assessment of water resources and risk of water losses due to climate changes and human activities. The Scientific Heritage. 2019,34-3, 3-11.

4. Makhmudov, R. et al. Regional climate changes in Azerbaijan and assessment of their impact on water resources with a new method. *Reliability: Theory &Applications*. 2024, 19(SI 6 (81)), 830-837.

5. Mammadov, G.S. et al. Climate change effects on soil fertility and moisture in the Nakhchivanchay River Basin, Azerbaijan. *International Journal of Agriculture and Biosciences*. 2026, 15(1), 77-86.

6. Teymurov, M.A. Assessment of soil-vegetation cover and water resources on the basis of modern scientific innovation. Scientific advances and innovative approaches. In *III International Scientific Conference.* 2023, (pp. 28-32).

7. Teymurov, M.A. Estimation of rivers' current water resources and prediction in the period until 2050. Materials of the international Scientific-Practical Conference. *Water resources, hydraulic facilities and environment*, 2017. 15.

8. Makhmudov, R. et al. Assessment of the water balance of the territory and rivers water resources using a new operational-interactive method. *Reliability: Theory & Applications*. 2023, 18(SI 5 (75)), 500-509.

9. Hashimov, E.G. et al. (2016). Terrain orthophotoplanes making for military objects revealing. *National security and military sciences*, *2*(4), 14-20.

10. Bayramov, A. (2016). Seismic location station for detection of unobserved moving military machineries. *Journal of Management and Information Science*, *4*(2), 61-66.

11. Bayramov, A.A. et al. The supervisory control systems deployment in mountainous terrain. In *VIII Int. Conf."Modern development trends of ICT and control methods*. 2018. (p. 3-4).

12. Hashimov, E.G. Detection unobserved moving armored vehicles by seismic method. *National Security and Military Sciences*, 2015, 1(1), 128-132.

13. Zulfugarov B. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.

14. Hashimov, E.G. About some aspects of using a flock of UAVs. *İn* Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023, 1, 4-5.

15. Nasibov, Y.A. et al. (2019). Modelling of the rationally deployment of observing systems. *Сучасні інформаційні системи*, (3,№ 2), 10-13.

16. Zulfugarov, B. S., Manafov, A., & Hashimov, E. G. (2025). Fostering a culture of sustainable use of clean and green energy sources. *In* Current directions of development of information and communication technologies and control tools. 2025, Vol. 4: sect. 6. p.66

17. Hashimov, E.G. (2013). About one method of navigation task solution. *AHMC after H. Aliyev. Scientific Review*, *1*(20), 45-49.

18. Garayev M. F. Analysis of the possibilities of the photogrammetry method in object detection / Проблеми інформатизації : тези доп. 12-ї міжнар. наук.-техн. конф. Харків: Impress, 2024.Т.2. – С. 6.

19. Garayev M. F. About one electrical compound as a source of energy //Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. – 2024. – Т. 3. – С. 117.

20. Zulfugarov B.S., et al. Multi-criteria evaluation of energy accumulation technologies for defense energy security. *In* Current directions of development of information and communication technologies and control tools. 2025.Volume 1: sections 1,5. pp.137

21. Hashimov, E.G. The flight dynamics of drones. *National security and military sciences*. 2016, 2(3), 11-16.

22. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. March 6, 2026. P.107-116

23. Teymurov M. A. et al. Geomorphological development of Inner Mountain Dagestan and some aspects of the history of its flora //South of Russia: ecology, development. – 2010. – Т. 3. – С. 39-44.

24. Makhmudov R., Teymurov M. Importance of using space information and GIS technologies in the process of selecting analogue terrains in hydrological research //Intercontinental Geoinformation Days. – 2023. – Т. 6. – С. 110-112.

25. Teymurov M., Jabrayilov E., Mammadov Z. Water balance estimation of river basins using an innovative hydrological techniques //Universidad y Sociedad. – 2026. – Т. 18. – №. 1. – С. e5273-e5273.

26. Hashimov E., Teymurov M., İsayeva R. Assessment of the natural regulation level of rivers and their runoff during intensive irrigation period. Norwegian Journal of Development of the International Science, 2026. 175, 6-12. https://doi.org/10.5281/zenodo.18840564

27. Makhmudov R., Teymurov M., Aliyev V. Assessment of the Water Balance in the Karabakh and Eastern Zangezur Regions //International Journal of Sustainability and Risk Control. – 2025. – Т. 1. – №. 2. – С. 25-30.

STAGED METHODOLOGY FOR MOVING OBJECT RECOGNITION USING UAV VIDEO STREAMS

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The recognition of moving objects from unmanned aerial vehicle video streams has become an important research and application area in surveillance, border monitoring, infrastructure protection, emergency assessment, and situational awareness systems.

The relevance of this problem is determined by the need to obtain reliable real-time information under conditions of dynamic backgrounds, changing illumination, camera motion, variable flight altitude, image blur, noise, and substantial variation in target size and appearance.

This study aims to develop and justify a staged methodological framework for recognizing moving objects using UAV-based video data, while also defining the principal performance indicators that determine system effectiveness. The proposed approach is organized as an integrated sequential pipeline that includes data acquisition, time synchronization, noise suppression, image stabilization, background modeling, motion segmentation, candidate region extraction, multi-frame tracking, feature extraction, classification, and final decision stabilization. Particular attention is given to the fact that the output of each processing stage forms the input basis for the next stage, making the overall effectiveness dependent on the coordinated performance of the entire chain rather than on any single recognition block in isolation.

The methodology combines geometric, texture, and dynamic object features, including contour characteristics, aspect ratios, edge density, motion velocity, acceleration, and trajectory behavior, and supports probabilistic classification across alternative object classes.

The study also systematizes a set of evaluation indicators, including detection probability, false alarm rate, recognition accuracy, tracking continuity, target loss probability, and latency. A formal representation of overall effectiveness as the product of stage-level probabilities is used to show that the weakest stage constrains final system performance.

The analysis demonstrates that image stabilization quality, adaptive background updating, and the relationship between flight altitude and effective spatial resolution are among the dominant factors affecting recognition results. It is further shown that dynamic features become more informative as altitude increases and object pixel size decreases, while the integration of thermal and optical channels can improve detection performance when spatial and temporal alignment is maintained.

The proposed framework provides a practical basis for comparative assessment, parameter optimization, and bottleneck identification in UAV-based moving object recognition systems operating in complex real-world conditions.

References

1. Bayramov A.A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
2. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.
3. Rustamov, A., et al. Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.
4. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
5. Hashimov E. G. et al. Development of the multirotor unmanned aerial vehicle //National security and military sciences. – 2017. – Т. 3. – №. 4. – С. 21-31.
6. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
7. Mashaev E.T. et al. System of systems at war: UAV enabled sensing and strike integration. *In* Problems of informatization. 2025.Vol. 2., section 3,7. p.112-113
8. Balayev F.R. et al. Methodology and applications of AI enabled image recognition in UAVs. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.102-103
9. Bayramov A.A., et al. Movement Dynamics of Unmanned Aircraft //Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. – 2024. – Т. 2. – С. 21-22.
10. Hashimov E. G. et al. Terrain orthophotomap making and combat control //Proceeding of Internatonal Conf."Modern Call of Security and Defence". 2016. T.19. C.68-71.
11. Atayev S.U., et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025, vol.2., sect. 3,7. p.100-101
12. Hashimov E. et al. GIS technology and terrain orthophotomap making for military application //Journal of Defense Resources Management. – 2017. – Т. 8. – №. 2. – С. 81-90.
13. Dergachov, K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment. / CEUR Workshop Proceedings. 2025. Vol.3981. P.103-114
14. Maharramov, R. et al. Application of C4ISR systems in military and security operations. *Матеріали конференцій МЦНД*, (15.08.2025; Харків, Україна), 125–134.
15. Rzayev M. et al. Problems of mathematical modeling in the swarm deployment of UAVs. *Collection of Scientific Papers «SCIENTIA»*, (August 22, 2025; Bern, Switzerland), 115–121.
16. Hasanov A.H. et al. About detecting moving objects. *In* Problems of informatization. 2025. Vol. 3. p.114-115.
17. Hasanov A.H., et al. Hybrid GIS-UAV framework for revealing concealed objects in mountainous landscapes. *In* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.60.

ACTIVE UAV TRAJECTORY CONTROL FOR RELIABLE PHOTOGRAMMETRIC 3D RECONSTRUCTION

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This article investigates an embedded, real-time control approach for unmanned aerial vehicles designed to improve image-based three-dimensional scene reconstruction. The study addresses a key limitation of conventional UAV photogrammetry workflows, where image acquisition and image processing are separated and insufficient overlap between successive images often causes reconstruction failure. The main objective is to create a low-cost UAV architecture capable of analyzing image content during flight and adaptively modifying the trajectory to preserve enough feature overlap for later photogrammetric reconstruction. By linking onboard image processing with active flight control, the framework aims to reduce disconnected models, improve reconstruction completeness, and increase the reliability of UAV-based 3D mapping.

The methodology combines embedded hardware integration, computer vision benchmarking, active control logic, and experimental validation. The UAV platform was built around a custom hexacopter equipped with a flight controller, telemetry link, high-resolution camera, low-resolution proxy camera, and a single-board embedded computer. To test whether real-time feature extraction was possible on embedded hardware, several implementations of the Scale-Invariant Feature Transform algorithm were benchmarked. A control strategy was then developed using keypoint matching ratios between sequential images. When the matching ratio dropped below a predefined threshold, the UAV backtracked to an intermediate waypoint and captured additional imagery. This mechanism was tested in both a virtual environment and real flight conditions, and post-flight 3D reconstruction was used to assess model completeness and quality.

The results show that reducing image resolution and processing low-resolution imagery onboard made real-time keypoint detection feasible. In simulation, the reference flight without active control produced six disconnected reconstruction models, whereas the threshold-based backtracking strategy generated a single unified model and increased the number of reconstructed points. Additional virtual experiments confirmed that the improvement was not caused simply by taking more images, but by correcting insufficient feature overlap at specific locations. In real-life experiments, the same principle produced a complete crown reconstruction from actual UAV imagery, while lower matching thresholds resulted in partial and fragmented models. These findings confirm that image-informed trajectory adaptation can substantially improve reconstruction reliability and model density.

The study concludes that embedded real-time vision and control can transform UAV photogrammetry from a passive acquisition process into an adaptive sensing

system. The proposed architecture offers a practical and relatively inexpensive solution for obtaining more complete 3D reconstructions, especially where repeat flights are difficult, costly, or impossible. The authors also note limitations, including dependence on predefined keypoint-matching thresholds and the computational restrictions of lightweight onboard hardware. Future work should focus on stronger onboard computing platforms, more advanced real-time estimation of reconstruction success, and further optimization of embedded visual processing pipelines.

References

1. Kovtun A., et al. *Techno* economic assessment of a hybrid solar, wind, and biomass system for suburban power supply. *Collection of Scientific Papers «SCIENTIA»*, (October 17, 2025; London, England, UK), 112–119.
2. Tabunenko, V. et al. The dynamics of UAV flight integrated with route planning. *Collection of Scientific Papers «SCIENTIA»*, (October 10, 2025; Antwerp, Belgium), 46–56.
3. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
4. Hashimov E. G., et al. Terrain orthophotomap making and combat control //Proceeding of Internatonal Conf."Modern Call of Security and Defence". 2016. Т.19. С.68-71.
5. Bayramov A. A. et al. SMART control system of systems for dynamic objects group //Bulgarska Voenna Misal.–2018. – 2018.
6. Hashimov E. G., et al. Terrain orthophotoplanes making for military objects revealing //National security and military sciences. – 2016. – Т. 2. – №. 4. – С. 14-20.
7. Bayramov A. A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.
8. Huseynov B. S. Characteristics of UAVs application during the second Karabakh war //İn Problems of informatization. – 2023. – Т. 3. – С. 10-11.
9. Hashimov E., et al. GIS technology and terrain orthophotomap making for military application //Journal of Defense Resources Management. – 2017. – Т. 8. – №. 2. – С. 81-90.
10. Muradova E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференції МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.
11. Zulfugarov B., et al. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.
12. Ibrahimov B.G. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system //Advanced Information Systems. – 2024. – Т. 8. – №. 2. – С. 58-64.
13. Hashimov E. G. About one method of navigation task solution //AHMC after H. Aliyev. Scientific Review. – 2013. – Т. 1. – №. 20. – С. 45-49.
14. Hashimov E. G. et al. Development of the multirotor unmanned aerial vehicle //National security and military sciences. – 2017. – Т. 3. – №. 4. – С. 21-31.

INTEGRATED WATER RESOURCES ASSESSMENT IN AZERBAIJAN UNDER TRANSBOUNDARY DEPENDENCE AND WATER QUALITY RISK

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Water resources in Azerbaijan represent a strategically significant component of environmental security, economic resilience, and social stability. Because the country is situated within semi-arid and arid climatic zones, and because a substantial part of its water balance depends on transboundary inflows, the assessment of water resources cannot be limited to volumetric estimates alone. It requires an integrated analytical framework capable of capturing both quantitative availability and qualitative suitability of water under conditions of climatic variability, anthropogenic pressure, and spatial heterogeneity. This study develops and applies an integrated methodological approach for assessing water resources in Azerbaijan from quantitative and qualitative perspectives, with the aim of supporting sustainable management and risk-informed decision-making. The proposed framework combines four complementary analytical blocks: quantitative assessment of basin-scale water balance, indicator-based evaluation of water quality, spatial and temporal integration within a geographic information system environment, and risk-oriented interpretation under uncertainty. Within this structure, hydrometeorological time series, runoff observations, reservoir indicators, groundwater monitoring data, and laboratory water quality results are consolidated into a unified database, preprocessed for homogeneity and completeness, and then analyzed to identify key structural determinants of water security.

The quantitative block is based on a basin-scale water balance formulation that includes precipitation, surface inflow and outflow, groundwater exchange, evaporation, anthropogenic abstraction, and storage change. Particular attention is paid to the transboundary share of runoff as a structural risk factor for national water security. Groundwater resources are evaluated through the ratio of abstraction to renewable recharge in order to identify zones of unsustainable use. The qualitative block applies a normalized indicator system based on hydrochemical parameters and an aggregated water quality index that enables inter-site and temporal comparison relative to regulatory thresholds. These indicators are then integrated spatially through GIS-based zoning and interpolation procedures to construct composite maps of water scarcity and water quality risk. The results show that Azerbaijan's water resource system is characterized by pronounced inter-basin and interannual heterogeneity. In several major basins, a high dependence on incoming transboundary flow coincides with declining internally generated runoff, increasing strategic vulnerability. At the same time, water quality assessment reveals that even where quantitative availability remains relatively stable, actual usability may be

constrained by pollution associated with industrial activity and intensive agriculture. The integrated composite risk map demonstrates that the most critical zones emerge where quantitative scarcity overlaps with qualitative deterioration. The study concludes that effective water governance in Azerbaijan requires a unified, risk-based assessment framework that jointly considers quantity, quality, spatial heterogeneity, and uncertainty. Such an approach provides a scientifically grounded basis for regional prioritization, adaptive planning, and the design of more resilient water management strategies.

