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# CONTENT

## ARTS

**Pogrebnyak M.**

TECHNIQUES AND EXAMPLES OF USING MULTIMEDIA  
TECHNOLOGIES IN THE WORK OF BALLET MASTERS  
OF THE LATE 20<sup>th</sup> AND EARLY 21<sup>st</sup> CENTURIES .....4

**Bakirova T.**

PEDAGOGICAL APPROACHES FOR DEVELOPING  
STUDENTS' THREE-DIMENSIONAL THINKING .....9

## BIOLOGICAL SCIENCES

**Cholakidou A., Petrov A.**

LION'S MANE MUSHROOM – MEDICAL BENEFITS .... 17

## EARTH SCIENCES

**Shevchenko I.**

'STORM GLASS' IS A SOLAR INFLUENCE DETECTOR.  
STRUCTURING OF WATER CLUSTERS IN 'STORM  
GLASS' UNDER THE SOAR EXPOSURE AND WHEN  
MOOVING IN SPACE ..... 26

## ECONOMIC SCIENCES

**Guliyeva G., Həsənova T.**

ESTABLISHING FINANCIAL CONTROL IN ACCORDANCE  
WITH MODERN REQUIREMENTS: IN THE WORLD AND  
IN AZERBAIJAN ..... 30

**Kostadinov O.**

ANALYSIS OF THE ROLE OF WATER TRANSPORT IN  
COMBINED, INTERMODAL AND MULTIMODAL  
TRANSPORT .....33

## JURISPRUDENCE

**Hoxhaj O., Hoxhaj Xh.**

THE PROTECTION OF MINORITY RIGHTS IN A  
GLOBALIZED WORLD ..... 39

## MATHEMATICAL SCIENCES

**Ma Lijun**

REFLECTIONS ON TEACHING THE METHOD OF  
CONSTANT VARIATION..... 46

## MEDICAL SCIENCES

**Gotseva A., Kunchev M.**

HEPATITIS E INFECTION - A REVIEW .....50

## PEDAGOGICAL SCIENCES

**Klochko A., Prokopenko A., Venher S.**

AREAS OF APPLICATION OF ARTIFICIAL INTELLIGENCE  
TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT OF  
THE EDUCATIONAL PROCESS ..... 54

**Zhantayeva M.**

WAYS TO ORGANIZE A MUSIC LESSON IN  
ELEMENTARY SCHOOL.....58

## PHILOLOGICAL SCIENCES

**Heydarova Kh.**

GEOGRAPHICAL TERMS IN THE WORK OF THE 14TH  
CENTURY AZERBAIJANI POET IMADED-DIN NASIMI... 62

## PHILOSOPHICAL SCIENCES

**Kozubaev O., Karabukaev K.**

ETHICAL SKETCHES TO THE QUESTION OF ARTIFICIAL  
INTELLIGENCE..... 66

## TECHNICAL SCIENCES

**Deev D.**

AUTOMATED BIOGAS PLANT CONTROL SYSTEM ..... 71

**Jabbarova K., Ismayilov H.**

THE USE OF DATA ANALYSIS TO ANALYZE EDUCATION  
TRENDS IN AZERBAIJAN ..... 75

**Shalitauri G.**

MODULS OF SUBGRADE REACTION WITH DIFFERENT  
NORMS ..... 78

**Nasirov N., Bashirov R.**

OPTIMIZATION OF MATERIAL SELECTION IN GUN  
BARREL PRODUCTION WITH ARTIFICIAL  
INTELLIGENCE ..... 80

**Ziyadkhanli S.**

ENHANCING RAILWAY TRANSPORTATION THROUGH  
DATA ANALYTICS: A COMPREHENSIVE REVIEW AND  
PREDICTIVE MODELING APPROACH ..... 93

**Kachura M., Ovcharuk I.**

BOARD ROLE-PLAYING GAMES AND THEIR  
COMPUTER ANALOGUES ..... 96

# ARTS

## TECHNIQUES AND EXAMPLES OF USING MULTIMEDIA TECHNOLOGIES IN THE WORK OF BALLET MASTERS OF THE LATE 20<sup>th</sup> AND EARLY 21<sup>st</sup> CENTURIES

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## ПРИЙОМИ ТА ПРИКЛАДИ ВИКОРИСТАННЯ МУЛЬТИМЕДІЙНИХ ТЕХНОЛОГІЙ В РОБОТІ БАЛЕТМЕЙСТЕРІВ КІНЦЯ XX – ПОЧАТКУ XXI СТОЛІТТЯ

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<https://doi.org/10.5281/zenodo.15536073>*

### Abstract

The media have a powerful influence on mass consciousness, forming certain images of certain cultural phenomena. The using of multimedia technologies and multimedia tools by directors and choreographers today gives them the opportunity to create original scenography for author's performances and high-tech concerts that attract the audience with their novelty, interactivity and spectacle.

**The purpose** of this scientific exploration is specification and systematization of the methods of possible using of multimedia technologies by ballet masters of the late 20<sup>th</sup> and early 21<sup>st</sup> centuries in their creative activities.

**The research methodology** is based on the using of the source studies and the method of included observation in the study of the creative works of individual choreographers in the field of contemporary theatre and show programs; analyzes and syntheses – to identify, concretization and systematization of techniques for the possible using of multimedia technologies by choreographers of the late 20<sup>th</sup> and early 21<sup>st</sup> centuries in their creative activities.

**The scientific novelty** lies in the identification, concretization and systematization of techniques for the possible using of multimedia technologies by ballet masters of the late 20<sup>th</sup> and early 21<sup>st</sup> centuries in their creative activities.

**Results.** Thus, as result of clarifying the meaning of the term «multimedia», the differences between the concepts of «multimedia technologies», (MMT); «multimedia tools» and «multimedia products»; as well as a result of analyzing the creative works of individual ballet masters of the late 20<sup>th</sup> and early 21<sup>st</sup> centuries, specific and systematized techniques of multimedia technologies have been identified that can be used in the work of ballet masters when creating scenography for choreographic works. Namely: computer graphics, computer animation, multimedia projection on a fog screen, 3D printing and others. In addition, the features of the creative methods of William Forsyth and Merce Cunningham using computer programs «Improvisation Technologies», «Life Forms», are vivid examples of a possible solutions to the scenography of stage choreographic works, the construction of a modified separate choreographic text, in particular in the interaction on stage between both artists and virtual characters.

### Анотація

У статті з'ясовано зміст терміну «мультимедіа»; а також різницю понять: «мультимедійні технології» (ММТ); «мультимедійні засоби» і «мультимедійні продукти». Проаналізовано творчі роботи окремих балетмейстерів кінця XX – початку XXI століття та виявлені і систематизовані прийоми мультимедійних технологій, які можуть бути використані в роботі балетмейстера при створенні сценографії хореографічних творів. А саме: комп'ютерна графіка, комп'ютерна анімація, мультимедійна проекція на туманний екран, 3D-друк та інші. Досліджено, що особливості творчих методів Уільяма Форсайта і Мерса Каннінгема з використанням комп'ютерних програм «*Improvisation Technologies*», «*Life Forms*», є яскравими прикладами можливого вирішення сценографії сценічних хореографічних творів або побудови модифікованої окремої хореографічної лексики, або модифікованого хореографічного тексту, зокрема у взаємодії на сцені і артистів і віртуальних персонажів. Виявлені і конкретизовані хореографічні вистави окремих балетмейстерів і окремі мініатюри хореографів шоу-програм XXI століття з використанням мультимедійних технологій.

**Keywords:** multimedia technologies, computer graphics, computer animation, multimedia projection on a fog screen, 3D printing, ballet masters, choreography, scenography, choreographic work.

**Ключові слова:** мультимедійні технології, комп'ютерна графіка, комп'ютерна анімація, мультимедійна проекція на туманний екран, 3D-друк, балетмейстер, хореографія, сценографія, хореографічний твір.

**Постановка проблеми.** Медіа потужно впливають на масову свідомість, формуючи певні образи тих чи інших культурних феноменів. Використання режисерами-хореографами мультимедійних технологій і мультимедійних засобів сьогодні надає їм можливість створювати оригінальну сценографію авторських вистав та високотехнологічних концертів, що привертають публіку своєю новизною, інтерактивністю, видовищністю.

**Аналіз досліджень.** На сторінках своїх монографій О. Чепалов і М. Погребняк торкаються питань використання мультимедійних технологій у творчій діяльності Уільяма Форсайта і Мерса Канінгема [18; 12]; Триколенко С. Т. розглядає використання мультимедійних технологій для оформлення сучасних хореографічних постановок на прикладі шоу-балету «Барон Мюнхгаузен» [17]. Але у мистецтвознавстві не існує наукових розвідок, присвячених *конкретизації та систематизації* прийомів можливого використання мультимедійних технологій балетмейстерами кінця XX – початку XXI у своїй творчій діяльності, що і є **метою** даної статті.

**Методологія дослідження** ґрунтується на використанні джерелознавчого та методу включеного спостереження у вивченні творчих робіт окремих хореографів у галузі сучасного танцю та шоу-програм; аналізу і синтезу – для виявлення, конкретизації та систематизації прийомів можливого використання мультимедійних технологій балетмейстерами кінця XX – початку XXI ст. у своїй творчій діяльності.

**Виклад основного матеріалу.** З'ясуємо зміст терміну «мультимедіа», який поширився завдяки англомовним джерелам. О. П. Пінчук зазначає, що термін «мультимедіа» виник шляхом поєднання двох англійських слів «multy, multiple» (множинний, складний, зіставлений з багатьох частин) і «media» (середовище, засіб) [14, с. 2]. Б. Б. Корчевський і В. В. Дякова визначають мультимедіа як «спектр інформаційних технологій, що використовують різноманітні програмні та технічні засоби з метою найефективнішого впливу на користувача (що став одночасно і читачем, і слухачем, і глядачем). Завдяки застосуванню в мультимедійних продуктах і послугах одночасної дії графічної, аудіо- (звукової) і візуальної інформації ці засоби володіють великим емоційним зарядом і активно включають увагу користувача (слухача)» [7, с. 118]. Г. М. Коджаспирова визначає мультимедіа як «технологію, що забезпечує роботу з нерухомим зображенням, відеозображенням, анімацією, текстом і звуком... Інформація після відповідної обробки і з додаванням тексту, анімації та спец ефектів записується в мультимедійний файл. Мультимедіа створює взаємодію візуальних і аудіо ефектів» [5].

Таким чином, дослівно «мультимедіа» перекладають як «багато середовищ» [14 с. 2]. У науковій та технічній літературі зустрічаються різні означення мультимедіа, що змінюються в залежності від місця та об'єкта, для якого передбачається його використання. Пінчук О. П. цитує визначення тер-

міну «мультимедіа» за Шликовою О. В. як «полісередовища», єдиного простору, який в синкретичному вигляді представляє різні види та способи надання інформації (тексту, графіки, звуку та ін.) [14, с. 3]. Дослідниця визначає і чітко розрізняє наступні поняття: «мультимедійні технології» (ММТ) – технології, які окреслюють порядок розробки, функціонування та застосування засобів обробки інформації різних модальностей; «мультимедійні засоби» та «мультимедійні продукти», які створюються на основі ММТ [14, с. 4]. Завдяки застосуванню в мультимедійних продуктах і послугах одночасної дії графічної, аудіо- (звукової) і візуальної інформації ці засоби володіють великим емоційним зарядом і активно включають увагу користувача (слухача). Тому мультимедійні технології як спосіб оформлення виступів відразу отримали найвищі оцінки як режисерів та сценографів, так і глядачів. Серед мультимедійних технологій, що використовуються у танцювальних шоу-програмах та сучасних балетних виставах найчастіше використовуються: *фото та відео-проекції, інсталяції, лазерні ефекти, різноманітні графічні програми, мультимплікація, або анімація.*

*Комп'ютерну графіку* визначають як вид діяльності, в якій комп'ютер використовується як інструмент для синтезу та обробки візуальної інформації, отриманої з реального світу [6].

Поява 3D-друку представила такий собі міст для медіа-мистецтва, що з'єднує *віртуальний та фізичний світи*. Розвиток цієї технології дозволив художникам поєднувати цифровий аспект медіа-мистецтва з традиційною фізичною формою скульптури. Першовідкривачем у цій галузі став художник Джонті Хурвітс, який за допомогою цієї техніки створив анаморфозну скульптуру [11].

У сучасних світових хореографічних виставах можна зустріти такий технічний засіб як **туманний екран** (димовий екран), на якому відбивається *мультимедійна проекція*. Ключова особливість димового екрану – *можливість безперешкодно пройти крізь інсталяцію*, не руйнуючи її (такі декорації дають змогу артистам вільно пересуватися по сцені). При цьому хореографічні номери можуть набувати «нереального» звучання, а танцюристи здаються незвичними, схожими на видіння [1].

Мультимедійні прийоми, які використовуються в практиці сучасного хореографічного мистецтва, включають анімацію. У буквальному сенсі **анімація** (від латинського anima – душа і похідного французького animation – оживлення) – вид кіномистецтва, твори якого будуються за допомогою *фіксації послідовних фаз руху* намальованих (графічна анімація) або тривимірних (3D-анімація) об'єктів. Ці твори називаються *анімаційними* або *мультимплікаційними фільмами (мультфільмами)*.

*Комп'ютерна анімація* – це вид анімації, який використовує комп'ютерні засоби для створення об'єктів. У сценографії сучасних балетних вистав використовуються *Комп'ютерна 2-D і 3-D анімація*. За методом *анімування* розрізняють:

«**Покадрова технологія**» – це техніка, в якій кожен кадр малюється окремо, що дозволяє вносити майже будь-які зміни в об'єкт для досягнення найвибагливіших ідей; **техніка «ключових кадрів»** передбачає створення не всіх кадрів, а лише «ключових»; **«технологія захоплення руху»** – це відносно молода технологія, в якій об'єкти рухаються або змінюють форму внаслідок аналогічних дій реальними істотами. Ця технологія допомагає фіксувати найскладніші реалістичні рухи реальних чи неживих об'єктів, до яких прикріплені датчики, під'єднані до комп'ютера.

*Комп'ютерну анімацію* можна визначити за різними типами об'єктів: **«Техніки руху»** – дозволяють передавати рух об'єктів або їхніх частин; **прийоми «морфіngu»** – використовуються для перетворення одного об'єкта на інший. **Анімація кольору** – технології трансформації забарвлення об'єкта [2].

Метод «3D-шоу» спершу було використано в театральному мистецтві. Так, у 2005-му році в одному з театрів британської компанії «Birmingham Stage Company» було продемонстровано нову технологію «Bogglevision», яка дає змогу відображати тривимірні об'єкти, які не тільки витають у повітрі, а й реагують на те, що відбувається на сцені та в залі. Для сприйняття таких тривимірних ілюзій глядачам було видано спеціальні окуляри, на кшталт тих, що використовуються при перегляді стереофільмів.

Шоу «Барон Мюнхгаузен» (творці визначили жанр як «3D-шоу», постановка К. Томільченка за мотивами п'єси Г. Горіна «Той самий Мюнхгаузен») – перша масштабна вистава, «декораційне оформлення якої практично повністю побудоване на використанні проєкційних технологій... Завдяки сучасним матеріалам та технологіям авторам вдалося створити фантастичне середовище, котре захоплює, заворожує, шокує. Стилiзація елементiв готики, архiтектури вiкторiанської доби, реалiстичних та абсолютно фантастичних пейзажiв, вiдтворених у декорацiях на сценi та в 3D-технологiях на спеціальних екранах перетворює все дійство у єдину гармонійну структуру, актори та оточення здаються єдиним цілим», свiдчить С. Триколенко [17, с. 108].

Трансляція у форматі 3D-постановки «Лебединого озера» на сцені Маріїнського театру відбулася завдяки ідеї з'єднання найвищих технологій і найкращих балетів класичної спадщини, яка виникла у художнього керівника, директора, головного диригента Маріїнського театру Валерія Гергієва ще багато років тому. Тоді в режимі стерео був записаний балет «Жизель». 3D-трансляція в режимі реального часу стала можливою завдяки компанії «Cameroon-Pace Group».

Головним оснащенням було сім 3D-камер, з'єднаних з телеапаратурою Маріїнського театру. Вони були розташовані в декількох точках залу – перш за все, перед самою сценою. Також була камера над залом – на довгому крані, який дозволяє знімального апарату буквально літати і над публікою, і над артистами.

У головних партіях виступили Катерина Кондаурова, Тимур Аскеров, Андрій Єрмаков. Оркестром диригував Валерій Гергієв. Провідною трансляції виступила російська топ-модель Наталія Водянова. Виставі передувала коротка відеозаставка з видами Санкт-Петербурга і двох сцен Маріїнського театру. Публіка також побачила короткі інтерв'ю з артистами і звернення Валерія Гергієва, який запросив глядачів приїхати до Санкт-Петербургу. Постановником трансляції виступив колишній танцівник лондонського театру «Ковент-Гарден» Росс МакГіббон [9].

В Києві, на головній сцені країни, в Палаці «Україна» прем'єра «Лебедине озеро 3D» за участю зірок світового балету відбувалася в 2021 році. Партію Принца Зіґфріда виконала зірка світового балету, етуаль-прем'єр Віденської опери Деніс Черевичко, якого порівнюють з самим Вацлавом Ніжінським, і який за оцінкою видавництва ELLE входить до списку «5 чоловіків українського балету, які підкорили світ». Віртуозна прима-балерина Словацького національного театру в Братиславі Ольга Челпанова втілила на сцені дві протилежні ролі – ніжну Одетту та фатальну Оділію.

Класична хореографія в поєднанні із сучасними віртуальними декораціями максимально посилює враження від майстерності артистів балету і можливостей людського тіла. Простір сцени стає безмежним за рахунок проєкції на LED-екрани унікальної 3D-анімації, розробленої спеціально для цього перформансу [8]. Завдяки цьому ефекту кожен глядач може максимально поринути в атмосферу легендарного «Лебединого озера». Для людей, які тільки починають пізнавати балет, 3D-графіка допоможе краще розуміти сюжет і мову танцю.

Місія проєкту – наблизити сучасного глядача до мистецтва, не порушуючи основи, поєднуючи високе мистецтво і новітні технології. До того, 3D-технології в шоу – це гідна альтернатива традиційним декораціям, усвідомлений крок у екологічність в мистецтві [9].

Одним з прикладів окремих хореографічних мініатюр з використанням мультимедійних технологій є ексклюзивний «Holographic Dance 360» Олександра Лещенко, який він презентував у своєму концерті. Номер розповідає про складний і багатограний світ артиста, який збирається вийти на сцену до широкої аудиторії. Перформанс візуалізує загадковий, експресивний, динамічний світ артиста. Всі рухи Олександра чітко синхронізовані з проєкціями у 3D кубі [16].

Відео-контент для спектаклів пишеться високопрофесійними художниками-аніматорами. Мультимедійний контент – не тільки заміна звичайних декорацій, а ще й повноцінний простору, де відбувається розвиток драматургічних ліній балету.

Вистави театру російського балету «Talarium et Lux» – це інтеграція хореографії та можливостей комп'ютерної графіки. У глядача створюється відчуття, що персонажі живуть усередині фантазмагорії. Для цього сценографи створили спеціальну конструкцію з п'яти екранів воедино з декількома планами, завдяки яким дія переноситься зі сцени на

екрани і назад. Графіка – це не просто прикраса. Вона рухає дію, допомагає розкривати історію на сцені, підкреслювати її казковість.

На відміну від звичайних декорацій, використання проєкційних екранів надає можливості візуально миттєво змінювати геометрію простору, робити графічні акценти, трансформувати місце події. Щоб поєднання графіки та хореографії було найбільш виразним, спеціально змінюються деякі мізансцени.

Таким чином, персонажі можуть спочатку з'являтися на проєкційних екранах і, трансформуватися, переходити в реальний сценічний простір, стаючи живими дійсними особами і відповідно, з'являється *можливість взаємодії на сцені і артистів і віртуальних персонажів, що існують у просторі анімаційного відео*. Артистам потрібно буде не лише виконувати хореографію; встигати за музикою, вжитися в сценічний образ, але і пам'ятати, які зміни відбуваються на екранах, щоб діяти синхронно з анімацією [3; 15].

Цікавим прикладом використання мультимедіа в творчій роботі хореографа є комп'ютерна програма «Improvisation Technologies», створена У. Форсайтом. Спочатку вона планувалася як допоміжний засіб для професійного тренінгу артистів балету франкфуртської трупи та з часом набула універсальних функцій, що дозволяють аналізувати будь-який рух танцівників.

У цьому проєкті всі рухи танцюристів вписані у віртуальний простір. «Технологія імпровізації» («Improvisation Technologies») стала основою його творчого методу. Використання ряду технологічних прийомів, таких як переорієнтація підлоги («floor reorientation»); присвоєння лінії («assignment to a line»); стиснення часу («time compression»); падіння по кривій («dropping curves»); паралельний зріз («parallel shear»); екзерсис на м'якість частин тіла («soft-body-part exercise») дозволяє балетмейстеру створювати безмежну різноманітність лексичних новоутворень. Несподівані лексичні новоутворення зі словника класичного танцю У. Форсайт створює, починаючи малювати уявні фігури в повітрі, використовуючи всі частини тіла – ноги, руки, голову, коліна, вуха, підборіддя і т. ін. Так він створює різноманітну геометрію танцю, «яка графічними засобами креслить повний об'єм потенціальних рухів людського тіла...». Хореографічний текст складається з «fouette» зі зміщенням осі обертання танцюриста; «tour lent» зі зміною поз; різноманітних поз «attitudes» зі складною координацією корпусу та рук, виворотних «passe» тощо [13, с. 8–9; 19].

Мерс Каннінгем у 1991-му р. почав використовувати у своїй хореографії комп'ютерну програму під назвою «Life Forms» («Форми життя»), за допомогою якої можна «оживляти» фігуру людини та створювати танець. Результатом таких експериментів можна вважати постановки балетмейстера «Beach Birds for Camera» (1991-й р.) з жорсткими і незграбними рухами рук і ніг і «Viped» (1999-й р.). Балет «Viped» складається з двох частин: «живе» виконання хореографічної партитури танцюристами та відеопроєкції, яка варіюється від абстрактних фігур до анімованих відео з намальованими танцівниками.

Для створення анімації на трьох виконавицях встановлювали рецептори, які фіксувалися відеокамерами. Всі рухи переводилися в 3D моделі людських силуетів, а потім проєктувалися на сцену, де з ними взаємодіяли живі перформери. Танцюристи-перформери цієї вистави виконуючи модифіковані «tombe», «tour» із зігнутою попереду ногою, різноманітні «attitudes» з «flat backe», «tour channe», «grand battement», акробатичні підтримки в позу «l arabesques» [4; 13, с. 9; 10].

**Висновок.** Таким чином, в результаті з'ясування змісту терміну «мультимедіа», різниці понять: «мультимедійні технології» (ММТ); «мультимедійні засоби» і «мультимедійні продукти»; а також в результаті здійснення аналізу творчих робіт окремих балетмейстерів кінця XX – початку XXI століття, виявлені, конкретизовані і систематизовані прийоми мультимедійних технологій, які можуть бути використані в роботі балетмейстерів при створенні сценографії хореографічних творів. А саме: *комп'ютерна графіка, комп'ютерна анімація, мультимедійна проєкція на туманний екран, 3D-друк та інші*. Крім того, особливості творчих методів Уільяма Форсайта і Мерса Каннінгема з використанням *комп'ютерних програм «Improvisation Technologies», «Life Forms», є яскравими прикладами можливого вирішення сценографії сценічних хореографічних творів, побудови модифікованої окремої хореографічної лексики або модифікованого хореографічного тексту, зокрема у взаємодії на сцені і артистів і віртуальних персонажів*.

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## PEDAGOGICAL APPROACHES FOR DEVELOPING STUDENTS' THREE-DIMENSIONAL THINKING

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### Abstract

The practice of fostering visual thinking and the ability to create three-dimensional imagery in students is a crucial component of architectural design education. This study emphasized the importance of enhancing students' creative thinking skills and their capability to devise and execute spatial solutions. To achieve this, a design studio was established for first-year university students, where they examined current conditions and utilized design tools and visual elements to depict space in three dimensions.

The one-semester training program, developed and implemented within the design studio, focused on the perception of three-dimensional scenes, considering spatial organization, movement, orientation, the arrangement of basic visual elements, and the application of light and color. Students were actively engaged in expressing their concepts through three-dimensional space representations.

The findings demonstrated that using space as a catalyst for creative thinking and as a method for studying design, which underscores the significance of visual communication, can markedly enhance students' creative thinking abilities. Consequently, this approach significantly boosts the effectiveness of the creative design processes.

**Keywords:** Teaching methods, three-dimensional thinking, spatial perception, design education, visual thinking, creative development

**Introduction.** Spatial thinking transcends the mere visualization and manipulation of three-dimensional objects; it also enhances students' abilities in abstraction, synthesis of elements, and structural analysis. This cognitive skill is pivotal in discerning primary elements from secondary ones, which is essential in the design process. The article delves into how spatial thinking influences students' success and creativity during their educational journey and subsequent practical endeavors. The research highlights that honing this ability not only fosters creativity but also augments analytical skills and elevates the overall professional competency of design students.

Human development encompasses multiple stages, each contributing to various facets of intelligence and cognitive skills, including spatial thinking. Irrespective of innate capabilities, the development of spatial thinking is not significantly constrained by initial intelligence levels. This critical skill can and should be nurtured, independent of a person's starting point.

The significance of cultivating spatial thinking in students is particularly pronounced in design education. The field of design demands creativity coupled with spatial perception and modelling capabilities, enabling future designers to effectively tackle challenges related to the creation of three-dimensional objects and structures. Throughout design education, considerable emphasis is placed on the use of visual aids and materials, which are instrumental in developing these skills. This approach not only bolsters creativity but also sharpens analytical proficiency and overall professional preparedness among design students.

**Problems and approaches.** The cultivation of spatial thinking in students encounters several challenges. Firstly, there is a notable lack of systematic

methodologies and techniques specifically designed to effectively enhance this cognitive skill. Secondly, resources are often limited, including access to contemporary tools and technologies such as 3D modelling software and virtual reality platforms. Psychological barriers also contribute, as transitioning from two-dimensional to three-dimensional perception demands significant effort and time.

Despite these obstacles, several proven strategies can help mitigate these difficulties. The implementation of visual aids and materials, such as graphic diagrams, drawings, and models, facilitates students' comprehension and visualization of three-dimensional structures. Additionally, interactive technologies like virtual reality and 3D modelling software offer substantial opportunities for advancing spatial thinking.

**Types of thinking.** In analyzing various cognitive styles, the significance of spatial thinking as a crucial element in the educational framework for future designers is emphasized. Spatial thinking enables the detailed and three-dimensional visualization of objects, encompassing the following abilities:

- Distinguishing essential elements from less critical ones;
- Integrating diverse elements into a cohesive whole;
- Abstracting from specific details to perceive the overall context;
- Representing the structure of objects within space;
- Concrete realization of ideas and concepts.

This mindset is integral to the development of future designers, as it supports the creation and manipulation of three-dimensional objects and structures,

thereby enhancing both their creative and analytical capabilities.

**Impact of spatial thinking on problem-solving and creativity.** These cognitive abilities are crucial for addressing a wide range of theoretical and practical problems. The article explores the profound influence of spatial thinking on the success and creativity of students throughout their education and practical aspirations in design. The development of spatial thinking enhances both analytical and creative skills, making it an invaluable tool for students, particularly in the design field.

Spatial thinking not only aids students in visualizing and constructing three-dimensional models but also fosters the development of innovative solutions, a critical aspect of professional training. By honing these skills, students can better integrate elements, and abstract concepts, and create comprehensive and practical designs, ultimately leading to improved problem-solving abilities and heightened creativity. This cognitive approach enables future designers to navigate complex spatial challenges and contribute effectively to their field.

**Research of methods.** The article examines the study of Tung Y-H and Chang C-Y in "How three-dimensional sketching environments affect spatial thinking: Virtual reality research using functional magnetic resonance imaging", which analyzes differences in cognitive processes when using 2D and 3D sketching tools. The study involved 20 students with experience in painting landscapes by hand. Their brain activity was compared while using 2D tools (iPad Pro and Apple Pencil) and 3D tools (Oculus Quest VR). Significant differences were found in the activation of different brain regions when drawing in 2D and 3D environments, especially in areas such as the right medial temporal gyrus, both sides of the parietal lobe and the left medial occipital gyrus. Visual-spatial functions were also investigated: in which the use of 3D tools in virtual reality activated more visual-spatial brain functions compared to 2D tools. Differences in brain activation were noted when performing tasks related to drawing lines, and geometric and naturalistic objects, which highlights the enhanced spatial perception and navigation capabilities provided by 3D tools. The study highlights the potential of immersive virtual reality tools to improve design-related processes and spatial thinking. This makes such tools valuable for educational practices in the field of design, as they help to improve students' spatial perception and creative abilities.[1]

**Exploration of spatial thinking in design education.** In the research by Ya. A. Lugin and O. M. Koshelev titled "The Development of Spatial Thinking Among Design Students," the authors highlight the importance of defining the concept of space in design to understand the development of spatial thinking. They identify two primary approaches: Objective space: This approach views space as a physical reality, referring to the arrangement of simultaneously existing real objects.

Subjective space: This approach considers space as a way of organizing the world related to cultural and

artistic perspectives. It emphasizes that everyone, influenced by their cultural context, has a unique understanding of the world [3].

Similarly, Park, E.J., and Kim, M.J., in their study "Visual communication for students' creative thinking in the design studio: translating filmic spaces into spatial design," stress the importance of nurturing creative thinking within design education, especially in architectural design [2]. They argue that traditional design education often relied on subjective methods rather than systematic academic approaches, potentially hindering the development of creativity.

Practical application in education. The study describes a visual design studio for first-year architecture students at a university in Korea, which integrates cinematic elements into architectural design. This innovative approach helps students transform cinematic elements into spatial design, thereby enhancing their creative thinking. Tasks in this studio focus on stimulating creativity rather than merely addressing functional aspects, reflecting a shift in educational environments to foster creative development.

This method aims to provide students with alternative ways to cultivate creative thinking, thus preparing them to tackle complex and multidisciplinary challenges in their future professional careers.

The design studio fosters a procedural exploration of design challenges, emphasizing the importance of rethinking problems and employing various representation methods throughout the design process. This approach facilitates a deeper understanding of the relationships between cinema and real space, the development of new architectural expression methods, and the overall enhancement of creativity in architectural education.

Three-dimensional thinking in design education core competence in design careers: Three-dimensional thinking is essential for a successful career in design, enabling designers to visualize and create objects within space, comprehend their interaction with the environment, and propose innovative solutions. Developing this skill in design students requires a comprehensive approach that combines theoretical learning, practical assignments, and the use of modern technologies.

Introducing students to three-dimensional thinking involves familiarizing them with spatial thinking and visualization. This includes understanding the necessity of considering objects and processes in three dimensions and recognizing the importance of three-dimensional perspectives in various fields. Early education on this topic helps students grasp the fundamental principles of three-dimensional thinking, which they will apply in advanced studies and practical work.

Three-dimensional thinking is crucial in creating visually appealing and functional products. It enables designers to envision the final product in real space, considering all its aspects and interactions with the surrounding environment. This skill aids in producing more precise and detailed projects, improving the quality of final products and enhancing their market competitiveness.

The psychological and cognitive aspects of three-dimensional thinking encompass spatial imagination,

visual-spatial memory, and cognitive flexibility. Developing these skills enhances the learning and practical performance of designers. Research indicates that regular exercise and training can significantly improve these cognitive abilities, positively impacting three-dimensional thinking.

Teaching visualization and spatial thinking involves various techniques such as drawing, sculpting, and modeling. These practices help students develop observation and visualization skills and improve their understanding of proportions and perspective. Regular practical sessions and exercises foster the development of spatial imagination and visual-spatial memory, which are essential for effective design education.

Designing and modeling in three-dimensional space are crucial aspects of educating design students. This includes using various materials and tools to create prototypes and models. Working with physical objects helps students better understand three-dimensional structures and their interactions. Additionally, the use of computer programs to create digital models and animations allows students to develop skills in working with modern technologies.

The role of technology in the development of three-dimensional thinking is significant. Modern computer programs such as AutoCAD, 3ds Max, Blender, and others provide powerful tools for creating and visualizing three-dimensional models. Learning these programs enables students to create sophisticated digital prototypes and animations. Virtual reality (VR) and augmented reality (AR) open up new opportunities for learning and practice, allowing students to immerse themselves in and interact with three-dimensional spaces. Furthermore, 3D printing provides students with the chance to create physical models of their projects, aiding in the visualization and testing of ideas in the real world, thereby improving their understanding of the shape and functionality of objects.

Modern technologies contribute to the development of students' three-dimensional imagination. However, they can also interfere with the independent formation of consciousness and intelligence. While technological capabilities speed up the learning process, they can ultimately slow down the development of visual thinking. Technology supports students' thinking and imagination by facilitating modeling and self-expression processes, but overuse can lead to dependence and limit independent development.

Howard Gardner is known for his theory of multiple intelligences, which revolutionized the understanding of intelligence and learning processes. Gardner argued that traditional IQ tests treat intellectual abilities too narrowly, emphasizing that people have many different types of intelligence. In his theory, he identified eight main types of intelligence: linguistic, logical-mathematical, spatial, bodily-kinesthetic, musical, interpersonal, intrapersonal, and naturalistic[5].

Gardner emphasized the importance of recognizing and developing these diverse intellectual abilities in educational settings to create a comprehensive and inclusive learning environment. For instance, spatial intelligence, which involves the capacity to visualize and

manipulate objects in three-dimensional space, is crucial for fields such as architecture, engineering, and design.

To foster three-dimensional thinking in students, Gardner's theory advocates for teaching methods that include hands-on projects, interactive simulations, and visual arts, engaging students in spatially oriented tasks [6].

While Gardner's theory has significantly influenced educational practice by promoting an individualized approach to learning, it has also faced criticism for its lack of empirical support and the difficulty of clearly distinguishing each type of intelligence from broader cognitive abilities. Despite this, Gardner's ideas continue to shape modern educational strategies, particularly in enhancing creativity and problem-solving skills across various disciplines.

According to Gardner, individuals possess multiple intelligences: "As unique beings, we humans are endowed with a range of relatively autonomous intelligence "[4, c. 25].

An experiment was conducted among first-year design students to assess their knowledge and skills required by the course. It included tasks aimed at evaluating their mathematical thinking, drawing skills, and ability to complete assigned projects.

The primary goal of the design studio was to develop critical thinking, design skills, and the ability to think in both 2D and 3D. The preparation process for the tasks was organized around a sequence of four design studies, which served as the main tool for achieving the course objectives. Each project focused on a set of tasks aimed at developing conceptual, technical, and analytical skills. Various methodological approaches were used, such as two- and three-dimensional composition, design and modeling, form generation processes, transformation and conversion, analytical and comparative studies, and the study of the relationship between architectural space and visual elements.

Students were expected to analyze and synthesize information in the context of other subjects, identify their strengths and interests, and then go beyond the minimum course requirements. These assignments helped students develop creative thinking and improve design processes, allowing them to take risks and experiment with new ideas and approaches.

#### **Course objectives and learning outcomes:**

1. **Skill development:** Students should develop the conceptual, technical, critical, and analytical skills necessary to shape, develop, evaluate, and express a coherent design proposal. This includes the ability to generate ideas, bring them to life, and then critically assess their alignment with the set objectives.

2. **Questioning and conclusions:** Students should learn to ask thoughtful and precise questions, draw justified conclusions, and verify the compliance of their work with established criteria and standards. This is important for both analyzing existing projects and developing new proposals.

3. **Effective management of design elements:** The course aims to develop skills in managing the fundamental elements of architecture and design, such as form, space, structure, order, proportion, mass, surface,

light, program, space, human body scale, and material properties. Students should learn to intuitively and effectively manage these elements.

4. Application of architectural elements: Students should be able to apply the basic elements of architecture and design to create spaces with clear and appropriate area relationships. This includes creating harmonious and functional spaces that meet specified requirements.

5. Expression of design ideas: At each stage of the design process, students should be able to express the concept and ideas of the project orally, as well as through sketches and models.

This contributes to the development of both two-dimensional and three-dimensional thinking [24]. The primary outcomes of the course pertain to the following aspects:

1. Theory, precedents, and design methods: Students are expected to master theoretical foundations, study existing precedents, and learn design methods.

2. Design skills: The course emphasizes the development of practical design skills.

3. Design tools: Proficiency in various tools used in the design process is essential.

4. Software analysis: Students should be able to analyze and use specialized design software effectively.

5. Design context: Understanding the context in which design is implemented and the ability to integrate design into existing environments is crucial.

6. Project documentation: The ability to create detailed project documentation is an important outcome.

7. Critical thinking and communication: Developing critical thinking and communication skills is a key focus.

8. Cultural diversity and global perspectives: Understanding and considering cultural diversity and global perspectives in the learning process is essential.

**Course structure:** To achieve these goals, the course includes 180 hours of classes (6 credits), consisting of theoretical and practical sessions designed for the first semester. The main theme of the final project is the design of an exhibition environment, the development of a spatial solution, and the application of visual elements in space according to the concept [Fig.1].

This approach promotes the comprehensive development of students, preparing them to tackle complex tasks in the field of architecture and design. Architectural space and its visual realization reach their pinnacle when their construction demonstrates a unique interplay of parts, creating a sense of enchantment. In such a scenario, the construction becomes an effective art form, evoking a sense of mystery among viewers. Using the same elements in different combinations, however, can result in the loss of this magic of form. Thus, knowledge of the structure of architectural form and its space is essential for achieving perfection. Each culture addresses this task in its unique way.

To address such issues, we have transitioned from descriptive analysis to structural analysis. The artistic language of architectural form and its spatial resolution are among the most complex aspects, and difficult to describe analytically. Therefore, presenting the intended concept, realizing the idea, and developing three-dimensional thinking in students require a special approach [23].

Course topics

- **Topic 1: Introduction to the subject. Course requirements, introduction to literature. Introduction to the topic. Overview and use of technology in visual design.** This topic introduces students to the course, outlining its requirements and expectations. It provides an overview of key literature and resources, highlighting the primary concepts in visual design. Students will also receive information on the software tools they will be using and how to apply them to complete assignments.
- **Topic 2: Research and concepts. Foundations of research. Linear thinking/Lateral thinking. Visualization of ideas.** This topic delves into research methodologies and conceptual frameworks. It contrasts linear and lateral thinking approaches, helping students understand different ways of visualizing and developing ideas.
- **Topic 3: Elements in design. Introduction to design elements through projects.** Students will explore design elements through practical projects, such as creating color schemes using graphic software. They will learn about the use of color, lines, shapes, space, and texture in design.
- **Topic 4: Elements of design. Fundamental elements in 2-D and their definitions. Theories of Image and text.** This topic covers the basic elements of 2-D design, including negative and positive space, void, line, plane, volume, form, size, and value. It also examines texture, pattern, and their significance in visual design.
- **Topic 5: Element of design: Light and Color. Definition and Importance of Color. Color associations and contrast.** Students will study the definition of color, its variations, and its importance in communication design. They will learn about lighting principles, calculating illumination levels, and understanding light intensity in spaces.
- **Topic 6: Principles of design 1.Design principles: composition, balance, saturation, emphasis, dominance, unification.** This topic introduces students to essential design principles that guide composition and visual balance.
- **Topic 7: Principles of design 2. Symmetry and asymmetry, proportions, scale, hierarchy, contrast.** Students will explore advanced design principles, including symmetry, asymmetry, proportions, scale, and the creation of visual hierarchies and contrast.
- **Topic 8: Visual elements in composition. Exploring visual elements in composition for visual expression.** This topic focuses on the arrangement and impact of visual elements in creating compelling compositions.
- **Topic 9: Group and system concepts. Hierarchy of elements in planes and space. Creating balance in constructive composition.** Students will learn about the grouping and systematization of design elements, understanding how to create balance and hierarchy in both two-dimensional planes and three-dimensional spaces.
- **Topic 10: Rules of spatial placement. Principles of element placement in space. Element significance and symmetry.** This topic covers the fundamental principles of placing elements within a space, including understanding element significance, force fields, and system symmetry in visual design.
- **Topic 11: From concept to visualization. Initial concepts and idea organization. Coordination and creation of visual series.** Students will learn how to translate initial concepts into visual designs, focusing on coordination, visual series creation, photography, and illustration.
- **Topic 12: Studio tools and skills. Software proficiency, page layouts, digital photography, image manipulation and computer illustration.** This topic emphasizes the technical skills required in the studio, including proficiency with design software, creating page layouts, digital photography, image manipulation, and computer illustration.
- **Topic 13: Visualization of design concepts. Space saturation and artistic solutions. Informative Space.** Students will study the visualization of design concepts, focusing on the artistic and informative aspects of space.
- **Topic 14: Content and form in space. Design model in space. Structural units and complexity of plastic elements.** This topic covers the integration of design models into spaces, examining structural units and the complexity of plastic elements.
- **Topic 15: Design concept of selected environment. Main and additional functions of zones. Functional unit division. Facades, walls, zone functions, compositional elements.** Students will develop a design concept for a selected environment, considering the main and additional functions of different zones, the division of zones into functional units, and the role of facades, walls, and compositional elements.

*Fig. 1. Syllabus of the course.*

This curriculum fosters a comprehensive development of students, preparing them for complex tasks in architecture and design. Understanding the interaction of architectural space and its visual representation is crucial for achieving excellence, as each culture ap-

proaches this task uniquely. By transitioning from descriptive to structural analysis, the course helps students present their ideas effectively and develop three-dimensional thinking skills.

The methodological foundation of the research is based on new knowledge about the nature of the artistic

language of architecture. According to the theory, the artistic form of architecture should be considered not as a universal phenomenon but as a method of self-expression of a particular culture [7]. In this case, it is easier to determine the components of the artistic form in the architecture of a specific culture, the methods of their structuring, and the criteria for evaluation. It also becomes simpler to find answers to questions about the specifics of the artistic language of the architecture of a particular culture and the possibilities of influence by the methods of other cultures.

Comparing artistic methods of constructing architectural forms in parallel or opposite cultures, using different means and dramaturgical solutions, also becomes more accessible. This methodology has long been used in linguistics, where there are models of language structure that explain its functioning [22].

The form of expression of three-dimensional thinking and especially its creation in the imagination of space is a key skill for designers in their work. Spatial thinking is a type of mental activity that allows for the formation of the dimensional and spatial parameters of objects and ensures the functioning of all elements in the process of solving practical and theoretical problems. Bringing to life the three dimensions of any space in the imagination occurs through the constant transition from two-dimensional perception [18,14].

The main question is what methods to use for developing three-dimensional thinking in students. These methods include:

- Development of three-dimensional imagination through sketches.
- Creation of linear, planar, volumetric, and spatial compositions that imply three-dimensionality.
- Involvement of students in the process of creating compositions corresponding to each topic [25].
- Expression of the conceived idea through emotions and consciousness.
- Use of models for visualization and construction.
- Guiding creative thinking following the given task.

List of practical tasks [Fig. 2]:

Task 1: Creating a composition of lines. The aim of the task: to develop skills in working with lines as a key element of visual perception and to teach students to create effective compositions.

Task 4a: Skills in using visual elements in a given interior space.

Task 1a: creating a composition of lines in space. The aim of the task: to develop skills in working with lines as an important visual element in interior design and to learn to create effective compositions.

Task 2: creating a composition of planes. The aim of the task: to develop students' skills in working with planes as an important element of visual design and to teach them to create interesting and balanced compositions. This task provides an opportunity for students to develop their skills in working with planes and experiment with various aspects of visual design, creating original and effective compositions.

Task 2a: creating a composition of planes in space. The aim of the task: to develop students' ability to transform two-dimensional compositions of planes into three-dimensional spatial compositions, enriching the visual experience and adding depth. This task allows students to experiment with transforming two-dimensional compositions into three-dimensional ones, developing their skills in creating spatial visual compositions.

Task 3: creating a composition of volumetric figures. The aim of the task: to develop students' ability to work with volumetric figures, forming compositions using three-dimensional elements. This task will help students develop their skills in working with volumetric forms, creating original and characteristic compositions using three-dimensional elements.

Task 3a: creating a volumetric-spatial composition from geometric figures. The aim of the task: to develop students' ability to transform compositions from volumetric figures into more complex three-dimensional spatial compositions, deepening the visual experience and adding elements of the surrounding space. This task allows students to delve into working with three-dimensional elements, transforming simple compositions from volumetric figures into complex three-dimensional works and expanding their visual perception.

Task 4: creating a spatial composition from lines, planes, and volumetric figures. The aim of the task: to develop students' skills in placing various geometric forms in three-dimensional space, enriching the composition and visual experience. This task allows students to experiment with different forms in three-dimensional space, creating a composition considering visual, spatial, and color aspects.

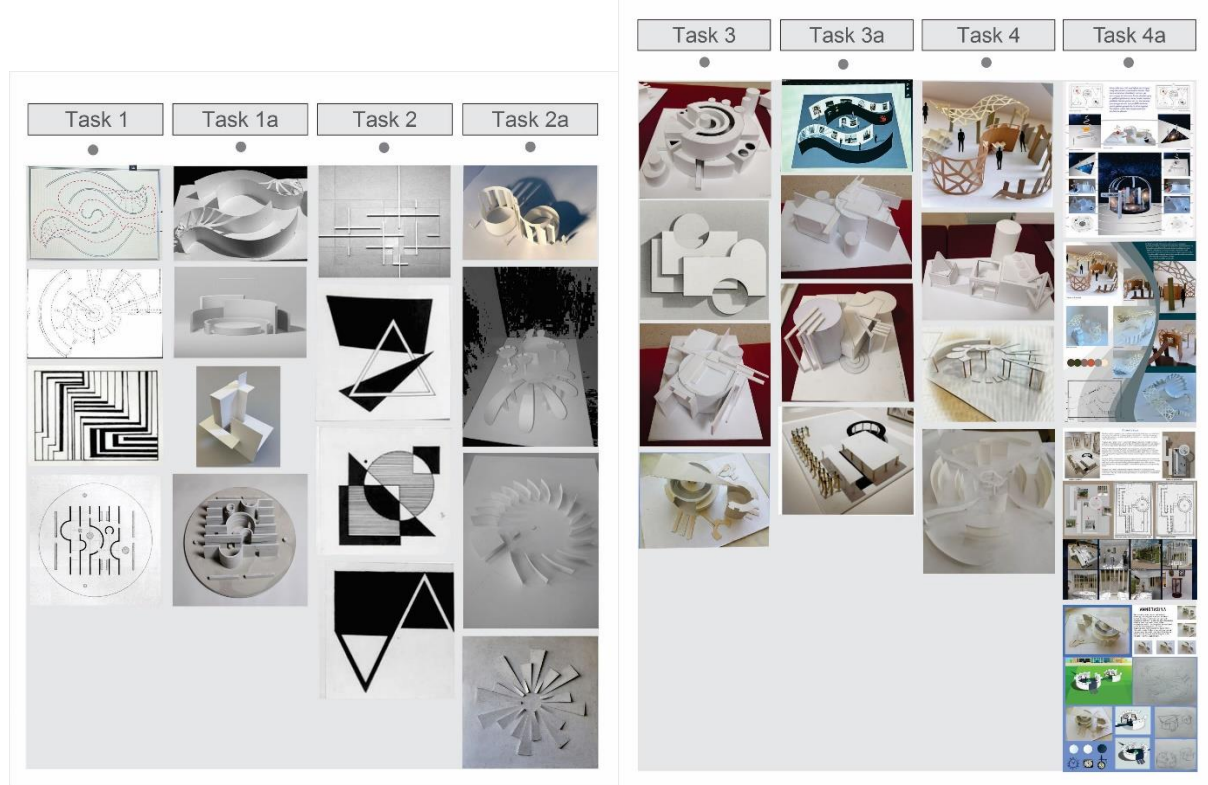


Fig. 2. Examples of students' work on the topic of assignments.

This method is based on the premise that questions arising in the world of art can serve as examples of solutions. Art, always one step ahead of science, constantly influences the development of creative thinking.



Fig.3. Creative expressions in art. a. Barbad Plays for Khusraw, 1539-43, British Library, London [12]; b. Dream City, Klee Paul, 1921-22 [13]; c. Victor Vasarely, Planetary folklore No 1, 1969 [11].

Art, often associated with creativity, imagination, and aesthetic expression, and science, characterized by logic, observation, and empirical data, have a deep interconnection that transcends their apparent differences. Together, they form a symbiotic relationship that mutually enriches each other, expanding the boundaries of human understanding and creativity [8]. Both art and

science are essentially methods of exploring the world: science seeks to understand and explain phenomena through careful observation, experiments, and analysis, while art explores the world through subjective interpretations, emotions, and sensory experiences.

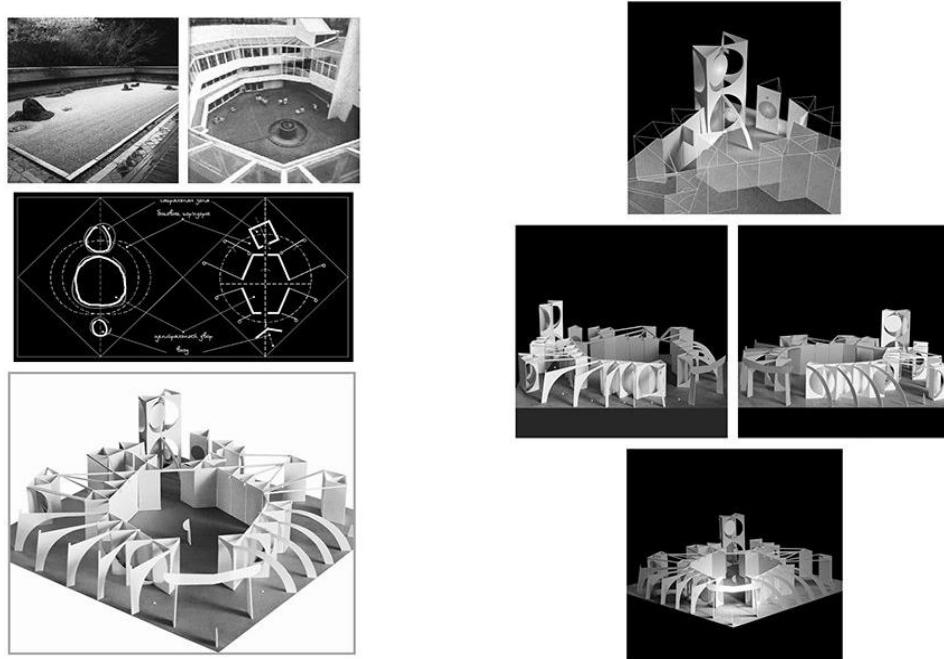


**Fig.4.**

*The scientific model of spatial construction is based on methods and concepts that allow for the exploration and representation of complex spatial structures. It includes specific components and fragments that provide understanding and visualization of space. a. model of spatial structure; b. fragments of space visualization [7].*

Nick Zangwill's research, "The Concept of Aesthetics," is dedicated to the nature and scope of aesthetic properties and judgments. Zangwill studies aesthetic experience, the characteristics that make an object aesthetically appealing or repulsive, and the criteria for making aesthetic judgments. He analyzes how aesthetic properties are related to the physical and formal characteristics of objects and how they interact with human perception and cultural context [9].

Art is the expression or application of human creative abilities and imagination through various forms such as painting, sculpture, music, theater, literature, cinema, and much more. It encompasses a wide range of disciplines and forms of expression, reflecting subjective interpretations, emotions, aesthetics, and cultural context. Artistic works are often created to evoke feelings, provoke thoughts, convey ideas or experiences, giving people the opportunity to explore and express their perception of the world. The goal of art is to inspire, evoke emotions and convey ideas through subjective expression, contributing to cultural comprehension, empathy, and social change [17].

Art and science, despite their differences, intersect: art helps convey scientific concepts to the general public, and science inspires the creation of new artistic works. Both fields contribute to our intellectual and cultural development, enriching life and expanding our perspectives. Developing three-dimensional thinking in students through art and science includes developing skills such as creative and analytical thinking, problem-solving, critical thinking, visualization, and communication [Fig. 4].

Based on the methods used in art and science, which foster creative inspiration, visualization, observation, experimentation, communication, and aesthetic perception, key points can be highlighted:

- Art draws inspiration from scientific concepts, embodying them in artistic works [Fig. 3].
- Visualization and representation are crucial in both art and science for conveying ideas and concepts.
- Experiments and research push boundaries and reveal new truths.
- Communication and self-expression are important in both art and science for conveying emotions, ideas, and research results.
- Aesthetics and beauty are valued in both fields, appreciating the visual appeal and elegance of both artistic and scientific creations [9].

Thus, the methods and approaches used in art and science mutually enrich each other, contributing to creative inspiration, visualization, observation, experimentation, communication, and aesthetic perception.

Architectural studies and design education still need to develop such knowledge, which should become the content of its theory, so necessary for architectural science, the education system, and creative practice [10].

**Conclusion.** The article thoroughly examines the problems and approaches to developing spatial thinking in design students, highlighting the use of visual aids and materials. Spatial thinking allows students to visualize and manipulate three-dimensional objects, improving their ability to abstract, synthesize elements, and perform structural analysis. This is critically important in design development.

Modern technologies such as 3D modeling and virtual reality play a significant role in developing these skills [15]. Research shows that the use of 3D tools activates more visual-spatial functions of the brain and provides additional opportunities for creative thinking and solving complex problems [16].

The methodological basis of the research, based on Howard Gardner's theory of multiple intelligences,

emphasizes the importance of recognizing and developing various intellectual abilities in educational institutions to create a comprehensive and inclusive learning environment [19].

Main conclusions of the article:

- The key role of spatial thinking: Spatial thinking is critically important for the successful professional activities of designers, as it allows for effectively solving tasks related to creating three-dimensional objects and structures [20].
- The use of modern technologies: 3D modeling and virtual reality significantly contribute to the development of spatial thinking, activating more visual-spatial functions of the brain and improving students' creative abilities [21].
- Systematic approach to learning: To effectively develop spatial thinking, it is necessary to use systematic approaches and methods that include visual aids and materials.
- Diversity of intellectual abilities: The development of spatial thinking should consider the theory of multiple intelligences, allowing for the creation of a comprehensive and inclusive educational environment.

Overall, the article concludes that developing spatial thinking in design students is a key element of their professional training, enhancing their creativity and analytical abilities and contributing to success both in the learning process and in their future careers.

In conclusion, it should be noted that developing spatial thinking in design students is a critically important aspect of their educational program. Effective use of visual aids, interactive technologies, and visual materials can significantly improve students' ability to perceive and model space, ultimately enhancing their creativity and success in professional activities. Thus, creating a systematic and integrated approach to developing spatial thinking in design education is necessary for preparing highly qualified and creative specialists ready to solve complex tasks in the field of design.

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# BIOLOGICAL SCIENCES

## LION'S MANE MUSHROOM – MEDICAL BENEFITS

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## ГЪБАТА „ЛЪВСКА ГРИВА“ – МЕДИЦИНСКИ ПОЛЗИ

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### Abstract

The health benefits of mushrooms are gaining popularity, but their hidden potential remains a mystery due to limited research. There are over 270 species of mushrooms known to possess various therapeutic properties. Mushrooms from the Basidiomycete class, one of which is *Hericium* (Lion's Mane), have been used in cooking for centuries by various peoples around the world in the form of extracts, concentrates or powder. Nowadays, they are grown in laboratories under strict control. With the advancement of technology, active substances – polysaccharides – have been isolated from them, which have strong immunostimulating and anticancer properties.

**Objective:** To investigate how familiar people are with medicinal mushrooms and specifically Lion's Mane.

**Methods:** Documentary method - literature review of the problem. Sociological method - development of a questionnaire and conducting an anonymous survey; Statistical method - the data were processed with MS Excel and the results were presented in graphical images.

**Results:** Although a large portion of respondents are unfamiliar with the products (87%), most would choose them as a means of treatment (82%) and would trust their effectiveness, especially if prescribed by a doctor (92%).

**Conclusion:** In the long term, however, scientists believe that the intake of "Lion's Mane" may play a crucial role in preventing the listed diseases. Its widespread use has immunomodulatory, anti-diabetic, anti-inflammatory and antimicrobial effects.

### Резюме

Ползите за здравето от гъбите намират все по-голяма популярност, но все още техният скрит потенциал остава мистерия поради ограничените проучвания. Съществуват над 270 вида гъби, за които се знае, че притежават различни терапевтични свойства. Гъбите от клас Базидиеви, една от които е *Hericium* (Лъвска грива), от столетия се използват в кулинарията от най-различни народи в целия свят под формата на екстракти, концентрати или прах. В наши дни се отглеждат в лаборатории под строг контрол. С напредването на технологиите от тях са изолирани активни вещества – полизахариди, които имат силни имуномодулиращи и противоракови свойства.

**Цел:** Да се проучи до колко хората са запознати с лечебните гъби и конкретно „Лъвска грива“.

**Методи:** Документален метод - литературен обзор на проблема. Социологически метод - разработване на анкетна карта и провеждане на анонимна анкета; Статистически метод - данните са обработени с MS Excel и резултатите са поместени в графични изображения

**Резултати:** Въпреки, че голяма част от анкетираните не познават продуктите (87%), повечето биха ги избрали като средство за лечение (82%) и биха се доверили на тяхното действие, особено ако са предписани от лекар (92%)

**Заклучение:** В дългосрочен план все пак учените смятат, че приема на „Лъвска грива“ може да има решаваща роля за превенция от изброените заболявания. Нейното широко приложение оказва имуномодулиращо действие, антидиабетно, противовъзпалително и антимикробно.

**Keywords:** *Hericium erinaceus*, Lion's Mane, hericinone, erinacin, Alzheimer's, diabetes, cancer

**Ключови думи:** *Hericium erinaceus*, Лъвска грива, херицинон, еринацин, Алцхаймер, диабет, рак

### Въведение

Използването на гъбите датира от древни времена. Данни от целия древен свят показват дълбоката обвързаност на различни култури с употребата на гъби. Примери за това са древна Гърция, Индия, Китай, Америка и др. Поради тяхната уникална природа, те винаги са всявали високо уважение към тези които ги изучават и страх към тези, които не ги познават. Историческите данни разкриват че гъбите са използвани и със злонамерни цели. Например Клавдий II и папа Климент VII са били отровени с Аманита. А според легендите, Буда е бил отровен от гъба, подарена от придворен селянин, който му казал че е деликатес. Най-старите доказателства за връзка между човека и гъбите датират от преди 5000 години преди новата ера. Открита е каменна статуетка изобразяваща шаман под формата на гъба.



От екологична гледна точка гъбите могат да бъдат разглеждани под три основни вида: сапрофитни, паразитни и мицелни. Мицелните нишки, които растат под земята, могат да се разпространят до смайващи размери. Те се свързват с почти всички растения и дървета и по-специално техните коренови системи. Еколози са стигнали до извода, че наличието на мицел в почвата е добър показател за здравето на една гора, тъй като те спомагат растежа на растенията и предпазват от други зарази. Някои смятат дори, че най-големият жив организъм на земята е мицелна нишка, намираща се в Blue Mountain, щата Орегон. Установено е че тя се простира на главоземайващите 10 квадратни километра!