References

1. Teymurov, M.A. Assessment of soil-vegetation cover and water resources on the basis of modern scientific innovation. Scientific advances and innovative approaches. In *III International Scientific Conference*. 2023, (pp. 28-32).
2. Teymurov, M.A. Estimation of rivers' current water resources and prediction in the period until 2050. Materials of the international Scientific-Practical Conference. *Water resources, hydraulic facilities and environment*, 2017. 15.
3. Mammadov R., & Teymurov M. Assessment of water resources and risk of water losses due to climate changes and human activities. The Scientific Heritage. 2019,34-3, 3-11.
4. Makhmudov, R. et al. Regional climate changes in Azerbaijan and assessment of their impact on water resources with a new method. *Reliability: Theory &Applications*. 2024, 19(SI 6 (81)), 830-837.
5. Mammadov, G.S. et al. Climate change effects on soil fertility and moisture in the Nakhchivanchay River Basin, Azerbaijan. *International Journal of Agriculture and Biosciences*. 2026, 15(1), 77-86.
6. Teymurov M.A. et al. Integated assessment of water resources in Azerbaijan from quantitative and qualitative perspectives // Технології, інструменти та стратегії реалізації наукових досліджень: збірник наукових праць з матеріалами XI Міжнародної наукової конференції. 2026. с. 109-120
7. Bayramov, A.A. et al. The supervisory control systems deployment in mountainous terrain. In *VIII Int. Conf."Modern develop. trends of ICT and control methods* 2018. P.3-4
8. Nasibov, Y.A. et al. Modelling of the rationally deployment of observing systems. *Сучасні інформаційні системи*, 2019. (3,№ 2), 10-13.
9. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
10. Hashimov, E.G. About some aspects of using a flock of UAVs. *İn* Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023, 1, 4-5.
11. Hashimov, E.G. The flight dynamics of drones. *National security and military sciences*. 2016, 2(3), 11-16.
12. Teymurov M. et al. Integrated approaches to water resource optimization in Azerbaijan. Scientific Forum: Theory and Practice of Research. Collection of Scientific Papers «SCIENTIA» 2026. p.189-198
13. Makhmudov, R. et al. Assessment of the water balance of the territory and rivers water resources using a new operational-interactive method. *Reliability: Theory & Applications*. 2023, 18(SI 5 (75)), 500-509.

APPLICATIONS AND OPERATIONAL CHALLENGES OF UAVs IN CONTEMPORARY TECHNOLOGICAL ENVIRONMENTS

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This article presents a systematic analysis of the principal application areas and operational challenges of unmanned aerial vehicles within the framework of contemporary technological development. The study is based on the premise that UAVs should not be interpreted solely as aerial platforms, but as integrated technological ecosystems combining sensor payloads, communication channels, navigation support, control algorithms, ground control infrastructure, and data processing procedures. Such a perspective makes it possible to classify UAV application domains more rigorously, reveal the causal relationships that shape their operational limitations, and outline a conceptually grounded basis for future development. The article examines the major sectors in which UAVs have become strategically important. In the military and security domain, UAVs support reconnaissance, surveillance, target detection, border observation, route assessment, and the monitoring of critical facilities, while reducing direct personnel exposure to high risk environments. In civil security and emergency management, they enable rapid situational assessment during fires, floods, earthquakes, industrial incidents, traffic accidents, and mass events by supplying real time visual and measurement data for timely decision making. In environmental monitoring and agriculture, UAVs contribute to the observation of atmospheric pollution, soil degradation, water body conditions, biodiversity patterns, and forest health, while also supporting multispectral crop analysis, yield forecasting, irrigation optimization, and the early identification of agronomic stress factors. Across all these areas, the operational value of UAVs arises from their capacity to generate spatially accurate, time sensitive, and decision relevant information.

Alongside these advantages, the study identifies a set of interrelated technical, security, legal, and ethical challenges that constrain the sustainable deployment of UAV systems. The most significant technical limitations concern energy capacity, flight endurance, payload balance, communication resilience, and navigation reliability, especially in mountainous, urban, or electromagnetically complex environments. Additional risks emerge from the vulnerability of control and data transmission channels to interference, signal manipulation, telemetry falsification, software weaknesses, and configuration failures. The article also emphasizes that legal and ethical concerns, including airspace regulation, flight authorization, registration, responsibility allocation, privacy protection, and data governance, are becoming increasingly decisive in UAV operations.

The analysis demonstrates that the effective and secure use of UAVs depends on an integrated scientific approach in which technical design, cybersecurity architecture, operational procedures, and regulatory adaptation are treated as

mutually connected elements of a single system. On this basis, the article concludes that future progress in UAV development will require not only technological advancement, but also coherent institutional frameworks capable of ensuring reliability, accountability, and long-term operational sustainability.

References

1. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
2. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
3. Bayramov A.A. Application SMART for small unmanned aircraft system of systems //Handbook of Research on Artificial Intelligence Applications in the Aviation and Aerospace Industries. – IGI Global Scientific Publishing, 2020. – С. 193-213.
4. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, 2025; Вінниця. 347–350.
5. Hashimov E. et al. Mathematical aspects of determining the motion parameters of a target by UAV //Advanced Information Systems. – 2023. – Т. 7. – №. 1. – С. 18-22.
6. Huseynov B. S. Characteristics of UAVs application during the second Karabakh war //İn Problems of informatization. – 2023. – Т. 3. – С. 10-11.
7. Rustamov, A., et al. Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.
8. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
9. Muradov S., et al. Determining the location of the UAV equipped with a homing device based on radio beacons //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 54-56.
10. Hashimov E. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – Т. 8. – №. 3. – С. 53-58.
11. Hashimov E. G., Bayramov A. A. The flight dynamics of drones //National security and military sciences. – 2016. – Т. 2. – №. 3. – С. 11-16.
12. Hashimov E. et al. Determination of coordinates of targets from unmanned aerial vehicles //Intelligence. – 2022. – Т. 2. – №. 5.
13. Zulfugarov B. et al. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.
14. Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment // Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.
15. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.
16. Javadov J. Application of UAV in the protection of state borders: GIS integration and risk management. *Матеріали конференцій МЦНД*, (15.08.2025; Харків, Україна), 115–124. https://doi.org/10.62731/mcnd-15.08.2025.003

ENHANCING OIL PIPELINE SAFETY THROUGH THE APPLICATION OF THE V-MODEL

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This article examines the application of the V-model to the protection of oil pipelines and interprets it as a structured methodological framework for improving safety, reliability, and operational sustainability. The relevance of the study is determined by the strategic importance of oil pipelines as critical infrastructure that ensures the transport of hydrocarbons over long distances and supports economic stability, environmental protection, and public safety.

Failures in pipeline systems, including leaks, cracks, corrosion, pressure anomalies, and other malfunctions, may lead not only to technical disruption, but also to large-scale environmental damage, financial loss, and threats to human life. Against this background, the purpose of the article is to show how the V-model can be applied to the design, testing, operation, and protection of oil pipelines, and to demonstrate its advantages in the early identification of risks, the detection of weak points, the organization of verification procedures, and the integration of automated monitoring technologies.

The article presents the V-model as a systems engineering approach in which each development stage is linked to a corresponding testing and validation stage. The left side of the model covers requirements analysis, system design, and development, while the right side includes verification, testing, and confirmation of performance and safety. When transferred to the field of oil pipeline protection, this logic creates the conditions for identifying safety gaps at an early stage, evaluating project decisions through parallel testing procedures, and reducing the probability of large accidents during operation. Particular attention is given to high-risk segments of pipelines, inaccessible routes, underwater sections, and areas exposed to natural hazards. In this way, the pipeline is not treated as a uniform technical line, but as a complex system composed of segments with different threat profiles and protection needs.

The practical value of the V-model is justified in three main dimensions. First, it improves risk management by enabling the early detection of leaks, corrosion, pressure instability, and related vulnerabilities through phase-based testing. Second, it supports the detailed analysis of critical points and the optimization of protection measures in structurally or environmentally sensitive sections. Third, it strengthens the role of automation by facilitating the introduction of real-time monitoring and leak detection systems capable of recording dangerous changes and supporting rapid intervention. The article also refers to practical cases, including Azerbaijan's major pipeline projects such as the Baku-Tbilisi-Ceyhan corridor, to illustrate the applicability of this approach.

The study concludes that the V-model should be regarded not only as a project management tool, but also as a methodological instrument for systematic risk

control, coordinated testing, and long-term pipeline protection. Its application contributes to safer operation, stronger environmental security, reduced accident probability, and lower long-term costs, which confirms its value for future oil pipeline protection strategies.

References

1. İsmayil İsmayil. Security and protection of Azerbaijan's oil and gas pipelines: cybersecurity and risk management approaches. *Матеріали конференцій МЦНД*, (11.07.2025; Львів, Україна), 136–144.
2. İvanchenko O., et al. Technical aspects of wind energy production. *Collection of Scientific Papers «SCIENTIA»*, (October 24, 2025; Florence, Italia), 65–72.
3. Muradova E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.
4. Kovtun A., et al.. Techno economic assessment of a hybrid solar, wind, and biomass system for suburban power supply. *Collection of Scientific Papers «SCIENTIA»*, (October 17, 2025; London, England, UK), 112–119.
5. Garayev M., et al. Wind, sun, and hydroenergy: a look into Azerbaijan's green energy future. *Collection of Scientific Papers «ΛΟΓΟΣ»*, (August 1, 2025; Seoul, South Korea), 125–133.
6. Zulfugarov B., et al. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.
7. Bakhshali V. I. et al. Hybrid energy systems in Azerbaijan: Resilience metrics and spatial constraints //Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. – 2025. – Т. 4. – С. 94-96.
8. Petrovski A. A., et al. A multi criteria AHP framework for hybrid renewable supply in suburban contexts //Problems of Informatization: Proceedings of the 13th International Scientific and Technical Conference. – 2025. – Т. 4. – С. 97-100.
9. İsmayil I., et al. G. V-model application in oil pipeline protection: risk-oriented integration and test strategies across the lifecycle. *In* Problems of informatization. 2025. Vol. 4, section 5,6. p.108-109
10. İsmayil İ. et al. System-level optimization of Azerbaijani wind projects: AEP, LCOE, and grid stability. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.138-139
11. Ismayilov et al. Ensuring the integrity and safety of pipeline infrastructure. *In* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.41
12. Suleymanov J. F. et al. Modern approaches to technical safety in oil and gas pipelines. *In* Current directions of development of information and communication technologies and control tools. 2025. -pp.40
13. Zulfugarov B. S. et al. Fostering a culture of sustainable use of clean and green energy sources. *In* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.66

HIGH-FREQUENCY ELECTROMAGNETIC COUNTERMEASURES FOR DRONE SWARM NEUTRALIZATION

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This article examines the potential of high-frequency electromagnetic field technologies as a non-kinetic means of countering drone swarms and evaluates their relevance in the context of emerging security threats. The growing use of unmanned aerial vehicles in military, civilian, and unlawful activities has significantly increased interest in swarm-based systems that can operate autonomously, coordinate collectively, and execute missions with speed, flexibility, and reduced cost. Such systems pose a serious challenge to conventional defense measures because their distributed structure, AI-supported autonomy, and dynamic communication patterns reduce the effectiveness of traditional interception methods. In response to this problem, the study investigates whether high-frequency electromagnetic interference can disrupt swarm coordination, degrade communication, and create a safer alternative to physically destructive countermeasures.

The methodological design combines qualitative and quantitative approaches in order to produce a broader and more balanced assessment. The qualitative component is based on in-depth interviews with 15 experts representing military practice, cybersecurity, drone engineering, and electronic warfare. These interviews focus on three core dimensions: operational challenges in applying high-frequency electromagnetic field technologies, existing technical limitations, and the practical principles governing their deployment against coordinated drone groups. The quantitative component is based on a structured survey of 405 respondents from military and civilian sectors. The survey is used to evaluate perceptions of the effectiveness of electromagnetic countermeasures, the performance of jamming techniques, the feasibility of reprogramming-related approaches, and the most important practical barriers affecting implementation. This mixed methodological framework enables the study to connect expert judgment with a broader empirical perception of technological applicability.

The preliminary findings indicate that high-frequency electromagnetic field technologies have substantial potential for disrupting drone swarms by weakening communication links, reducing coordination, and interfering with navigation and control channels. Their principal advantage lies in the possibility of neutralizing a swarm without relying on direct physical destruction, which is especially important in densely populated or infrastructure-sensitive areas. The study highlights jamming as one of the most effective mechanisms within this technological category, particularly when adaptive and real-time responsive systems are used. The reported results also show variation in effectiveness depending on drone type, signal

architecture, speed, and protective communication protocols, which suggests that counter-swarm measures must remain flexible and threat-specific.

The article concludes that high-frequency electromagnetic technologies represent a promising direction in counter-swarm defense, but their effectiveness depends on continued technical refinement, improved signal recognition, and the development of faster and more adaptive interference systems. Further research is recommended on power intensity, frequency selection, and real-time tracking and analysis tools in order to strengthen future operational capability.

References

1. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
2. Muradov S., et al. Determining the location of the UAV equipped with a homing device based on radio beacons //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 54-56.
3. Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment // Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.
4. Rustamov, A., et al. Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.
5. Hashimov E. G. About one method of navigation task solution //AHMC after H. Aliyev. Scientific Review. – 2013. – Т. 1. – №. 20. – С. 45-49.
6. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
7. Bayramov A.A. Application SMART for small unmanned aircraft system of systems //Handbook of Research on Artificial Intelligence Applications in the Aviation and Aerospace Industries. – IGI Global Scientific Publishing, 2020. – С. 193-213.
8. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.
9. Hashimov E. et al. Mathematical aspects of determining the motion parameters of a target by UAV //Advanced Information Systems. – 2023. – Т. 7. – №. 1. – С. 18-22.
10. Huseynov B. S. Characteristics of UAVs application during the second Karabakh war //İn Problems of informatization. – 2023. – Т. 3. – С. 10-11.
11. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
12. Hashimov E. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – Т. 8. – №. 3. – С. 53-58.
13. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.
14. Zulfugarov B. et al. Comparative analysis of the efficiency of various energy storages //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 42-45.

SECURING UAV MISSIONS IN CRITICAL INFRASTRUCTURE UNDER ENERGY AND LATENCY CONSTRAINTS

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This study examines the security of unmanned aerial vehicles deployed in critical infrastructure missions under conditions of limited onboard energy, constrained computation, strict timing requirements, and exposure to multilayer attack surfaces. The article starts from the premise that UAV security can no longer be treated as a narrow problem of communication protection or software hardening, because these platforms now function as cyber physical decision nodes in energy monitoring, pipeline inspection, logistics supervision, emergency communications restoration, border surveillance, agricultural diagnostics, and special purpose operations. In such missions, the attack surface extends across hardware supply chains, telemetry and control links, remote identification mechanisms, artificial intelligence models, swarm coordination protocols, and digital records. The main objective of the study is to reconstruct this security problem through an integrated and mission oriented framework and to develop an evaluation model that jointly considers protective effectiveness, energy burden, latency, resilience, implementation maturity, and digital evidentiary value.

The methodological contribution of the article is an integrated risk resilience model in which the utility of a security mechanism is assessed not only by its ability to reduce threats, but also by its operational cost and evidentiary relevance. Security quality is decomposed into hardware and physical protection, communication and network protection, algorithmic resilience, and swarm decision reliability. This structure is combined with an explicit energy constraint showing that the energy consumed by security mechanisms must not undermine the minimum flight duration required for safe mission completion. The model also incorporates a risk indicator based on threat probability, vulnerability, and consequence severity, and introduces an implementation maturity coefficient that differentiates between simulation validation, hardware loop testing, and real platform verification. In parallel, digital evidence preparedness is evaluated through record immutability, time stamping reliability, traceability between commands and telemetry, and export standardization.

The results show that optimal security decisions differ across mission domains. In agricultural applications, data integrity and anomaly detection are central. In energy infrastructure missions, communication protection, immutable logging, and evidence preservation become dominant because manipulated telemetry may trigger cascading failures. In logistics and emergency response, lightweight authentication and secure fallback control are preferable due to the tradeoff among energy use, latency, and agility. In military and special purpose missions, anti capture measures,

signal jamming resistance, agile key renewal, and swarm trust monitoring become priorities. The study concludes that UAV protection for critical infrastructure should be designed as an adaptive, risk oriented, and evidence aware architecture that balances security strength with operational suitability rather than maximizing isolated safeguards.

References

1. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.
2. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116
3. Javadov J. Application of UAV in the protection of state borders: GIS integration and risk management. *Матеріали конференцій МЦНД*, (15.08.2025; Харків, Україна), 115–124. https://doi.org/10.62731/mcnd-15.08.2025.003
4. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
5. Bayramov A.A. Application SMART for small unmanned aircraft system of systems //Handbook of Research on Artificial Intelligence Applications in the Aviation and Aerospace Industries. – IGI Global Scientific Publishing, 2020. – С. 193-213.
6. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350.
7. Hashimov E. et al. Mathematical aspects of determining the motion parameters of a target by UAV //Advanced Information Systems. – 2023. – Т. 7. – №. 1. – С. 18-22.
8. Huseynov B. S. Characteristics of UAVs application during the second Karabakh war //İn Problems of informatization. – 2023. – Т. 3. – С. 10-11.
9. Rustamov, A., et al. Application of artificial intelligence in the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.
10. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
11. Muradov S., et al. Determining the location of the UAV equipped with a homing device based on radio beacons //Modeling, Control and Information Technologies: Proceedings of International scientific and practical conference. – 2023. – №. 6. – С. 54-56.
12. Hashimov E. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – Т. 8. – №. 3. – С. 53-58.
13. Hashimov E. G., Bayramov A. A. The flight dynamics of drones //National security and military sciences. – 2016. – Т. 2. – №. 3. – С. 11-16.
14. Hashimov E. et al. Determination of coordinates of targets from unmanned aerial vehicles //Intelligence. – 2022. – Т. 2. – №. 5.
15. Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment // Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.

ISSUES REALTED TO THE PLACEMENT OF LOGİSTİCS CENTERS İN THE PROCESS OD TROOP REDEPLOYMENT

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Modern military logistics represents a complex, multi-layered system that ensures the continuous operational readiness of armed forces under both peacetime and wartime conditions.

One of its most critical components is the logistics infrastructure, which integrates procurement, transportation, storage, maintenance, and distribution processes into a unified framework.

In the context of troop redeployment, the importance of optimally locating military logistics centers (MLCs) increases significantly. Changes in troop deployment patterns alter transportation routes, supply chains, and maintenance requirements, thereby affecting both capital investments and operational efficiency.

Unlike civilian logistics systems – where profitability and return on investment are the primary criteria – military logistics focuses on ensuring combat readiness, minimizing response time, and maintaining sustainability under uncertain and dynamic conditions [1]. Therefore, classical economic indicators are insufficient, and alternative performance metrics must be introduced [2-6].

This study proposes a cost-oriented economic–mathematical model aimed at determining the most efficient location of an MLC by considering both capital expenditures and annual operational costs, as well as introducing a relative cost indicator per unit of equipment.

Capital investment model. The total initial investment required for establishing a logistics center can be expressed as a function of several infrastructure components. Let the total capital investment be denoted by:

$$K = \beta_C \cdot (K_D + K_T + K_W + K_G + K_P + K_F + K_M + K_S), \quad (1)$$

where: K – total capital investment, K_D – capital investment, K_T – real estate and construction cost, K_W – water supply and sewage system costs, K_G – gas supply system costs, Power supply (K_P), K_F– fuel station infrastructure costs, K_M – machinery and maintenance equipment costs, K_S – security and surveillance system costs, β – contingency coefficient (typically β = 1.05)

This formulation allows flexibility in evaluating two alternative scenarios: construction of new facilities and reconstruction of existing infrastructure.

Production costs model. Annual repair plans regulate fleet readiness by tracking usage and defining maintenance and spare parts needs [7]. The logistics center manages procurement, storage, delivery, and repairs, with costs reflecting overall resource use. A rotation principle ensures balanced workload and quarterly supply deliveries [8].

Annual operating costs consist of several interrelated components associated with logistics processes.

1. Transportation of spare parts. Let the total transported mass of spare parts and materials be:

$$W = \sum_{k=1}^{4} \sum_{i=1}^{N} \sum_{j=1}^{J} w_j r_{ikj} b_{ikj} a_{ik}, \quad (2)$$

where: w_j – weight of item j, r_{ikj} – quantity required, b_{ikj} – usage indicator, a_{ik} – maintenance plan indicator. The transportation cost is then:

$$Z = (\gamma + d \cdot \delta) \cdot W, \quad (3)$$

where γ – cost per ton from central depot to terminal, δ – cost per ton-km, d – distance to logistics center.

2. Delivery to military units. Mobile repair in military logistics improves efficiency by servicing equipment on-site, reducing transport needs and preserving machinery. This requires optimized routing of repair teams. The task is modeled as a Traveling Salesman Problem (TSP), aiming to find the most efficient routes [9-22]. Route selection considers not only distance but also terrain, road conditions, and security, ensuring reliable support and combat readiness. Once the optimal route has been determined the total expenditure required for transportation (T_1) can then be calculated:

$$T_1 = \sum_{s=1,2,\ldots} \{c_s d_s \cdot \sum_{k=1}^{2} \sum_{i \in G_s} \sum_{j=1}^{J} w_j r_{ikj} b_{ikj} a_{ik}\}, \quad (4)$$

where: G_s – set of equipment in unit s, d_s – distance to unit s, c_s – transportation cost coefficient.

3. Mobile repair teams. Organizing technical services also requires deploying mobile repair teams. The number of trips depends on the amount of equipment at each unit. The total transportation cost T_2 can be expressed accordingly.

$$T_2 = 2 \cdot c_b \cdot \theta \cdot \sum_{s=1,2,\ldots} \{u_s \cdot \sum_{k=1}^{2} \sum_{i \in G_s} a_{ik}\}, \quad (5)$$

where: c_b – cost per km for personnel transport, θ – proportionality factor, u_s – route distance.

4. Evacuation costs. A key operational task is transporting equipment needing medium or major repairs to the MLC. In peacetime, about 35% of vehicles (φ_1) require evacuation due to loss of mobility, while armored equipment is always transported (φ_2=1.00) to preserve engine life [12]. Annual evacuation costs (T_3) depend on the distance to the MLC (u_s) and the number of units, reflecting the high resource demands of heavy equipment transport.

$$T_3 = \sum_{s=1,2,\ldots} \left\{u_s \cdot \left[\sum_{i \in G_s^{(1)}} \varphi_1 + \sum_{i \in G_s^{(2)}} \varphi_2\right]\right\}, \quad (6)$$

where: φ_1, φ_2 – evacuation coefficients for different equipment types

5. Total annual operating cost. The total annual production costs (Y) of the MLS are calculated by summing operational, transportation, depreciation, and payroll expenses. Contingency coefficients (μ_P, $\mu_M \approx 1.4$) are included to account for unforeseen repairs and additional costs. This integrated model ensures financial stability by covering both fixed and variable expenses, allowing the MLS to operate effectively under changing conditions.

$$Y = \mu_P \cdot (Z + T_1 + T_2 + T_3) + A_T + \mu_M \cdot (W_1 + W_2 + W_3)\,, \qquad (7)$$

where: A_T– depreciation costs, W_1, W_2, W_3 – labor costs, μ_P, μ_M – risk coefficients.

The study concludes that the effective placement of a MLC cannot be determined through a narrow focus on cost minimization.

Instead, it requires a comprehensive evaluation framework that integrates capital and operational expenditures with critical spatial and infrastructural variables.

By unifying these expenditures into a single analytical structure, the proposed economic–mathematical model introduces a relative cost indicator per unit of equipment.

This metric provides a more accurate measure of efficiency in military contexts than traditional commercial profitability markers.

Key contributions and practical implications of the research include:

– geographical and infrastructural optimization: The model explicitly incorporates distance, transport infrastructure quality, and routing conditions into its cost functions. This allows for the minimization of both transportation outlays and long-term maintenance costs, ensuring the logistics system remains resilient under varying operational pressures;

– strategic decision support: The approach serves as a robust decision-support tool for defense planners. It enables the objective comparison of alternative locations based on economic and geographic criteria, directly enhancing operational readiness and significantly reducing non-combat losses related to logistics delays;

– integrated resource management: The framework provides a structured basis for balancing competing priorities – economic efficiency, environmental impact, and national security requirements – within a single planning phase.

Ultimately, the results underscore that geographically informed decision-making and the application of specialized performance indicators are essential for developing a modern, cost-effective, and highly responsive military logistics infrastructure.

This adaptation of classical modeling to military-specific constraints ensures that logistics remains a strategic enabler rather than a bottleneck.

References

1. Ruda, R.V. An analysis of the effective operation of an enterprise: Necessity and methodology, Visnyk Berdyanskkoho unyversitetu menedzhmentu i biznesu, № 4 (20), pp.109-111 (2012)

2. Zeimpekis, V, Kaimakamis, G, Nicholas J. Daras. Military Logistics. Research Advances and Future Trends, p.180. Springer, Switzerland (2015)

3. NATO Logistics Handbook, 2012.

4. Hari, Bucur-Marcu, Philip Fluri and Todor Tagarev, Defence management: An introduction. Security and defence management series, №1, p.200. Geneva, Kyiv (2011),

5. Pînzarıu S., Mînea C.D. The Military Units' Logistic Support Principles. *Land Forces Academy Review* Vol. XXIV, № 1(93), pp.20-28 (2019).

6. Wan Jiea, Wang Wenb, Research on 6R Military Logistics Network, Physics Procedia 33, pp.678–684 (2012).

7. Talibov, A.M. The planning model of activity of the auto technical support system, Modern trends of development and communication technologies and management tools, Abstrsct of the tenth international scientific conferevce. 2020, vol 1, section 1, №2 p.7

8. Talibov, A.M. Methodology for determaining the location of warehouses in the logistics system of automative technical support of the troops, pp.12–24, Hərbi icmal №1, Baku (2019)

9. Smirnov, I.M., Kosareva, T.M, Transports logistics. Study guide, p.224 (2018), in Ukrainian

10. Seraya, O.V. The fuzzy traveling salesman problem, Mathematics modeling, № 2 (17), pp.13-15 (2007), in Russian

11. Kolesnikov, A.V., Kirikov, I.A., Listopad, S.V., Rumovskaya, S.B. and Domanitsky, A.A. Solving complex traveling salesman problems by methods of functional hybrid intelligent systems, ed. A.V. Kolesnikov, p.295, IPI RAN, Moscow, (2011).

12. Tarasenko, P.N., Repair of military vehicles, textbook, BNTU, Minsk, 258 p., (2018), available at: https://www.rep.bntu.by›Remont_voennoj_avtomobilnoj_tekhniki

13. Talibov A. M. et al. On the optimal placement of logistics centers //Baku: Informatics and Control Problems,(43). – 2023. – С. 51-58.

14. Hashimov E., Talibov A., Iskandarov K. The Socioeconomic Impact of the Zangezur Corridor on the South Caucasus Region //Social Development and Security. – 2025. – Т. 15. – №. 4. – С. 1-18.

15. Talibov A.M. et al. On the issue of determining the optimal location of prospective logistics centers. *In* Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. 2024. Vol. 2. -p.21.

16. Salmanov, E. Et al. (2025). Ways to ımprove logıstıcal support ın the Azerbaıjanı army. *Collection of Scientific Papers «SCIENTIA»*, (October 17, 2025; London, England, UK), 88–95.

17. Hashimov , E. Et al. (2026). Research of the efficıency multıservıce networks usıng MIMO technology. *Advanced Information Systems*, *10*(1), 66–71. https://doi.org/10.20998/2522-9052.2026.1.08

18. Talibov A.M. et al. Estimation of transport costs in the process of military logistics. *In* Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. 2024. Vol. 3. p.140-141.

19. İsmayil, İsmayil (2025). Securıty and protectıon of Azerbaıjan's oıl and gas pıpelınes: cybersecurıty and rısk management approaches. *Матеріали конференцій МЦНД*, (11.07.2025; Львів, Україна), 136–144. https://doi.org/10.62731/mcnd-11.07.2025.004

20. Ibrahimov B.G. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system //Advanced Information Systems. – 2024. – Т. 8. – №. 2. – С. 58-64.

21. Talibov A.M. et al. Mathematical aspects of calculation of transport costs. *In* Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. 2024. Vol. 2. p.17-18.

22. Hazarkhanov U.A. et al. Evaluation of the effectiveness of autotechnical support planning and management. *In* Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. 2024. Vol. 3. -p.119-120.

THE FORMATİON AND DEVELOPMENT OF MİLİTARY LEXİCON İN THE CONTEXT OF TURKİC–SLAVİC LANGUAGE RELATİONS

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Language is one of the most important indicators of the historical and cultural development of nations. İn particular, the lexical system of a language is among the areas where the mutual influence between different languages is most clearly reflected. Military lexicon holds special significance in this context, as socio-political relations, conflicts, and military alliances between nations further strengthen linguistic interactions. As a result of the existing socio-political and historical-cultural ties between the Azerbaijani language and Slavic languages, a number of shared lexical units have taken a place in the vocabulary of these languages. Notably, these shared lexical units are predominant in the field of military terminology. A large portion of the common words in the military lexicon of Slavic and Azerbaijani languages consists of Turkmen-origin lexical units. These words have entered the Slavic languages either directly or through intermediary languages.