### Медицински ползи на гъбите

Ползите за здравето от гъбите набират все по-голяма популярност, но все още техният скрит потенциал остава мистерия поради ограничени проучвания. Много форми на хронични заболявания като рак или сърдечни проблеми могат да бъдат предизвикани именно от диетата ни. Връзката между болестта и храненето в наши дни е еволюирала до концепцията наречена „Функционални храни“. Според Американската академия на науките, функционална храна означава всяка модифицирана храна или хранителна съставка, която е богата на нутриенти и носи благоприятен ефект на човешкия организъм. Функционалните храни не могат да излекуват болест, но могат да бъдат силен фактор за превенция.[2, с.1839-1845]

Гъбите от клас Базидиеви се използват от столетия в кулинарията от най-различни култури по целия свят. Римляните ги наричали „Храната на Боговете“, египтяните „Дар от Бог Озирис“, докато китайците ги считали за „Елексира на живота“. Съществуват над 270 вида гъби, за които се знае, че притежават различни терапевтични свойства. Сред тях са *Lentinula* (Шийтаке), *Hericium* („Лъвската грива“), *Flammulina* (Зимна Припънка), *Pleurotus* (Кладница), *Tremella* (Жълта Тремела). Най-често се намират по стеблата на мъртви или живи дървета или по земята. В миналото често срещан начин за приготвянето им включва приготвянето на екстракти, концентрати или под формата на прах. В наши дни се отглеждат в лабораторни условия под строг контрол и много високо ниво на стерилност. С напредването на технологиите успешно са изолирани активните вещества в някои от гъбите, това са полизахариди, които имат силно имуностимулиращи и противо ракови способности. Тези полизахариди са водноразтворими  $\beta$ -D-глюкани, свързани с хетерозахаридни вериги от ксилоза, маноза и галактоза или уронова киселина. Способността им да потискат или увеличават имунния отговор се дължи на следните фактори:[3, с. 24]

- Дозировка
- Начин на приложение
- Време и честота на приложение
- Механизъм на действие

Някои от тези съединения са доказали, че потенцират вродения специфичен и неспецифичен имуен отговор и също така активират множество имунни клетки, отговорни за поддържането на хомеостазата. Например макрофаги, моноцити, неутрофили, НК – клетки и дендритни клетки.

В индустрията, медицински хранителни добавки и лекарства на пазара се предлагат под формата на течни екстракти, таблетки или капсули. Главният пазар за тази ниша са главно страните от Ориента и все повече се засилва интересът в Съединените щати и Европа. Гъбата Рейши е водеща в продажбите като продажбите в световен мащаб само на тази гъба са оценени на 1,6 млрд. \$.[2, с.1839-1845]

***Hericium erinaceus, Yamabushitake или „Лъвската грива“.***

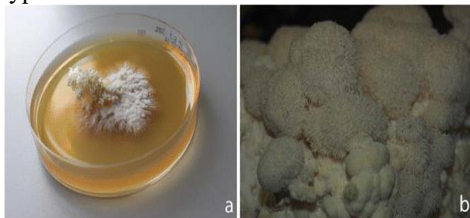
**Описание:** Екзотична дървесна гъба, разпространена в Китай, Япония и Корея. Среща се и в Северна Америка и Европа. У нас е застрашен вид, включена в Червената книга на България. На външен вид е бяла, изградена от множество бели висулки, които висят надолу. Те са с дължина до 40 см в дивата природа. В ранния стадий на живота си преминава от розово към снежно бяло, а към края започва обезцветяване към кафяво или жълто от тялото на гъбата към висулките.

**Хабитат:** Расте върху мъртви или умиращи дървета, най-често върху, дъб, бук, орех и явор, върху дънери или стволлове.

**Микроскопска характеристика:** Спорите са бели, 5,5- 7,0 x 4,5- 5,5µ. Елипсоидни са и гладки.



**Мицелна характеристика:** Бял на цвят, формира се в триъгълна зона, изниквайки от основата (наподобява върха на замръзвала планина) Растейки, културата преминава в жълтеникав до розов цвят. В петри се образуват малки островчета от плодовете на гъбата за период от 2 до 3 седмици на температура от 24°C.



**Химичен състав:** Гъбата съдържа голям набор от активни вещества – над 70 различни биологично активни вещества - полизахариди, стероли, лактони и Витамин B12. [3, с. 24]

Вторични метаболити, изолирани от гъбата:

1. Еринацин: Еринацините са дитерпеноиди, изолирани от гъбата *Herichium Erinaceus* (общо 20 на брой), за които се смята, че имат невропротективно действие, стимулират растежа на невроните и поддържат тяхната функция, [1, с.115-127]

2. Ароматни съединения (Херицинон): Херициноните имат противораково действие. Дължи се на херициноните А-К. Все още не е напълно изяснен противораковият механизъм. Според проучване, херициноните А и J инхибират растежа на левкемиеви клетки HL-60, като индуцират апоптоза. [1, с.115-127]

3. Стероли. В гъбата е открит и ергостерол. Изложен на UV лъчи се превръща във Витамин Д. Количеството ергостерол, изолирано от гъбата е много малко, едва 2,33мг/г. [3, с. 24]

В маслото от Херициум се намира и хексадеканова киселина, линолова киселина, фенилацеталдехид, бензалдехид. [3, с. 24]

**Хранителна стойност.** Тъй като гъбите нямат хлорофил и няма как да получават енергия от слънчевите лъчи, те си набавят всички необходими вещества от растения и техните останки. Гъбата съдържа 16,20-26,60/100гр протеин, 52-64/100гр въглехидрати, 2-3/100гр ненаситени мастни киселини, както и линоленова киселина. Добър източник са на магнезий, фосфор и калий (2,6- 3,7гр/кг). Гъбата съдържа още мед, цинк и желязо, правейки я още по-добър кандидат за набавяне на важните микро и макронутриенти. [1, с. 115-127]

#### Разнообразно хранене

- Като добавка към хляб. Изпечен хляб с добавени 5% мицел от *H. erinaceus*, съдържат γ-аминобутирова киселина, която подпомага мозъчната функция.

- Като добавка към вино или зехтин. Използвана е гъбата за направата на вино и зехтин, като след 9 дни ферментация, 5% мицел от *H. erinaceus* са добавени към вино. Готовото вино притежава антиоксидантни ефекти. [4, стр. 225]

#### Антибактериални способности.

При проучване е доказано, че еринацините и полизахаридите имат антибактериални свойства, включително към антибиотично-резистентни бактерии - Метилицин-Резистентен Стафилококус Ауреус (MRSA).

Все повече нараства опасността от антибактериално резистентни бактерии. Рискът за човешкото здраве расте със всеки изминал ден, както и нуждата от нови препарати, с които да ги борим. В едно петри са поставени изолирани еринацини от *H. erinaceus*, които са показали силна антибактериална активност срещу MRSA. [9, с. 3805-3822]

При експеримент с мишки, заразени със *Salmonella typhimurium*, не се наблюдава особен успех при *in vitro* лечение, но сухият екстракт от гъбата е предпазил мишките от летална инфекция, стимулирайки макрофагите. Два от общо четири екстракта са предпазили мишките от смърт и поражения по черния дроб. Известно е че хроничната Салмонела предизвиква чернодробна некроза. Учените са стигнали до извода, че тези мишки подложени на лечение с екстракта от гъбата са били предпазени от чернодробни инфекции и че това се дължи на стимулацията на имунните клетки там да нападат патогените. [10, стр. 1-11]

#### Противоракови способности

Конвенционалните методи за лечение на рак са скъпи и са придружени със странични ефекти. Химиотерапията успешно унищожава тумори, но също така уврежда здрави клетки и тъкани. Затова учените търсят алтернативни методи за лечението, които да щадят организма повече. Гъбите са богати на множество полизахариди, за които се счита че притежават силни противоракови ефекти. [1, стр. 115-127], [6, стр. 258-274]

При опит с мишки, при които са трансплантирани СТ-26 ракови клетки на дебелото черво, е проведено лечение с инжекционен разтвор с екстракт

от *H. erinaceus*. Наблюдаван е ефектът на  $\beta$ -глюкан, който е редуцирал размерите на тумор с 38% в продължение на 2 седмично лечение. [7, с. 898-904]

Проведено е проучване, с което се доказва, че водни и етанолни екстракти от *H. erinaceus* могат да индуцират апоптоза в човешки U937 моноцитни левкемични клетки. Процесът включва индуцирането на медираната от митохондриите каспаза 3 и 9. За целта е използван сух екстракт от гъбата, от който по-късно е получен обикновен воден и етанолов екстракт. Използвани са нормални здрави клетки и левкемични. Клетките са взети от American Type Tissue Culture Collection (ATCC, Manassas, VA). Изводът до който учените са достигнали е, че екстрактът от *H. erinaceus* индуцира продукцията на NO (азотен оксид) при макрофагите. Те от своя страна силно потискат пролиферацията на U937 клетки, като индуцират апоптоза, чрез активирането на митохондриално-медирана каспаза. Това проучване разкрива потенциала на гъбата да бъде прилагана при лечението на човешка левкемия в бъдещето. [8, с. 336-342]

### **Helicobacter Pylori**

*Helicobacter pylori* е Грам-отрицателна бактерия, която живее в стомаха. Тя е добре приспособена да устоява на тежките условия в стомаха и е трудна за справяне за нашата имунна система. Причинява широк спектър от симптоми, свързани със стомашно чревния тракт и изисква целенасочено лечение. Може да причини язва, гастрит или рак на стомаха.

При клинично проучване са използвани екстрактите на 14 вида гъби, включително и на „Лъвската грива“, за да се проверят антибактериалните способности срещу *H. pylori*. За да се установи минималната инхибиторна концентрация (МИК) на гъбата е използвана посявка с агар. При опита са наблюдавани следните случаи: При използването на етанолов екстракт от гъбата, не е имало особен ефект върху бактерията. При МИК = 10мг/мл успешно е инхибиран растежът на *Staphylococcus aureus*, но не имало никакъв ефект върху *E. coli* въпреки че дозата е била увеличена. (МИК > 10мг/мл). До момента е известно, че етанолов екстракт от *H. erinaceus* има известен антибактериален ефект срещу множество патогени, въпреки че самият механизъм на действие не е ясен, тъй като не е същият както имуномодулиращия ефект на полизахаридите. [10, стр. 1-11]

### **Невропротективни способности**

Често наричана „Епидемията на 21 век“, старческата деменция и болест на Алцхаймер се превръща в бързо растящ социален проблем в това ново и развито икономическо общество, което неминуемо застарява. В комбинация със стресов начин на живот, вредни навици като тютюнопушене и алкохол, както и консумирането на вредна храна, се увеличава рискът за развитието на болестта. Според данни на Гражданско сдружение Алцхаймер България, на територията на страната има около 100000 души, страдащи от деменция. Около 60000 са хората, диагностицирани с Алцхай-

мер. При този тип органични и симптоматични психични разстройства се наблюдават когнитивни симптоми, както и типичните изменения в мозъка. Болестта на Алцхаймер се очаква да бъде все по-често срещано заболяване в световен мащаб, като прогнозата е в следващите 40 години всеки 1 на 85 души да бъде засегнат. Очакваният брой е около 100 милиона души. Най-важно е идентифицирането на генетичния риск за наличието на Аполипопротеин Е4 (АпоЕ4), който може да се наследява. С напредването на болестта се получават многобройни амилоидни плаки в мозъка и настъпва дегенерация на неврофибрилите. [1, стр. 115-127]

От особено значение за регулирането и оцеляването на нервите са клетъчните растежни фактори (NGF – Nerve growth factor). Те са сигнални протеини и са около 50 на брой. Имало е опити за лечение на Алцхаймер с тези протеини, но приложението им е изключително трудно тъй като те не преминават кръвно-мозъчната бариера. Учените търсят алтернативни начини чрез други съединения с ниска молекулна маса, които да стимулират синтеза на клетъчните растежни фактори. [1, стр. 115-127]

За гъбата *Yamabushitake* (*H. erinaceus*) вече са създадени методи на култивация, които могат да осигурят ежемесечна продукция. [5, с. 387] Херицинон С и Н, Еринацин А и I са съединения, които могат да стимулират клетъчните растежни фактори. Поради това откритие е направен опит с хора, за да се провери въздействието на гъбата върху когнитивните способности. Проведено е плацебо двойно-сляпо контролирано проучване върху 30 японци – мъже и жени на възраст между 50 и 80 години с диагноза леки нарушения на когнитивните способности. Използвана е Скалата за откриване на деменция на Хасегава (Revised Hasegawa Dementia Scale HDS-R) В момента на проучването пациентите са били в добро здраве, без други заболявания и без промени в битовите им навици в рамките на проучването.

Гъбата е била приготвена под формата на таблетки с 96% съдържание на *Hericium erinaceus*. Пациентите са били разделени на две групи – такива, които приемат гъбата, и такива с плацебо. Те приемали по четири таблетки съдържащи гъбата/ плацебо три пъти дневно в продължение на 16 седмици. Проучването продължило 22 седмици, от които две седмици са били оценявани без да приемат каквото и да е, след това 16 седмици по време на приема, и накрая за четири седмици е била прекратена дозата, за да се наблюдават ефектите и резултатите при двете групи. По време на проучването пациентите са били ограничени да не взимат Донепезил (единственото лекарство в Япония с разрешително за лечение на Алцхаймер), както и други лекарства, стимулиращи мозъчната дейности като амантадинов хидрохлорид и сермион. Хранителни добавки като жен-шен и гинко билоба също са били спрени. На пациентите е било наредено да водят записки на това какви промени са усещали по време на проучването.

По време на проучването, първите четири седмици и двете групи са имали почти еднакви резултати, след това през 16 седмица, групата която приема гъбата са показали значителна преднина пред плацебо групата. Обаче през последните четири седмици, когато е прекъснато лечението и на двете групи, е наблюдаван рязък спад в резултатите и на двете групи. През целия период на проучването 7 души от групата приемаща гъбата и 6 души от плацебо групата са се оплакали от леки до умерени стомашни болки и диария, но без никакви усложнения.

Резултат от проучването: групата, приемаща *Herinaseus* е показала значително по-добри резултати от плацебо групата през 8,12 и 16 седмица, но след прекратяване на приема през последната 4 седмица, резултатите са се понижали драстично. Изводът е че *Yamabushitake* значително подобрява състоянието при хора, диагностицирани с леки когнитивни нарушения, но в голяма степен зависи от поддържане на дозата в дългосрочен план.

До момента е установено, че Херицинон С и Н е способен да индуцира растежа на клетъчните растежни фактори NGF, но всички експерименти са били проведени върху гризачи и не е ясно дали би имало същия ефект и при човешките клетки, нито дали херициноните ще успеят да преминат кръвно-мозъчната бариера. Пълното лечение на болестта на Алцхаймер остава задача за бъдещето, но учените предполагат, че ако се приема храна, които да стимулират NGF факторите е възможно да послужат като превенция към заболяването.[1, с. 115-127]

#### Продукти съдържащи *Hericium erinaceus*

Продуктите, съдържащи гъбата на българския пазар, се предлагат в различни форми - на твърди капсули, на прах и на капки.

Според производителя „Витаголд“ гъбата е с имуностимулиращо действие, кръвоспиращо, при злокачествени проблеми в стомаха, хранопровода и кожата, регулира кръвната захар, триглицеридите и при повишен холестерол в кръвта. Препоръчва се при следните заболявания: заболявания на периферната нервна система, стрес и леки форми на депресия, нарушена функция на черния дроб, заболявания на щитовидната жлеза, висок холестерол, триглицериди и високо кръвно налягане, диабет и инсулинова резистентност, възпалителни заболявания на стомаха и червата, психично нервно напрежение и тревожност.

Препоръчителен прием: 3 пъти дневно по една капсула, 30 минути преди храна. В източните страни като Китай и Япония, пазарът изобилства от продукти съдържащи гъбата. Предлагат се в най-различни форми и количество тъй като там тя е изключително популярна.

#### Собствено проучване

Направено е проучване, с което да се проучи до колко хората са запознати с лечебните гъби и конкретно „Лъвска грива“. Проучването е под формата на анкета. Участвали са общо 62 души на възраст от 18 до 60+. Участието им е доброволно. Анкетата е проведена в периода 01.04.2025 до 15.05.2025г.

В таблица 1 са показани полът на участниците, техният брой и какъв процент от тях са жени и мъже.

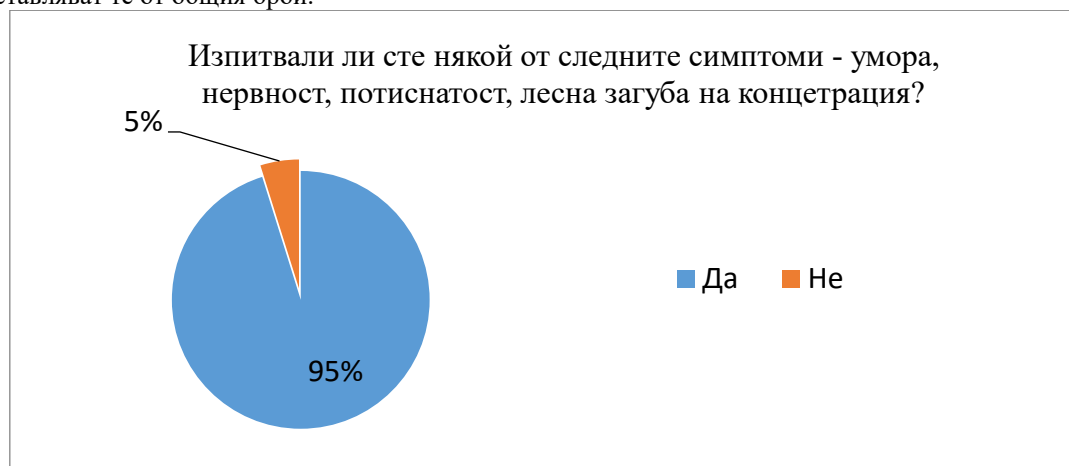
Таблица 1

| Пол  | Брой участници | Процент |
|------|----------------|---------|
| Жена | 40             | 65%     |
| Мъж  | 22             | 35%     |

Таблица 2

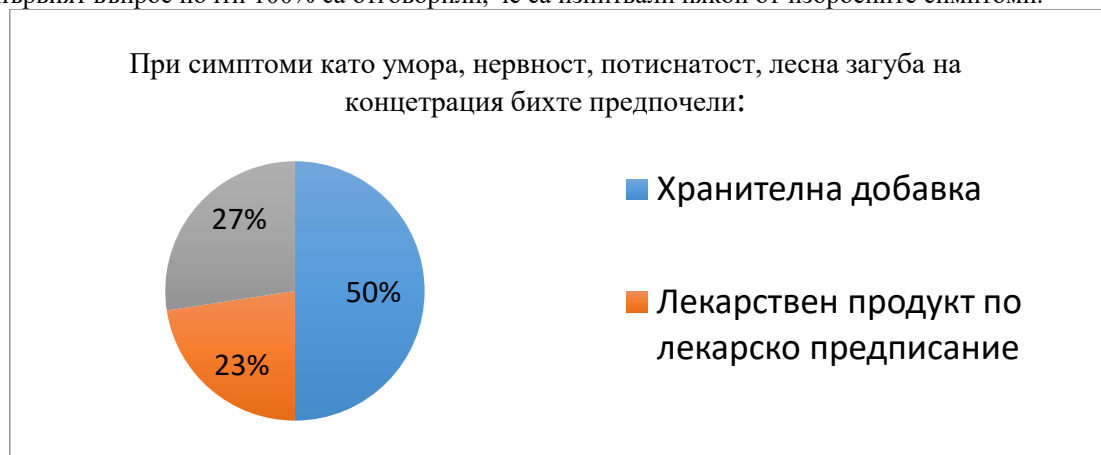
| Години | Брой участници | Проценти |
|--------|----------------|----------|
| 18-30  | 33             | 53%      |
| 31-40  | 11             | 18%      |
| 41-50  | 12             | 19%      |
| 51-60  | 1              | 2%       |
| >60    | 5              | 8%       |

В таблица 2 са показани възрастовите граници и броя на участниците във всяка, както и процентът, който представляват те от общия брой.



Фиг 1

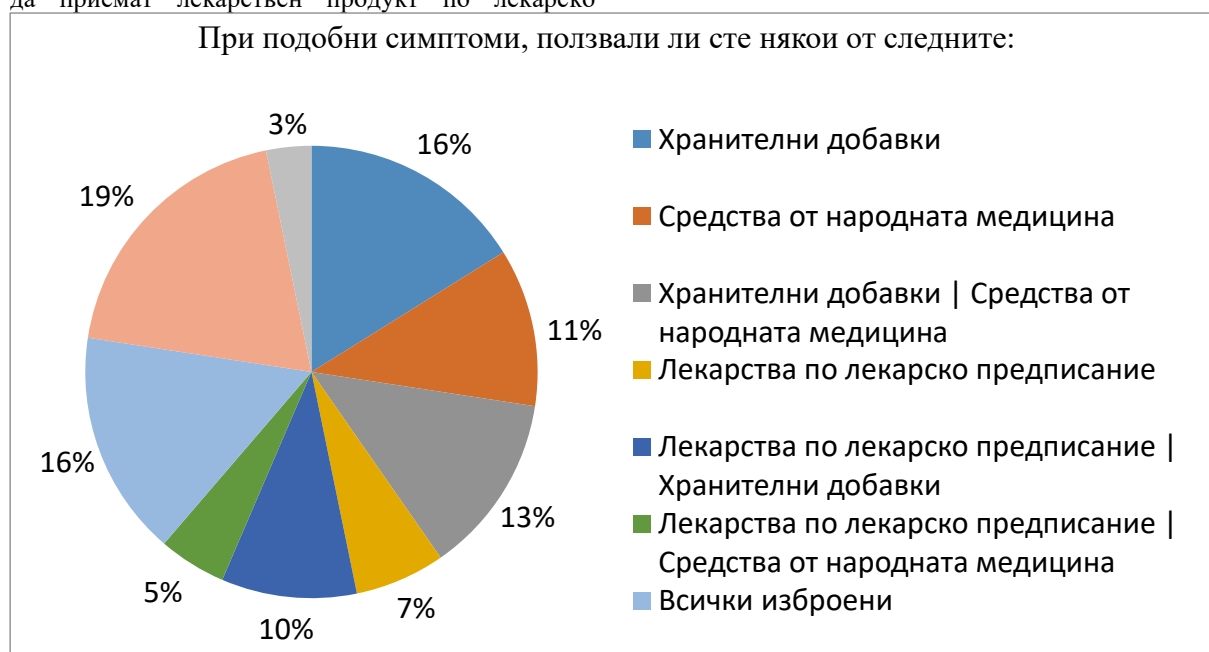
На първият въпрос почти 100% са отговорили, че са изпитвали някои от изброените симптоми.



Фиг. 2

От диаграмата на втория въпрос се вижда, че 50% от хората биха предпочели хранителна добавка, избягвайки приема на лекарства по лекарско предписание. 23% не биха се поколебали да приемат лекарствен продукт по лекарско

предписание, а 27% биха избрали алтернативен метод за лечение, който може да включва съответно народна медицина, медитация, спорт или друг метод.



Фиг. 3

На фигура 3 се вижда какъв е бил опитът на участниците със справянето с подобни симптоми. 16% се падат на хората избрали само хранителни добавки, а 10% са избрали и лекарства по лекарско предписание и хранителни добавки. 13% са избрали комбинация от хранителните добавки и средства от народната медицина. 11% процента отиват при хората разчитащи изцяло на средства от народната медицина, а 7% и 5% на хората, избиращи само лекарства или комбинация с народна медицина. 19%

от участниците не са избрали нито едно от изброените и 3% процента не са имали подобни симптоми. Изводът е, че голяма част от хората имат недоверие към лекарствата. По-голямата част биха избрали да се лекуват с хранителни добавки и народна медицина, а също не малка част избират алтернативни методи, по всяка вероятност спорт, добра храна, медитация и др.

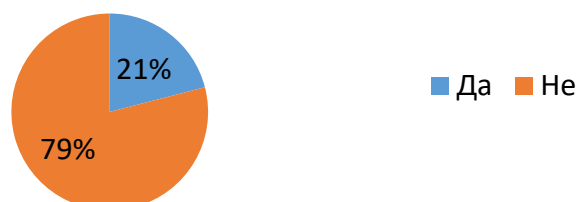
Известни ли са Ви някои от следните лечебни гъби :  
Рейши, Майтаке, Кордицепс, Йамабушитаке, Шийтаке?



Фиг. 4

По-голяма част от хората са чували за някои от тези лечебни гъби. Това не е в контраст с предишните отговори, където повечето хора биха предпочели продукти на растителна основа, а не синтетични лекарства.

Запознати ли сте лечебните свойства на гъбата Лъвска грива?



Фиг. 5

Тук участниците са попитани дали са запознати конкретно с гъбата „Лъвска грива“. По-голямата част от тях не знаят за нея, но 21% я познават.

Бихте ли избрали гъбите като средство за лечение?



Фиг. 6

На фиг. 6 преобладават позитивните отговори, като 82% от участниците са склонни да изберат лечение с някоя от лечебните гъби. 18% не биха се доверили на гъбите.

Познавате ли хранителни добавки, съдържащи лечебни гъби?



Фиг. 7

Въпреки интереса на повечето участници към хранителни добавки и народна медицина, 62% от тях не познават продукти на българския пазар, съдържащи лечебни гъби.



Фиг. 8

На анкетираният бе показана продукта „Херициум“ на фирма Витаголд. 87% от хората не познават този продукт. Това отново навежда на мисълта, че въпреки засиленият интерес към хранителните добавки, повечето хора остават неинформирани или не са направили сами проучване какво се предлага на пазара, за да задоволи техните нужди.



Фиг. 9

Въпреки, че не познават достатъчно хранителни добавки или конкретно тези с лечебна гъба, 92% от участниците имат високо доверие към лекарите, ако им бъде назначена терапия с лечебни гъби. 8% подхождат с недоверие.

Последният въпрос е с отворен отговор. Участниците бяха попитани дали смятат лечебните гъби за полезни или за вредни. Трима от участниците са отговорили, че е възможно гъбите да имат вредни странични действия. По-голямата част от хората не знаят или не са запознати достатъчно с темата. Подкрепят лечебните свойства на гъбите 29 от анкетираният.

#### Извод

По-голямата част от участниците в анкетата предпочитат продукти на растителна основа или методи от народната медицина за справяне със симптоми като умора, нервност или обърканост. Малка част от тях прибягват към лекарства по лекарско предписание. Въпреки големия интерес към хранителните добавки и алтернативните методи, повечето хора са незапознати със свойствата на лечебните гъби, но биха се доверили ако лекар им предпише терапия, която ги включва. Известна част от участниците са запознати както с гъбите, така и със свойствата им.

#### Заклучение

В дългосрочен план все пак учените смятат, че приема на „Лъвска грива“ може да има решаваща роля за превенция от изброените заболявания. Нейното широко приложение оказва имуномодулиращо действие, антидиабетно, противовъзпалително и антимикробно. Освен това, тя често се използва в кулинарията. С напредването на технологиите, са открити множество важни свойства за гъбата, като механизмът на действие на еринацините и херициноните. Макар и механизмът им на действие да остава ненапълно изяснен, гъбата *Hericium erinaceus* става все по-популярна сред страните от Америка и Европа. Използвана от десетилетия, тя е утвърдила своето място в Китайската и Японската медицина, като ефективно средство за борба с редица заболявания, онкологични, болест на Алцхаймер, бактериални инфекции, Хеликобактер пилори. Гъбата има доказани противоракови способности срещу U937 левкемични клетки. Срещу болестта на Алцхаймер и деменцията, показва много добри резултати в ранните стадии на болестта, но не е подходящ кандидат за борбата с тежки хронични заболявания в бъдеще. У нас все още се гледа с известно недоверие към терапията с гъби и много хора не са информирани за тях. Въпреки това, нарастваща е тенденцията за лечение с хранителни

добавки и растения, все повече хора преоткриват гъбите както за лечение, така и за включването им в една по-пълноценна диета.

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# EARTH SCIENCES

## 'STORM GLASS' IS A SOLAR INFLUENCE DETECTOR. STRUCTURING OF WATER CLUSTERS IN 'STORM GLASS' UNDER THE SOAR EXPOSURE AND WHEN MOVING IN SPACE

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### Abstract

In the 19th century, it was discovered that camphor dissolved in the water-ethanol solution forms crystals, which quantity constantly changes at different periods of time even at a constant temperature. Since no one doubted that this phenomenon was caused by weather changes, a sealed glass ampoule with such a solution was called Storm Glass. But in the 20th century it became clear that this phenomenon has a more complex mysterious nature and is not suitable for predicting the weather. It was studied in detail, but the real reason remained unclear. We have recently discovered that fluctuations in solar activity and distribution of solar energy around the Earth have a very strong influence on the stability and size of water clusters. Therefore, the same solution of water in organic solvents can consist of a small number of large clusters, or large number of small clusters. This also occurs in the water-ethanol solution in 'Storm Glass'. Since camphor is soluble in ethanol and insoluble in water, it crystallizes out of solution under strong solar influence, when water clusters are decomposed and small, and dissolves again when the influence of the Sun decreases and water clusters reunite. Therefore, Storm Glass really reacts to changes in the weather, but not atmospheric, but space weather. Studying the influence of the Sun on Storm Glass in different places unexpectedly led to the discovery of another unique phenomenon. When Storm Glass moves through space, water clusters quickly become structured, their number decreases and camphor crystals noticeably dissolve. This happens quickly, within 10-20 minutes after the start of movement. This phenomenon also depends on solar exposure.

**Keywords:** storm glass, solar influence, water clusters, structuring, space weather.

### Introduction

In the 19th century, it was discovered that camphor dissolved in a water-ethanol solution, containing also  $\text{NH}_4\text{Cl}$  and  $\text{KNO}_3$ , forms crystals, which quantity constantly changes over different periods of time. [1] Since this occurs even at a constant temperature, no one doubted that this mysterious phenomenon has something to do with weather changes, therefore, for a long time they tried to use it to predict the weather, and a sealed glass ampoule with such a solution was called 'Storm Glass'.

In the 20th century the understanding gradually matured that this phenomenon has a more complex nature, associated with some unknown external influence and is not suitable for predicting the weather. In 1990, Nakamoto and Hiroi experimentally showed that changes in the appearance of crystals are not caused by changes in atmospheric pressure, humidity, or electric and magnetic fields, but solely by changes in temperature. [2] No correlation was found between changes in crystallization and changes in weather useful for weather forecasting. In 2008, after studying the growth and shape of the crystals only the effect of temperature was again recorded. [3] However, temperature affects all crystallizations equally, and the number of crystals in Storm Glass varies greatly even at a constant temperature, so the true reason for this mystery has remained unclear.

Until now, no one could have imagined that the cause of this mysterious phenomenon could lie outside

the Earth and that fluctuations in solar influence can exert an extremely strong effect on water, which is a key component in Storm Glass. Such an extraterrestrial influence on water is evidenced by another fundamental phenomenon recently discovered. We have found that solar radiation breaks hydrogen bonds between water molecules and destroys water clusters. For this reason, due to constant fluctuations in solar activity and distribution of solar energy due to the rotation of the Earth around its axis and around the Sun, the hydrolytic activity of the same solution of water in an organic solvent is very dynamic as it can contain either a large number of small active clusters or a small number of large passive clusters. For example, the rate of hydrolysis of triethyl phosphite  $[(\text{EtO})_3\text{P}]$  in water-acetonitrile solution can vary up to 200 times over 11-year solar cycle, displaying also diurnal and very large annual variations. [4] (Fig. 1) Thus, the rate of this reaction is an accurate indicator of the intensity of the Sun's impact on the Earth.

Decomposition of water clusters may be explained by the influence of muons which are constantly generated in the upper atmosphere by the solar wind. This is confirmed by the fact, that during the solar eclipse the hydrolytic activity of water clusters significantly decreases. [4] Muons reach the surface of the Earth and penetrate to some depth underground. Their amount and energy, modulated by the solar activity and position of the Sun in the sky, strongly influence the hydrolytic activity of water clusters. [5]

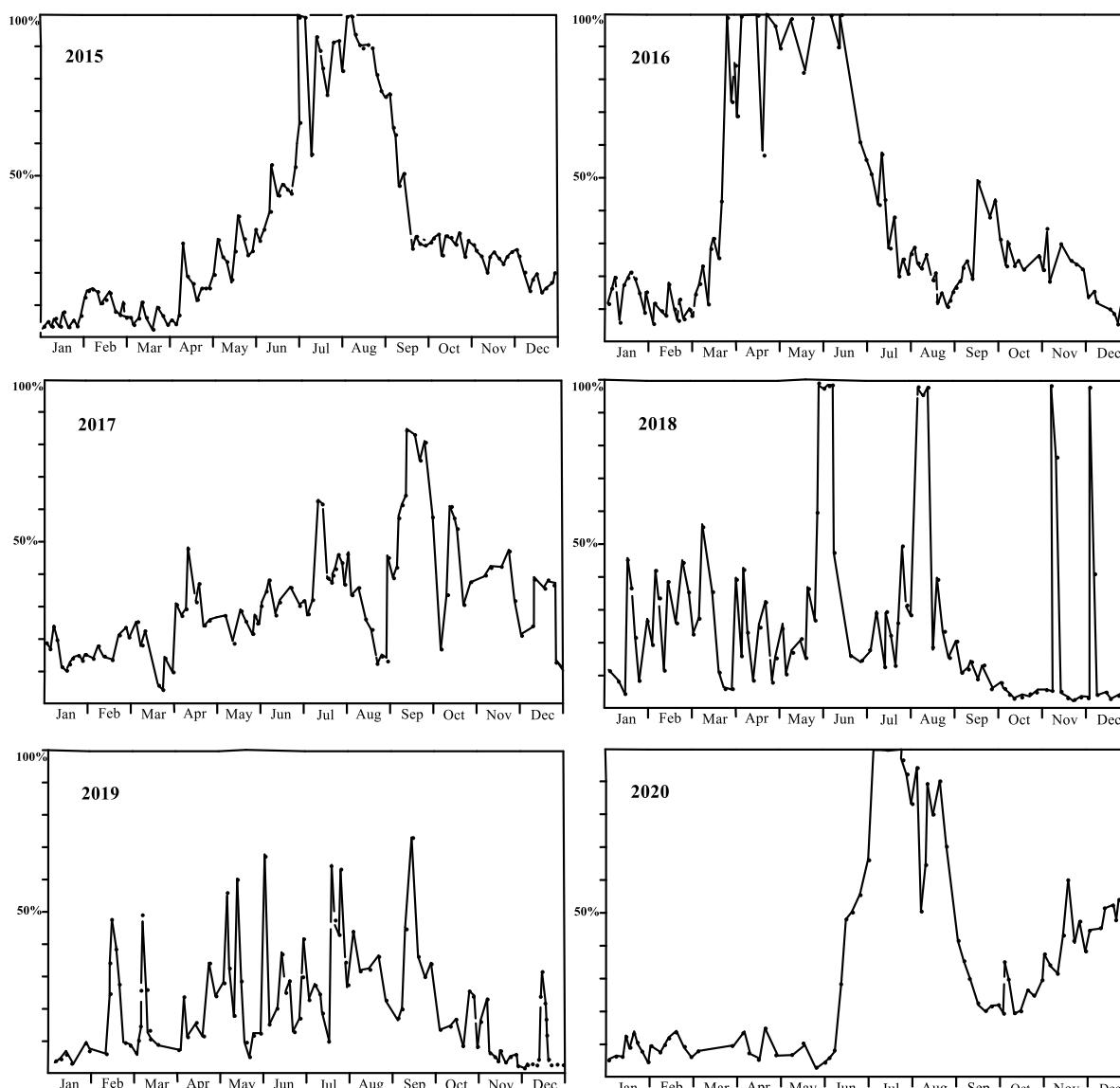


**Fig. 1.** Variations of the rate of hydrolysis of triethyl phosphite in acetonitrile in 2015-2020 at 50° North latitude. This period includes the second half of the 24-th solar cycle 2015-2019 and the first year 2020 of the 25-th cycle.

### Results and discussion

Regular measurements of the rate of hydrolysis of triethyl phosphite for 6 years 2015-2020 (Fig. 1) showed that under the influence of the Sun, the hydrolytic activity of water and the rate of hydrolysis of triethyl phosphite change all the time at a constant temperature. The dynamics of these changes appeared to be very similar to the changes in the amount of camphor crystals in the Storm Glass, indicating that variations in solar influence may be the common cause of these phenomena. Large fluctuations in the size and concentration of water clusters in an organic solvent should significantly affect not only the hydrolytic activity of the water-acetonitrile solution, but also the dissolving ability of the water-ethanol solution in Storm Glass. Camphor is well soluble in ethanol and insoluble in water, therefore its solubility in a water-ethanol solution strongly depends on the quantity and size of water clusters, which constantly vary in very large limits under the solar influence. Under strong solar influence, when

water clusters decompose and their concentration increases, camphor crystallizes from water-ethanol solution, and when the influence of the Sun decreases water clusters reunite, their number in ethanol decreases and camphor crystals dissolve again.

To confirm that solar influence is the common cause of these two phenomena, it was important to discover the simultaneity of their manifestations. Measurements of the rate of hydrolysis of triethyl phosphite by water clusters in acetonitrile were carried out while simultaneously monitoring the number of camphor crystals in Storm Glass. It was found that as the rate of triethyl phosphite hydrolysis increases, the number of camphor crystals in Storm Glass also increases. However, the sensitivity of these two phenomena to the solar influence is very different. The rate of hydrolysis of triethyl phosphite responds very dynamically to even small and short changes in the structuring of clusters under the solar influence and can be quickly and accurately measured by nuclear magnetic resonance. In contrast, in Storm Glass the crystallization of camphor

from the solution and its dissolution occurs much more slowly and can only be assessed visually. Therefore, the simultaneity of these phenomena is clearly manifested during strong and abrupt changes in solar influence and the intensity of the muon flux. The experiments were carried out in Kyiv and Bremen at 50° and 53° northern latitude respectively. At such a distance from the equator, the rate of hydrolysis of triethyl phosphite in acetonitrile and the amount of camphor crystals in Storm Glass were always higher in summer than in winter. The coordination of these two phenomena was especially evident in 2015, 2016 and 2020, when the difference in solar influence between summer and winter was particularly large. (Fig. 1)

Long-term measurements of the rate of hydrolysis of triethyl phosphite showed that the structuring of water molecules in clusters depends on the degree of shielding of solar influence and therefore can be different in the open air and underground. [4] It also depends on the position of the Sun in the sky and can differ markedly even in different places in a large building. [5,6] It was logical to assume that shielding of the solar influence underground will increase the size of water clusters also in water-ethanol solution. This should lead to a decrease in their concentration in Storm Glass and to the dissolution of camphor crystals. This assumption was experimentally confirmed in Kiev, where one metro station is located at the depth of 105 meters. In July 2020, during strong solar exposure, the number of camphor crystals underground was significantly lower than on the surface. At the same time, for comparison, the hydrolysis of triethyl phosphite in acetonitrile was carried out, which also proceeded much more slowly underground than on the surface.

It is important to note that outdoors under the brightly shining Sun the temperature was higher than underground, but despite this, camphor dissolved underground and crystallized on the surface. This proves that the solar radiation exerts a strong influence on Storm Glass. It is also important that in the open air and underground, the change in the solubility of camphor in water-ethanol solution in Storm Glass agrees with the change in the rate of hydrolysis of triethyl phosphite in water-acetonitrile solution. In these different experiments, only water is a common component. This indicates that fluctuations in solar activity can affect all processes in which structured water molecules take part.

Careful and long-term observation of Storm Glass in different places unexpectedly led to the discovery of another very interesting unique phenomenon. It has been found that camphor crystals can quickly dissolve when Storm Glass moves through space. This happened within 15-20 minutes when moving in any direction, on any type of transport, and even at walking speed. This new phenomenon also depends on the intensity of solar influence and is well noticeable when the amount of camphor sediment is quite large. It is interesting to note that after the Storm Glass stops moving, camphor remains dissolved for quite a long time and the initial number of its crystals, with constant solar influence, can only be restored the next day.

The rapid dissolution of camphor when moving in space may indicate the presence of some field or lines

of force, the intersection of which can cause the structuring of water clusters and an increase in ethanol concentration. Assumptions about the existence of some lines of force have already been made by other scientists (Hartmann Lines, Curry Lines, Benker Lines) however they could not be detected with measuring devices.

We also studied the dissolution of camphor when Storm Glass moved around in different places in the same room. It was found that crystals dissolve even when moved within 0.5 m<sup>2</sup>, for example, when rotated in a horizontal plane in a circle with a diameter of 70-80 cm. This means that if Hartmann lines exist, they do not affect the dissolution of camphor. This conclusion is further supported by the fact that dissolution of camphor also occurred if the Storm Glass was moved 1 meter up and down vertically for 30 minutes.

The dissolution of camphor in a water-ethanol solution of Storm Glass when moving in space can only occur due to an increase in the concentration of ethanol and a decrease in the concentration of water clusters. This means that movement in space should cause the structuring of water clusters and a decrease in their number due to an increase in their size. Obviously, this occurs under the influence of the Sun. This is evidenced by the fact that when moving Storm Glass in a large building, the rate of dissolution of camphor is approximately 1.5 times slower than in the open air, and at night it can be several times slower than at noon.

The influence of the Sun on the structurization of water clusters in Storm Glass is confirmed by an increase in the number of camphor crystals after irradiation with hard ultraviolet light. Ultraviolet light also destroys water clusters. This is confirmed by the strong acceleration of the hydrolysis reaction of triethyl phosphite in acetonitrile. After 5 minutes of irradiation of this reaction in a NMR-tube with a 9 W ultraviolet lamp, its rate can increase up to 100 times.

#### **Influence of salts**

By measuring the rate of hydrolysis of triethyl phosphite in a water-acetonitrile solution, we found that the presence of salts greatly promotes the structuring of water molecules. The size of water clusters increases, and their concentration in solution and hydrolytic activity decrease. [4] Therefore, ammonium chloride and potassium nitrate (NH<sub>4</sub>Cl, KNO<sub>3</sub>) in water-ethanol solution of Storm Glass perform an important function. Small water clusters, after the decrease in the influence of the Sun, combine faster, and the solubility of camphor is accelerated. Without these salts, visualization of the effect of solar exposure on water in Storm Glass would be significantly weakened.

#### **Materials and methods**

##### **Solar influence on Storm Glass.**

Two identical Storm Glass vessels containing the same amount of camphor sediment were placed underground at a depth of 105 meters and on the surface. Due to shielding of solar influence underground, camphor dissolves more strongly and the number of its crystals becomes less than on the surface. These changes are clearly visible during periods of high solar influence, when the amount of camphor crystals in the Storm

Glass is large, and the degree of shielding of solar influence underground is high. With low solar influence, camphor dissolves and the difference in the number of its crystals in the two Storm Glasses decreases or disappears. Away from the equator, this experiment should be carried out in summer, when strong solar influence is more common.

**Solar influence Solar influence on the hydrolysis of triethyl phosphite.** Two 5 mm NMR-tubes containing 400 mg of acetonitrile, oriented vertically, were placed outdoors away from large buildings and underground. In 30 minutes, fresh water (7 mg) was added to them and mixed briefly by shaking. In 10 minutes, 25 mg of triethyl phosphite was added and mixed briefly by shaking. The reaction rate was determined by measuring the integral intensities of the signals in the  $^{31}\text{P}$ -NMR spectra. Commercial acetonitrile containing 0.02% water was used. The NMR-tubes should be protected from light by a cardboard screen.

### Conclusions

Solar cosmic rays have a strong influence on the self-organization of water molecules, as well as on the stability, size and concentration of water clusters in organic solvents. For this reason, the solubility of camphor and the amount of its crystals in Storm Glass constantly change at constant temperature. In the open air and underground the solar influence is different and the change in the solubility of camphor in water-ethanol solution in Storm Glass is consistent with the change in the rate of hydrolysis of triethyl phosphite in water-acetonitrile solution. In these different experiments, only water is a common component. This indicates that fluctuations in the intensity of the solar influence on the Earth can affect all processes in which structured water molecules take part. Thus, Storm Glass is a detector of the solar influence and can be considered as a chemical weather indicator, but not atmospheric, but space weather.

The structuring of water clusters as they move through space requires additional study in different places on Earth, at different latitudes and during different periods of the 11-year solar cycle. This could yield important results for biology, physics and environmental science.

### Competing interest

There are no conflicts to declare.

### Acknowledgements

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# ECONOMIC SCIENCES

## ESTABLISHING FINANCIAL CONTROL IN ACCORDANCE WITH MODERN REQUIREMENTS: IN THE WORLD AND IN AZERBAIJAN

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### Abstract

Public financial control is an integral part of an effective governance system. This control mechanism ensures the transparent, accountable, and efficient use of state financial resources, strengthens fiscal discipline, and enhances citizens' trust in public authorities. As one of the key components of public administration, financial control plays a crucial role in maintaining fiscal discipline and ensuring the proper allocation of resources. This article explores the organization of public financial control in accordance with modern requirements and analyzes the main directions for its further development.

In the context of global economic challenges, the digitalization process, and growing public demands for transparency, the role of financial control has become increasingly relevant. This article analyzes reforms implemented in various countries, international best practices, and digital control tools. It emphasizes the importance of shifting financial control from retrospective audits to proactive risk-based assessment mechanisms as a critical factor in ensuring effective oversight.

**Keywords:** Digitalization of the financial sector, public financial management, international experience, modern challenges.

### Introduction

In the modern era, financial control plays a vital role in ensuring the effective functioning of both the public and private sectors. The globalized economic environment, rapid advancement of information technologies, and increasing financial risks necessitate the adoption of new approaches and reforms in this field. It is essential that financial control is not limited to traditional auditing functions but also incorporates preventive, analytical, and strategic dimensions.

In order to establish financial control in line with modern requirements, it is essential to base the system

on the principles of transparency, accountability, and responsibility. Strengthening internal and external audit systems, as well as utilizing electronic monitoring and digital reporting tools, are important steps in this direction. Furthermore, control mechanisms aligned with international financial standards not only help reduce corruption risks but also ensure the efficient use of public funds. The formation of a qualified human resources base and the regular organization of training programs are also of great importance for the effective implementation of financial control in state institutions and large enterprises.

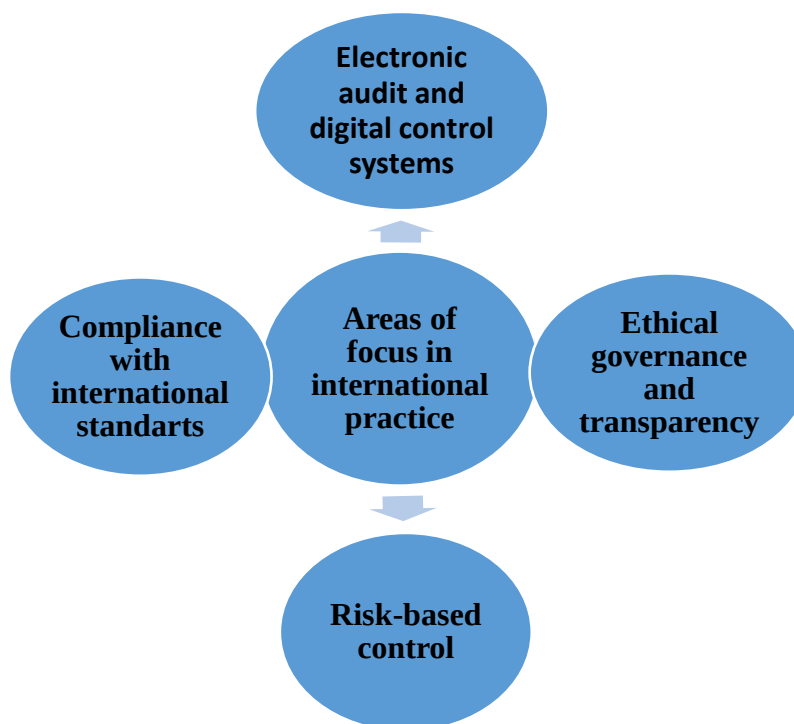


*Fig:1 Source: prepared by author*

Financial control is a continuously evolving field and is closely linked to the economic conditions of countries. Globally, the development of financial control has generally passed through three main stages:

- ✓ Traditional financial control
- ✓ Digital financial control
- ✓ Innovative financial control

Until the mid-20<sup>th</sup> of century financial control was primarily carried out through documentation, manual verification and the physical recording of each transaction. Government bodies and financial institutions relied on traditional methods to audit financial reports monitor budget usage, and collect taxes.

At the beginning of the 21<sup>st</sup> century, however, with the spread of the internet and the acceleration of technological advancements, digital transformation in financial control also began. The main areas of development during this period include:

- ✓ Digitalization of financial data – Financial transactions began to be tracked more quickly and accurately through digital formats.
- ✓ E-reporting and online financial management tools – Enabled faster and more transparent sharing of financial information between governments and businesses.
- ✓ Tax and budget management systems – Through digital platforms, governments began to build more efficient systems for tax collection and budget administration.

In recent years, with the accelerated advancement of technology, new approaches have begun to be applied in financial control. This period is primarily associated with blockchain technology, big data, artificial intelligence, and other innovative technologies. The characteristics of innovative financial control include:

- ✓ Blockchain technology and cryptocurrencies

- ✓ Big data and artificial intelligence
- ✓ Automation and analytics

Looking at countries around the world, the United States is one of the most advanced nations in the development of financial control. Financial oversight is primarily conducted through institutions such as FEMA and the Government Accountability Office (GAO). These organizations monitor the use of financial resources, prepare extensive annual audit reports, and adapt tax policies to modern technologies. China, on the other hand, possesses highly developed state administration systems for implementing financial control. In particular, compliance with tax legislation and electronic control systems are notably strong.

The global economic challenges of the modern era have not spared Azerbaijan. Significant reforms have been carried out in Azerbaijan aimed at structuring financial control and aligning it with international best practices. In this field, the legal and institutional framework has been partially improved, digital solutions have been introduced, and electronic budgeting systems, tax control mechanisms, and digital reporting platforms have been established. Over the years, the volume of data collected through electronic platforms has increased, and the opportunities for using analytical tools within government agencies have expanded. Recent reforms in Azerbaijan have created favorable conditions for approaching international standards in this area:

- development of the state financial control system – Oversight activities carried out by the Chamber of Accounts, the Ministry of Finance, and other institutions are being conducted in a more systematic and transparent manner
- E-government and digitalization initiatives – Real-time monitoring capabilities within government agencies have been expanded;

➤ improvement of the legislative framework – Updates have been made to the “State Financial Control” law and other relevant legislation;

➤ development of human resources and international cooperation – The involvement of experts in audit and control in international training programs is increasing.

However, analyses indicate that there are several challenges to fully establishing financial control at the level of modern requirements:

- The predominance of traditional audit approaches;

- Weak development of risk-based control systems;

- Limited inter-agency information exchange;

- Uneven levels of professional expertise among human resources.

Global experience shows that organizing the financial control system based on modern requirements plays a decisive role in economic stability, the proper execution of the state budget, and the efficient use of public funds. Technological and methodological changes in the field of financial control should also be implemented in Azerbaijan, as control acts as a guarantor of the country's economic stability and sustainable development.

Taking into account the problems mentioned above, it is deemed appropriate to undertake measures in the following directions:

*Harmonization of the normative-legal framework with international standards:* Legislative acts related to financial control should be updated based on the recommendations of INTOSAI and other international organizations, ensuring the elimination of legal gaps.

*Strengthening integration among control bodies:* Coordination between institutions should be enhanced through the integration of information systems and the creation of a unified control database.

*Development of electronic control infrastructure:* The implementation of artificial intelligence, analytical tools, and automated audit programs will significantly enhance the agility and effectiveness of financial control, as the adoption of advanced technologies has become not a choice but a necessity.

*Professional development and human capital enhancement:* It is essential to engage financial control specialists in continuous training programs, implement international certification systems, and strengthen codes of ethical conduct.

*Implementation of risk-based control mechanisms:* The expansion of a risk-based approach in the financial control system should be ensured to optimize resources and prioritize high-risk areas. Such an approach reduces repetitive and less significant audits, ensuring more efficient protection of state resources.

#### **Conclusion:**

Financial control is not only about monitoring financial flows but also one of the key tools supporting strategic decision-making in economic management. A financial control system that meets modern requirements, is flexible, and technologically equipped serves the sustainable development of both public finances and the business sector. Research shows that, against the backdrop of the dynamic development of the global economy, organizing financial control in accordance with contemporary standards has become a priority for every country. Digitalization, risk-based control, and regulatory mechanisms aligned with international standards, as implemented in developed countries, ensure the resilience of the financial system.

In conclusion, the application of comprehensive approaches and the study of advanced practices are of great importance for establishing financial control in accordance with modern requirements both globally and in Azerbaijan.

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## ANALYSIS OF THE ROLE OF WATER TRANSPORT IN COMBINED, INTERMODAL AND MULTIMODAL TRANSPORT

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<https://doi.org/10.5281/zenodo.15536083>**Abstract**

This article examines the role and importance of water transport in the context of combined, intermodal, and multimodal freight transport. It presents the definitions, principles, and basic technical and legal aspects of these transport concepts. Special attention is paid to intermodal transport units and their application in combining sea transport with various types of specialized vessels, such as container ships, train ferries, Ro-Ro ships, lighters, and pallet carriers. The organization of multimodal transport is analyzed, in which the multimodal transport operator (MTO) is responsible for the entire transport chain, including the participation of subcontractors such as sea and inland waterway carriers. The article also explores **combined transport**, where water transport—particularly sea and inland waterways—constitutes the main segment of the route, while road transport is limited to short initial or final legs. The regulatory framework related to multimodal and combined transport is discussed, emphasizing its importance for the development of international trade and logistics. In conclusion, the article highlights the key role of water transport in effectively implementing sustainable and integrated international transport chains.

**Keywords:** combined transport (CT); intermodal transport; multimodal transport; water transport; intermodal transport units (ITU/ILU); multimodal transport operators (MTO); combined maritime transport; container ships; Ro-Ro ships; train ferries; lighterage ships (LASH); legal framework

**1. Introduction**

In the current conditions of globalization and expanding international trade, the efficiency of transport systems is crucial for ensuring sustainable economic growth and competitiveness. Intermodal and multimodal transport are increasingly emerging as dominant approaches, integrating different modes of transport—such as road, rail, and water—to achieve higher efficiency, flexibility, and reduced environmental impact. In this framework, water transport plays a key role as a sustainable and cost-effective component of the logistics chain. Its contribution is especially important in efforts to optimize freight movement across national and international corridors.

A central aspect of modern logistics strategies is the balanced use of different modes of transport. As noted by Koritarov and Dimitrakiev (2024), "the modal distribution is defined as the allocation of freight transport among various transportation modes, including road, rail, and inland waterways. The evaluation of this distribution offers insights into the efficiency of the transport network and the environmental impact of hinterland activities. Achieving a well-balanced modal distribution is imperative for enhancing logistics performance and reducing transport expenses." [1] This highlights the growing importance of inland and maritime transport within intermodal and multimodal systems.

This article aims to analyze the role and significance of water transport in the context of intermodal and multimodal freight systems, by examining its advantages, limitations, and future development opportunities.

**2. Theoretical aspects of intermodal and multimodal transport**

Intermodal transport is the transport of goods using more than one mode of transport, but within the

same loading unit (e.g., container), without interruption of the load itself. Multimodal transport also involves the use of different modes of transport, but under the management of a single operator and using a single transport document. The main difference between the two types is in the coordination and responsibility along the supply chain. In both cases, the aim is to use the advantages of each mode of transport to achieve greater efficiency, sustainability, and economy.

**2.1. Intermodality: Meaning and Application**

When transporting goods over long distances, geographical conditions do not always allow for the same means of transport. Depending on the cargo quantity and the transportation distance, the effectiveness of each individual mode of transport varies. Additionally, due to certain technical limitations, it is not always feasible to provide the most suitable mode of transport at the goods' place of origin, necessitating the use of a different transport method at the start of the journey. Changing the means of transport requires the transshipment of the goods from one means of transport to another. Transshipment is accompanied by at least five negative consequences:

- additional costs
- delay in delivery
- losses of goods due to spillage, loss, theft, etc.
- mechanical damage to the goods during re-loading
- damage to the goods when exposed to less favorable weather conditions

In form, goods can be in bulk or in bulk. When they are in bulk and in large batches, also if the nature of the goods themselves allows, the same can be transported in bulk to the end user. In other cases, the goods must be appropriately packaged. The packaging can be

boxes, bags, crates, etc. facilitate reloading and transportation, it is necessary to consolidate the packaging. In this regard, transport engineering has created pallets. Pallets serve as a simplified load unit, facilitating the arrangement and strengthening of bulk loads in bags, boxes, and other containers. This activity is called palletization and allows it to be carried out at the place of production of the goods, after which it can be easily and reliably stored, loaded, unloaded, reloaded onto a truck, from a truck to a wagon, etc. During transportation and when reloading pallets from one mode of transport to another, the goods are sufficiently protected for short distances, and the pallets also allow them to be reloaded mechanically and relatively quickly. This is the meaning of intermodalism. The main element of this theoretical concept is the consolidated loading unit, also referred to as a transport unit, which serves to reduce the negative consequences associated with transshipment activities. The phrase "intermodal transport unit" or "Intermodal Transportation Unit" (ITU) is also referred to as "intermodal loading unit" or "Intermodal Loading Unit (ILU).

This technique for transportation and transshipment is not new. Various techniques have been applied over the years, in simpler forms and technically possible for their time.

UNICE 's definition of intermodal transport is "a transport system in which goods are transported in the same transport unit (ITU) or vehicle using at least two transport modules (types) without handling the load."

(Working Party on Intermodal Transport and Logistics [WP.24], 2014). In addition, the term intermodality is used to describe a transport system in which two or more modes of transport are used for the same transport unit in an integrated manner, without manipulating the cargo during transport— "door-to-door transit". [2]

#### ❖ **Intermodal transport units (ITU or ILU):**

The European Commission directives specify that intermodal units include containers, swap bodies, and truck trailers. According to a more extended understanding, intermodal units are:

- **Containers**—used as intermodal units transported by road, rail, and water transport
- **Trucks and trailers with and without tractors** are used as intermodal units transported by rail cars and water transport.
- **Railway wagons**—used as intermodal units transported by sea ferries (train ferries).
- **Lighters** are unmanned, non-self-propelled vessels used as intermodal units; they are moved by pushers in rivers and then reloaded at their mouths onto lighter-type ships for transport along the sea route.
- **Pallets** are used as intermodal units transported in aviation, road transport, and water transport.

The above five intermodal units are also transported by specialized water transport vessels.

#### **2.2. Multimodality—Necessity and Application**

(United Nations, 2004). The basic feature of multimodal transport is that at least two modes of transport are used. The definition jointly given by the United Nations Economic Commission for Europe (ECE), the European Conference of Ministers of Transport (ECMT) and the European Commission (EC) is "Multimodal transport: carriage of goods by two or more modes of transport".[3]

The implementation of international transport of goods is carried out using more than one type of transport. In addition to the transshipment of goods, which is a problem solved with the intermodal concept, another problem is their organization. The task of organizing the entire transport of goods, from the place of origin to the place of its realization, is beyond the capabilities of individual traders. The use of individual modes of transport and the corresponding transshipment is accompanied by the conclusion of numerous contracts and coordination of the entire transport with individual carriers. As a result of the development of international trade in transport services, transport companies with international representation were created, which are technically capable of organizing complete international transport of goods. In this regard, the need arose for the legal regulation of these services. Users of transport services, in addition to a good price, also seek reliability of transport in all its dimensions. On the other hand, international trade, which is closely related to and dependent on transport, also has its requirements regarding transport documents (bills of lading, waybills, etc.), which are necessary for payments in commercial transactions. As a result of all this, the need arose to negotiate the entire transport with only one carrier company, under one transport contract for the entire section of the transport, including the use of at least two modes of transport. In addition, the goods must be transported with only one transport document. The solution to this need is the concept of multimodality.

Related to this concept is the United Nations Conference on a Convention on International Multimodal Transport, Geneva, 1980.

According to the Convention, "International multimodal transport (international multimodal "transport" means the carriage of goods by at least two different transport modules (means) based on a multimodal contract from a place in one country where the goods are accepted by the responsible multimodal transport operator to a specified place of delivery located in another country. The carriage and delivery of goods carried out under a contract involving only one transport module, if so specified, shall not be considered international multimodal transport."

By convention, the carrier is responsible for the entire carriage, even if it is performed by several modes of transport (e.g., rail, road, and sea). The carrier is not required to own all the means of transport, and in practice, it typically does not. Sub-carriers, also referred to as "actual carriers," typically perform the carriage. The carrier who is responsible for the entire transport is also called a multimodal transport operator, or MTO.[4]

According to the Convention, a "multimodal transport operator" (MTO) means any person who, in his name and on his account or through another person acting on his behalf, concludes a multimodal transport contract and who, as principal (entrepreneur), not as agent or on behalf of the consignee of the goods or the carriers involved in the multimodal transport operations, assumes responsibility for the performance of the contract.