Linguistic relations between Turkic and Slavic peoples. İn all cases, the historical and cultural relations between the Turkic and Slavic peoples are among the factors that directly influenced their languages. According to M. Tekeli, the massive influx of words from Turkic languages into the Slavic languages – such as *ataman*, *bayraq*, *kurqan*, *divan*, *yasavul*, *yarlıq*, *yanıçar*, etc.—began between the 1st and 8th centuries [3, 5], and the lexical units of that period reflected all aspects of the cultural and social way of life: "…a vast number of Turkic-origin words have been used for a long time both as 'building materials' and as 'sources of imagery,' conditioned by the historical-political and literary-cultural context, reflecting actual historical events" [3]. The linguistic phenomenon of words of Turkic origin becoming common vocabulary in Slavic languages as a result of historical processes is confirmed by linguistic facts such as *arshin*, *baraban*, *burun*, *çalma*, *qandal*, *qaytan*, *nabat*, *tabun*, *tabor*, *yarlıq*.

Turkic languages serve Slavic languages not only as a source of loanwords but also as an undeniable means influencing word formation from various directions: *baş*, *karaul*, *sultan*, *tabun* are among the lexical units actively affecting the word-formation processes in Slavic languages. At the same time, words such as *bahadur*, *əsgər*, *qundaq*, *karaul*, *kurqan*, *katorqa*, *köşk*, *jilet*, *nabat*, *sultan*, *tabor* , *talan*, *tarif*, *rota*, *neft*, *meydan*, *yarlıq*, *şerenqa*, *sultan*, *yasavul*, *yançar* are considered Turkic-origin words actively used in Slavic languages.

İn Slavic languages, particularly in Ukrainian, one can encounter Turkic-origin words from various thematic groups, which attract attention with their lexical-semantic features. Within the vocabulary of Slavic languages, Turkic-origin lexical units related especially to the military sphere are widely distributed.

Turkic-origin military lexical units in slavic languages. The lexical unit *bahadur* is considered to belong to the Turkic languages and has maintained active usage. According to M. Tekeli, in Bulgarian, the word appears in the phonetic form

багатур, denoting a rank or title, while in some Slavic languages it is used in the phonetic form *богатырь* to mean "fairy-tale hero." This represents an interesting example of the semantic development of the word. The researcher notes that when the term *bogatyr* acquires a figurative meaning, unlike in Turkic languages, it conveys moral qualities and feminine nobility, rather than the meanings "warrior," "valiant," or "hero" [3]. Furthermore, the word *bahadur*, in its Slavic form *богатырь*, has partially adapted phonetically to the graphic system of Slavic languages.

The lexical unit *Ertaul* denotes the "front part of the army" and has also appeared in the phonetic forms *ertoul* and *irtoul*, of Turkic origin. According to Y. Mammadli, it is derived from the word *yeravul* (Mongolian: *mangolay*), which referred to the second military unit in the Oghuz army structure [1]. The lexical unit originally denoted a reconnaissance detachment moving at the front of the troops and was, at one time, an active term in the military terminology of Slavic languages. Based on research, M. Tekeli has shown that this military term developed under Mongol-Tatar influence and underwent transformation into the forms *яртаул~ертаул* [3]. The word *gorda*, used by Turkic peoples, refers to a "type of cutting cold weapon." It appeared in the phonetic form *Кордъ* in Ukrainian and Polish. In the phonetic forms *Korda* and *harda* in Polish and Serbian, it was used with the same meaning, demonstrating once again that the Turkic-origin lexical unit functioned as an active etymon in the Slavic languages [3].

Karaul is one of the ancient Turkic-origin military lexical units, which entered Slavic languages and distinguished itself through active usage. In the language of early Turkic written monuments, it appeared in the phonetic form *karağu* with approximately similar meanings [2]. This lexical unit in Slavic languages functioned not only as a loanword but also as an active term participating in the word-formation process: in Azerbaijani, the word denotes "guard" or "protection," while in Slavic languages it appears in the form *караул*, conveying the meanings "guard detachment" as well as "sentry duty."

The lexical unit *Nabat* has been used in both Azerbaijani and Slavic languages to denote a military signal. Among the Turkic-origin lexical units widely disseminated in Slavic languages, *nabat* as a signal stands out. It is considered a Turkic-origin word that entered the Slavic languages. In these languages, this lexical unit conveys a military meaning, specifically "alarm signal." Researchers note that in one of the Slavic languages, the lexical unit appeared in the form *набат* and later acquired figurative meanings such as "gossiping," "chattering," or "making a commotion" [3]. The word *Nişan* also belongs to the military lexicon, used to denote a "target." In Slavic languages, it underwent phonetic changes, taking the form *мишень*. Found in the dictionaries of 11th-century Turkic languages, *nişan* is considered an ancient Turkic word. Research suggests that it may have entered Slavic languages in the 14th century in the phonetic form *нишень*. In Serbian, it appears as *мишан* and even in the same phonetic form as in Azerbaijani, *нишан* [3]. One of the active units of military terminology, the word *tabur*, is considered, in terms of origin, a lexical item of Turkic provenance, but it has also been actively used in the Ukrainian language. In Turkish, the phonetic form *tabur* conveyed the

meaning “camp surrounded by wagons,” while in Crimean Tatar it expressed the meaning “Turkic camp” in the same phonetic form [4]. Thus, the lexical item *tabur*, used in Azerbaijani in this form, initially denoted “camp,” whereas in Slavic languages it came to be used in the sense of “military unit” or “company.”

The word *şerenka* existed in the Turkic languages in the phonetic form *çerqa* and later entered Polish in the phonetic form *çereq*. Research indicates that it also transferred into Hungarian and Russian in various phonetic forms and has been reflected as an actively used lexical unit in the form *шеренга* [3]. It is actively used in contemporary military terminology to denote “military formation.”

The lexical item *yasavul* was transferred from Slavic languages into the Ukrainian language as an active lexical unit in the phonetic form *єсаул*, expressing the meaning “rank.” In scholarly literature, researchers have offered various hypotheses regarding this lexical item: M. Təkləli suggested that the etymology of the word derives from the term *yasa* in the sense of “law,” whereas Y. Məmmədli proposed that in the fifth army unit of the Oghuz, soldiers were designated as *yasavul* [1]. Moreover, lexical units such as *ataman* and *praporşik*, which are used in both Azerbaijani and Slavic languages, denote military service ranks and are notable in terms of their formation and cross-linguistic semantic exchange. The word *ataman* is one of the Turkic-origin lexical units employed in Slavic languages, based on the root *ata* (“father”). The Slavic words *parpor* and *porfiri*, i.e., *praporşik*, originate from the reduplicative forms *pur-pur* or *par-par*, meaning “person with the lowest officer rank.” It is the equivalent of the Slavic-derived word *gizir*, which has gained functional currency in Azerbaijani through linguistic utilitarianism [1].

Turkic and Slavic language contacts and the formation of shared military lexicon. İn the lexicon of Slavic languages, Turkic-origin words with military connotations occupy a distinct place, exhibiting diverse semantic and phonetic characteristics. These Turkic-derived words enrich the recipient language’s lexicon, regardless of whether their phonetic form or meaning closely corresponds to the source language. Such lexical units in military terminology not only expand the vocabulary of a language but also reflect the historical connections that existed among different peoples. Consequently, historical and cultural interactions between peoples inevitably leave their mark on their languages. Loanwords present in the lexicons of Turkish and other language groups facilitate linguistic interconnections and contribute to the formation of a shared vocabulary. The study of common military lexicon holds significant scholarly value both in linguistics and historical research.

References

1. Memmedli, Y. *Military Lexicon of the Azerbaijani Language*. Baku: University Publishing House, 1997. 132 p.

2. Shukurov, Ə.C., Meherremov, A.M. *The Language of Ancient Turkic Written Monuments*. Baku: API, 1976, p. 71-83.

3. Tekleli, M. *Turkish Words in the Russian Language*. Baku: “Nurlar” Publishing and Printing Center, 006. 272 p.

4. Radlov, V.V. *An Attempt at a Dictionary of Turkic Dialects.* St. Petersburg: Eastern Literature Publishing, Vol. 1, Part 1, 1893. 968 p.

THE ROLE OF TOLUENE IN THE MODERN MILITARY INDUSTRY: ENVIRONMENTAL RISKS OF EXPLOSIVE MATERIALS

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Toluene is one of the most important aromatic hydrocarbons used in chemical industry and military technology. It serves as a key raw material in organic synthesis and in the production of various strategic compounds. One of the most important products derived from toluene is trinitrotoluene (TNT), which is among the most widely used explosives in the world. TNT was first synthesized in 1863 by the German chemist Julius Wilbrand through the nitration of toluene with nitric acid. Initially, it was used as a yellow dye in the textile industry. However, with the development of detonator technology in the late nineteenth century, TNT began to be widely used as a military explosive. Due to its high chemical stability, resistance to moisture, and relatively low sensitivity to mechanical impact, TNT became a preferred explosive material for artillery shells and other military ammunition.

Synthesis and Properties of TNT

TNT is produced through the stepwise nitration of toluene. The process typically occurs in several stages, beginning with the formation of mononitrotoluene and dinitrotoluene, and finally producing 2,4,6-trinitrotoluene. These reactions are usually carried out using a mixture of nitric and sulfuric acids. Physically, TNT is a yellow crystalline substance with a melting point of approximately 81.6°C. It is practically insoluble in water and relatively insensitive to mechanical shock or friction. TNT can detonate underwater and has a detonation velocity of approximately 6900 m/s. These properties make TNT particularly suitable for use in military munitions. It can also be used in mixtures with other explosives, such as RDX or ammonium nitrate, to enhance explosive performance.

Applications of TNT

TNT has been widely used in both military and civilian sectors. In military applications, it is commonly used as a filling material in artillery shells, bombs, mines, grenades, and rocket warheads. Its stability allows long-term storage in ammunition depots. In civilian industries, TNT is used in mining operations, quarrying, tunneling, and controlled demolitions. Additionally, TNT serves as a reference standard for measuring the explosive power of other explosives, commonly known as the "TNT equivalent".

Environmental risks

Despite its technological advantages, TNT poses significant environmental risks. TNT residues can contaminate soil and groundwater, especially in military training areas, ammunition production facilities, and former battlefields. In the environment, TNT undergoes chemical and biological transformations that produce various metabolites, including aminodinitrotoluenes and other derivatives. Some of these compounds may be even more toxic and mobile in the environment.

TNT and its degradation products can negatively affect aquatic organisms such as fish and invertebrates. Additionally, TNT contamination can disrupt soil microbial

communities and inhibit plant growth. In some cases, these compounds may accumulate in sediments and enter the food chain. Human exposure to TNT-contaminated environments may occur through soil, water, or industrial contact. Studies have shown that prolonged exposure may cause hematological disorders, liver damage, and other health problems. The research demonstrates that TNT has played a significant role in both military and industrial applications due to its stability and effective explosive properties. However, its production, storage, and use may result in environmental contamination and potential health risks.

Therefore, it is essential to strengthen environmental monitoring in contaminated areas and develop safer alternative explosive technologies. Future research should focus on environmentally friendly formulations and effective remediation methods for TNT-contaminated sites.

References

1. Meyer R., Köhler J., Homburg A. Explosives. Wiley-VCH, Weinheim, 2007.
2. Urbanski T. Chemistry and Technology of Explosives. Pergamon Press, Oxford, 1984.
3. Yinon J. Toxicity and Metabolism of Explosives. CRC Press, Boca Raton, 1990.
4. Singh S., Kulkarni P., Bhasin V. Environmental fate of TNT in contaminated soils. Journal of Hazardous Materials, 2015.
5. ATSDR. Toxicological Profile for Trinitrotoluene (TNT). U.S. Department of Health and Human Services, 2018.
6. Pennington J., Brannon J. Environmental fate of explosives. Environmental Science & Technology, 2002.
7. Гашимов Э. Г., Байрамов А. А. Пьезоэлектрических композиты для разработки на их основе приемно-передающих акустических антенн //Евразийский Союз Ученых. – 2015. – №. 5-3 (14). – С. 38-40.
8. Garayev M. F. et al. Application of composite materials for military purposes //Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. – 2024. – Т. 3. – С. 25.
9. Amanov Y. K. et al. Tribological characterization of surface layer hardness and wear resistance under abrasive scratching //International Journal on Technical and Physical Problems of Engineering. – 2025. – Т. 17. – №. 3. – С. 414-420.
10. Garayev M. F. About one electrical compound as a source of energy //Problems of informatization. Proceedings of 12-th International Scientific and Technical Conference. – 2024. – Т. 3. – С. 117.

ARTIFICIAL INTELLIGENCE AND INTERNATIONAL HUMANITARIAN LAW: LEGAL REGULATION OF ARTIFICIAL INTELLIGENCE IN ARMED CONFLICTS

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Artificial intelligence (AI) technologies are rapidly developing in the contemporary era and are increasingly being applied across various fields, including

security and military domains. In particular, autonomous weapon systems, combat drones, and other robotic technologies possess the potential to replace human decision-making in armed conflicts. This development makes the application of AI in armed conflict not only a technological innovation but also a source of serious legal and ethical challenges for international humanitarian law (IHL). International humanitarian law constitutes the primary normative framework aimed at limiting and regulating the use of violence against civilians and combatants during armed conflicts. The core principles of IHL—proportionality, distinction, and precaution—form the legal foundation of military operations. However, while these principles have traditionally been developed on the basis of human decision-making, autonomous systems may partially or fully exclude the human factor from decision-making processes. This creates the necessity to reconsider existing legal frameworks.The aim of this article is to analyze the compatibility of artificial intelligence applications in armed conflicts with international humanitarian law norms, identify legal challenges, and demonstrate, on a scientific basis, the prospects for international legal regulation.

Theoretical Framework: International humanitarian law is an integral part of human rights law and the international security system. The principles of IHL—proportionality, distinction, and precaution—ensure maximum protection for civilians during the planning and execution of military operations. This principled approach has traditionally been based on human judgment and responsibility [1]. The legal status of artificial intelligence is widely debated in international legal scholarship. Autonomous weapon systems (LAWS—Lethal Autonomous Weapon Systems) are capable of selecting and engaging targets without direct human control. This raises a fundamental legal question: who bears legal responsibility and accountability—the system's programmer, the operator, or the state? This issue creates significant gaps in international law and demonstrates the insufficiency of existing legal mechanisms [2]. In contemporary international law doctrine, the primary debate concerning autonomous weapon systems revolves around the required level of human control. Several scholars emphasize the importance of maintaining "meaningful human control." According to this view, retaining final human decision-making authority in target selection and engagement is essential for safeguarding the fundamental principles of international humanitarian law [3].

Application of Artificial Intelligence in Armed Conflicts: AI-driven systems are already being used by various states in military operations. Autonomous combat drones, robotic mobile platforms, target recognition systems, and intelligence algorithms have become integral components of modern warfare. These technologies have the potential to reduce human casualties, increase operational speed, and optimize military decision-making. However, they also generate significant legal and ethical risks. According to IHL principles, it is necessary to distinguish between civilian and military objects, take precautionary measures before attacks, and ensure proportionality in the use of force. When autonomous systems make decisions without human oversight, ensuring strict compliance with these principles becomes highly challenging [1].For instance, such systems may fail to correctly identify whether a

target is a civilian object, potentially causing significant harm to civilian populations. This is particularly problematic in urban environments and areas where irregular armed groups operate, where distinguishing between civilians and combatants is algorithmically complex. This creates a potential conflict between IHL principles and AI deployment [4].Another significant issue is the lack of transparency in AI decision-making processes. Many algorithms operate as "black boxes," making it impossible to determine the exact criteria behind specific decisions. This complicates legal accountability and post-incident investigation [5].