According to the Convention, a "multimodal transport contract" refers to an agreement in which a multimodal transport operator commits, in exchange

for freight payment, to carry out or guarantee the execution of international intermodal transport.

According to the Convention, a "multimodal transport document (multimodal transportation document) means a document that is evidence that a contract for multimodal transport has been concluded, the assumption of responsibility for the goods by the multimodal transport operator, and his guarantee that he will deliver the goods in accordance with the terms of the contract."

According to the Convention, "Consignor of the goods (Consignor) means any person by whom or on whose behalf the contract of multimodal transport is concluded with the multimodal transport operator, or any person by whom or on whose behalf the goods are made available to the multimodal transport operator in connection with the multimodal transport contract."

The Convention defines "Consignee" as the legal recipient of the goods. According to the Convention, "Goods" include containers, pallets, or similar articles used for transport or packaging that are supplied by the consignor.

The concept of multimodal transport is not new. There are examples of popular science literature.

According to the United Nations (2004). "In the 17th century, a French writer described how his cart was loaded onto a barge and traveled 400 km down the Rhine River to avoid poor travel on the undeveloped road network at the time. This example is given as Ro-Ro transport." - This example can be argued to what extent it is multimodal transport, since it is not stated that it was carried out on the transport of foreign cargo for freight.

A contemporary writer asserts that the invention of modern multimodal transport occurred in the context of railway transport. On the first railway in 1830, the coach body was removed from the chassis and loaded onto a flatbed wagon to save passengers from the inconvenience of changing coaches for wagons. This approach may have been a strategy to gain acceptance for this new mode of transport. Some cities strongly opposed this system.[5]

Not enough countries have ratified the Convention on Multimodal Transport to achieve international recognition. However, it is successfully applied in transport using intermodal units such as containers, trailers, and semi-trailers, as well as railway wagons. In connection with the convention, Ordinance No. 53 of February 10, 2003, on combined transport of goods of the Republic of Bulgaria was promulgated in the State Gazette, No. 18 of February 25, 2003.

#### ❖ **Application of intermodal and multimodal transportation in water transport:**

The concept of intermodality is associated with intermodal transport units, with which the goods loaded in them are transported by two or more modules (types) of transport, with the transshipment being carried out without manipulating the goods. Multimodality refers to contracts for the international transport of goods involving two or more modules of transport, which are concluded between the shipper and the multimodal transport operator (MTO) responsible for the entire transport. In addition, on these means of transport, only one transport document, Bill of Lading or Waybill, valid for the entire transport, is issued.

The principle of negotiation is based on the convention on multimodal transport. Multimodal transport operators (MTOs) operate the intermodal transport units that they use to transport the goods. The intermodal units can be owned by the MTO or be rented. MTOs conclude contracts with shippers for the carriage of goods along the entire multimodal transport chain. In addition to shippers, MTOs conclude contracts for the carriage of intermodal transport units with the relevant actual carriers for each section of the transport chain. Actual carriers are companies that own and operate road transport, rail transport, air transport, or water transport with any of the types of specialized container ships, Ro-Ro, ferries, lighters, or pallet carriers. In relation to multimodal transport contracts, actual carriers appear as subcontractors (subcarriers). Actual carriers do not have direct contractual relations with shippers. The MTO issues the appropriate multimodal transport document on its behalf after the goods are loaded, and this document is valid for the duration of the goods' transportation.

#### **2.3. Combined sea transport**

Sea transport of intermodal transport units is carried out with specialized seagoing vessels used in liner shipping. Liner shipping has undergone an evolution because of which traditional liner transport of general cargo continues today, but liner transport with intermodal transport units has also developed. These transports in Bulgarian terminology are also called combined sea transports. In these transports, sea carriers, as noted above, act as subcontractors of the MTO. We can divide combined sea transport into separate sectors:

- Transportation of containers with container ships.
- Transportation of trucks and trailers by Ro-Ro ships.
- Transportation of railway wagons with ships, such as railway wagon ferries.
- Transportation of lighters with lighter-type ships; pallet cargo transportation with pallet trucks.

In combined sea transport, the operator of the intermodal transport unit, as the MTO, concludes a multimodal transport contract with the shipper. Sea carriers are subcontractors (subcarriers) of the MTO who are responsible to the shipper for the entire transport. The responsibility for the goods to their recipient is borne by the MTO, which to a counterclaim against the sea carrier in cases where damage to the goods occurred during sea transport.

#### ❖ **Analysis of the EU Combined Transport (CT):**

(European Commission, 2015). The CT market has been defined by various definitions, including Maritime CT and Continental CT. The CT Directive refers to the transport of goods between Member States, involving the movement of CT load units on CT services between MS. However, available data on freight traffic flows does not provide sufficient detail on these criteria to verify which traffic flows qualify as CT.

The CT market has traditionally been split into two broad segments: Maritime CT, primarily related to the movement of ISO-standard shipping containers between seaports and inland terminals, and Continental CT, primarily related to movement of CEN-standard European swap bodies between inland terminals in European countries. However, recent developments have

blurred the distinction between the two definitions due to increasing liberalization of the railway industry.

To provide clear and distinct definitions, further segmentation is necessary, such as by CT modal combination (CT RR), geographic coverage (intra-MS), and type of service (UCT) or accompanied (ACT). These definitions are used in a consistent format, with CT rail/road > Intra-EU > Unaccompanied. This helps to provide a more transparent analysis of the CT market and ensures that the industry can better understand and understand the CT market.[6]

### **2.3.1. Combined sea transport with container ships**

Multimodal container transport occupies the largest share of all multimodal and combined sea transport. They are very flexible and meet the requirements of the largest number of users. Additionally, regarding load capacity and cargo capacity, containers are comparable to both road transport and rail transport. Containers can transport nearly 90% of the cargo that rail wagons carry. The door-to-door system (door this door) is very convenient and efficient.

#### **❖ Combined sea transport of containers is carried out with two types of ports:**

- Feeder or power ports (feeder ports) serve to collect and redirect containers from and to the final points of the transport chain served by land transport and rail transport.
- A hub port is a type of port that consolidates and distributes containers. Each hub port is fed with containers from its feeder ports, and vice versa, containers are directed from the hub ports to the corresponding feeder ports.

Combined sea transport of containers is carried out with two types of container ships:

- Feeder container ships (feeder ships)—these are small-capacity ships and are used to transport containers between feeder ports and consolidating ports.
- Mainline container ships (mega ships)—these are large-capacity ships and are used to transport containers only between consolidating ports (hub ports).

In combined maritime transport with container ships, the concept of “**hub**” is applied and “**spoke**” which is also applied in aviation. The basis of this model is the economic concept of economies of scale. In this model, containers are first transported from the place where they are loaded with goods to the nearest port, which acts as a feeder port of the respective line. The feeder ports are served by feeder container ships (feeder ships) that transport containers to hub ports (hub ports), where ships are transshipped onto large container ships (megaships). Each hub port has a certain number of feeder ports from which they provide goods for container transport. Large container ships (mega ships) transport containers to the hub port that serves the feeder port, which is closest to the final point on land where the container is to be delivered. Feeder line transport is short, usually within a single sea basin and over less than 1000 nautical miles. Trunk line transports are long-distance, oceanic, and usually between hub ports located on different continents.

### **2.3.2. Combined transport with Ro-Ro ships**

**Christodoulou, Raza, and Woxenius (2019)** examine the integration of Ro-Ro shipping in sustainable intermodal transport chains. Ro-Ro shipping services, a

maritime segment, can easily integrate into intermodal transport systems as they do not require port lifting.[7]

Users of Ro-Ro ships are car carriers. In these transports, the intermodal transport unit is the truck with a trailer and a driver, or the trailer without a driver. There is a transport scheme in which the trailers are towed along the land sections by different tractors on both sides of the sea line, with the Ro-Ro ship transporting only the trailer with the goods.

### **2.3.3. Combined transport with railway ferries**

Combined transport with railway ferries Users of ferries are railway operators, which can be companies with railway rolling stock or wagon fleets. The intermodal unit is the railway wagon. In ferry transport, the railway operator, as the MTO, concludes a multimodal transport contract with the shipper. Sea carriers are sub-contractors (subcarriers) of the railway operator, who is responsible for the entire transport.

(Fomin, Lovska, & Horban, 2021). The transport industry significantly benefits from combined transport systems such as train ferries, which integrate railway and maritime infrastructure to enhance the efficiency and sustainability of freight and passenger movement. These systems have been extensively analyzed to provide a comprehensive understanding of their historical development, operational features, and strategic importance. Train ferry routes—both sea-based and those crossing rivers and lakes—have played a crucial role in improving national economies and strengthening military logistics. A notable example is Ukraine’s network of train ferries connecting with Bulgaria, Georgia, and Turkey, with specific emphasis on the structural and technological characteristics of modern ferries operating in the Black Sea, Caspian Sea, and Baltic Sea regions. These services facilitate the transportation of rail wagons and even passenger trains, requiring specialized vessels and infrastructure.[8]

In the Bulgarian context, ferry services have a well-established tradition. The first train ferry line was launched in 1978 between the ports of Varna and Illichevsk, followed by the Varna–Port Kavkaz route. The development of such lines is guided by intergovernmental agreements and cooperation between national railway carriers, which are crucial for establishing and operating the necessary ferry terminals and ensuring interoperability. These projects demand significant investment and are often preceded by detailed analyses of trade potential and strategic connectivity among the participating countries. The successful operation of train ferries thus depends not only on technical and infrastructural readiness but also on institutional coordination and long-term bilateral cooperation.

These shipments are largely like Ro-Ro shipments. Ferry ships for transporting railway wagons are technically also suitable for transporting trucks.

### **2.3.4. Combined transport with lighter carriers**

In this transport system, the lighter is the intermodal cargo unit. Lighters are non-self-propelled vessels used for river transport. The means of transport is the lighter carrier, which carries out ocean transport connecting the mouths of rivers or canals to inland waterways. Usually the lighter and lighter carrier (LASH system) is owned and operated by a single commercial company. In this system, goods are loaded onto lighters at a river port, after which the lighters are taken on board by a lighter carrier, which transports them to the

mouth of another river and canal on an inland waterway, where they are towed as non-self-propelled vessels to the river port where the goods are to be unloaded. After unloading the lighters, they are loaded onto other goods and returned on the return journey. It is practically possible for lighter lines to also serve shallow water seaports.

The barge transport that connected the European countries along the Danube River with ports in the Far East has already been discontinued; they remain only of theoretical importance, although such lines are still maintained in other parts of the world. Given its environmental friendliness, we can anticipate its eventual restoration. This transport system can be developed between the mouths of the Danube and the Don Rivers, with those of central and western Europe.

#### 2.3.5. Combined transport with pallet trucks

In these transports, the intermodal unit is the pallet, which is transported by a specialized ship-type pallet carrier. The characteristic of these ships is that they are multi-deck with low cargo spaces adapted for the transport of containers only. These ships were used in the 80s of the last centuries but gave way to container ships. Nowadays, similar ships are used for the transport of some fruits requiring constant temperatures.

#### 2.3.6. Allocation of Carrier Responsibility in Combined Maritime Transport

In private marine law, the identification of maritime carriers is a critical issue, further complicated by the allocation of responsibility for both the transport process and the cargo itself. Carriers may act as maritime entrepreneurs without owning vessels, necessitating a distinction between carriers operating under charter agreements and those acting under a bill of lading. Several legal entities, such as shipowners, time charterers, and even sub-charterers, may distribute obligations and responsibilities in cases involving chains of charter parties.

(Dimitrakiev, Koritarov, & Velinov, 2025). This distinction is particularly important during cargo discharge, where inconsistencies in the quantity or condition of goods may arise. Determining which party holds liability is essential for assessing claims for damage or loss. The problem becomes even more complex in combined or multimodal transport chains, where the sea leg is integrated with inland or port operations. In such cases, identifying the contractual carrier — especially when multiple parties have overlapping roles — is crucial for enforcing liability under legal instruments such as the Hague-Visby Rules, Hamburg Rules, or Rotterdam Rules.[9]

Moreover, in door-to-door transport services, carriers may subcontract segments of the journey, making it difficult for cargo owners to pinpoint the responsible party when loss or damage occurs. Therefore, clear contractual arrangements and transparent documentation remain essential tools for assigning liability in combined sea transport.

#### 2.4. Definitions of Multimodal, Intermodal, and Combined Transport

In the context of transport policy and regulation, unified terminology is essential for clarity and interoperability between transport modes. In 2001, three key institutions—the European Conference of Ministers of Transport (now the International Transport Forum), the

United Nations Economic Commission for Europe (UNECE), and the European Commission—agreed on standardized definitions of the terms multimodal, intermodal, and combined transport (Reis et al., 2013). According to these definitions:

- **Multimodal Transport** is the “carriage of goods by two or more modes of transport”;
- **Intermodal Transport** is the “movement of goods in one and the same loading unit or road vehicle, which uses successively two or more modes of transport without handling the goods themselves in changing modes”;
- **Combined Transport** is the “intermodal transport where a major part of the European journey is by rail, inland waterways or sea and any initial and/or final legs carried out by road are as short as possible”.

Furthermore, the **European Commission** later introduced the concept of **co-modality**, defined as the “efficient use of different modes on their own and in combination” (European Commission, as cited in Reis et al., 2013, p. 18). This terminology plays a vital role in shaping transport strategies and integrating water transport into modern logistics chains.[10]

#### 3. Importance and advantages of water transport

Water transport has advantages that make it preferred in many cases:

- **Economy:** It is one of the most cost-effective modes of transport when large volumes of cargo over long distances.
- **Environmental friendliness:** Compared to road and air transport, water transport emits fewer harmful emissions per unit of transported cargo.
- **Large capacity:** Sea and river vessels can carry large amounts of cargo at once, reducing the need for multiple trips.
- **Low infrastructure cost:** Unlike road and rail transport, water transport uses natural infrastructure—seas and rivers.

#### 4. Role of water transport in intermodal and multimodal transport

Water transport is an essential component of intermodal and multimodal systems, especially in international transport. Seaports are often the starting or ending point of a freight chain connecting to rail and road transport. For example, containers arriving by sea are loaded onto trains or trucks for distribution inland. (Caris et al., 2014). **Water transport, particularly inland navigation, plays a crucial role in enhancing the efficiency and sustainability of intermodal supply chains.** It provides a vital connection between the hinterland and seaports, especially in regions with well-developed river networks such as the Danube basin. **Integrating inland waterway transport (IWT) into the intermodal chain offers significant opportunities for improving supply chain service performance, reducing external costs, and supporting green logistics.** Future research efforts focus on developing system-wide models for IWT, integrating operational planning tools, and optimizing bundling networks. **Additionally, better alignment of intermodal transport decisions with broader supply chain strategies is essential for achieving seamless and sustainable freight movement.**[11]

#### 5. Main problems and challenges

Despite its advantages, water transport faces challenges:

- **Dependence on natural conditions:** Navigation on rivers and seas depends on climatic and hydrological factors.
- **Limited speed:** Water transport is slower than others, which is a disadvantage when transporting goods with a short shelf life.
- **Infrastructure constraints:** Insufficiently modernized ports, lack of logistics terminals, and connectivity with other modes of transport hinder effective integration.
- **Regulatory barriers and administrative burdens:** In many countries, there is still a lack of sufficient coordination and synchronization of regulatory regimes between different modes of transport.

#### 6. Development prospects and opportunities for improvement

In view of the increased focus on sustainable development and the "green transition," waterborne transport has significant potential for expansion. The EU, through strategies such as the "Green Deal," is promoting the use of environmentally friendly means of transport, including inland waterway transport. Necessary are:

- In port modernization and multimodal terminals.
- Development of digital systems for coordination and tracking cargo.
- Improving compatibility between different types of transport.
- We are fostering public-private collaborations to build a logistics network.

#### 7. Conclusion

Water transport, with its economic and environmental efficiency, is unchanged apart from modern intermodal and multimodal transport systems. Despite some challenges, in the presence of strategic vision, adequate investments, and improvements in coordination between transport types, there is the potential to play a more important role in global logistics. Bulgaria, as a country with access to the Black Sea and an important participant by the River Danube, has significant potential for development in this direction.

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# JURISPRUDENCE

## THE PROTECTION OF MINORITY RIGHTS IN A GLOBALIZED WORLD

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### Abstract

In recent decades, globalization has increasingly blurred geographical borders, fostering a more culturally integrated society. Despite this, the protection of minority rights remains a significant challenge in international law. Minorities exist in every country, often occupying a vulnerable position due to periodic discrimination. Existing international legal frameworks are insufficient to effectively safeguard the constitutional rights of minorities. While civil and cultural rights formally uphold states' obligations to ensure equal rights, practical implementation requires additional international mechanisms, blending hard and soft law, to standardize minority rights protection. The absence of a binding international treaty with a clear definition of minorities has led to misinterpretations, double standards, and ineffective legal mechanisms. This paper utilizes a comparative methodology to explore the declarative nature of international and national acts and underscores the importance of minority rights as an essential component of human rights. Recognizing linguistic, traditional, and cultural diversity as unifying societal values, this study advocates for enhanced legal measures to promote harmonious coexistence in an increasingly globalized world.

**Keywords:** discrimination, diversity, globalization, international acts, the rights of minorities.

### INTRODUCTION

The phenomenon of globalization has significantly reshaped the social, economic, and political landscapes across the globe. Over the past few decades, the concept of diminishing geographical borders has gained traction, leading to increased cultural exchange and interdependence among nations. This shift towards a more interconnected world has profound implications for various aspects of human life, including the protection of minority rights. Despite the strides made towards creating a more inclusive global society, the issue of minority rights remains a contentious and challenging aspect of international law and policy. Minorities, defined by their distinct ethnic, religious, linguistic, or cultural identities, are present in virtually every country. These groups often face systemic discrimination and marginalization, rendering their social positions more vulnerable compared to the majority population. This vulnerability necessitates robust legal protections to ensure their rights are upheld and respected. However, the current international legal framework has proven inadequate in effectively safeguarding the constitutional rights of minorities. While various international legal instruments recognize and promote civil and cultural rights, there is a significant gap between formal recognition and practical implementation. International law, through instruments such as the Universal Declaration of Human Rights (UDHR) and the International Covenant on Civil and Political Rights (ICCPR), provides a broad framework for the

protection of human rights, including those of minorities. However, these instruments often lack specific provisions tailored to the unique challenges faced by minority groups. The absence of a binding international treaty that clearly defines minorities and delineates their rights has resulted in ambiguous interpretations and inconsistent application of legal standards. This ambiguity fosters a landscape where double standards and ineffective legal mechanisms prevail, undermining the protection of minority rights. The global landscape is further complicated by the interplay between hard law, which refers to legally binding agreements, and soft law, encompassing non-binding guidelines and principles. While hard law provides a concrete legal basis for enforcing rights, soft law plays a crucial role in shaping norms and influencing state behaviour. In the context of minority rights, the integration of hard and soft law mechanisms is essential to develop a cohesive and effective approach to protection. This integration can help bridge the gap between declarative international commitments and actionable national policies.

The need for a comprehensive and binding international treaty on minority rights is underscored by the diverse and dynamic nature of minority groups themselves. Minorities contribute to the rich tapestry of human civilization through their languages, traditions, and cultures. Recognizing and respecting this diversity is not merely a legal obligation but a moral imperative that enhances social cohesion and harmony. In a globalized world, the protection of minority rights becomes

even more critical as cultural interactions intensify and the potential for conflicts increases. As authors Shapiro and Cordon have reflected in their paper, there is a strong tendency to associate democracy with a wide range of activities and outcomes that people value (Shapiro and Cordon, 1999). This paper aims to explore the complexities surrounding the protection of minority rights in a globalized context. By employing a comparative methodology, it seeks to identify the gaps and inconsistencies in both international and national legal frameworks.

The study will critically analyze existing legal instruments, assess their effectiveness, and propose strategies for enhancing the protection of minority rights. Through this analysis, the paper will highlight the importance of a unified approach that respects the diversity of minority groups while promoting their integration and participation in the broader society. In conclusion, the protection of minority rights is an integral component of human rights and a cornerstone of a just and equitable society. As globalization continues to reshape our world, it is imperative that international law evolves to address the unique challenges faced by minorities. This paper endeavours to contribute to this ongoing discourse by providing a thorough examination of the current legal landscape and offering recommendations for a more inclusive and effective protection regime for minority rights.

#### **HISTORICAL CONTEXT AND EVOLUTION OF MINORITY RIGHTS PROTECTION**

The protection of minority rights has roots that extend deep into history, long before the establishment of the modern international legal system. Early efforts to address the rights of minority groups were often context-specific and limited in scope, primarily focused on religious minorities. One of the earliest significant developments in the protection of minority rights was the Peace of Westphalia in (1648), which ended the Thirty Years' War in Europe. These treaties recognized the sovereignty of states and laid the groundwork for the modern nation-state system. Importantly, they included provisions for religious tolerance, mandating that states allow the practice of different religions within their territories. This was a groundbreaking step toward acknowledging the rights of religious minorities, as it aimed to reduce religious conflicts that had plagued Europe for decades.

Another early example of minority rights protection can be found in the Ottoman Empire's millet system. This system allowed various religious communities, such as Christians and Jews, to govern themselves according to their own laws and traditions while remaining under the sovereignty of the Ottoman Sultan. Each millet had considerable autonomy, including control over education, religious practices, and legal matters. While the millet system was not a model of equality by modern standards, it represented a pragmatic approach to managing a diverse empire and protecting the rights of religious minorities within its dominion. A characteristic of the Ottoman system was its prioritization of collective benefits over individual ones, and its emphasis on justice over freedom (Aral, 2004). The Edict of Nantes, issued by Henry IV of France in

(1598), was another landmark in the early protection of minority rights. The Edict granted substantial rights to French Huguenots (Protestants), including freedom of worship, the right to hold public office, and the establishment of Protestant courts. Although the Edict was later revoked in 1685, leading to renewed persecution, its initial implementation marked a significant acknowledgment of the need to protect religious minorities within a predominantly Catholic nation.

The American and French Revolutions of the late 18th century introduced principles that would later underpin modern human rights, including minority rights. The United States' Declaration of Independence (1776) and the French Declaration of the Rights of Man and of the Citizen (1789) proclaimed ideals of liberty, equality, and the inherent rights of individuals. While these documents primarily focused on the rights of citizens in general, they laid the intellectual groundwork for later developments in minority rights by emphasizing the universality of human rights. In the 19th century, international attention to minority rights began to emerge more formally. The Congress of Vienna (1814-1815), which sought to restore order after the Napoleonic Wars, included discussions on the treatment of minorities. However, these early international efforts were sporadic and often secondary to other geopolitical considerations.

#### **POST-WORLD WAR II AREA**

The aftermath of World War II marked a pivotal moment in the evolution of international human rights, including the protection of minority rights. The atrocities committed during the war, particularly the Holocaust, underscored the urgent need for a robust international framework to protect human rights and prevent future genocides and mass atrocities. This period saw the establishment of key international institutions and the creation of foundational legal instruments that significantly advanced the protection of minority rights. In 1945, the United Nations (UN) was founded with the primary objective of maintaining international peace and security. The UN Charter emphasized the promotion of human rights and fundamental freedoms for all, without distinction as to race, sex, language, or religion. This commitment laid the groundwork for subsequent efforts to protect minority rights on a global scale. Adopted by the UN General Assembly in 1948, the Universal Declaration of Human Rights (UDHR) was a landmark document that set out, for the first time, fundamental human rights to be universally protected. While the UDHR did not explicitly mention minorities, its provisions on equality and non-discrimination provided a crucial foundation for the protection of minority rights. Article 2, for instance, proclaimed that everyone is entitled to all the rights and freedoms set forth in the Declaration, without distinction of any kind, including race, language, or religion.

Building on the principles of the UDHR, the International Covenant on Civil and Political Rights (ICCPR) and the International Covenant on Economic, Social and Cultural Rights (ICESCR) were adopted in 1966. The ICCPR, in particular, included Article 27, which explicitly recognized the rights of minorities, stating that persons belonging to ethnic, religious, or

linguistic minorities shall not be denied the right, in community with other members of their group, to enjoy their own culture, to profess and practice their own religion, or to use their own language. Adopted in 1948, the Convention on the Prevention and Punishment of the Crime of Genocide (1948) was another critical development. It defined genocide and obligated signatory states to prevent and punish acts of genocide, including those targeting national, ethnical, racial, or religious groups. This convention represented a significant commitment by the international community to protect vulnerable groups from the most extreme forms of persecution.

#### **RECENT TRENDS AND GLOBALIZATION**

The late 20th and early 21st centuries have witnessed significant shifts in the landscape of minority rights protection, largely driven by the forces of globalization. As the world becomes increasingly interconnected through advancements in technology, communication, and trade, the issues surrounding minority rights have gained heightened visibility and urgency. Globalization has both positively and negatively impacted the protection of minority rights, presenting new opportunities and challenges for the international community. One of the positive trends resulting from globalization is the increased visibility of minority issues on the global stage. The proliferation of digital media and the internet has enabled minority groups to raise awareness about their struggles and mobilize support more effectively than ever before. Social media platforms, in particular, have become powerful tools for advocacy, allowing minorities to document human rights abuses, organize campaigns, and build transnational networks of solidarity. This heightened visibility has pressured governments and international organizations to address minority rights more proactively. According to Poe and Tate, the idea that there is a negative relationship between democracy and the level of oppression is elaborated (Poe and Tate, 1980),

Globalization has also facilitated greater international cooperation in the protection of minority rights. International organizations, such as the United Nations, the European Union, and the Organization for Security and Co-operation in Europe (OSCE), have played pivotal roles in developing and promoting standards for minority rights protection. Mechanisms like the UN's Universal Periodic Review (UPR) and the EU's Copenhagen criteria for accession candidates include specific provisions for the protection of minority rights, thereby encouraging states to improve their legal and policy frameworks. However, globalization has also posed significant challenges to minority rights. The spread of global culture, driven by the dominance of Western media and consumer products, can lead to cultural homogenization, threatening the distinct identities and traditions of minority groups. Furthermore, economic globalization has often exacerbated inequalities, leaving minorities disproportionately disadvantaged. In response to these challenges, there has been a resurgence of nationalist and populist movements in many parts of the world. These movements often exploit fears of cultural dilution and economic insecurity, promoting exclusionary policies that marginalize minorities. The rise

of such ideologies presents a serious threat to the progress made in minority rights protection, as they can lead to increased discrimination, xenophobia, and even violence against minority groups.

#### **INTERNATIONAL LEGAL FRAMEWORKS FOR MINORITY RIGHTS PROTECTION**

Adopted in 1948 by the United Nations General Assembly, the Universal Declaration of Human Rights (UDHR) is a foundational document that articulates fundamental human rights to be universally protected. Although the UDHR does not explicitly address minority rights, its principles of equality and non-discrimination are integral to the protection of minorities. Article 2 of the UDHR asserts that everyone is entitled to all rights and freedoms set forth in the declaration without distinction of any kind, including race, language, or religion. This broad principle forms the basis for later, more specific instruments focused on minority rights. The strengths of the UDHR lie in its universal acceptance and its role as a moral guide for nations. It has inspired numerous international and regional human rights treaties and national constitutions. However, its limitations include its non-binding nature, meaning that while it sets standards, it does not impose legal obligations on states.

The International Covenant on Civil and Political Rights (ICCPR), adopted in 1966, is a legally binding treaty that elaborates on many of the rights outlined in the UDHR. It includes specific provisions for the protection of minority rights, most notably in Article 27. This article states that in countries with ethnic, religious, or linguistic minorities, individuals belonging to these minorities shall not be denied the right, in community with other members of their group, to enjoy their own culture, to profess and practice their own religion, or to use their own language. The ICCPR's strengths include its binding nature, which obligates signatory states to adhere to its provisions and be subject to international scrutiny through mechanisms such as the Human Rights Committee. However, the ICCPR's limitations are evident in its enforcement challenges. The effectiveness of Article 27, for instance, depends heavily on the political will of states and the robustness of domestic legal frameworks to implement these protections.

Adopted in 1965, the Convention on the Elimination of All Forms of Racial Discrimination (CERD) is another key international instrument aimed at combating racial discrimination and protecting minority rights. CERD obligates its signatories to condemn racial discrimination and pursue policies to eliminate it in all its forms. Article 1 defines racial discrimination broadly, encompassing any distinction, exclusion, restriction, or preference based on race, color, descent, or national or ethnic origin. One of CERD's notable strengths is its detailed reporting and monitoring mechanism. The Committee on the Elimination of Racial Discrimination (CERD Committee) reviews periodic reports from states and issues recommendations. This oversight can pressure states to improve their practices. However, like other international instruments, CERD faces limitations related to enforcement and the varying levels of compliance by states. Some states may submit reports

irregularly or fail to implement the committee's recommendations fully.

The Council of Europe adopted the Framework Convention for the Protection of National Minorities (FCNM) in 1995, providing a comprehensive regional instrument specifically focused on minority rights. The FCNM obligates its signatories to protect the rights of national minorities, covering aspects such as non-discrimination, preservation of culture, and participation in public life. One of the FCNM's strengths is its detailed approach, providing specific guidelines and obligations for member states. The convention also establishes a monitoring mechanism through the Advisory Committee, which assesses the implementation of the convention and provides recommendations. However, the FCNM's limitations include its flexibility in defining national minorities, leading to inconsistent application across member states. Additionally, the convention's effectiveness is often contingent on the political and social context within each country.

Adopted in 1981 by the Organization of African Unity (now the African Union), the African Charter on Human and Peoples' Rights (ACHPR) provides a regional framework for the protection of human rights, including those of minorities. The ACHPR recognizes the rights of individuals and peoples, including the right to equality, non-discrimination, and the preservation of cultural heritage. The ACHPR's strengths lie in its holistic approach, integrating civil, political, economic, social, and cultural rights. The African Commission on Human and Peoples' Rights oversees the implementation of the charter and can hear complaints and issue recommendations. However, the charter faces limitations in its enforcement, with challenges such as limited resources, political interference, and varying levels of commitment among member states.