Legal Challenges and Regulatory Gaps: One of the most significant legal challenges associated with AI and autonomous weapon systems is the issue of accountability. Under traditional international humanitarian law, legal responsibility for unlawful acts lies with individuals and states. However, when AI systems make decisions without human intervention, determining responsibility becomes increasingly complex. It remains unclear how liability should be distributed among system programmers, operators, manufacturers, and deploying states [2].The United Nations and other international organizations have launched various initiatives to address these issues. In particular, discussions under the framework of the Convention on Certain Conventional Weapons (CCW), through the Group of Governmental Experts, aim to establish a normative framework regulating autonomous weapon systems.The primary objective of these discussions is to develop general international standards governing the use of autonomous systems [6]. Nevertheless, no unified legal framework has yet been established. Issues such as the level of human control, distribution of responsibility, ethical considerations, and legal limitations on autonomous weapons remain highly contested. Some states advocate for a complete ban on such systems, while others support conditional use [7]. Different national approaches further highlight regulatory challenges. For example, the United States extensively employs AI-enabled drones and systems but primarily regulates their compliance with IHL through domestic frameworks. China and Russia prioritize rapid military technological development while aligning legal compliance mechanisms with their national strategies.These differences among states demonstrate the complexity of achieving international harmonization [8]. The absence of unified legal standards at the regional and global levels hampers legal convergence and increases the risk of widening legal gaps in future armed conflicts.

Legal Regulation Perspectives: The establishment of a unified international legal framework for regulating artificial intelligence in armed conflicts is essential. Such a framework should define legal responsibility in the use of autonomous systems, ensure the preservation of human control, and reduce legal risks. International conventions and protocols should be adopted to strengthen ethical standards and reinforce the role of human oversight. The recognition of the "meaningful human control" principle as a binding legal norm and the restriction of fully autonomous lethal decision-making systems may be considered in such instruments [9].Through international cooperation platforms, states and international organizations should synchronize normative standards. In this regard, the United Nations, NATO, and other organizations could establish joint monitoring and

reporting mechanisms. Additionally, a specialized international tribunal or monitoring body for AI use in warfare may be created at the global level [10–19]. Furthermore, a mandatory pre-deployment legal and ethical assessment mechanism for AI-based weapon systems is recommended. States should evaluate compliance with international humanitarian law before operational deployment and report findings to relevant international bodies.

Conclusion. The study demonstrates that the use of artificial intelligence in armed conflicts is directly linked to international humanitarian law, and significant legal gaps exist in this field. The legal status of autonomous systems, the level of human control, and issues of accountability remain unresolved in international law. The rapid development of AI technologies necessitates a reassessment of existing principles of international humanitarian law. Strengthening legal frameworks, adopting unified standards, and enhancing global cooperation mechanisms may ensure the lawful and ethical application of AI. Future research should further examine the distribution of legal responsibility, international tribunal mechanisms, the principle of human control, and the application of ethical standards to artificial intelligence systems.

References

1. Dinstein, Y. (2016). *The conduct of hostilities under the law of international armed conflict* (3rd ed.). Cambridge University Press.

2. Schmitt, M. N. (2013). Autonomous weapon systems and international humanitarian law: A reply to the critics. *Harvard National Security Journal, 4*, 1–37.

3. Roff, H. M. (2016). The strategic robot problem: Lethal autonomous weapons in war. *Journal of Military Ethics, 15*(3), 211–227.

4. Sharkey, N. E. (2012). The inevitability of autonomous robot warfare. *International Review of the Red Cross, 94*(886), 787–799. https://doi.org/10.1017/S1816383112000228

5. Boulanin, V., & Verbruggen, M. (2017). *Mapping the development of autonomy in weapon systems*. Stockholm International Peace Research Institute (SIPRI).

6. United Nations. (2021). *Report of the Group of Governmental Experts on Emerging Technologies in the Area of Lethal Autonomous Weapons Systems*.

7. United Nations Office for Disarmament Affairs. (2019). *The weaponization of increasing autonomy in weapon systems*.

8. European Parliament. (2020). *Artificial intelligence in military applications*. European Parliamentary Research Service.

9. International Committee of the Red Cross (ICRC). (2019). *Artificial intelligence and machine learning in armed conflict: A human-centred approach*.

10. NATO. (2021). *NATO Artificial Intelligence Strategy*.

11. Bayramov A.A. et al. Unmanned aerial vehicle applications for military GIS task solutions // Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

12. Radovanovic M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy. Системи управління, навігації та зв'язку. 2024. Т. 3. №. 77. С. 55-69.

13. Rustamov, A. et al. (2025). Applıcatıon of artıfıcıal ıntellıgence ın the command and control system of naval forces. *Collection of Scientific Papers «SCIENTIA»*, (November 7, 2025; Strasbourg, France), 103–111.

14. Bayramov A. Seismic location station for detection of unobserved moving military machineries //Journal of Management and Information Science. 2016. Т. 4. №. 2. С. 61-66.

15. Hashimov E. G. Detection unobserved moving armored vehicles by seismic method //National Security and Military Sciences. – 2015. – T. 1. – №. 1. – C. 128-132.

16. Ibrahimov B. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system // Advanced Information Systems. – 2024. – T. 8. – №. 2. – C. 58-64.

17. İskhandarov, K. et al. (2025). Artıfıcıal ıntellıgence ın logıstıcs operatıons. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 433–445.

18. Hashimov E., Khaligov G. The issue of training of the neural network for drone detection //Advanced Information Systems. – 2024. – T. 8. – №. 3. – C. 53-58.

19. İbrahimov, Ramil, et al. "Artificial Intelligence Applications in Higher Education: Prospects for Personalized Learning AND Governance Efficiency." *Grail of Science*, no. 55, 22 Aug. 2025, pp. 601-614, doi:10.36074/grail-of-science.22.08.2025.071.

THE QURAN AND ARTIFICIAL INTELLIGENCE

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The protection and storage of data as well as ensuring the reability of the source, constitute fundamental challenges within information systems. Concept such as immutability, auditability, provenance, and single source of truth constitute the core principles of modern architectures. Storage systems following the “write once, read many” paradigm, blockchain-based ledgers and cryptographic attestation mechanisms are widely employed as technical solutions to these challenges. Conversely, the Qur’an establishes some remarkable logical parallels with modern technologies, including artificial intelligence. Artificial intelligence and its associated technologies also fall within this framework. The Qur’an reflects the principles of information preservation and immutability: it is presented as the “Glorious Qur’an,” and is stated to be inscribed in the “Preserved Tablet” (al-Lawh al-Mahfuz) [1]. In classical Islamic tafsir, is interpreted as a protected, immutable, and supreme source [2].

Methodology

Comparison matrix. This tool enables a parallel representation of structural and functional characteristics. The key attributes of the theological concept are compared with analogous principles of information systems, and their correspondence is evaluated using qualitative criteria.

Modeling principles. The analysis is based on functional and structural similarities between Qur’anic verses and modern concepts of information and AI. Analogical analysis does not imply ontological identity, but examines similarities in structure, function, and role.

Linguistic and Theological foundations.

The expression *al-Lawh al-Mahfuz* (اللوح المحفوظ) consists of two Arabic words: *lawh* and *mahfuz* [1]. The root of *lawh* (ل و ح) consists Arabic letters “lam-waw-ha” which constitute a verb encompassing meanings including “appeared”, “manifested,” and additionally “suspended in the air” or “dried from thirst”. The core meaning of the root encompasses the notion of clarity, manifestation and the medium

upon which this manifestation is inscribed. The literal meaning of word refers to be writing tablet or a broad bone [3]. In classical Arabic, the term lawh was additionally used to denote an archive. In its esoteric meaning, lawh functions as the bearer of explicit information, acting as an intermediary between the world of recorded (*al gayb*) and the world of revelation (*ash-shahadah*) [4].

The root of *mahfuz* (حَفِظَ) consists Arabic letters "ha-fa-za" which constitute a verb encompassing meanings including "preserved", "protected", "retained" and "memorization".

The use of this term in the Qur'anic verse indicates the absolute integrity and security of the information [2], thus confirming its immutable character. This constitutes an active from of preservation, maintained without exposure to any external interference, distortion, forgetfulness or destruction. In Surah Al-Buruj (85:22), *mahfuz* functions as an attribute adjective modifying *lawh*. Grammatically the two are linked through genitive agreement by adjacency (idafa) whereby preservation (*hifz*) is presented as an inherent and inseparable attribute of the *lawh* itself [5].

Technological parallels.

The *lawh* as a quantum memory substrate. It may be conceptualized as an archetype of a quantum medium, where information exists beyond conventional space–time, analogous to quantum entanglement.

The *mahfuz* as a cryptographic integrity mechanism. Similar to checksums, hash functions, and digital signatures, it represents a state where data integrity is intrinsic to the structure itself.

The *al-Lawh al-Mahfuz* as an immutable ledger. Its immutability ("My Word is not subject to change…" [1]) parallels modern immutability algorithms, including blockchain, canonical branches, and WORM storage.

The *lawh* as a reference point. It serves as an authoritative source, analogous to the single source of truth, implemented in systems via centralized archives, smart contracts, or digital certificates [6].

The *lawh* as an access-controlled system. Its inaccessibility corresponds to concepts such as access control, privilege separation, and key management.

Connection with other analogies. Verses [1] through their emphasize "read", "pen", and "teaching", constitute a call to reading and learning, while the Lawh al-Mahfuz is regarded as the source of this knowledge [7]. In this conceptual analogy, the *lawh* is understood as a divine repository of knowledge, comparable to hard disk, while mahfum denotes the protective and cryptographic layer that secures and preserves its integrity.

The revelation sent to prophets may be likened to authorized access to data stored on a secured disk: just as an artificial intelligence system retrieves and outputs information from its protected memory in order to generate responses, information from the Lawh al-Mahfuz is within the bounds of divine authorization, "read" and conveyed to the world trough the agency of prophets.

Structural-analogy model. Cloud storage systems or an idealized, highly resilient server that preserves all data and is resistant to cyberattacks, data loss and

corruption may be regarded as an earthly model of the *al-Lawh al-Mahfuz*. However, while such models on (Earth any servers and data systems) are susceptible to destruction or corruption, the "original" (*Lawh al-Mahfuz*) is conceived as being entirely secure and inviolable. These comparisons presented are of a hermeneutic and metaphoric character.

Directly linking religious or theological claims to technological systems may introduce methodological error and risks of theological misinterpretation. For this reason the technological analogy is intended solely to establish conceptual parallels at he level of structure and properties. The existence and preservation of the *al-Lawh al-Mahfuz* are matters of divine truth, while classical exegesis varies regarding its nature and location [2]; therefore, these parallels should not be treated as ontological equivalence.

Discussion

The *al-Lawh al-Mahfuz* represents an eternal, protected repository of knowledge. Human technologies attempt to approximate this ideal, yet remain inherently limited and vulnerable. Analogously, just as digital actions are logged, all events in the universe are inscribed in the *lawh*. It may be understood as the primordial code of reality, expressed in a unique divine language, infinitely surpassing human programming languages.

Conclusion

The Qur'anic concepts of writtenness, preservation, immutability, and comprehensiveness can be structurally and functionally compared with principles of artificial intelligence and information systems. This correspondence is conceptual rather than ontological and cannot be treated as empirical. The proposed structural–analogy model should be regarded as a symbolic and theoretical framework for interpreting the religious text.

References

1. Musayev, Ə. Qurani Kərim və Azərbaycan dilində mənaca tərcüməsi / Ə. Musayev. – Mədinə: Qurani Kərimin nəşri üzrə Kral Fəhd adına Kompleks, – 2013. – 912 s.

2. İbn-Katheer, Tafsir (explication): [Electronic resource] / آيـــات - القرآن الكريم Holy Quran - مشروع المصحف الإلكتروني بجامعة الملك سعود. URL: https://quran.ksu.edu.sa/tafseer/katheer/sura85-aya22.html?utm

3. Arabic Student's Dictionary: [Electronic resource] / URL: https://www.arabicstudentsdictionary.com/word?word_id=158cd311-3e0a-47db-ad78-792b9d79e7e1&root_id=3d208f63-15cf-420a-975c-43ee3c6ab674&action

4. Chauvet, A. Cosmographical Readings of the Qurʾan // American Journal of Islam and Society, – 2023. Volume 40 (1-2), – pp. 8-38; https://doi.org/10.35632/ajis.v40i1-2.3175

5. The largest library contains thousands of free books: [Electronic resource] / Ketabonline. URL: https://ketabonline.com/en

6. Mesfar, S. Standard Arabic formalization and linguistic platform for its analysis [Electronic resource] / Franche-Comté University. – Laseldi, 2018. URL: https://aclanthology.org/2006.bcs-1.8.pdf

7. تدبر سورة العلق: [مصدر إلكتروني] / تدبر القران معانيه ومقاصده وتفسيره. URL: https://tadabbur-alquran.com/تدبر-سورة-العلق

ARTIFICIAL INTELLIGENCE AND THE MODERNIZATION OF THE MILITARY EDUCATION SYSTEM

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In the contemporary era, digital transformation has generated qualitative changes across all levels of education and has also contributed to the emergence of new methodological approaches in military education. In particular, the rapid development of artificial intelligence technologies has had a substantial impact on the content, management, personalization, and assessment of military education systems. Since military education is based on the integration of classical academic training with practical and professional skills, technological innovations in this field are not limited to the automation of instruction, but also encompass decision-making, situational analysis, simulation-based training, risk assessment, and competency-oriented development mechanisms. In this context, artificial intelligence should be regarded not merely as a technical instrument, but as a strategic factor ensuring the structural and functional modernization of the military education system.

The application of artificial intelligence in military education primarily enables the development of a personalized learning model. While traditional educational approaches often impose uniform content and a common pace on all cadets and trainees, artificial intelligence algorithms can analyze learners' levels of preparation, cognitive characteristics, depth of understanding, and recurring error patterns in order to build adaptive learning trajectories. This makes it possible to select educational materials according to individual training needs, regulate the level of difficulty, and eliminate learning gaps in an оператив manner. As a result, the efficiency of the educational process increases, knowledge acquisition becomes more sustainable, and the professional formation of military personnel becomes more targeted and effective.

One of the major advantages of artificial intelligence lies in its capacity to model complex operational, tactical, and managerial environments. In military education, the development of decision-making skills, the formation of behavioral patterns under uncertain and dynamic conditions, the assessment of various threat scenarios, and the conduct of multivariate situational analysis are of particular importance. For this purpose, artificial intelligence-based simulation environments create training conditions close to real operational settings and enhance the ability of cadets and officers to think under stress, compare alternatives, allocate resources, and select response measures. Compared with conventional training grounds, such systems offer greater flexibility, repeatability, and measurable outcomes. At the same time, they make it possible to reproduce complex combinations of combat, informational, cyber, and command situations, which is especially relevant in the context of the contemporary security environment.