#### **CASE STUDY OF NATIONAL LEGAL SYSTEMS**

Canada is often cited as a model for the protection of minority rights, particularly due to its robust legal framework and multicultural policies. The Canadian Charter of Rights and Freedoms, part of the Constitution Act of 1982, guarantees fundamental rights and freedoms, including the rights of minority groups. Section 27 explicitly recognizes the multicultural heritage of Canadians, promoting the preservation and enhancement of cultural diversity. Canada's strengths include its comprehensive legal protections, active policies promoting multiculturalism, and mechanisms for redress, such as the Canadian Human Rights Commission. However, challenges remain, particularly regarding the rights of Indigenous peoples, who continue to face systemic issues such as land disputes and socio-economic inequalities.

India's approach to minority rights is enshrined in its constitution, which provides for various safeguards to protect the rights of religious and linguistic minorities. Articles 29 and 30 of the Indian Constitution grant minorities the right to conserve their culture and establish and administer educational institutions. The National Commission for Minorities (NCM) oversees the implementation of these constitutional protections. India's strengths include its constitutional guarantees and the existence of dedicated institutions like the NCM.

However, the country faces significant challenges, including communal tensions, discrimination, and occasional outbreaks of violence against minority groups. Effective implementation of legal protections and addressing socio-economic disparities remain critical issues.

Myanmar presents a stark contrast, with a troubled record in protecting minority rights. The Rohingya crisis highlights severe deficiencies in the country's legal and policy frameworks. Despite being a signatory to various international treaties, Myanmar has failed to protect the rights of the Rohingya, leading to widespread violence, displacement, and allegations of genocide. Myanmar's situation underscores the limitations of international and national legal instruments when political will is lacking. The international community's response, including sanctions and calls for accountability, illustrates the challenges of enforcing minority rights protections in countries with deep-seated ethnic conflicts and authoritarian governance.

#### **CHALLENGES AND LEGAL AMBIGUITIES IN THE IMPLEMENTATION OF MINORITY RIGHTS**

The protection of minority rights remains a complex issue despite the existence of comprehensive legal frameworks at international, regional, and national levels. Various challenges impede the effective implementation of these rights, ranging from legal and institutional barriers to socio-economic issues and cultural and political obstacles. This part of our paper delves into these challenges, providing a detailed analysis of the factors that hinder the protection and promotion of minority rights.

One of the significant legal barriers to the protection of minority rights is the ambiguity in legal definitions and provisions. Many international and national legal instruments lack clear definitions of what constitutes a minority, leading to inconsistent interpretations and applications. For instance, the absence of a universally accepted definition of minorities in the International Covenant on Civil and Political Rights (ICCPR) leaves room for states to interpret the term based on their national contexts, which can lead to selective or inadequate protection.

The implementation of minority rights often requires strong political will, which is frequently lacking. Governments may prioritize other political or economic agendas over minority rights, especially in contexts where minority groups are politically marginalized or perceived as a threat to national unity. Political leaders may also exploit minority issues to gain political leverage, exacerbating divisions and hindering the implementation of protective measures. Weak institutional frameworks significantly impede the enforcement of minority rights. Some countries refuse to follow international human rights standards, subjecting minorities to arbitrary rule by a predatory majority (O'Brien, Conor Cruise. 1983).

In many countries, institutions responsible for protecting human rights, including minority rights, suffer from inadequate resources, insufficient training, and lack of independence. Corruption and bureaucratic inefficiencies further undermine these institutions' ability

to act effectively. The absence of robust monitoring and accountability mechanisms allows violations of minority rights to go unaddressed, perpetuating a cycle of neglect and abuse. In this context, we should refer to the approach of Linz and Stepan (1999), according to which democracy has become the only game in town when no significant political group seriously attempts to overthrow the democratic regime or secede from the state. Although democracy should be competitive and inclusive, according to Przeworski, elections may not represent the will of all population groups (Przeworski, 1999).

Minority groups often face disproportionate levels of poverty and economic marginalization, which exacerbate their vulnerability. Economic disparities limit minorities' access to essential services such as healthcare, education, and employment opportunities, perpetuating cycles of disadvantage. In many cases, minority communities are relegated to low-paying jobs and face barriers to economic advancement, leading to systemic poverty and social exclusion.

Education is a critical factor in empowering minority groups and ensuring their rights are protected. However, minorities frequently have limited access to quality education due to socio-economic barriers, discriminatory practices, and linguistic challenges. The lack of education restricts their opportunities for socio-economic mobility and reinforces their marginalization. Moreover, education systems that fail to accommodate minority languages and cultures can alienate minority students and undermine their cultural identity. Affirmative action and other socio-economic policies can play a crucial role in addressing the challenges faced by minority groups. Policies that promote equal access to education, employment, and healthcare can help mitigate economic disparities and foster social inclusion. However, the implementation of such policies often encounters resistance and can be marred by inefficiencies and corruption. Ensuring that affirmative action policies are effectively designed and implemented is essential for their success in improving the socio-economic conditions of minority communities.

Cultural biases and prejudices against minority groups are pervasive obstacles to the realization of minority rights. Discriminatory attitudes and stereotypes, often deeply ingrained in society, lead to social exclusion and unequal treatment. These biases can manifest in various forms, including hate speech, violence, and systemic discrimination in public and private institutions. Overcoming cultural prejudices requires comprehensive education and awareness campaigns to promote tolerance and respect for diversity. Time has increasingly proven that democracy reduces the possibility of discrimination, especially of ethno-political minorities, and thus the possibility of political oppression (Gurr, Ted, 1993).

The resurgence of nationalist movements in many parts of the world poses a significant threat to minority rights. Nationalist ideologies often emphasize homogeneity and view minority groups as outsiders or threats to national identity. This rhetoric can lead to exclusionary policies, discrimination, and even violence against minorities. Nationalist movements can also undermine

international efforts to protect minority rights by promoting sovereignty and non-interference, challenging the implementation of international human rights norms. According to Alfredsson, Gudmundur and Danilo Turk. (1993), many democratic states face violent challenges from minority groups within their borders. This demonstrates an inherent weakness in democracy, that majority rule is not necessarily friendly or understanding to minorities and their wishes and needs.

Political instability and conflict can severely impact the protection of minority rights. In regions experiencing political turmoil, minority groups are often disproportionately affected by violence, displacement, and human rights abuses. Political instability weakens state institutions and disrupts the implementation of protective measures. In conflict zones, minorities may be targeted for their perceived association with opposing factions, exacerbating their vulnerability. Addressing cultural and political obstacles to minority rights requires a multifaceted approach. Promoting inclusive national identities that celebrate diversity can counter nationalist ideologies. Education systems should incorporate curricula that emphasize human rights, tolerance, and respect for cultural diversity. According to Errol A. Henderson, the "democratic peace proposition" has not been clearly tested with reference to post-colonial third world states, where most civil wars take place (Henderson, 2002).

Media can play a pivotal role in shaping public perceptions and countering negative stereotypes by providing balanced and positive representations of minority groups. International organizations and civil society must continue to advocate for minority rights and hold states accountable for their obligations. Diplomatic pressure, sanctions, and international legal mechanisms can be employed to address gross violations of minority rights in politically unstable regions. Additionally, supporting peacebuilding efforts and promoting inclusive governance can help create environments conducive to the protection of minority rights.

#### **TOWARDS A UNIFIED APPROACH FOR MINORITY RIGHTS PROTECTION - INTEGRATING HARD AND SOFT LAW MECHANISMS**

The protection of minority rights can be significantly enhanced through the strategic integration of hard and soft law mechanisms. Various authors have clearly emphasized in their papers that the type of political system significantly influences the nature of protest in a country. Thus, democracies are supposed to have more widespread, but less deadly, protests than autocracies (Gur, 1993; Swain, 2002; Zimmermann, 1980). Hard law refers to legally binding agreements, such as treaties and conventions, that impose clear obligations on states. Soft law, on the other hand, encompasses non-binding guidelines, principles, declarations, and codes of conduct that, while not legally enforceable, can influence state behaviour and international norms. One successful example of integrating hard and soft law mechanisms is the European Framework Convention for the Protection of National Minorities (FCNM) and the accompanying recommendations and guidelines issued by the Council of Europe. The FCNM

is a binding treaty that obligates states to protect minority rights, while the soft law guidelines provide detailed, flexible approaches for implementing these obligations. This dual approach allows for both legal accountability and practical guidance, enhancing the overall effectiveness of minority rights protection. Another example is the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). Although UNDRIP is a non-binding soft law instrument, it has significantly influenced national and international legal frameworks by setting standards and expectations for the treatment of indigenous peoples. Its principles have been incorporated into binding agreements and national laws, demonstrating how soft law can shape hard law over time.

To enhance the synergy between hard and soft law mechanisms, several steps can be taken:

1. **Strengthening Monitoring and Reporting:** Establishing robust mechanisms for monitoring and reporting on the implementation of both hard and soft law instruments can ensure greater accountability. Regular reports and reviews by international bodies can highlight areas of progress and identify challenges.
2. **Capacity Building:** Providing technical assistance and capacity-building programs for states can help them better understand and implement their obligations under hard law treaties, while also benefiting from the flexibility and practical guidance offered by soft law instruments.
3. **Harmonizing Standards:** Developing harmonized standards and guidelines that bridge hard and soft law instruments can create a more cohesive framework for minority rights protection. This can involve aligning the provisions of binding treaties with the principles outlined in non-binding declarations and guidelines.
4. **Encouraging State Commitment:** Promoting voluntary commitments and pledges by states to adhere to soft law principles, even in the absence of binding obligations, can foster a culture of compliance and enhance the overall protection of minority rights.

International cooperation is crucial for the effective protection of minority rights. Collaborative efforts among states, international organizations, and civil society can lead to more comprehensive and consistent approaches to minority rights protection. International organizations, such as the United Nations (UN) and the European Union (EU), play a pivotal role in fostering cooperation among states. The UN, through its various agencies and bodies, provides a global platform for dialogue, advocacy, and the development of international norms and standards. The Office of the High Commissioner for Human Rights (OHCHR) and the Human Rights Council (HRC) are instrumental in monitoring compliance with international human rights obligations and addressing violations. The EU, through its legal and policy frameworks, promotes the protection of minority rights within its member states and beyond. Instruments such as the Charter of Fundamental Rights of the European Union and the Copenhagen criteria for EU accession emphasize the importance of minority rights.

The EU also supports initiatives aimed at enhancing the capacity of member states to protect minority rights through funding, technical assistance, and policy guidance. There is potential for the development of new international treaties specifically focused on minority rights. Such treaties could address gaps in existing legal frameworks and provide more explicit protections for minorities. For example, a comprehensive international treaty on the rights of indigenous peoples, building on the principles of UNDRIP, could establish binding obligations and create stronger enforcement mechanisms. Additionally, regional treaties that reflect the specific contexts and needs of minority groups in different parts of the world could be developed. These treaties could complement existing international instruments and provide more targeted protections.

## CONCLUSION

The protection of minority rights in a globalized world presents multifaceted challenges and opportunities. The gradual dissolution of geographical borders has brought about a more interconnected society, yet the protection of minority rights remains a persistent issue within international law. The analysis provided in this paper underscores the critical need for comprehensive approaches that integrate legal, socio-economic, cultural, and political dimensions to effectively safeguard minority rights. The historical evolution of minority rights demonstrates significant progress, from early declarations to robust frameworks developed in the post-World War II era. Notably, recent trends in globalization have both heightened the visibility of minority issues and complicated their resolution, as cultural integration and national sovereignty sometimes clash. Despite the existence of extensive legal frameworks, numerous barriers impede the effective implementation of minority rights.

To address the challenges, a unified approach that integrates hard and soft law mechanisms is essential. Examples such as the European Framework Convention for the Protection of National Minorities and the United Nations Declaration on the Rights of Indigenous Peoples highlight the potential for synergy between binding and non-binding instruments. Enhanced international cooperation plays a pivotal role in fostering collaboration among states. The role of international organizations, particularly the UN and the EU, is crucial in monitoring compliance, providing technical assistance, and facilitating dialogue. Additionally, the potential for new international treaties specifically focused on minority rights could address existing gaps and provide stronger protections.

The protection of minority rights is a fundamental aspect of human rights and social justice. As globalization continues to reshape societies, the international community must remain vigilant and proactive in addressing the evolving challenges faced by minority groups. By fostering inclusive policies, enhancing international cooperation, and integrating comprehensive legal frameworks, the goal of ensuring equal rights and opportunities for all individuals, regardless of their minority status, can be progressively realized. In conclusion, the path towards effective minority rights protection is complex and requires a concerted effort from

states, international organizations, and civil society. Through continued commitment and collaboration, it is possible to create a more equitable and harmonious global society where the rights of all minorities are fully respected and protected.

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# MATHEMATICAL SCIENCES

## REFLECTIONS ON TEACHING THE METHOD OF CONSTANT VARIATION

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### Abstract

The method of constant variation is an effective method for solving linear differential equations. It is the result of Lagrange's eleven-year research, but we only use its conclusion without any process, which makes beginners feel mysterious and confused. In order to help students to understand the concept of the method of constant variation, and to stimulate them to think well, liberate their minds and be creative, this paper analyses and explores the method of constant variation.

**Keywords:** the method of constant variation; doubts; profiling

First-order linear ordinary differential equations, as one of the basics of ordinary differential equations, has a complete and systematic theoretical foundation and a rich practical background, which is of great significance to enhance students' motivation and thinking ability in learning the subsequent contents. Therefore, it is necessary to pay great attention to it in teaching. For first-order linear ordinary differential equations, the key lies in mastering its solution, which is usually introduced in the textbook is the method of constant variation, which has clear ideas, concise and ingenious derivation, and it is easy for teachers and students to grasp the basic steps. However, most of the students were confused about the method of constant variation in which a constant  $C$  is transformed into an unknown function  $c(x)$ , which was not explained in the textbook. Therefore, on the premise of elaborating the theoretical basis of the method of constant variation, this paper explores the solution method from the structural characteristics of the equation itself and the general solution of the corresponding chi-square linear differential equations in response to the problems of the students in learning the content of this section. Students' ability to raise, analyse and solve problems is cultivated from different perspectives, and the teaching effect of eliminating doubts and knowing the causes and consequences of the results is achieved, which greatly promotes the expansion of students' thinking ability.

### 1 Introduction to the method of constant variation

First-order non homogeneous linear ordinary differential equation

$$y' + P(x)y = Q(x) \quad (1)$$

where  $P(x), Q(x)$  is a continuous function with respect to  $x$ .

When  $Q(x) \equiv 0$ , the equation

$$y' + P(x)y = 0 \quad (2)$$

is a homogeneous linear differential equation.

Firstly, the general solution of the corresponding homogeneous linear differential equation (2) is solved,

and the general solution of equation (2) can be obtained by applying the method of separated variables as

$$y = ce^{-\int P(x)dx} \quad (3)$$

where  $C$  is an arbitrary constant.

Step 2 Let  $y = u(x)e^{-\int P(x)dx}$  (changing any constant  $C$  into an unknown function  $u(x)$ ) be the solution of equation (1), and substituting into (1), we get

$$u(x) = \int Q(x)e^{\int P(x)dx} dx + d,$$

where  $d$  is an arbitrary constant.

Step 3 Substituting

$u(x) = \int Q(x)e^{\int P(x)dx} dx + d$  back gives the general solution of equation (1) as

$$y = e^{-\int P(x)dx} \left( \int Q(x)e^{\int P(x)dx} dx + d \right),$$

where  $d$  is an arbitrary constant.

### 2 The Idea of the method of constant variation

The above is the method of constant variation introduced in the current university textbook on ordinary differential equations, which is a practical and effective method for solving non homogeneous linear ordinary differential equation with clear ideas, compact and concise derivation, easy to be grasped by both teachers and students, and clear to be applied. However, when students learn the method of constant variation, they will have the following doubts: Why do we need to transform non homogeneous linear ordinary differential equation into homogeneous linear ordinary differential equation to solve them? And how do you think of turning an arbitrary constant  $C$  into a function to be determined  $u(x)$ ? The textbook does not provide a detailed explanation. Therefore, it is necessary to discuss the thinking process of the method of constant variation.

#### 2.1 Find the general solution of equation (1) from the characteristics of the equation itself

**Method 1** As with the familiar solution of the separation of variables equation, equation (1) is deformed into

$$dy = (Q(x) - P(x)y)dx, \text{ or } \frac{dy}{y} = \left( \frac{Q(x)}{y} - P(x) \right) dx,$$

Integrating both sides gives

$$\ln|y| = \int \frac{Q(x)}{y} dx - \int P(x) dx + c',$$

where  $c'$  is an arbitrary constant.

Since  $y$  is a function of  $x$ , note that

$$\varphi(x) = \int \frac{Q(x)}{y} dx, \text{ where } \varphi(x) \text{ is the unknown}$$

function, substituting into the above equation yields

$$y = ce^{\varphi(x)} e^{-\int P(x) dx}, \text{ Denote by } u(x) = ce^{\varphi(x)}, \text{ then}$$

$y = u(x) e^{-\int P(x) dx}$ , where  $u(x)$  is the function to be found. The second step of the method of constant variation is then used to find the general solution of equation (1) as

$$y = e^{-\int P(x) dx} \left( \int Q(x) e^{\int P(x) dx} dx + d \right),$$

where  $d$  is an arbitrary constant.

$$y = u(x)v(x) = \left( \frac{1}{c_1} \int e^{\int P(x) dx} Q(x) dx + c_2 \right) c_1 e^{-\int P(x) dx} = \left( \int e^{\int P(x) dx} Q(x) dx + c \right) e^{-\int P(x) dx},$$

(where  $c = c_1 \cdot c_2$ ).

Further observation shows that solving the differential equation  $v'(x) + P(x)v(x) = 0$  containing  $v(x)$  is essentially solving the general solution of the homogeneous linear ordinary differential equation  $y' + yP(x) = 0$ . Solve for  $y = ce^{-\int P(x) dx}$ , where  $c$  is an arbitrary constant.

Substituting  $y = u(x)e^{-\int P(x) dx}$  into equation (1) solve for  $u'(x)e^{-\int P(x) dx} = Q(x)$ . Solve for  $u(x)$  and substitute for  $y = u(x)e^{-\int P(x) dx}$  to get the answer

$$y = e^{-\int P(x) dx} \left( \int Q(x) e^{\int P(x) dx} dx + c \right).$$

**Method 3** Inspired by the Leibniz formula

$$\frac{d}{dx} u(x)v(x) = v(x) \frac{du(x)}{dx} + u(x) \frac{dv(x)}{dx}$$

**Method 2** Let  $y = u(x)v(x)$ , where both  $u(x)$  and  $v(x)$  are functions with respect to  $x$ . Substituting  $y = u(x)v(x)$  into equation (1), the collation yields

$$u'(x)v(x) + u(x)[v'(x) + v(x)P(x)] = Q(x), (4)$$

if we now want to solve for  $u(x)$  by the method of separation of variables, then we need to make  $v'(x) + v(x)P(x) = 0$ , separate the variables and integrate, which gives us

$$v(x) = c_1 e^{-\int P(x) dx}, (5)$$

where  $c_1$  is an arbitrary constant.

The result  $v(x)$  has now been solved, and we proceed to solve for  $u(x)$ . Substituting equation (5) into equation (4), we get

$$c_1 \frac{du}{dx} e^{-\int P(x) dx} = Q(x),$$

continuing to separate variables and integrate, we have

$$u(x) = \frac{1}{c_1} \int e^{\int P(x) dx} Q(x) dx + c_2,$$

consequently

multiplying both sides of equation (1) by  $\varphi(x)$  ( $\varphi(x) \neq 0$ ), we have

$$\varphi(x) \frac{dy}{dx} + \varphi(x)P(x)y = \varphi(x)Q(x).$$

How to choose  $\varphi(x)$ , such that  $\frac{d\varphi(x)}{dx} = \varphi(x)P(x)$ , then the above equation can be

$$\frac{d(\varphi(x)y)}{dx} = \varphi(x)Q(x),$$

integrating both sides gives  $\varphi(x)y = \int \varphi(x)Q(x)dx + c$ , where  $c$  is an arbitrary constant. Integrate the two sides of  $\frac{d\varphi(x)}{dx} = \varphi(x)P(x)$  to get  $\varphi(x) = ce^{\int P(x) dx}$ ,

and substitute back into the above equation to get

$$y = e^{-\int P(x) dx} \left( \int Q(x) e^{\int P(x) dx} dx + k \right).$$

**2.2 Solving the general solution of equation (1) from the general solution of homogeneous linear ordinary differential equation**

Observation of equations (1) and (2) reveals that equation (2) is a special case of equation (1), in that they agree at the left end and differ at the right end. Therefore, it is conceivable that there is a correlation but also a difference between their solutions. An attempt is made to solve the general solution of equation (1) by means of the general solution (3) of equation (2). Obviously, this is not true if equation (3) is substituted directly into equation (1). For equation (1) to be always equal, there must be an additional function on  $x$  on the left side of the equation corresponding to  $Q(x)$  on the right side. According to the formula for the derivative of the product of functions, It is necessary to transform equation (3), and then the derivation of the equation gives an additional function on  $x$ .

Observing the expression of equation (3), it can be found that equation (3) consists of two parts: constant  $C$  and exponential function  $e^{-\int P(x)dx}$ . To make equation (3) a function on  $x$  with an extra term after derivation, it can be transformed as follows.

The function  $u(x)$  ( $u(x) \neq 0$ ) with respect to  $x$  is introduced by the four fundamental operations at different positions of equation (3), i.e., the following transformations are available:

$$y = ce^{-\int P(x)dx} + u(x) \quad (6)$$

$$y = ce^{-\int P(x)dx} - u(x) \quad (7)$$

$$y = cu(x)e^{-\int P(x)dx} \quad (8)$$

$$y = \frac{c}{u(x)} e^{-\int P(x)dx} \quad (9)$$

$$y = (c + u(x))e^{-\int P(x)dx} \quad (10)$$

$$y = (c - u(x))e^{-\int P(x)dx} \quad (11)$$

$$y = ce^{-\int P(x)dx + u(x)} \quad (12) \quad y = ce^{-\int P(x)dx - u(x)} \quad (13)$$

$$y = ce^{-u(x)\int P(x)dx} \quad (14) \quad y = ce^{\frac{-\int P(x)dx}{u(x)}} \quad (15)$$

where  $C$  is an arbitrary constant.

Substituting equation (6) into equation (1), we have

$$u'(x) = P(x)u(x) + Q(x),$$

this equation is also a non homogeneous linear ordinary differential equation, which is cyclic and difficult to solve  $u(x)$ . Therefore, it is not possible to find the solution of equation (1) by transforming equation (6). Equation (7) is similar to equation (6), so the solution of equation (1) cannot be obtained by transforming equation (7).

Substituting equation (8) into equation (1), we

have  $u'(x) = \frac{Q(x)e^{\int P(x)dx}}{c}$ , and integrating both sides we have

$$u(x) = \int \frac{Q(x)e^{\int P(x)dx}}{c} dx + c_1,$$

substituting  $u(x)$  into equation (8), let  $cc_1 = c'$

, then  $y = e^{-\int P(x)dx} \left( \int Q(x)e^{\int P(x)dx} dx + c' \right)$  is the general solution of equation (1), where  $c'$  is an arbitrary constant.

Substituting equation (9) into equation (1), we

have  $\frac{u'(x)}{u^2(x)} = -\frac{Q(x)e^{\int P(x)dx}}{c}$ , integrating both sides we have

$$\frac{1}{u(x)} = \int \frac{Q(x)e^{\int P(x)dx}}{c} dx + c_1,$$

substituting  $\frac{1}{u(x)}$  into equation (9), let  $cc_1 = c'$

, then  $y = e^{-\int P(x)dx} \left( \int Q(x)e^{\int P(x)dx} dx + c' \right)$  is the general solution of equation (1), where  $c'$  is an arbitrary constant.

Substituting equation (10) into equation (1), we

have  $u'(x) = Q(x)e^{\int P(x)dx}$ , integrating both sides we have

$$u(x) = \int Q(x)e^{\int P(x)dx} dx + c_1,$$

substituting  $u(x)$  into equation (10), let

$c + c_1 = c'$ , then  $y = e^{-\int P(x)dx} \left( \int Q(x)e^{\int P(x)dx} dx + c' \right)$  is the general solution of equation (1), where  $c'$  is an arbitrary constant. Equation (11) is similar to equation (10), and by the same token, the solution of equation (1) can be found by transforming equation (11).

Substituting equation (12) into equation (1), we

have  $u'(x)e^{u(x)} = \frac{Q(x)e^{\int P(x)dx}}{c}$ , integrating both sides we have

$$e^{u(x)} = \int \frac{Q(x)e^{\int P(x)dx}}{c} dx + c_1,$$

substituting  $e^{u(x)}$  into equation (12), let  $cc_1 = c'$

, then  $y = e^{-\int P(x)dx} \left( \int Q(x)e^{\int P(x)dx} dx + c' \right)$  is the general solution of equation (1), where  $c'$  is an arbitrary constant. Equation (13) is similar to equation (12), and by the same token, the solution of equation (1) can be found by transforming equation (13).

Substituting equation (14) into equation (1), we have

$$\frac{dce^{-u(x)\int P(x)dx}}{dx} = -cP(x)e^{-u(x)\int P(x)dx} + Q(x),$$

let  $\varphi(x) = e^{-u(x)\int P(x)dx}$ , then

$$\frac{dc\varphi(x)}{dx} = -cP(x)\varphi(x) + Q(x),$$

this equation is a non homogeneous linear ordinary differential equation, so the form of the required equation appears cyclically, therefore, the solution of equation (1) can not be found by transforming equation (14). Similarly, the case of equation (15) is similar to that of equation (14) and is omitted here.

Comprehensive analysis shows that among the 10 different deformations, only 6 transformations (8), (9), (10), (11), (12) and (13) can find the general solution of equation (1). The 6 transformations are carefully analysed, and it is found that all of them can be reduced to transforming any constant  $C$  in equation (3) into an unknown function  $u(x)$ , and then substituting it into equation (1) to find out  $u(x)$ , and then to find out the general solution of equation (1).

### 3 Teaching Summary

Teachers in teaching this section of the content, can not be limited to the textbook analysis of the explanation, need to start from the characteristics of the equation itself, with the help of students familiar with the knowledge, for students to carry out detailed in-depth analysis, and to carry out specific derivation, layer by layer questioning, and gradually cultivate the

students to find, analyse and problem-solving skills. At the same time, students in the study of the content of the section, should not be a passive recipient of knowledge, but should be actively and enthusiastically into the learning, encountered there are doubts and uncertainty, should take the initiative to ask questions, with questions, follow the teacher's thinking, layer by layer, in-depth, personal deduction. Only in this way, we can achieve the elimination of doubt, not only know the truth but also know the reason for the effectiveness of teaching.

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# MEDICAL SCIENCES

## HEPATITIS E INFECTION - A REVIEW

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### Abstract

This review article summarizes the current knowledge about hepatitis E virus (HEV) infection and focuses on its the potential impact on human health. HEV has four major genotypes that cause human disease. Clinical severity of infection varies with HEV genotype, age and immune status of infected individuals. HEV generally causes self-limiting acute hepatitis in young adults. Genotypes HEV-3 and HEV-4 have been responsible to the development of chronic infection in immunocompromised or transplant patients, those with pre-existing liver disease and cancer patients. HEV is associated with progression to fulminant liver failure and high maternal and fetal mortality during pregnancy, particularly in the third trimester. HEV-induced extrahepatic complications can occur in both acute and chronic infection. Standard diagnostic tests for hepatitis E include the serologic and molecular assays.

**Keywords:** Hepatitis E, HEV genotypes, anti-HEV IgM/IgG, HEV RNA

### Introduction

Hepatitis E is an inflammation of the liver caused by infection with the hepatitis E virus (HEV). It is estimated that approximately one-third of the global population has been exposed to HEV. Each year more than approximately 20 million estimated cases of HEV infection occur globally [1]. HEV is an important cause of acute hepatitis, chronic infection and may lead to fulminant hepatic failure (FHF) by risk groups. HEV infection has been associated with a wide spectrum of extrahepatic manifestations. The disease is a major public health concern, in both developing and industrialized countries. There are distinct epidemiological patterns of hepatitis E in different geographic regions. HEV is responsible for multiple epidemics in resource-poor countries and has become increasingly prevalent as a zoonotic viral infection in developed countries as well. HEV seroprevalence is high in the hyperendemic regions, where the source is usually contaminated water. The reported rates of anti-HEV antibodies in adults in these areas are 30 to 80% [2]. In the low endemic regions, which include developed countries (the Americas and Europe) zoonotic transmission plays an important role and hepatitis E occurs as isolated cases and small outbreaks. The prevalence HEV in the Bulgarian population remains underestimated [3]. For the first time, HEV infection in Bulgaria was reported in 1995.

### Etiology, Epidemiology

Historically, Hepatitis E virus was first recognized in 1978 during an epidemic in Kashmir Valley in northern India, with 52 000 cases of hepatitis resulting in 17 000 deaths [4]. In 1983, during an unexplained hepatitis outbreak among soldiers the Russian virologist Mikhail Balayan visualized the virus through electron microscopy and confirmed the existence of HEV through self-experimentation by oral administration of pooled stool extracts of 9 patients. This experiment led to the identification of HEV as an

enterically transmitted virus [5]. In 1990, Reyes et al. cloned and sequenced hepatitis E virus genome.

HEV is a hepatotropic, single-stranded RNA virus, non-enveloped, of the Hepeviridae family. The viral genome is approximately 7.2 kb in length, comprising a short 5' noncoding region (NCR), a 3' NCR, and three open reading frames (ORF1-3). Among these regions, ORF1 encodes nonstructural (functional) proteins (e.g., RNA-dependent RNA polymerase, methyltransferase), ORF2 encodes the viral capsid protein, which is highly immunogenic, and antibodies against this protein have neutralizing and protective features. ORF3 is a small protein, necessary for viral release from infected cells and ORF4 is critical for the replication process [6].