The role of artificial intelligence in military education is not confined to content delivery and simulation. These technologies also create important opportunities for monitoring the educational process, objectively assessing results, and improving

management. For example, learners' performance indicators, task completion times, situational reactions, test results, and patterns of practical activity can be digitally collected and subjected to analytical processing. This approach enables instructors not only to evaluate final results, but also to assess the dynamics of the learning process itself. Consequently, strengths and weaknesses can be identified at earlier stages, training programs can be adjusted in accordance with actual outcomes, and management decisions can be made on a more evidence-based foundation. For institutional leadership, artificial intelligence-based analytical systems provide the opportunity to assess the effectiveness of personnel training, the relevance of curricula, and the efficiency of resource use in an integrated manner.

Another important area concerns the support of instructors and training personnel. Artificial intelligence should not be viewed as a mechanism replacing the teacher, but rather as an intelligent assistant that expands pedagogical and methodological capabilities. Functions such as the optimization of training plans, the structuring of educational content, the preparation of assessment tools, the generation of situational tasks, and the analysis of educational outcomes can significantly enhance the quality of teaching. At the same time, the ability of instructors to use artificial intelligence tools effectively must itself be formed as a separate area of competence. Otherwise, the mere availability of technology does not automatically guarantee its effective application. Therefore, issues related to digital pedagogy, data culture, and algorithmic literacy require particular attention within the military education system.

However, the integration of artificial intelligence into military education is also accompanied by a number of limitations and risks. First of all, issues of data security, confidentiality, and the protection of service-related information are especially sensitive. A portion of the data used in military education may have operational significance, may be intended for official use only, or may carry strategic importance. For this reason, information security requirements must be treated as a primary priority when selecting and implementing artificial intelligence platforms. On the other hand, risks such as algorithmic bias, inaccurate outputs, excessive reliance on automated recommendations, and the weakening of the human factor must also be taken into account. In the context of military decision-making, ethical responsibility, professional judgment, and command logic cannot be replaced by technological solutions. Therefore, the implementation of artificial intelligence should follow a hybrid approach, combining technological tools with human oversight and expert evaluation.

The theoretical and practical relevance of this topic lies in the fact that, in the current security environment, the military education system should be viewed not only as an institutional structure transmitting knowledge, but also as an intellectual training platform capable of adapting to highly dynamic operational realities. Artificial intelligence acts as an accelerator of this transformation by increasing the adaptability, responsiveness, analytical depth, and result orientation of education. At the same time, the successful implementation of these technologies requires the parallel development of a regulatory framework, technological infrastructure,

teacher preparation, information security provisions, and ethical governance mechanisms. Such an approach makes it possible to shape the future development of the military education system not only in terms of technological modernization, but also through systematic renewal in content, methods, and management. Ultimately, the purposeful and scientifically grounded use of artificial intelligence in military education can make a substantial contribution to the formation of more prepared, analytically capable, adaptive, and professional military personnel.

References

1. Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.

2.Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.

3.Piriyev, H.K., et al. (2016). Provide interactive training methods. Methodological materials. *Baku: Military publishing house*.

4.İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071

5.Piriyev H.K. et al. Some aspects of optimization of control / Current directions of development of information and communication technologies and control tools. Proceedings of 14-th International Scientific and Technical Conference. Volume 1. 2024. -pp.18-19.

6.Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.

7.Dergachov, K. et al. (2025). AI based physical and cyber defense for energy grids and transportation systems.

8.Ibrahimov B.G. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system //Advanced Information Systems. – 2024. – Т. 8. – №. 2. – С. 58-64.

9.Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment // Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.

10. Dadashov, A. (2024). Applying didactic teaching principles to professional engineering education in military higher education institutions. Journal of Defense Resources Management, 15(2), 152–163. https://doi.org/10.64404/jodrm.2024.2.10

11. Dadashov A. S. Integration of new technologies into the teaching methods of engineering education in military institutions //Modern directions of development of information and communication technologies and management tools. 14th International Scientific and Technical Conference. – 2024. – Т. 2. – С. 3-6.

12. Dadashov A. S. Some results of the study on the didactic design of engineering training in military higher education. – 2025.

13. Dadashov A. S. Possibilities of applying information technologies in the formation of the didactic design model of military engineer training. – 2024.

14. Piriyev H.K., et al. Training methods in military education. Methodological materials // - Baku: Military publishing house, 2017, 52 p.

MODERN EDUCATIONAL TECHNOLOGIES AS A STRATEGIC FACTOR IN THE TRANSFORMATION OF CONTEMPORARY EDUCATION

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Modern educational technologies have become one of the central directions in the transformation of contemporary education under the conditions of rapid digitalization, the expansion of the knowledge economy, and the growing demand for new competencies in the labor market. Traditional instructional models were largely based on the transmission, reproduction, and standard assessment of knowledge. However, the development of digital platforms, artificial intelligence-based tools, adaptive learning environments, distance education systems, blended learning models, virtual and augmented reality solutions, learning analytics, and personalized instructional approaches has significantly reshaped both the structure and the logic of the educational process. In this context, modern educational technologies should not be understood merely as technical instruments. They represent a broader pedagogical and organizational transformation that affects curriculum design, methods of teaching, forms of interaction, learning assessment, and the overall management of educational processes.

The main purpose of this study is to analyze the conceptual foundations, structural components, functional possibilities, and pedagogical significance of modern educational technologies in a comprehensive and systematic manner. The study examines the theoretical basis of these technologies, classifies their principal forms, evaluates their integration into teaching and learning processes, and identifies their influence on student motivation, cognitive activity, individual development, and the acquisition of practical competencies. At the same time, the study considers the methodological, organizational, technical, and ethical challenges associated with their implementation in different educational settings.

The analysis demonstrates that one of the major advantages of modern educational technologies lies in their capacity to make learning more flexible, interactive, personalized, and outcome oriented. Digital learning resources, cloud based educational systems, and online platforms provide learners with greater freedom in terms of time, place, and pace of study. This is especially important in the context of lifelong learning, continuing professional development, and the construction of individual learning trajectories. Adaptive learning systems make it possible to modify content, assignments, and instructional pathways according to the learner's prior knowledge, pace of progress, and personal characteristics. As a result, a more balanced and efficient learning environment can be created for students with different levels of academic preparedness within the same instructional setting.

Another essential feature of modern educational technologies is their ability to strengthen interactive and collaborative learning. Discussion forums, video conferencing tools, digital collaboration platforms, simulation environments, and project-based learning systems do not only support knowledge acquisition but also contribute to the development of critical thinking, communication, teamwork,

decision making, and problem-solving skills. In this regard, blended learning occupies a particularly important place because it combines the strengths of face-to-face instruction with the advantages of digital resources and online interaction. Such a model increases instructional flexibility and promotes a shift in the role of the teacher from a simple transmitter of information to a facilitator, coordinator, consultant, and designer of meaningful learning experiences.

The growing use of artificial intelligence in education has opened a new stage in the development of modern educational technologies. Automated assessment systems, intelligent tutoring tools, predictive learning analytics, recommendation systems, and data driven monitoring mechanisms enable more precise tracking of student progress and faster pedagogical intervention. These technologies can identify poorly mastered topics, detect students at academic risk, and support evidence based instructional decision making. At the same time, the use of artificial intelligence in education introduces serious concerns related to data privacy, algorithmic bias, transparency of assessment procedures, and the possible weakening of the human dimension of teaching. Therefore, the implementation of modern educational technologies should be approached not as a purely technical modernization process, but as a complex educational transformation requiring pedagogical, normative, and ethical regulation.

The findings of the study indicate that the effectiveness of modern educational technologies depends primarily on the quality of their pedagogical design and their alignment with instructional objectives. The presence of technology by itself does not guarantee improved educational outcomes. Its value emerges only when it is integrated into the learning process in accordance with didactic goals, content requirements, and student needs. Technologies used merely for presentation or administrative control often have limited influence on learning quality. In contrast, when they are combined with problem-based learning, research-oriented teaching, project-based instruction, simulation methods, and the flipped classroom model, their pedagogical impact becomes much more substantial and sustainable.

At the same time, the expansion of educational technologies reveals several limitations and risks. These include digital inequality, uneven access to infrastructure, differences in teachers' digital competencies, the lack of quality standards for electronic resources, cognitive overload, and the danger of superficial learning. In many educational systems, especially those undergoing structural modernization, the issue is not only the availability of digital tools but also the ability to use them in a pedagogically meaningful and methodologically justified way. For this reason, the successful integration of modern educational technologies requires not only technical provision but also institutional strategy, teacher training, methodological support, continuous monitoring, and quality assurance mechanisms.

In conclusion, modern educational technologies possess significant potential for the renewal of teaching and learning, the expansion of educational accessibility, the development of personalized and adaptive learning environments, and the improvement of educational quality. Their effective application accelerates the digital transformation of education, creates new models of interaction between teachers and learners, and makes

learning more measurable, flexible, and responsive to individual needs. Nevertheless, the realization of this potential requires a balanced approach based on pedagogical appropriateness, ethical responsibility, technological competence, and long-term institutional support. Under such conditions, modern educational technologies can be regarded not simply as auxiliary tools, but as a strategic factor reshaping the philosophy, culture, and practice of contemporary education.

References

1. İbrahimov R.İ. Artificial intelligence applications in higher education: prospects for personalized learning and governance efficiency / Grail of science. 2025, N55. Pp.601-614. DOI 10.36074/grail-of-science.22.08.2025.071
2. Agayev, S.O., et al. (2016). Modern pedagogical technologies in military education. Textbook. Part I. *Baku: Military Publishing House*.
3. Piriyev, H.K., et al. (2014). Some issues of pedagogical staff training for special-purpose higher education institutions. *Military knowledge*, (4), 3-9.
4. Tahirov R.K., Hashimov E.G. Professional military education and the development of strategic human capital / Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.35
5. Hasanov A.H. Exploring the impact of online learning platforms on higher education. *In* Current directions of development of information and communication technologies and control tools. T.4: section 6. 2025. C. 39.
6. Ibrahimov B.G. et al. Research and analysis of efficiency indicators of critical infrastructures in the communication system //Advanced Information Systems. – 2024. – T. 8. – №. 2. – C. 58-64.
7. Dergachov K. et al. Adaptive algorithm for visual positioning of UAVs in the local environment. *In* Proceedings of the International Workshop on Computational Methods in Systems Engineering (CMSE 2025) Kyiv, Ukraine, June 12, 2025.
8. Dadashov A. S. Integration of new technologies into the teaching methods of engineering education in military institutions. *In* Modern directions of development of information and communication technologies and management tools. 2024. – T. 2. – C. 3-6.
9. Piriyev H.K., et al. Training methods in military education. Methodological materials // - Baku: Military publishing house, 2017, 52 p.

FORMAL REQUIREMENTS FRAMEWORK FOR UAV-BASED ENVIRONMENTAL MONITORING SYSTEMS

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Unmanned aerial vehicle based environmental monitoring systems are increasingly used in applications that require rapid deployment, flexible mission planning, high spatial resolution, and access to areas that are difficult or unsafe for conventional ground-based observation. Despite these operational advantages, the scientific and practical value of UAV-based monitoring is often constrained by the absence of a unified framework that systematically links mission objectives, measurement quality, calibration procedures, safety limitations, communication performance, and data integrity requirements into a single end-to-end architecture.

In many existing implementations, the UAV platform, sensor payload, navigation subsystem, communication link, and post-processing chain are treated as partially independent components, while the validity of monitoring results depends on their tightly coupled behavior under real field conditions. This fragmentation reduces comparability between missions, complicates verification, and weakens the reproducibility of results. The present study addresses this deficiency by developing a systematic formalization of requirements for UAV-based environmental monitoring systems and by proposing a structured methodology that transforms mission-level objectives into measurable technical criteria, verification procedures, acceptance thresholds, and risk-aware operational constraints.

The paper considers the monitoring system as an integrated measurement chain that includes the aerial platform, payload and sensors, control and navigation functions, communication channels, data acquisition, data processing, and result visualization. Within this interpretation, the object of analysis is not an isolated technical subsystem but the entire functional sequence through which environmental information is collected, transmitted, validated, and converted into decision-relevant output. The study focuses on the formalization of requirements across this chain and introduces a hierarchical structure in which mission requirements, functional requirements, measurable technical requirements, verification and acceptance requirements, and risk impacts are explicitly interconnected. Each requirement is assigned at least four mandatory attributes: a measurable criterion, a verification method, an acceptance threshold, and an assessment of risk impact in the event of non-compliance. This requirement-centered approach allows the system designer to move from descriptive intentions to operationally testable conditions and ensures that performance claims can be validated objectively rather than interpreted qualitatively.

A central contribution of the study is the formal linkage established between measurement quality indicators and mission parameters. The paper argues that key indicators such as accuracy, bias, repeatability, sensitivity, detection limit, spatial resolution, temporal resolution, continuity, and completeness of data cannot be left as generic quality aspirations. Instead, they must be translated into quantitative constraints on altitude, speed, sampling frequency, and mission geometry. For imaging-based observations, spatial resolution is related to flight altitude, detector pixel size, and focal length through a simplified ground sample distance relationship, showing that altitude is not merely a flight planning variable but a direct determinant of measurement capability. For point-based observations, the spatial interval between successive samples is expressed as a function of flight speed and sensor sampling frequency, demonstrating that sampling density requirements impose explicit bounds on admissible combinations of motion and acquisition rate. These minimal formal relationships are important because they operationalize the idea that mission planning and measurement quality are inseparable. As a result, environmental monitoring missions can be designed from the outset to satisfy scientific quality criteria instead of attempting to correct deficiencies after data collection has already occurred.

The study also devotes significant attention to the metrology and calibration chain, identifying it as a foundational element of trustworthy UAV-based monitoring.

It proposes that metrological assurance must be structured across three stages: laboratory calibration, field verification with updating of correction functions, and in-mission stability control with drift compensation. In this framework, calibration is treated not as a one-time certification step, but as a continuing process that supports traceability, uncertainty evaluation, and environmental adaptability under real operational conditions. The paper formalizes requirements related to calibration functions, confidence intervals, temperature and humidity compensation, drift monitoring, and the allocation of the uncertainty budget across system components. A simplified representation of the measurement result as the sum of a true value, systematic bias, and random error is used to show that acceptance criteria must define not only maximum allowable deviation but also explicit upper bounds for systematic and stochastic components of uncertainty. This orientation strengthens the scientific rigor of UAV monitoring by embedding metrological traceability directly into requirement design rather than treating it as an external laboratory issue.

Another major outcome of the research is the conceptual repositioning of flight safety and data integrity as core acceptance conditions rather than secondary constraints. The paper argues that a monitoring mission cannot be considered successful if data are collected with high nominal sensor quality but the flight is not completed safely, regulatory constraints are violated, timestamps are inconsistent, or transmitted records are incomplete or mutable. On this basis, safety requirements are grouped into flight safety and communication-data integrity blocks. Flight safety requirements include endurance margins, energy balance sufficient for mission completion and safe return, tolerance to meteorological conditions, emergency behavior in the event of communication or control loss, geofencing, and compliance with restricted-area regulations. Data integrity and communication reliability requirements include packet loss thresholds, timestamp synchronization tolerance, local storage under link interruption, secure transmission after link restoration, and archival immutability mechanisms that prevent later alteration of measurement records. This treatment expands the classical view of UAV monitoring from a sensing problem into a system assurance problem in which operational safety and scientific reliability are jointly optimized.

To support implementation, the article introduces a requirements matrix as the principal mechanism for integrating design, verification, testing, and acceptance. The matrix links each requirement category to a measurable criterion, a concrete verification method, an acceptance threshold, and a risk impact level. Verification methods are explicitly differentiated as laboratory testing, field testing, flight testing, comparative measurement, simulation, or combined procedures. This is methodologically important because vague verification labels often conceal the actual evidentiary basis of compliance claims. By contrast, the proposed matrix approach forces precision and reveals which requirements are validated under controlled conditions, which are validated under operational conditions, and which require comparative or analytical confirmation. The matrix also supports prioritization because the risk impact of each requirement can be assessed in relation to measurement quality, flight safety, and the decision value of results. In this sense, the proposed framework is not limited to

documentation. It becomes an analytical instrument for rational allocation of resources, planning of tests, and transparent acceptance of the monitoring system as a scientifically credible and operationally reliable mechatronic platform. Overall, the study establishes a coherent methodological basis for the systematic formalization of UAV-based environmental monitoring requirements and demonstrates that only an integrated, measurable, and verifiable requirement structure can ensure repeatability, comparability, traceability, and practical usefulness of monitoring outcomes.

References

1. Akhundov R. Enhancing the efficiency of the military environmental security system through the implementation of advanced technical means //Моделювання, керування та інформаційні технології. – 2025. – №. 8. – С. 348-352.
2. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.
3. Radovanović M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.
4. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.
5. Javadov, J. M. et al. Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.116-117.
6. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.
7. Nasibov Y.A. et al. Modelling of the rationally deployment of observing systems //Advanced İnformation Systems. – 2019. – Т. 3. – №. 2. – С. 10-13.
8. Huseynov, M. et al. Application of modern multi-sensor technologies for ground target detection. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 172–182.
9. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.
10. Hashimov E.G. et al. About some aspects of using a flock of UAVs. Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023. Т. 1.секція 1,3,4. С. 4-5.
11. Huseynov B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. – 2025.
12. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.102-103
13. Atayev S.U., et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec. 3,7. p.100-101
14. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109
15. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.
16. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

END-TO-END MEASUREMENT AND EFFECTIVENESS FRAMEWORK FOR UAV-BASED ENVIRONMENTAL MONITORING

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Unmanned aerial vehicle based environmental monitoring has become an increasingly important instrument for high resolution, operationally flexible, and spatially adaptive observation of environmental conditions. Compared with conventional ground surveys and many satellite observation modes, UAV platforms offer a combination of rapid deployment, mission reconfiguration, fine scale data acquisition, and relatively low operational constraints. However, despite the growing number of studies devoted to UAV applications in environmental assessment, pollution tracking, hazard detection, and ecosystem analysis, the methodological treatment of the monitoring process often remains fragmented. In many cases, sensing, calibration, georeferencing, filtering, mapping, and interpretation are described as separate procedural steps rather than as an integrated and traceable measurement system. This weakens reproducibility, reduces comparability between studies, and obscures the cumulative influence of uncertainty introduced at different stages of the monitoring workflow. The present study addresses this gap by proposing an integrated measurement chain and effectiveness framework for UAV based environmental monitoring. The purpose of the study is to formalize UAV based environmental monitoring as an end-to-end measurement chain in which each stage is explicitly linked to the next through data, correction procedures, quality control operations, and uncertainty propagation mechanisms. Within this logic, the object of research is the UAV based environmental monitoring process itself, while the subject of research is the methodological organization of causal relations among mission parameterization, metrological assurance, minimal data processing, spatial transformation, map generation, and evaluation of applied value. The study develops a structured framework that connects conceptual modeling, operational implementation, and prototype level verification. The main scientific premise is that the reliability and usefulness of UAV monitoring outputs cannot be justified solely by the nominal technical characteristics of sensors. Instead, the final quality of the result depends on the internal coherence of the full measurement chain, including how the mission is planned, how the data are time stamped and corrected, how errors are filtered and transformed, and how the processed outputs are finally presented for decision making.

The first contribution of the study is the formalization of the integrated conceptual structure of the measurement chain. In the proposed framework, UAV based monitoring is represented as a sequence of interdependent stages that includes mission planning, measurement and time stamping, metrological correction, quality control, spatial referencing, mapping, and result delivery. This organization emphasizes that the output of each stage becomes the input of the subsequent stage, and therefore uncertainties, systematic bias, and structural inconsistencies may

accumulate through the chain and affect the final map product. The framework shifts the analytical focus from isolated measurement events to the logic of traceable data transformation. In this sense, a monitoring result is not interpreted simply as a measured value, but as the outcome of a structured progression from raw signal acquisition to calibrated quantities, filtered observations, spatially referenced records, mapped surfaces, and decision-oriented reporting products. Such formalization improves methodological clarity and enables identification of weak links that may remain hidden in conventional software centered descriptions of UAV data processing. The second contribution is the justification of a minimal but reproducible end to end data processing pipeline. To reduce ambiguity and improve repeatability, the study systematizes data processing into five essential stages: initial filtering and anomaly removal, time synchronization and packet integrity verification, application of metrological corrections and calibration functions, spatial referencing and projection alignment, and mapping with uncertainty assessment and result presentation. Each of these stages is defined not only by its technical role but also by its function in preserving traceability and measurement validity. Initial filtering stabilizes the raw signal by reducing noise and removing outliers. Time synchronization ensures consistency across multisensor data streams and limits the spatial effects of temporal misalignment.

Metrological correction links field measurements to calibration functions and standardized units while compensating for drift and environmental influence. Spatial referencing integrates measurement data with navigation parameters and assigns stable positional meaning to each observation. Mapping and uncertainty assessment convert point or track based information into interpretable spatial products while preserving information about confidence and reliability. A key methodological principle of this pipeline is the separate retention of corrected values and associated uncertainty components at each stage. As a result, the final output is conceived as a dual product consisting of both a value surface and a confidence surface. This dual representation strengthens decision support because it allows users to distinguish between areas of high environmental concern and areas where confidence in the measurements is lower.

The third major contribution of the paper is the formalization of monitoring effectiveness as a measurable system of indicators rather than a vague notion of general quality. The study argues that effectiveness should be evaluated at three interrelated levels. The first level includes measurement level indicators such as accuracy, bias, repeatability, detection limit, spatial resolution, and temporal resolution. These indicators characterize compliance with core metrological requirements and define the primary quality of the sensor output. The second level includes processing and map level indicators, among them data completeness, gap ratio, map consistency, spatial smoothing effects, and the uncertainty field. These metrics reflect how information is transformed, lost, or stabilized during the data processing pipeline and how that process shapes the final mapping product. The third level includes application level indicators such as timeliness, risk signal delay, and the balance between resource expenditure and information gain. These metrics

capture the practical utility of monitoring results for operational or managerial decision making. Through this three level structure, the study demonstrates that a monitoring system should be evaluated not only according to whether it measures correctly, but also according to whether it delivers information in a timely, reliable, and operationally meaningful form.

An important aspect of the framework is its orientation toward prototype testing and acceptance-based validation. For each effectiveness indicator, the paper identifies the required input data, the logic of calculation, and the relevant stage of application. This shifts the discussion of monitoring effectiveness from qualitative description to quantitative assessment. In practical terms, the proposed framework provides a basis for evidence-based optimization of mission parameters, processing settings, and metrological procedures. For example, the study highlights the direct relationship between flight speed and measurement density. Higher flight speed may increase spatial coverage in a limited time interval, but it also reduces measurement density per unit area and may increase interpolation requirements and uncertainty during mapping. This illustrates that mission parameters should not be selected purely on the basis of platform capability, but in accordance with the reliability requirements of the intended output.

The study also considers limitations. The proposed concept is adaptable to different UAV platforms and sensor configurations, but comparative validation may be constrained by limited access to ground reference measurements, logistical challenges, and environmental variability. Perfect temporal and spatial matching between UAV observations and reference data is often difficult to achieve. Therefore, the paper supports a combined validation strategy based on selective reference measurements, internal quality control procedures, statistical concordance analysis, and scenario-based verification where direct reference data are incomplete. Even under such constraints, the framework preserves a formal basis for internal reliability management and recalibration.

In conclusion, the study develops a coherent methodological basis for integrating mission design, metrological assurance, data processing, uncertainty tracking, and effectiveness assessment within a single UAV based environmental monitoring framework.

Its scientific value lies in establishing traceable causal relations across the full monitoring chain, while its practical value lies in enabling measurable prototype level evaluation of decision relevant outputs. The proposed approach therefore contributes both to methodological standardization and to the operational credibility of UAV based environmental monitoring systems.

References

1. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116

2.Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350

3.Akhundov R. Enhancing the efficiency of the military environmental security system through the implementation of advanced technical means //Моделювання, керування та інформаційні технології. – 2025. – №. 8. – С. 348-352.

4. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.

5.Radovanović M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.

6. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.

7. Javadov, J. M. et al. Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.116-117.

8. Bayramov A. A. et al. SMART control system of systems for dynamic objects group //Bulgarska Voenna Misal.–2018. – 2018.

9. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

10. Nasibov Y.A. et al. Modelling of the rationally deployment of observing systems //Advanced İnformation Systems. – 2019. – Т. 3. – №. 2. – С. 10-13.

11. Huseynov, M. et al. Application of modern multi-sensor technologies for ground target detection. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 172–182.

12. Islamov, I., et al. Prospects for the use of robotic complexes in eliminating the consequences of environmental accidents at military facilities. *Матеріали конференцій МЦНД*, (07.11.2025; Дніпро, Україна), 301–311.

13. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

14. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. Problems of informatization. 2025, vol.1., s.1,2. p.72-74

15. Hashimov E.G. et al. About some aspects of using a flock of UAVs. Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023. Т. 1.секція 1,3,4. С. 4-5.

16. Huseynov B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. – 2025.

17. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.102-103

18. Atayev S.U., et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec. 3,7. p.100-101

19. Atayev S.U. et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec.3,7. p.100-101

20. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

21. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

22. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

METHODOLOGICAL CHALLENGES IN UAV BASED ENVIRONMENTAL MONITORING

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Unmanned aerial vehicles have rapidly emerged as an important technological platform for environmental monitoring because they combine operational flexibility, high spatial resolution, rapid deployment capability, and the possibility of adapting mission parameters to specific observation tasks. In comparison with conventional ground-based monitoring systems and many satellite-based observation approaches, UAV platforms provide a unique balance between local precision and operational responsiveness. This has led to their increasing use in a wide range of environmental applications, including atmospheric pollution assessment, monitoring of water quality indicators, evaluation of soil conditions, detection of thermal anomalies, and observation of radiological contamination. Despite this rapid growth in applications, the methodological basis of UAV-based environmental monitoring remains insufficiently unified. A significant portion of existing studies is limited to local experimental implementations, while key issues such as metrological assurance, field calibration, uncertainty decomposition, repeatability of results, and the formal relationship between flight parameters and measurement quality are often addressed only partially or descriptively. As a result, the reproducibility, comparability, and scientific reliability of monitoring outputs remain constrained.

The present study aims to provide a systematic synthesis of UAV-based environmental monitoring from the perspective of measurement methodology and to identify the main scientific and applied gaps that must be addressed to construct a rigorous dissertation-level research framework. The object of the study is the end-to-end monitoring measurement chain, including the UAV platform, onboard and external sensors, flight profile parameters, communication subsystem, and the successive stages of data acquisition, synchronization, processing, geocoding, interpolation, and mapping. The subject of the study is the methodological organization of this chain, with particular emphasis on metrological assurance of UAV-based measurements, preservation and updating of calibration functions under real operating conditions, decomposition of uncertainty into identifiable components, and formalization of quantitative links between mission parameters and the quality of the final monitoring result. The study also treats environmental variability, vibration, aerodynamic disturbances, illumination changes, electromagnetic interference, and platform energy limitations as integral components of the operational environment rather than as secondary disturbances.

The first major result of the study is the systematization of the main application domains of UAV-based environmental monitoring and the classification of typical measured parameters within these domains. The literature review demonstrates that UAV monitoring is currently most actively used in atmospheric air quality measurement, observation of physical and chemical parameters of water bodies,

assessment of soil state, detection of thermal anomalies, and radiological monitoring. In each of these areas, the informational value of measurements depends not only on the nominal capability of the sensor but also on the physical properties of the monitored medium, the required spatial and temporal scale of analysis, and the operational conditions of the mission. The study therefore argues that sensor choice should not be treated as a purely technical selection problem. Instead, it must be justified through a structured relationship between the application area, measured parameter, mission profile, and expected quality criteria of the final result.

The second key contribution lies in the analysis of sensor classes and measurement principles used in UAV-based environmental monitoring. The study synthesizes the literature on electrochemical gas sensors, optical particle sensors, multispectral and hyperspectral cameras, thermal imaging systems, radiometers, dosimeters, and other sensor classes applicable to environmental tasks. It shows that the core methodological problem is not limited to choosing the appropriate device type. The more fundamental issue is the loss of calibration stability when sensors operate outside laboratory conditions. During real flight missions, measurement signals are influenced by temperature and humidity fluctuations, solar heating, vibration, airflow disturbances, aerodynamic loading, and electromagnetic noise. These factors alter both systematic and random error components, thereby changing the effective measurement characteristics of the sensor. Consequently, laboratory calibration data cannot be assumed to remain fully valid in field missions. This finding substantiates the need for dynamic calibration updating, decomposition of the uncertainty budget into operationally meaningful components, and explicit inclusion of field conditions in the metrological model of the measurement chain.

The third major result concerns the role of flight platforms and mission profiles in shaping measurement quality. The study shows that platform selection represents a trade-off among spatial coverage, measurement accuracy, and timeliness. Multirotor systems provide high positional stability and suitability for local high-resolution measurements, but their endurance is limited by payload and energy constraints. Fixed-wing systems provide broader area coverage and longer flight time, but may be less adaptable in low-altitude, fine-scale monitoring tasks. Beyond platform type, mission profile variables such as flight altitude, speed, trajectory step, sampling frequency, and sensor field of view have a direct influence on spatial resolution, sampling density, and uncertainty. The literature review indicates that these relationships are often treated empirically rather than formalized mathematically. The article therefore argues that one of the most important unresolved tasks in current UAV monitoring research is the construction of quantitative models linking mission parameters to measurement quality and uncertainty propagation.

A further important contribution of the study is the structured examination of the data processing and mapping chain. In many applied works, raw data processing is performed using standard functions embedded in commercial or open-source software packages, while the exact sequence of operations, selected parameters, and quality control rules are inadequately documented. This weakens reproducibility and

creates the possibility that the same raw dataset may produce different cartographic outputs under different processing configurations. The study therefore conceptualizes the processing chain as a sequence of logically linked operators that includes raw signal filtering, artifact removal, time synchronization, georeferencing, normalization, calibration correction, interpolation, and map generation. By presenting data processing as a formalized transformation from initial measurements to final mapped values, the paper highlights that methodological rigor in UAV monitoring depends not only on measurement acquisition but equally on the transparency of the processing sequence. This approach creates the basis for tracing the emergence of uncertainty at different stages and for ensuring comparability of results across different missions and studies.