Among the eight different genotypes identified to date, HEV-1, HEV-2, HEV-3, and HEV-4 are the most frequent genotypes causing infections in humans. The genotypes have distinct routes of transmission and geographical distributions. HEV-1 and HEV-2 only infect humans and they spread through fecal-oral route, able to result in large-scale outbreaks originating from contaminated water supplies. Genotypes 3 and 4 are detected mainly in Europe and North America, circulate in animal species such as pigs, wild boars and deer. They are primarily zoonotic and transmitted to humans through the consumption of raw or undercooked meat, such as pork and deer or shellfish. There are zoonotic reservoirs among swine, wild boars, deer and camels. Swine are the main reservoir and the most commonly implicated source of HEV-3 and HEV-4 [7]. Pig farms are known to have high rates of HEV infections, and the consumption of pork products, especially those containing pig liver is associated with these infections [8]. To summarize, HEV-1 and HEV-2 cause epidemic and endemic diseases in resource poor countries, primarily spreading through contaminated drinking water. HEV-3 and HEV-4 generally cause autochthonous infections and sporadic cases, mainly affecting adults aged older than 40. The

hepatitis E illness is uncommon in locations with improved water supply and sanitation. The poor hygiene and sanitation remain significant contributors to hepatitis E transmission in developing countries

The global distribution of HEV has distinct epidemiological patterns based on socioeconomic and ecological factors. Hepatitis E is found worldwide, but it is most common in sub-Saharan Africa and east and south Asia. Major hepatitis E outbreaks have been reported in Asia, the Middle East, Africa, and Central America [9]. Many hepatitis E cases were reported in refugee camps in South Sudan [10].

People are infectious during the detection of HEV in the stools. HEV can be transmitted via the fecal-oral route, zoonotic route, blood transfusion and vertical transmission (maternal-fetal). Infected blood or blood products from a viremic patient should be considered as a possible transmission route for HEV [11]. In recent years, the transmission of HEV-3 and HEV-4 through blood transfusions has been increasingly reported in Europe [12].

#### Clinical presentation

Hepatitis E can present with a wide range of clinical manifestations. The majority of HEV infections are asymptomatic. Symptomatic cases present as acute icteric hepatitis, which occurs in 5%-30% of infected people and resolves within 2–6 weeks [13]. Patients with acute infection may have prolonged cholestasis with protracted jaundice. An altered immune status, hormonal levels, and viral factors may be related to the severity of the disease [14]. HEV usually causes acute, self-limited hepatitis in immunocompetent individuals. The major risk groups for HEV infection are pregnant women, immunocompromised individuals and patients with underlying chronic liver diseases. Chronic infection, almost exclusively with HEV-3, occurs in immunocompromised individuals [15]. Approximately 20% of solid-organ transplant patients develop persistent HEV infection, often asymptomatic or with minor liver enzyme increases. Immunosuppressive therapy has been proposed to be a key factor for developing chronic hepatitis E in solid-organ transplant recipients. Pregnant women, recipients of solid organ transplants, those with pre-existing liver disease and immunocompromised patients, may develop fulminant hepatic failure. HEV is an important contributor to maternal morbidity and mortality. The pregnant women infected with HEV-1 are the risk group for a severe HEV course [16].

HEV infection in pregnancy is associated with high risk of preterm labor and vertical transmission, and can be life-threatening with mortality rate up to 30% due to the development of HEV-induced fulminant hepatitis [17]. The mechanism of liver injury is not yet clear. During pregnancy, levels of progesterone, estrogen, and human chorionic gonadotropin increase as pregnancy advances. These hormones play a considerable role in altering immune regulation and increasing viral replication. During an outbreak in Sudan in 2010 to 2011, among 39 pregnant women with HEV infection there were 14 intrauterine deaths and 9 premature deliveries [18]. During the HEV outbreak Niger in 2017, 44.7% of recorded deaths, were in pregnant

women [19]. Some studies have reported the prevalence of HEV among pregnant women in China from 0.2–4.11% (anti-HEV IgM) and 11.1–20.27% (anti-HEV IgG), respectively [20,21].

HEV-induced liver cirrhosis is a complication only seen in immunocompromised patients. HEV infection increases the rate of liver disease progression in patients with chronic HBV infection.

In addition to hepatic manifestations, extrahepatic complications (pancreatitis, renal impairment, neurological symptoms, hematological disorders, and mixed cryoglobulinemia) can occur in both acute and chronic HEV infection, [22]. The extrahepatic manifestations induced by different genotypes of HEV vary. Involvement of both the peripheral nervous system and CNS can occur together or in isolation. HEV infection has been associated with development of Guillain-Barré syndrome (GBS). Many studies have reported the high prevalence rate of HEV infection among GBS patients and several case reports have been documented showing the coexistence of acute hepatitis E with GBS. Also, cases of acute HEV infection have been found in pediatric patients with GBS [23]. GBS and neuralgic amyotrophy are the most frequent neurological manifestations. In the Netherlands and the UK, neuralgic amyotrophy has been reported in up to 10% of cases. It is characterized by painful upper extremity mononeuropathy and motor weakness, frequently affecting the brachial plexus [24]. Hematologic manifestations include anemia due to glucose-6-phosphate dehydrogenase deficiency, autoimmune hemolytic anemia and severe thrombocytopenia. Membranoproliferative glomerulonephritis and relapse IgA nephropathy with or without coexisting cryoglobulinemia appear to be the most common renal injuries related with HEV infection. Also, HEV infection has been associated with acute pancreatitis [25]. Membranoproliferative glomerulonephritis and relapse IgA nephropathy with or without coexisting cryoglobulinemia appear to be the most common renal injuries related with HEV infection. Renal biopsies in affected patients show histological patterns of membranoproliferative and membranous glomerulonephritis. Most typically, HEV genotypes 1 and 3 may be associated with glomerulonephritis. All extrahepatic signs are caused by either direct HEV replication in these tissues, or indirectly by various immune mediated mechanisms.

#### Diagnosis

Laboratory diagnosis of hepatitis E infection is usually based on the detection of HEV- specific antibodies (anti-HEV IgM/IgG) and detection of HEV RNA. Anti-HEV IgM antibodies have a positivity for a short period of time (approximately 3-4 months), but sometimes it persists for a year [26]. Anti-HEV IgG antibody is relatively long-lasting, but do not provide life-long immunity and their levels in the serum decreases over time. IgG anti-HEV represents current or past infection [27].

Serologic tests are not reliable enough tools in immunosuppressed patients. Because of the possibility of undetectable antibody levels, molecular testing is preferable over antibody testing in these individuals.

Detection of HEV RNA in blood or stool characterizes chronic or acute HEV infection. Chronic HEV infection is defined as an HEV viremia for more than 3 months. The detection of HEV RNA facilitates the diagnosis of HEV infection in immunocompromised patients without an adequate antibody response. The molecular diagnosis of HEV infection by polymerase chain reaction (PCR) exhibits high sensitivity and specificity. PCR assays are important for the detection of acute HEV infection as well for monitoring chronic cases of hepatitis E. Detection of HEV-RNA by molecular genetic methods has been considered the “gold standard” [28]. HEV RNA can be detected in the blood after 3 week of exposure, and viral shedding lasts approximately 4-6 week in the stool. In immunocompromised individuals, HEV can take up a more chronic course with prolonged viremia [29]. Immunosuppressive therapy has been proposed to be a key factor for developing chronic hepatitis E in organ transplant recipients. European Association for the Study of the Liver (EASL) suggests testing for hepatitis E in patients with unexplained flares of chronic liver disease.

#### Treatment, Prophylaxis

Ribavirin has antiviral activity against HEV. Within the past years, ribavirin has been successfully used to treat chronic HEV infections. The associated sustained virological response is approximately 80%.

The recombinant hepatitis E vaccine, the first prophylactic vaccine against HEV infection, was approved in China in December 2011 [30]. The vaccine is given in a three-dose schedule (0, 1, and 6 months). To reduce the risk of contracting HEV while traveling to endemic areas, it is important to maintain hygienic practices.

#### Conclusion

HEV has increasing prevalence worldwide. The HEV infection it was traditionally thought to occur in individuals travelling to areas where the disease is endemic, however, cases of sporadic hepatitis E have been reported in individuals with no history of recent travel. In the European countries, in most cases HEV infection is an autochthonous. Although HEV mainly results in acute self-limiting hepatitis in the immunocompetent individuals. Immunocompromised patients, infected with genotype 3 or 4 may develop chronic infection, which then may lead to cirrhosis. Certain populations, such as pregnant women are at particularly high risk of severe HEV infection. Progression to fulminant liver failure is rare.

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# PEDAGOGICAL SCIENCES

## AREAS OF APPLICATION OF ARTIFICIAL INTELLIGENCE TECHNOLOGIES FOR SUSTAINABLE DEVELOPMENT OF THE EDUCATIONAL PROCESS

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### Abstract

The article is devoted to the study of current trends in the implementation of artificial intelligence technologies in the educational process and analysis of their potential for ensuring sustainable development of modern education. The main attention is paid to four key areas of artificial intelligence in education: personalization of the educational process through adaptive systems that take into account the individual characteristics and needs of each student; automated knowledge assessment using natural language processing algorithms; introduction of intelligent chatbots and learning assistants for round-the-clock support of students; analysis of educational data, generation of educational content and creation of interactive learning environments using virtual technologies. Modern technologies for transcribing audio and video materials as an important tool for collecting and structuring educational information are analyzed in detail. The features of Google Cloud Speech-to-Text, OpenAI Whisper, transcription functions in Zoom and Google Meet platforms, as well as the possibility of their integration into the educational process are considered. A comparative characterization of the main transcription technologies by the criteria of accuracy, functionality, accessibility and scope is presented. The results of the study show that the introduction of artificial intelligence technologies contributes to improving the quality of education through personalization of learning, automation of routine tasks of teachers, and creation of a more inclusive educational environment. At the same time, certain limitations have been identified related to technical requirements, the need for staff training, and ensuring data confidentiality. The practical significance of the work is to systematize knowledge about the possibilities of artificial intelligence in education and to provide recommendations for the effective implementation of these technologies in educational institutions of various levels.

**Keywords:** artificial intelligence, educational process, personalization of learning, automated assessment, transcription, machine learning, adaptive systems, digital education.

**Introduction.** In today's world, artificial intelligence technologies are rapidly integrating into various spheres of human activity, and their impact on the educational process is particularly noticeable. Artificial intelligence is becoming a powerful tool that transforms traditional approaches to learning and creates new opportunities for personalizing education.

The modern educational system faces numerous challenges, including the need to provide quality education to an increasing number of students, adapt to different learning styles, support distance learning, and create an inclusive educational environment. Traditional teaching methods are often unable to effectively address these issues due to limited resources and a standardized approach that does not take into account the individual characteristics of each student. Given the rapid development of digital technologies and growing requirements for the quality of education, the introduction of artificial intelligence is becoming not only an opportunity but also a necessity to ensure the competitiveness of educational institutions.

The relevance of the study is due to the fact that the introduction of artificial intelligence technologies into the educational environment allows solving a number of key challenges: providing a personalized approach to each student, automating routine tasks of teachers, improving the availability of educational materials and making the learning process more efficient. Particularly noteworthy are the following areas of artificial intelligence in education: personalized learning, automated assessment, use of intelligent chatbots, and collection and processing of information from audio and video materials using various software solutions [3; 7; 9].

Another important aspect of the modern educational process is the need to effectively collect and organize information from various sources. With conferences, seminars, webinars, and online classes being held frequently, there is a need for fast and accurate conversion of audio and video content into text format for further analysis, archiving, and use. Automatic transcription technologies are becoming an integral part of

the modern educational process, especially in the context of distance and blended learning.

The purpose of this article is to analyze the main areas of application of artificial intelligence technologies to ensure the sustainable development of the educational process and to study modern tools for transcribing audio and video content that significantly expand the capabilities of the educational environment.

**Key areas of artificial intelligence application in education.** One of the key areas of application of artificial intelligence technologies in education is the personalization of the learning process. Adaptive learning systems based on machine learning algorithms analyze data on students' performance, preferences, and learning pace and, based on this analysis, offer individualized curricula and materials.

Such systems are able to identify problem areas for each learner and offer additional exercises or materials to help them better master complex topics. At the same time, the system can offer more challenging assignments for learners who are quick to learn, which keeps them engaged [1; 6].

An important aspect of personalization is also the adaptation of learning materials to the learning style of each learner. For example, for visual learners, the system can offer more graphic materials, while for audial learners, it can offer more audio materials. Examples of successful use of such systems are the Knewton and ALEKS platforms, which show a significant increase in learning efficiency when used.

Automated assessment is another important area of artificial intelligence in education. Thanks to natural language processing algorithms, artificial intelligence systems are able to analyze not only multiple-choice tests but also written works, evaluating them according to criteria such as grammar, style, and even content.

This significantly reduces the workload of instructors, freeing them from the routine work of checking assignments and allowing them to focus on more creative and interactive aspects of learning. In addition, automated assessment provides objectivity and instant feedback to students, which is an important element of effective learning [5].

Systems using large language models, such as GPT-3 or BERT, are able to provide detailed analysis of papers, identify logical errors, and provide recommendations for improving structure and argumentation. This contributes to the development of critical thinking and self-esteem of students.

Intelligent chatbots are becoming an increasingly common tool in education, especially in distance learning systems. They provide round-the-clock support to learners by answering their questions, making recommendations on learning materials, and explaining complex concepts.

AI-powered chatbots are able to understand the context of questions and provide relevant answers, making interaction with them natural and effective. They can help students plan their learning process, remind them of assignment deadlines, and recommend additional materials based on individual needs [11].

An important advantage of such systems is their accessibility at any time of the day, which is especially

valuable for learners who study at their own pace or have an atypical schedule. This creates a continuous learning process where each learner has access to support exactly when they need it.

In addition to the above, there are many other areas of artificial intelligence application in education that significantly expand the capabilities of the educational process. Educational data analysis allows AI-based systems to process huge amounts of information, identifying major trends, detecting student difficulties at early stages, and providing teachers with tools for timely support. Such analytical systems can detect that a certain group of students is struggling with a particular topic and recommend additional classes or materials for mastering, which allows not only to increase the level of knowledge but also to provide timely support to each student [13].

Generating educational content based on large language models is becoming an important tool for teachers. Thanks to the capabilities of artificial intelligence, you can quickly generate lesson plans, create additional learning tasks, or even prepare presentations. This makes preparing for classes much easier and allows you to focus on the quality of teaching, as well as use artificial intelligence to get recommendations on how to improve your teaching methods based on the analysis of student performance.

Virtual and augmented reality, combined with artificial intelligence technologies, allow for interactive learning environments where students can gain hands-on experience in a safe virtual space. For example, a student can learn chemistry by observing virtual reactions or study biology by traveling through a virtual cell. Not only does this make learning more engaging, but it also promotes a deeper understanding of the material through hands-on experience [2].

Creating educational games and simulations using artificial intelligence opens up new opportunities for developing practical skills without real risks. Students can participate in staff training exercises using artificial intelligence technologies, which allows them to assess the possible consequences of their decisions without risk. This creates a safe environment for experimentation and helps students develop practical skills, which is especially important when training military personnel or specialists in critical areas.

Query engineering, or formulating the right queries for artificial intelligence systems, is becoming an important aspect of working with large language models such as ChatGPT. The ability to correctly formulate a query affects the quality of the answer provided by the system. Therefore, it is important to teach students and teachers how to build queries correctly, ask clear and specific questions to get useful information and effectively use artificial intelligence in the educational process.

**Transcription technologies in the educational process.** An important aspect of the modern educational process is the efficient collection and processing of information from various sources, including audio and video materials. Transcription technologies that

convert voice content into text format open up new opportunities for documenting and analyzing educational content.

For a better understanding of the capabilities and features of different transcription technologies in the

educational process, Table 1 presents a comparative description of the main platforms and tools. The analysis shows that the choice of a particular technology depends on the specific needs of the educational institution, technical capabilities, and financial resources [4; 14].

Table 1

**Comparative characteristics of the main transcription technologies in the educational process**

| Technology                  | Google Cloud Speech-to-Text                                                                                                   | OpenAI Whisper                                                                                           | Zoom Transcription                                                                                                | Google Meet Transcripts                                                                            | OBS Studio + Whisper                                                                                         |
|-----------------------------|-------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------|
| <b>Advantages</b>           | High accuracy<br>Support for 125+ languages<br>Automatic punctuation<br>Cloud processing<br>Integration with Google Workspace | Free<br>Local processing<br>High accuracy<br>Support for different accents<br>Possibility of fine-tuning | Built-in function<br>Automatic saving<br>Integration with the calendar<br>Instant availability                    | Free for Workspace<br>Automatic saving to Drive<br>Integration with Google Calendar<br>Easy to use | Free of charge<br>Full control<br>High customization options<br>Local processing                             |
| <b>Disadvantages</b>        | Requires an internet connection<br>Paid service<br>File size limit (60 sec/10 MB)<br>Dependent on sound quality               | Requires technical skills<br>Resource-intensive<br>Longer processing time<br>Requires installation       | Requires a paid license<br>Limited functionality<br>Dependence on the quality of the connection<br>Lower accuracy | For computers only<br>Limited number of languages<br>Requires Workspace<br>Basic functionality     | Difficult to set up<br>Requires experience<br>Resource-intensive<br>Longer processing time                   |
| <b>Field of application</b> | Short audio recordings<br>Lectures<br>Seminars<br>Online conferences                                                          | Long records<br>Scientific conferences<br>Research<br>Content archiving                                  | Online classes<br>Web seminars<br>Working meetings<br>Distance learning                                           | Educational meetings<br>Corporate conferences<br>Virtual classes<br>Teamwork                       | Streaming of lectures<br>Recording of presentations<br>Creation of educational content<br>Professional video |

One of the key technologies in this area is Speech to Text, a system that converts spoken language into written text. Google Cloud Speech-to-Text is a powerful tool based on Google's deep learning neural network algorithms. This service supports more than 125 languages and dialects, ensuring high recognition accuracy even in the presence of different accents and speech features.

The process of using this technology involves several stages: audio data collection, pre-processing to remove noise, speech recognition, and post-processing to ensure the grammatical correctness of the text. An important advantage is the ability to automatically punctuate and format text, which increases its readability [10].

Whisper is an artificial intelligence-based speech recognition model developed by OpenAI that provides high accuracy in transcribing audio with different accents and speech features. It can work with a variety of audio formats and can be easily integrated into various software solutions to automate the transcription process.

OBS Studio, although originally designed for streaming and recording video, when combined with transcription technologies, becomes a powerful tool for creating text transcripts from video materials. This is especially useful for documenting lectures, seminars, and other educational events.

The main advantages of these tools are high accuracy of speech recognition, the ability to work with different languages and accents, and automation of the transcription process, which saves time and resources [8].

Modern video conferencing platforms, such as Zoom and Google Meet, also offer automatic transcription features, which is extremely useful for the educational process, especially in distance learning.

Zoom offers transcription capabilities for users with a Business, Education, or Enterprise license. The setup process includes activating cloud recordings and automatic transcriptions in your account settings. After recording a meeting, Zoom sends a link to the recording file and transcription.

Google Meet also supports a transcription feature that is available to users on a desktop or laptop. Transcripts are stored on the meeting organizer's Google Drive and contain everything that was said during the meeting [12].

These technologies greatly facilitate the process of documenting educational events, make information more accessible and structured, and provide the ability to quickly search for the information you need in text format.

**Conclusions.** The introduction of artificial intelligence technologies into the educational process opens up new horizons for improving the quality and accessibility of education. The main areas of artificial intelligence use, such as personalized learning, automated assessment, intelligent chatbots, and learning assistants, allow for a more adaptive and efficient learning environment that takes into account the individual needs of each student.

Transcription technologies, such as Speech to Text, Whisper, and transcription functions in Zoom and Google Meet, significantly expand the possibilities for collecting, processing, and analyzing educational information. They convert audio and video content into text format, making it easier to store, search, and use.

The use of these technologies not only increases the efficiency of the educational process, but also makes education more inclusive and accessible to all categories of students. Automation of routine tasks frees up teachers for more creative work and interactive interaction with students, which contributes to the quality of education in general.

However, it is worth noting that despite all the advantages, artificial intelligence technologies have certain limitations, such as dependence on the quality of input data, the need for significant computing resources, and possible accuracy issues in some cases. Therefore, for maximum effectiveness, these technologies should be used as a complement to traditional teaching methods, not as a complete replacement.

In the future, with the development of artificial intelligence technologies and increased computing capabilities, we can expect even deeper integration of these technologies into the educational process, which will help create a truly personalized, effective, and accessible educational environment for each student.

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## WAYS TO ORGANIZE A MUSIC LESSON IN ELEMENTARY SCHOOL

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## БАСТАУЫШ СЫНЫПТА МУЗЫКА САБАҒЫН ҰЙЫМДАСТЫРУ ЖОЛДАРЫ

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<https://doi.org/10.5281/zenodo.15536093>**Abstract**

This article discusses various approaches to organizing a music lesson aimed at developing creative abilities and musical perception of Primary School students. Attention is drawn to the fact that music lessons play an important role in the formation of aesthetic taste, emotional intelligence and social adaptation of students.

**Аннотация**

Бұл мақалада бастауыш сынып оқушыларының шығармашылық қабілеттер мен музыкалық қабылдауды дамытуға бағытталған музыка сабағын ұйымдастырудың әртүрлі тәсілдері қарастырылады. Музыка сабақтары оқушылардың эстетикалық талғамын, эмоционалды интеллектін және әлеуметтік бейімделуін қалыптастыруда маңызды рөл атқаратындығына назар аударылады.

**Keywords:** Primary school, teaching methods, game methods, interactive technologies, emotional perception of music.

**Кілттік сөздер:** Бастауыш сынып, оқыту әдістері, ойын әдістері, интерактивті технологиялар, музыканы эмоционалды қабылдау.

**Kіріспе**

Қазіргі кезеңде мектепте жүретін оқу пәндерінің сапасын көтеру, оқу-тәрбие саласындағы негізгі міндеттердің бірі болып отыр. Өйткені адамзат дамуы үшінші мың жылдыққа өтті. Ғылым мен техника дамудың жоғарғы шыңдарына жетті. Қазақстандағы жалпы білім беретін мектептерде музыкалық білім бері жүйесінде, музыка сабағында барысында әр-түрлі іс әрекеттерді музыкалық тәрбиенің мазмұны мен жаңа қоғам оқушысының заман талабына сай мәдениетін қалыптастыру болып табылады. Музыкаға үйрену, ақыл-ой, имандылық және дене тәрбиесімен де тығыз байланысты. Қоғам адамның эстетикалық даму деңгейін қамтамасыз етпейінші, еш уақытта рухани және материалдық бай бола алмайды. Оқушының рухани мәдениетін құнды және эстетикалық талғамдарын қалыптастыруда оның музыкалық сауаттылығын білім жетілдіруде мектеп үлкен рөл атқарады.

Бастауыш сынып оқушылары, еліміздің ертеңі, еліміздің тірегі болатын азаматтар. Жаңа Қазақстанның жаңа тұрпаттағы жаңа ұстаздарын даярлау, олардың біліктілігінің деңгейі әлемдік стандарттарға сай болуы бүгінгі күннің өзекті мәселесіне айналды. Заман талабына сай оқушының білімін қазіргі жаңа инновациялық технологияға сай қалыптастыру мектептегі білім беретін ұстаздар мен оқу - тәрбиені жаңа үлгіде

жүргізуге байланысты. Өнердің «басқа түрлері сияқты ол да өмірдегі әсемдікті, табиғат сұлулығын бағалауға және арасындағы жағдайларды түсініп, білуге үйретеді» [1]. Сондықтан сол жас ұрпақты дұрыс тәрбиелеу, оларды дұрыс жолға түсіру, аянбай еңбек етіп, балаларды әсемдікке, мәдениеттілікке, Отансүйгіштікке, жан жақты хабардар ету ұстаздарға міндеттеп отыр.

Оқушыларға эстетикалық тәрбие беруде музыка сабағының, яғни ән мен күйдің алатын орыны ерекше екендігі белгілі. Соңғы жылдарда музыка сабақтары арқылы балалардың музыкалық қабілетінің дамуын қалыптастыруға мүмкіндік тудыратын бағдарламалар кеңінен таралып өріс алуда. Бүгінде білім мен тәрбие ісін ойдағыдай жүргізу үшін алдымен әрбір пәннің бағдарламаларын жетілдіріп және қазіргі уақыт талабына сай етіп жасау міндеті күн тәртібіне қойылған.

**Негізгі бөлім**

Музыка - адамзаттың рухани азығы, жан серігі, өзінің көркем, нәзік мәнерлік құралымен адам сезімін баурап, олардың эмоциялық әсерленуін, рухани ләззаттануын қамтамасыз етеді, әрі оны көркем шығармашылық іс әрекеттерге жетелейді.

Жаңа қоғам жаңа оқушысының жалпы музыкалық білімін әлемдік өркениетке сай қалыптастыру, бүгінгі білім берудің жаңашыл бағыттарының бірі болып табылады.

Қазіргі жас ұрпақтың мәдениеті мен парасатты дамыған, өркениетті, жан дүниесі бай, міндеттерін ала отырып, музыка пәні мұғалімі өз ісіне жауапты қарап, психология, педагогика саласындағы біліктілікпен қатар өз мамандығына кәсіби тұрғыда жетілдіре отырып, музыка тілі арқылы оқушыларды тәрбиелеуі қажет.

«Балалар бойындағы қасиеттерін, музыкалық қабілеттерін азаматтық сезімдерін оятуға музыка пәнінің мұғалімі сияқты ешқандай педагогикалық мамандық жан-жақты алуан түрлі әдістемелік тәсілдерді талап етеді. Сонымен қатар басқа ешқандай мамандық тәрбиесінің қолына өз елін, оның табиғатын жырлайтын әндер, опералар, симфониялар, концерттер, балеттер түріндегі бай материалдарды бермейді. Сондықтан, мұғалім жалпы музыкалық мәдениетпен таныстыруда музыка арқылы, қызығушылықты арттырып, оқушы бойындағы шабытты оятады. Мұғалімнің әр айтқан әңгімесі әсерлі, тартымды бағдарламаға сай, жоғары сапада өткізу, сабақтың әрбір сәтін, кездесудің әрбір сәтін тиімді пайдаланып, берілген мазмұнын ойластырып, ұтымды өткізудің жолдарын талап етеді» [4].

Бастауыш сыныпта музыка сабағының басты мақсаты - қазақ халқының әдеп-ғұрпын, салт-дәстүрін, өнерін қадірлейтін, оның өмірі мен байланысын түсінетін, эстетикалық және музыкалық танымы дамыған, рухани бай жеке тұлғаны тәрбиелеуге бағытталған. Туған елінің әндері мен күйлерін білу туған жерін құрметтеуге тәрбиелейді, ал қазақ халқының ой-арманын музыка арқылы түсіну оның музыкалық мұрасын дұрыс қабылдауға және әсемдікті сезіне білуге тәрбиелейді. Сондықтан осы мақсатты жүзеге асыру үшін жасалған жаңа бағдарламаларды жете зерттей отырып, оның озық, тиімді жақтарын іскерлікпен пайдалана білу музыка мұғалімінің кәсіби шеберлігін танытады.

Музыка сабағындағы негізгі іс-әрекеттерге: ән үйрету, музыка тыңдату, музыкалық сауат; қосалқы іс-әрекеттер; балалар музыкалық аспаптарында ойнау, музыкалық-дидактикалық ойындар, музыкалық-ырғақтық қимылдар, балалар шығармашылығы жатады. Бұл іс-әрекеттер бір-бірімен тығыз байланыста болады. Негізгі байланыстың түп тамыры әрине, музыка болып табылады. Оқу бағдарламасында берілген ән репертуарлары әр сынып оқушыларының жас және физиологиялық ерекшеліктеріне қарай іріктеліп алынады.

Бастауыш сыныпта музыка сабағын ұйымдастыру балаларға оқуды қызықты ету үшін ерекше тәсілді қажет етеді. Міне, осындай сабақтарды ұйымдастыруға көмектесетін бірнеше жолдар:

**1. Ойын элементтері:** ойындарды музыка сабақтарына қосу балалардың назарын аударуға көмектеседі. Бұл музыкалық викториналар, ырғақтық ойындар немесе әуендерді болжау ойындары болуы мүмкін. Ойын элементтерін қолдана отырып, бастауыш сыныпта музыка сабағын ұйымдастыру жолдары:

- Музыкалық викториналар. Сабақ материалы бойынша қысқа викториналар өткізу (мысалы, аспаптардың, әуендердің немесе ырғақтардың атауларын болжау). Зейінді ынталандыру және білімді бекіту үшін суреттері немесе дыбыстары бар карталарды пайдалану;

- Ырғақты ойындар. Ырғақтық суреттерді қайталау үшін шапалақтау, аяқпен еденді ұру немесе ұрмалы аспаптарды қолдану. Балалар кезек-кезек қайталайтын немесе өздері жасайтын командалық ойындар құру;

- Әуендерді болжау ойындары. Белгілі әндердің немесе әуендердің қысқа үзінділерін қосып, балаларға тақырыпты немесе орындаушыны болжауды ұсынуға болады. Белсенді қабылдау үшін музыкалық карталарды немесе аудио жазбаларды пайдалану;

- Интерактивті музыкалық жаттығулар. Балаларды музыкалық аспаптар немесе дауыстар арқылы қарапайым әуендер немесе ритақтар жасауға тарту. Музыкалық бейнелерді білдіру үшін қимылдар мен қимылдарды қолдану.

**2. Интерактивті әдістер:** Мультимедиялық презентациялар, бейнелер және аудио жазбалар сияқты интерактивті технологияларды қолдану сабақтарды қызықты әрі көрнекі ете алады. Оқу процесінде интерактивті технологияны қолданудың бірнеше әдісі бар:

- Мультимедиялық презентациялар. Динамикалық және көрнекі презентациялар жасау үшін PowerPoint немесе Prezi сияқты бағдарламалар пайдаланылады. Күрделі ұғымдарды бейнелеу үшін анимацияларды, графиктерді және диаграммаларды қосуға болады;

- Бейнематериалдар. Тақырыптарды түсіндіретін немесе практикалық мысалдарды көрсететін қысқа бейнелерді қосуға болады. Білім беру бейнелерін іздеу үшін YouTube немесе Vimeo сияқты платформалар пайдаланылады;

- Аудио жазбалар. Оқушылар кез келген уақытта тыңдай алатындай дәрістер немесе пікірталастар жазылады. Тақырып бойынша білімді тереңдету үшін подкасттарды қосымша ресурс ретінде пайдаланылады;

- Интерактивті платформалар. Викториналар мен тесттер жасау үшін Kahoot немесе Quizizz сияқты онлайн курстар мен платформалар қолданылады. Оқу процесін ұйымдастыру және оқушылармен өзара әрекеттесу үшін Google Classroom немесе ұқсас құралдар пайдаланылады;

- Топтық жұмыс. Оқушылар бір-бірімен қарым-қатынас жасай алатындай етіп бейнеконференцияларды (Zoom, Microsoft Teams) қолдана отырып, шағын топтарда пікірталастар ұйымдастырылады. Тапсырмаларды бірлесіп орындау үшін Google Docs сияқты бірлескен құралдар қолданылады.