The study also performs a generalized analysis of methodological gaps in the existing literature. Four major gaps are identified. First, measurement quality indicators such as accuracy, repeatability, sensitivity, spatial resolution, and detection limit are rarely integrated into a common evaluative system. Second, metrological assurance and calibration updating under real flight conditions remain insufficiently addressed. Third, the causal chain linking flight parameters to result quality is seldom modeled explicitly.

Fourth, the practical effectiveness of UAV-based environmental monitoring, understood as the usefulness of information for timely and justified decision making, is rarely evaluated through a coherent system of indicators. These gaps significantly reduce the scientific and applied maturity of current UAV monitoring frameworks.

In conclusion, the article demonstrates that the future development of UAV-based environmental monitoring requires a transition from fragmented application studies to an integrated methodological model that connects sensors, flight planning, calibration, uncertainty assessment, data processing, mapping, and result evaluation within a single end-to-end measurement chain.

The scientific value of the study lies in refining the dissertation problem statement through the classification of applications, synthesis of sensor-related uncertainties, formal consideration of mission parameters, and identification of systemic methodological deficiencies.

Its practical value lies in substantiating the need for an integrated mechatronic and metrological framework capable of delivering reliable, repeatable, and decision-relevant environmental monitoring results under real operational conditions.

References

1. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116

2.Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350

3.Akhundov R. Enhancing the efficiency of the military environmental security system through the implementation of advanced technical means //Моделювання, керування та інформаційні технології. – 2025. – №. 8. – С. 348-352.

4. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.

5.Radovanović M. et al. Unleashing autonomous forces: Integrating AI-driven drones in modern military strategy //Системи управління, навігації та зв'язку. Збірник наукових праць. – 2024. – Т. 3. – №. 77. – С. 55-69.

6. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.

7. Javadov, J. M. et al. Integrating UAV imagery with GIS-based spatial analytics to forecast border risks. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.116-117.

8. Bayramov A. A. et al. SMART control system of systems for dynamic objects group //Bulgarska Voenna Misal.–2018. – 2018.

9. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

10. Nasibov Y.A. et al. Modelling of the rationally deployment of observing systems //Advanced İnformation Systems. – 2019. – Т. 3. – №. 2. – С. 10-13.

11. Huseynov, M. et al. Application of modern multi-sensor technologies for ground target detection. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 172–182.

12. Islamov, I., et al. Prospects for the use of robotic complexes in eliminating the consequences of environmental accidents at military facilities. *Матеріали конференцій МЦНД*, (07.11.2025; Дніпро, Україна), 301–311.

13. Huseynov, M. et al. Integrated application of remote sensing in defense and environmental oversight. In Problems of Informatization. 2025. Vol. 2, p. 114-115.

14. Barbashin, V. K. et al. Enhancement of operational readiness via predictive maintenance and network optimization. *In* Problems of informatization. 2025, vol.1., s.1,2. p.72-74

15. Hashimov E.G. et al. About some aspects of using a flock of UAVs. Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023. Т. 1.секція 1,3,4. С. 4-5.

16. Huseynov B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. – 2025.

17. Balayev F.R, et al. Methodology and applications of Aİ enabled image recognition in UAVs. *In* Problems of informatization. 2025. Vol. 2., section 3,7. p.102-103

18. Atayev S.U., et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec. 3,7. p.100-101

19. Atayev S.U. et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec.3,7. p.100-101

20. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

21. Akhundov, R. et al. (2026). Methodological limitations of normative design of physical protection systems for critical and military facilities in a dynamic threat environment // International scientific journal «Grail of Science». 2026. № 62. С. 873–889.

22. Akhundov, R. et al. (2026). Conceptual models of multi-level physical protection systems for special-purpose and critical infrastructure facilities. Grail of Science, (61), 591–608. https://doi.org/10.36074/grail-of-science.23.01.2026.066

EXPERIMENTAL, ANALYTICAL, AND COMPUTATIONAL ASSESSMENT OF MECHANICAL PARAMETERS IN OIL AND GAS TRANSPORTATION EQUIPMENT

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The safe and reliable operation of oil and gas transportation systems depends directly on the accurate determination of the mechanical parameters of their structural and functional elements. Pipelines, pump station pressure components, shut-off valves, flange connections, expansion joints, and welded assemblies are exposed in service to a complex combination of internal pressure, temperature variation, vibration, support displacement, corrosion damage, and local structural discontinuities. Under such conditions, the use of isolated or simplified assessment approaches is often insufficient for obtaining a scientifically justified picture of actual structural behavior. The article addresses this problem by proposing an integrated methodology and computational modeling framework for determining the mechanical parameters of oil and gas transportation equipment in a more systematic, verifiable, and engineering-relevant manner.

The relevance of the study is associated with the growing complexity of modern pipeline and transportation infrastructure. Contemporary oil and gas systems increasingly use high-strength steels, welded structural components, and equipment operating under variable thermomechanical regimes. At the same time, the service environment is characterized by defect evolution, corrosion pitting, local crack-like flaws, and stress redistribution near geometrical discontinuities. These factors substantially reduce the adequacy of conventional simplified strength calculations when applied in isolation. Therefore, the article develops a methodological sequence in which experimental material characterization, analytical load assessment, and finite element based computational modeling are treated not as independent alternatives, but as mutually reinforcing stages of a unified evaluation process.

The first stage of the proposed methodology is experimental determination of the principal mechanical characteristics of the material and structural zones of the equipment under study. The framework includes such key parameters as yield strength, ultimate tensile strength, elastic modulus, Poisson’s ratio, relative elongation, hardness, and impact toughness. Where welded joints are present, the methodology requires separate assessment of the base metal, the heat-affected zone, and the weld metal, because these regions may possess distinct mechanical behavior and may contribute differently to stress concentration and local failure mechanisms. In cases where fracture risk is significant, the methodology also extends to fracture toughness indicators such as the stress intensity factor and energy-based fracture parameters. This stage provides the primary data foundation for both subsequent analytical calculations and digital simulation.

The second stage focuses on the analytical assessment of service loads and stress components. The study systematizes the principal operating actions affecting

oil and gas transportation equipment, including internal pressure, axial loading, circumferential stress, thermal effects, support reactions, vibration, and local impact loads. For thin-walled cylindrical components, the methodology uses classical engineering expressions for hoop and axial stresses as the initial analytical basis, after which thermal stress contributions are incorporated when significant temperature differences are present. Equivalent stress is then estimated according to the von Mises criterion, making it possible to conduct a preliminary strength assessment and determine whether the stress state remains within allowable limits. This stage performs an important filtering and interpretive function. It transforms raw mechanical and loading information into an engineering representation that can guide the setup of more advanced numerical models.

However, the article demonstrates that analytical formulas alone cannot fully capture the behavior of real structures under operational conditions. In actual service, the presence of localized defects, welded discontinuities, corrosion zones, nonuniform geometry, and nonlinear material response may significantly alter the stress-strain state. For this reason, the third stage of the methodology introduces digital modeling based on the finite element method. At this stage, the structure is represented through an integrated computational model that combines geometric description, experimentally obtained material properties, applied loads, defect characteristics, and boundary conditions within a single simulation environment. The purpose of this stage is to determine the stress-strain state under different loading regimes, identify hazardous local concentration zones, and estimate the mechanical reserve of critical structural regions.

The computational framework can be adapted to different equipment types, including pipes, elbows, weld seams, flange elements, and valve bodies. Depending on the engineering problem, the material behavior may be represented either by an elastic or by an elastic-plastic constitutive model. For nonlinear deformation analysis, the article recommends the use of a Ramberg-Osgood type relation, which enables a more realistic characterization of strain hardening and plastic response under elevated loading. The modeling stage further includes a set of advisable loading scenarios such as normal operating pressure, maximum design pressure, combined pressure-temperature regimes, conditions with local corrosion or crack-like defects, and dynamic or vibration-influenced cases. By incorporating these scenarios, the model becomes capable of representing not only idealized strength conditions but also practically relevant service situations.

An important contribution of the article lies in its emphasis on verification and adequacy assessment. The practical utility of any numerical model depends on the degree to which it reproduces experimentally observed behavior. For this reason, the proposed methodology introduces a comparative criterion based on relative error between experimentally measured and computationally predicted parameters. The adequacy of the model is judged by the mean deviation for the principal output indicators, with a practically acceptable range discussed at the level of approximately 5 to 10 percent, subject to justification according to the available test database and the complexity of the model. Recommended verification indicators

include maximum equivalent stress, maximum displacement, plastic zone size, stress concentration factor near a defect, and structural response near critical pressure. Such verification is particularly important for welded joints and corrosion-affected areas, where material heterogeneity and geometric irregularity have a pronounced effect on the accuracy of prediction.

The results discussed in the article indicate that the proposed integrated methodology offers several scientific and practical advantages. First, it allows mechanical parameter determination to be linked not only to standardized material passport data, but also to the actual operational loading environment and defect configuration of the equipment. Second, it improves the traceability of engineering decisions by establishing a logical chain from laboratory measurement to analytical interpretation and finally to numerical simulation. Third, it enables the identification of dangerous stress concentration zones that may remain hidden under simplified assessment methods. As a result, the framework supports a more substantiated evaluation of structural safety margin, service reliability, and potential failure risk.

In a broader sense, the study demonstrates that the determination of mechanical parameters in oil and gas transportation equipment should be regarded as a multi-stage systems engineering problem rather than as a narrow material testing task. The integrated methodology developed in the article creates the basis for more accurate adaptation to specific object categories, including main pipelines, pump casings, flange joints, and welded assemblies. This makes the proposed framework suitable not only for theoretical generalization but also for object-specific dissertation-level and applied engineering research. Overall, the article contributes a coherent methodological platform for improving the scientific validity, practical reliability, and computational depth of mechanical assessment in oil and gas transportation infrastructure.

References

1. İsmayil, İsmayil, & Hashimov, E. (2025). Security and protection of Azerbaijan's oil and gas pipelines: cybersecurity and risk management approaches. *Матеріали конференції МЦНД*, (11.07.2025; Львів, Україна), 136–144.

2. Suleymanov, J. F. et al. Modern approaches to technical safety in oil and gas pipelines. *İn* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.40

3. Ismayilov, N. E. et al. Ensuring the integrity and safety of pipeline infrastructure. *İn* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.41

4. Amanov, Y.A., et al. Tribological characterization of surface layer hardness and wear resistance under abrasive scratching // International Journal on Technical and Physical Problems of Engineering. 2025, 17(3), pp. 414–420

5. Sakov, A. A. et al. Policy-oriented technology selection for environmental security assurance. In *Problems of Informatization.* 2025. Vol. 4, pp. 52-54.

6. Garayev M.F. Ecological monitoring: the role of new technologies in the conservation of natural resources // Grundlagen der modernen wissenschaftlichen Forschung: der Sammlung wissenschaftlicher Arbeiten «ΛΌΓΟΣ» zu den Materialien der VIII internationalen wissenschaftlich-praktischen Konferenz, Zürich, 4. Juli, 2025. p.103-111. https://doi.org/10.36074/logos-04.07.2025.017

7. Garayev M.F., Hashimov E.G. The development of renewable energy sources and ıts ımpact on Azerbaıjan's energy securıty // Технології, інструменти та стратегії реалізації наукових досліджень: збірник наукових праць з матеріалами IX Міжнародної наукової конференції, м. Запоріжжя, 2025. p.53-62. https://doi.org/10.62731/mcnd-25.07.2025.002

8. Teymurov M., et al. Multi-criteria optimization of UAV routes through integration of a risk map and communication quality. *In* Current issues of science, prospects and challenges: Collection of Scientific Papers «SCIENTIA». Sydney, Australia. 2026. P.107-116

9. Bayramov A.A. Development of UAV SoS flight combat reconnaissance mission program //Advanced Information Systems. – 2019. – Т. 3. – №. 1. – С. 152-156.

10. Garayev, M. F. et al. Analysis of shear stress resistance and abrasive wear in surface layers of materials for military use. *İn* Current directions of development of information and communication technologies and control tools. 2025. Volume 4: sections 6. p.55

11. Bayramov A. A. et al. SMART control system of systems for dynamic objects group //Bulgarska Voenna Misal.–2018. – 2018.

12. Muradova, E. et al. Analytical evaluation of UAV-based logistical operations in contemporary military systems. *Матеріали конференцій МЦНД*, (31.10.2025; Вінниця, Україна), 347–350

13. Bayramov A. A., et al. Unmanned aerial vehicle applications for military GIS task solutions //Automated systems in the aviation and aerospace industries. – IGI Global Scientific Publishing, 2019. – С. 273-296.

14. Nasibov Y.A. et al. Modelling of the rationally deployment of observing systems //Advanced İnformation Systems. – 2019. – Т. 3. – №. 2. – С. 10-13.

15. Huseynov, M. et al. Application of modern multi-sensor technologies for ground target detection. *Матеріали конференцій МЦНД*, (10.10.2025; Суми, Україна), 172–182.

16. Zulfugarov B.S. et al. Multi-criteria evaluation of energy accumulation technologies for defense energy security. *İn* Current directions of development of information and communication technologies and control tools. 2025. Volume 1: sections 1,5. p.137

17. Garayev, M., & Hashimov, E. (2025). Balancing Innovation and sustainability: the ecological risks of modern technologies. *Collection of Scientific Papers «SCIENTIA»*, (September 12, 2025; Sydney, Australia), 52–59.

18. Garayev, M. et al. (2025). Wind, sun, and hydroenergy: a look into Azerbaijan's green energy future. *Collection of Scientific Papers «ΛΟΓΟΣ»*, (August 1, 2025; Seoul, South Korea), 125–133. https://doi.org/10.36074/logos-01.08.2025.019

19. Hashimov E.G. et al. About some aspects of using a flock of UAVs. Сучасні напрями розвитку інформаційно-комунікаційних технологій та засобів управління. 2023. Т. 1.секція 1,3,4. С. 4-5.

20. Huseynov B. S. et al. Multisensor detection architectures on UAV platforms: methodology, indicators and implementation in Azerbaijan. – 2025.

21. Atayev S.U., et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., sec. 3,7. p.100-101

22. Atayev S.U. et al. Multimodal fusion methodology for detecting visually invisible targets on UAV platforms. *In* Problems of informatization. 2025. Vol. 2., s. 3,7. p.100-101

23. Elshan, H. et al. (2026). Constrained optimization of an integral security indicator for adaptive management of hazardous facilities. Grail of Science, (62), 1003–1014. https://doi.org/10.36074/grail-of-science.20.02.2026.109

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ОРГАНІЗАЦІЇ, ЯКІ ПРИЙНЯЛИ УЧАСТЬ У КОНФЕРЕНЦІЇ

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