**3. Практикалық сабақтар:** Музыкалық аспаптарда ойнау, ән айту және хор орындау сияқты практикалық әрекеттерді қосу балалардың оқу процесін айтарлықтай жақсарта алады. Мұны қалай жүзеге асырудың бірнеше жолы бар:

- Музыкалық аспаптар. Балалар әртүрлі аспаптарда ойнауды үйрене алады, бұл олардың музыкалық дағдыларын, үйлестіруін және шоғырлануын дамытады;

- Топтық сабақтар. Ансамбльде немесе оркестрде ойнау топтық жұмыс пен әлеуметтік интеграцияға ықпал етеді;

- Өн айту. Даралықты және өзіне деген сенімділікті дамытады. Есту қабілетінің, ырғақтың және командада жұмыс істеу қабілетінің дамуына ықпал етеді. Хор қойылымын әндер арқылы әртүрлі мәдениеттер мен тілдерді үйрену үшін де пайдалануға болады;

- Басқа пәндермен Интеграция. Музыка және математика: ырғақ пен әуенді үйрену бөлшектер мен пропорциялар сияқты математикалық ұғымдарды түсінуге көмектеседі;

- Шығармашылық жобалар. Музыкалық шығармаларды шығару немесе ән мәтіндерін жазу шығармашылық пен сыни ойлауды дамыта алады. Мектепте концерттер немесе музыкалық фестивальдар ұйымдастыру музыкаға деген қызығушылықты арттырып, қоғамдастықты нығайта алады;

**4. Басқа пәндермен интеграциялау:** Музыканы басқа пәндермен біріктіру білім беру процесін шынымен байытып, оны қызықты әрі жан-жақты ете алады. Музыканы басқа заттармен қалай байланыстыруға болатыны туралы бірнеше идеялар келтіріледі:

- Музыка және әдебиет. Лириканы талдау - поэтикалық лириканы үйрену оқушыларға метафора, аллегория және ырғақ сияқты әдеби құралдарды түсінуге көмектеседі. Белгілі ақындардың шығармаларымен салыстыруға болады. Әдеби шығармалар негізінде музыкалық шығармалар жасау оқушылар белгілі бір романдан немесе өлеңнен шабыттандырылған музыка жаза алады және өз шығармаларын ұсына алады.

- Музыка және өнер. Кескіндемедегі музыкалық тақырыптар - музыканың суретшілерді қалай шабыттандырғанын зерттеуді әйгілі картиналарды талдаумен байланыстыруға болады. Музыкамен көрнекі туындылар жасау - оқушылар белгілі бір музыканы тыңдау арқылы коллаждар сала алады немесе жасай алады, бұл олардың эмоциялары мен ассоциацияларын білдіруге көмектеседі.

- Музыка және тарих. Музыканың тарихи контексті - тарихи оқиғалар контекстіндегі әртүрлі музыкалық стильдер мен жанрларды зерттеу (мысалы, ренессанс, барокко, революциялық қозғалыстар музыкасы). Музыка наразылық құралы ретінде - әлеуметтік қозғалыстардың әнұранына айналған әндерді және олардың қоғамға әсерін талдау.

- Музыка және математика. Ырғақ және метр - музыкалық ырғақтарды үйрену оқушыларға бөлшектер мен бөлімдерді түсінуге көмектеседі. Оқушылар өздерінің ырғақты үлгілерін жасап, оларды талдайтын сабақтар өткізуге болады;

- Музыка және ғылым. Дыбыс физикасы - музыкалық аспаптармен практикалық

эксперименттер арқылы толқындарды, жиіліктерді және резонанстарды зерттеу. Музыка психологиясы - музыканың эмоциялар мен мінез-құлыққа әсерін зерттеу, әртүрлі музыкалық жанрлардың әртүрлі эмоционалды реакцияларды қалай тудыратынын талқылау.

**5. Мерекелер мен концерттер:** Мектепте концерттер мен музыкалық мерекелер ұйымдастыру-оқушылар үшін өз таланттарын көрсетуге және музыкаға деген қызығушылықтарын арттыруға тамаша мүмкіндік. Осындай іс-шараны ұйымдастыруға көмектесетін бірнеше қадамдар мен идеялар келтіріледі:

- Іс-шараның мақсаттарын анықтау. Таланттарды көрсету - оқушыларға музыкалық жетістіктерін көрсетуге мүмкіндік беру. Атмосфераны құру - мектепте достық және қолдау атмосферасын қалыптастыруға ықпал ету. Музыкаға деген қызығушылықты арттыру. Басқа оқушылар мен ата-аналарды музыкалық пәндерге қызықтыру.

- Команда құру. Ұйымдастыру комитеті - іс-шараны жоспарлау және ұйымдастыру үшін мұғалімдерден, ата-аналардан және жоғары сынып оқушыларынан тұратын топ құру. Әр түрлі аспектілерге жауаптылар - жарнама, техникалық қамтамасыз ету, безендіру, дайындық және т. б. үшін жауаптыларды тағайындау.

- Іс-шара форматын таңдау. Концерт - оқушылар жеке нөмірлермен немесе топтарда өнер көрсете алу. Музыка фестивалі - музыканың әртүрлі жанрларын қамтиды және шеберлік сабақтарын қамтуы мүмкін. Тақырып - белгілі бір тақырыпты таңдау мысалы, «Әлем музыкасы» немесе «Классика және қазіргі заман».

- Бағдарламаны дайындау. Кесте құру - қойылымдар мен жаттығулардың уақытын анықтау. Жанрлардың әртүрлілігі - бағдарламада әртүрлі музыкалық стильдер мен жанрлар бар екеніне көз жеткізу. Интерактивті элементтер - бағдарламаға көрермендерге арналған конкурстар немесе викториналар қосу.

- Жарнама және шақырулар. Плакаттар мен буклеттер - іс-шараны насихаттау үшін жарқын және ақпараттық материалдар жасау. Әлеуметтік медиа - оқиғаны жариялау және көрермендерді тарту үшін платформаларды пайдалану. Ата-аналарға және жергілікті қоғамдастыққа шақыру - концерт туралы ақпаратты ата-аналар мен жергілікті тұрғындарға таратыңыз. Бұл әдістер бастауыш сыныптағы музыка сабақтарында қызықты және өнімді атмосфераны құруға көмектеседі.

«Музыка мұғалімі өз сабағын шығармашылықпен ұйымдастыра отырып, әрбір сабақтың оқу-тәрбиелік міндетін, оның мақсатын алдын-ала бағдарлай біліп, сабақта кездесіп қалатын кездейсоқ қиындықты болжап, олай бола қалғанда, оны шешу үшін қажетті әдіс-тәсілдерді ойлап табуға, оқушылардың белсенділігін арттыру үшін өз сабағына балалардың музыкалық мәдениеттілігін қалыптастыратын, рухани байытатын құрал ретінде қарау мәселелерін сезіне

білуге дағдылануы тиіс. Мұғалім тұлғасы сабақ үстінде жан-жақты әр қырынан байқалады: ол тек белгілі бір шығарманы орындап немесе айтып қана қоймай, ол туындылар жөнінде әңгіме жүргізеді, өзінің сазгерге деген көзқарасымен пікір алысады, музыканың әсер ету күшінің мүмкіндігін жеткізе түсуге жағдай жасайды. Мұғалімнің оқушы алдында беделді болуы оның жауапкершілігіне, қамқорлығына талап ете білуіне байланысты» [2].

Осы орайда мұғалім тұлғасының маңыздылығы ескерілуі тиіс. Мұғалім сабақ үстінде жан-жақты әр қырынан байқалады: ол тек бір шығарманы орындап немесе айтып қана қоймайды, ол туындылар жөнінде әңгіме жүргізуді, өзінің композиторға деген көзқарасымен пікір алысады, музыканың әсер ету күшінің мүмкіндігін жеткізе түсуге жағдай жасайды.

Мұғалімнің оқушы алдында беделді болуы оның жауапкершілігіне, қамқорлығына талап ете білуіне байланысты. Музыкадан алған әсерінің жемісті болуы үшін балаға әрқашан мұғалім тарапынан қамқорлық, тірек болатын, ілтипат, ықылас қажет. Оның үстінде музыка сабағының өзі барлық баламен бірдей жұмыс жасауды талап етеді. Соның өзінде сабақ барысында мұғалім әр оқушыны, оның күшті және әлсіз жақтарын байқап, мүмкіндігінше, қосымша сұрақ қою, ризашылық білдіру, назар аудару т.б. арқылы әр баланы назардан тыс қалдырмаған жөн. Мұғалімнің дене, қолының қимылы және мимикасы да сабақты көтеріңкі бір лепте, бір демде өткізуде ерекше орын алады.

Шәкіртке дұрыс бағыт беріп, талабын қанағаттандыру - ұстаз қызметінің нақты мақсаты болып табылады. Мәдени эстетикалық тұлғасын қалыптастырудың педагогикалық негізі ретінде ұрпақты «тәрбиелеуде тиімді пайдалана білу, жеке тұлғаның жан - жақты өсіп дамуына, рухани адамгершілік» [3] пен мәдени эстетикалық тұлғаның өркендеуіне жаңаша жол ашу.

Мұғалім шығармашылығы, оның ұстаздық шеберлігі, тақырыптылығы мектеп табалдырығынан алға аттаған күннен бастап қалыптаса бастайды. Өз ісінің білгірі, шебер педагог болу үшін әр мұғалім өзінің бойындағы

жетістіктер мен кемшіліктерді дұрыс бағалап, өзі-өзі тәрбиелеу міндетті.

### Қорытынды

Бастауыш сыныпта музыка сабағын ұйымдастыру жолдарын қарастыру балалардың музыкалық мәдениетін, талғамын қалыптастырады және «ойын тұжырымдай білуге дағдыландырады. Өтілген сабаққа байланысты балалардың өмірден, музыкадан алған тәжірибелерін әрі қарай тереңдете түсуі, белсенділігін арттыру, жаңа ережелермен танысу, музыкалық іс-әрекеттердің барлық түрінде де алған білімдерін бекіту» [5]. Жалпы, бұл жұмыста мектепте өтетін музыка сабағының мазмұны, мақсаты, мәні, сабаққа қойылатын талаптар туралы жазылды. Сол сияқты қазіргі кезеңдегі музыка сабақтарында қолданылатын техникалық құралдар, оларды пайдаланудың тиімді жолдары қарастырылды. Музыка сабақтарын оқу үрдісі кезеңінде бір сарынды өткізбей, ғылым мен жаңа техника жаңалықтарының соңғы үлгілерін пайдаланып, өркениетті еліміздің болашағы жас буынды, өз дәуіріне сай тәрбиелеу, оқыту, білім беру ұстаз алдындағы ең бірінші міндет болып табылады. Сондықтан болашақтағы жас маман ретінде, өз сабақтарымды да заман талабына сай өткізу үшін, қолдағы бар мүмкіндікті пайдаланудың қажеттігі туындайтындығына көз жеткізілді.

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# PHILOLOGICAL SCIENCES

## GEOGRAPHICAL TERMS IN THE WORK OF THE 14TH CENTURY AZERBAIJANI POET İMADEDDİN NASİMİ

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### XIV ƏSR AZƏRBAYCAN ŞAİRİ İMADEDDİN NƏSİMİ YARADICILIĞINDA COĞRAFİ TERMINLƏR

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#### Abstract

This article explores the geographical terms used in the language of the 14th-century Azerbaijani poet İmadəddin Nəsimi. As a Hurufist, Nəsimi's poetry is rooted in symbolism, epithets, similes, and metaphors, following the traditions of Sufi literature. Therefore, geographical terms in his work are often employed figuratively rather than literally. The study provides a thematic classification of these terms and includes etymological and statistical analyses. It also examines the influence of the geographical classification system of the ancient Greek scholar Claudius Ptolemy as reflected in Nəsimi's poetic language. The geographical terms found in Nəsimi's work are grouped into the following thematic categories: terms denoting geographical regions, water basins, the edges of water bodies, high reliefs, plains, dry deserts, green plains, types of wind, underground cavities, the Earth's crust, forested areas, types of stone (e.g., raft stones), soil, and the horizon. The research reveals that Nəsimi used 14 geographical terms of Arabic origin, 10 of Turkic origin, and 15 of Persian origin.

#### Xülasə

Məqalədə XIV əsr Azərbaycan şairi İmadəddin Nəsiminin dilində işlənən coğrafi terminlər tədqiq olunur. Hürufi əqidəli şairimiz İmadəddin Nəsiminin yaradıcılığı təsəvvüf ədəbiyyatının ənənələrinə uyğun olaraq simvolika, epitet, təşbih və metafor üzərində qurulduğundan coğrafi terminlərin həqiqi mənadan çox məcaz anlamda işləndiyi müşahidə olunur. Məqalədə terminlərin tematik bölgüsü müəyyənləşdirilir, etimoloji və statistik hesablınması həyata keçirilir. Burada Nəsiminin dilində müşahidə olunan yunan alimi Klavdi Ptolomeyə məxsus coğrafiya təsnifatı təhlil olunur. Məqalədə şairin dilində işlənən coğrafi terminlər aşağıdakı tematik bölgülər üzrə klassifikasiya olunur: coğrafi bölgü bildirən terminlər, su hövzələrini bildirən terminlər, su hövzəsinin kənarını bildirən terminlər, hündür relyefi ifadə edən terminlər, düzənliklər, quru səhraları ifadə edən terminlər, yaşıllığı olan düzənliklər, küləklərin növləri, yer altında oyuqlar, yer qabığını ifadə edən terminlər, ağacılıq sahəsini ifadə edən terminlər, sal daşları bildirən terminlər, torpağı bildirən terminlər, üfuku bildirən terminlər. Tədqiqat nəticəsində ərəb mənşəli coğrafi terminlərin 14, türk mənşəli terminlərin 10, fars mənşəli coğrafi terminlərin isə 15 ədəd təşkil etdiyi müəyyənləşmişdir.

**Keywords:** geographical terms, yed(d)i iqlim, Nəsimi, terms denoting high relief, terms denoting water basins.

**Açar sözlər:** coğrafi terminlər, yeddi iqlim, Nəsimi, hündür relyefi ifadə edən terminlər, su hövzələrini ifadə edən terminlər.

Hürufi əqidəli şairimiz İmadəddin Nəsiminin yaradıcılığı təsəvvüf ədəbiyyatının ənənələrinə uyğun olaraq simvolika, epitet, təşbih və metafor üzərində qurulduğundan coğrafi terminlərin həqiqi mənadan çox məcaz anlamda işləndiyi müşahidə olunur.

Qeyd etmək lazımdır ki, Nəsimi yaradıcılığında coğrafi adlardan fərqli olaraq coğrafi terminlər heç də çoxluq təşkil etmir: *iqlim*, *yed(d)i iqlim*, *iqlimi-həft*, *dəniz/dəngiz*, *bəhr*, *dərya*, *sahil*; *bərr*, *bərrü bəhr*, *irmaq*, *su*, *cu(y)*, *dağ*, *kuh*, *sər*, *bəriyyə*, *səhra*, *biyaban*, *yaban*, *yaz*, *sərab*, *çəmən*, *yel*, *bad*, *badi-səhərgah*, *rih*, *ruzigar*, *səba*, *badi-səba*, *səmun*, *nəsim*, *kəhf*, *yer*,

*ğübra*, *səra*, *bişə*, *meşə*, *qaya*, *xak*, *torpaq*, *turab*; *kəsək*, *afaq*.

*İqlim* (إقليم) yunan dilində κλίμα *klima* ərəb dilinə *iqlim* şəklində keçmiş coğrafi termdir. Orta əsr coğrafiya elminə görə, *iqlim* şimal yarımkürəsində yaşayış olan quru ərazilərin yeddi bölgədən hər birinə deyilir. Nəsiminin dilində bu termin ayrıca işləndiyi kimi, termin-söz birləşməsi tərkibində eyni anlamda iki şəkildə müşahidə olunur: *yed(d)i iqlim*, *iqlimi-həft*. “Əhli-fəna olsa fəna, *iqlimi-həftin varına*” [7, II, p. 202]; “*Yeddi iqlimə məkanam laməkan*” [7, II, p. 318].

*Yeddi iqlim* I növ təyini söz birləşməsinin komponentləri türk və ərəb mənşəlidir. *İqlimi-həft* fars izafətidir. Birinci komponenti ərəb (iqlim), ikincisi fars mənşəlidir (həft).

*Yedi iqlim*, *iqlimi-həft* coğrafi termini müasir coğrafiya elminin anlayışlarından fərqli olduğuna görə, diaxron aspektdə araşdırma aparmalı olduq. İskəndər Pala bu termini Klavdi Ptolomeyə aid edir: “*Ekvator xəttindən şimal qütbünə doğru olan hissə yeddi bölgəyə ayrılmışdır. Hər birinə iqlim deyilən bu bölgələrin xaricində qalan qismə zülumat deyilir ki, İsgəndərin abi-həyatı axtarmağa getdiyi yerdir. Yeddi iqlimi əmələ gətirən bölgələr – İran mərkəz olmaqla Ərəbistan, Afrika, Roma, Türkiyə, Hindistan və Çin topraqlarıdır. .. Yuxarıdakı bölgələrin insanların irqinə görə fərqli təsnifatı da vardır: 1) Bərbər (müasir Misir, Liviya, Tunis, Əl-Cəzair və Mərakeşi əhatə edən Şimali Afrika – X.Heydərova) və Həbəşistan ölkələri ilə Yəmənin şimalından Sind (Pakistanın 4 əyalətindən biri – X.Heydərova), Hindistan və Çinə qədər uzanır. Xalqı qara dərilidir; 2) Məğrib, Sudan və Ərəb yarımadasının cənubundan Yəməni, Məkkə, Mədinə, Bəhreyn və Sindhə keçər. Xalqı əsmər dərilidir; 3) Məğribin şimalı ilə Misir, Qüds, Şam, Kufə, Bağdad, Bəsrə və fars ölkələrindən keçir. Xalqı sarıbənzərdir; 4) Əndəliüs (müsləman İspaniyası – X.Heydərova) və Firəngistan (Avropa – X.Heydərova), Anadoludan – Təbriz, Ərdəbil, Qəzvin, Xorasan, Xəta, Xütən və Çinin cənubundan keçir. Xalqı ağbənzərdir; 5) İspaniyanın cənubundan, Firəng diyarının ortasından, Anadolu, Sivas, Ərzurum, Şirvan, Xəzər bölgəsi, Geylan və Cam, Xarəzm, Səmərqənd, Buxara və Türkiyədən keçir. Xalqı ağ dərilidir; 6) Firəng diyarının güneyindən, İstanbuldan Qara dənizdən, Dağıstan, Gürcüstan, özbək və Cağatay diyarlarından keçir. Xalqı sarıbənzərdir; 7) Portuqaliya, İngiltərə, Bolqarıstan, Rusiya, Qıpçaq ölkəsindən Xəzərə qədər uzanır. Xalqı qızıla yaxın bənizlidir” [8, p. 212-213].*

“İslam ensiklopediyası”nda isə göstərilir ki, Yer üzünün yeddi iqlimə ayrılması fikri Klavdi Ptolomeyə aid edilsə də, əslində iranlılara məxsusdur. Onların təsnifatına görə, dünya coğrafiyası İran mərkəzdə qalmaq şərhlə Hindistan, Ərəbistan, Çin, İran, Afrika, Türk və Rum (Bizans, Anadolu) olmaq üzrə yeddi iqlimdən ibarətdir. Uzun müddət ərəb coğrafiyaşünasları bu təsnifatın təsiri altında olmuşlar. Bax: [11]

*Çəmən* (چمن) fars mənşəlidir və yaşıl otlar örtülmüş sahəyə deyilir. Nəsimi yaradıcılığında bu coğrafi terminin iki mənada işləndiyi müşahidə olunur: həqiqi və təsəvvüfi mənasında. Şairin əsərlərində baharın təsviri “quş dili”nə aid edilməyən yeganə mövzu hesab edilə bilər.

“*Çəmənlər müxtəlif oldu həzar əlvan çiçəklərdən Açıldı lələvi nəsrin, şükufə gəldi aşcarə*” [6, I, p. 44]

Təsəvvüfdə *çəmən* “ilahi maarif gülzarı” [2, p. 216] anlamını ifadə edir.

“*Ey çəmənü rövzə, boyun sidrəsi Hüsni məlahətdə rüxün müntəha!*” [7, II, p. 167] Adəmin surətinə müraciət edən şair onu “ilahi maarif gülzarı” adlandırır.

*Bişə* (بيشه) farscadan meşə deməkdir.

“*Nərrəşiri-bişeyi tövhidi-sahibqüdrətəm,*

*Tülkülər qaçan biləsidir bizim mə'vəmizi?!*” [7, II, p. 34]

*Meşə* (مشه) farsca “bişə” sözündən fonetik dəyişikliyə uğramış termindir. Ağaclar çox olan yerə deyilir.

“*Niçün əgər şir isən meşədə zinharə sən*” [7, II, p. 192]

*Dağ* (طاغ) türk mənşəli olub yerin dik, hündür, yamaclı və zirvəli hissəsinə deyilir.

“*Məsəldə təb'imizdir yeddi qat yer*

*Ağaclar tük olur, dağ üstüxanım*” [7, II, p. 327]

Şair burada Yer quruluşundan danışır: Yer yeddi qatdan ibarətdir, dağ sümük rolu oynayır, ağaclar tülkləridir. Həqiqətən də elm sübut etmişdir ki, dağın hündürlüyü qədər də yerin altında kökü var.

Şair dağın zirvəsini bildirmək üçün fars mənşəli *bər* ön qoşmasından və *sər* sözündən istifadə edir: “*Ki, Musa söylər idi bər-səri-Tur*” [6, I, p. 251].

Nəsiminin dilində işlənən türk mənşəli *dağ* termininə sinonim olaraq işlətdiyi fars mənşəli *kuh* (کوه) leksik vahidini misal gətirmək olar.

“*Mənsiz olmaz cahanda əşya çun*

*Gərçi kuhü və gərçi xaşxaşam*” [7, II, p. 238]

*Dəniz* (دکيز) türk mənşəli söz olub okeanın quruya toxunan bir hissəsinə deyilir.

“*Hər qayanın lə'li olmaz, hər dənizin gövhəri, Hər sədəfdən lö'löi-mərcan umarsan, nə əcəb!*” [7, II, p. 177]

Nəsiminin əsərlərində *ng* qovuşuq səsi ilə *dəngiz* fonetik variantına da təsadüf edilir.

“*Səndədir şol gənci-pünhan, gəzmə hər viranəyi, Dəngizə dal, andan istə, ey könül, dürdənəyi*” [7, II, p. 56]

Burada Nəsimi “ilahi həqiqət və ilahi eşq dənizi” təsəvvüfi mənasını istifadə etmişdir. Nəsimi dəniz mənasında ərəb mənşəli *bəhr* və fars mənşəli *dərya* coğrafi terminlərindən də istifadə edir.

“*Bəhri-mühitə düş kim, dəryayi-ə'zəm oldur*” [7, II, p. 166]

*Bəhri-mühit* təsəvvüf termini olub Haqq dənizi deməkdir.

*Sahil* (ساحل) ərəbmənşəlidir və dəniz, göl, çay kənarına deyilir.

“*Nə mə'dənsən, nə gövhərsən, nə dəryasan, nə xoş sahil!*” [7, II, p. 106]

*Su* (سو) türk mənşəli söz olub “*dənizləri, gölləri, çayları, bulaqları əmələ gətirən və hidrogenlə oksigenin kimyəvi birləşməsindən ibarət olan şəffaf rəngsiz maye*” [İzahlı lüğət, IV, s. 156] deməkdir. Nəsimi yaradıcılığında su Adəmin cismini təşkil edən dörd təbiət ünsüründən biridir: “*Odü su, torpağı yel adı nədəndir adəm?*” [6, I, p. 15]

*İrmaq* (ایرماق) türk mənşəli söz olub axan çay mənasını ifadə edir. Nəsimi şeirlərində yalnız iki yerdə təsadüf edilir. Hər ikisində cənnət çayı anlamında işlənmişdir:

“*Sormuşam lə'lində cənnət irmağı ləzzatını*” [7, II, p. 163]

“*Səkkiz oldu qapusu uçmağın,*

*Niyə dörd oldu suyu irmağın?*” [7, II, p. 249]

*Cu, cüy* (جو، جوی) fars mənşəli söz olub arx, irmaq, kiçik çay; sel mənalərini ifadə edir.

“*Sararmış ərgəvan bənzi kənarı-cuyidən tanıq*

*Sanasan Kə'bə sultanı üzün yur abi-zəməmdən*” [7, II, p. 69]

*Kəhf* (كهف) ərəbcə mağara deməkdir və eyni zamanda Quranda surə adıdır. Hürufilər kəhf sözünü Adəmin qəlbinə şamil etmişlər. Nəsimi tərəfindən “kəhf” Adəmin qəlbinə, yeddi əshabi-kəhfın yoldaşı olmuş itin (“kəlb”) Qətmir (قَطْمِير) adının ifadə etdiyi mənə isə hürufinin nəfsi istəklərdən arınmış qəlbinin təvazökar xarakterinə işarə edilir.

*“Həm cəbəl, həm kəhf, həm Əshabi-kəhfəm kəlb ilə,*

*Həm Qafin simurğuyam, həm quşların əsfuruyam;*  
*Əshabi-kəhfın sirrini görmüş liqayi-Turə sor,*  
*Niçün ki, “vəttur” əhlinin kəhfindədir*  
*Qətmirimiz”* [7, II, p. 111]

*Qaya* (قاي) türk mənşəli leksik vahiddir. Çox iri və sərt daşa deyilir.

*“Hər qayanın lə'li olmaz, hər dənizin gövhəri”* [7, II, p. 177]

*Bəriyyə* (برية) ərəb mənşəli coğrafi termindir. Çöl, səhra deməkdir.

*“Bəriyyə icrə qalanlara mə'tə fis-sələvat”* [6, I, p. 184]

*Bərr* (بر) ərəb mənşəli termindir. Quru yer (dəniz müqabili). *Bərrü bəhr* – dəniz və quru torpaq.

*“Uş bu bərrü bəhr içində kəndidir”* [7, II, p. 314]

*Səhra* (صحراء) ərəb mənşəli coğrafi termindir. Susuz və bitkisiz geniş çöl; biyaban, düzə deyilir.

*“Səba mişkin saçın buyı buraxdı müşkü səhrayə”* [6, I, p. 36]

*Biyaban* (بيابان) farsca olub otsuz, bitkisiz düz yerə; səhra, çöllüyə (bəzən, çöl-biyaban şəklində işlənir) deyilir.

*“Həm Yusifi mən çahi-biyabana buraxdım”* [6, I, p. 120]

*Yaban* (يابان) türk mənşəli söz olub şöl, düzənlik; səhra, çöl-biyaban; yiyəsiz yerə deyilir. Bu leksik vahidə “Kitabi Dədə Qorqud” dastanında [5, p. 7, 9, 22, 101] və İbn Mühənnə lüğətində [3, p. 177] təsadüf edilir.

*Afaq* (أفاق) ərəb dilində üfük sözünün cəmidir. Üfüqlər, göyün yerlə birləşmiş kimi görünən qismə deyilir.

*“Çü zülfün qoxusu afağı dutdu”* [6, I, p. 306]

*Sərab* (سراب) fars mənşəli olub susuz çöldə yer üstünə yığılan buxarın uzaqdan su kimi görünməsi, ilğım anlamındadır.

*“Həm şərabam, həm sərabam, həm susuzam, həm Fərat”* [7, II, p. 187]

*Yaz* (ياز) türk mənşəli sözdür və çöl, geniş düzən yerə deyilir. Bu arxaizm Budaqovun lüğətində müşahidə olunur. Bax: [10, II, p. 327].

*“Dağı mənəm, yazı mənəm, mən külli-dövrən olmuşam”* [6, I, p. 135]

*“Al əlindən atını yabana at”* [7, II, p. 265]

Şairin müraciət etdiyi mövzulardan biri də küləkdir. Nəsimi təbiətin dörd ünsüründən biri kimi çox zaman *yel* terminindən istifadə edir. *Yel* ييل türk mənşəli sözdür. Budaqovda [10, II, p. 389] və İbn Mühənnə lüğətində [3, p. 153] müşahidə olunur. Yüngül külək mənasını ifadə edir. Bundan başqa, şair yüngül meh mənasında ərəb mənşəli *nəsim* (نسيم), *səba* (صبا), *rih* (ريح), fars mənşəli *bad* (باد), *badi-səhərgah* (səhər mehi), *ruzigar* terminlərindən istifadə edir. Bunlar içərisində *səba* gecə ilə gündüz bərabər olduğu zaman cənubdan səhər-səhər əsən yüngül və lətif mehə deyilir. Divan ədəbiyyatında sevgilinin olduğu yerdən gələn xəbərci olaraq təsvir edilir.

*“Ey badi-səba, var, xəbəri yarə ilə kim*

*Hüdhüd dilidir bunu Süleyman dəxi bilməz”* [7, II, p. 11]

Bütün bunlardan başqa, Nəsimi səhralarda əsən çox güclü, iti, quru küləyin adını çəkir. Bu, ərəb mənşəli *səmmum* (سموم) terminidir:

*“Ta səmmumun narına yandırmışam şeytanı mən”* [7, II, p. 163]

*Yer* (ير) türk mənşəlidir. Mahmud Kaşğarının lüğətində [4, I, p. 65; II, p. 83], “Kitabi Dədə Qorqud” dastanında [5, p. 64, 65, 99] müşahidə olunur. Üzərində sakın olduğumuz planet, Yer kürəsi, Yer üzü mənasını ifadə edir.

*“Üzün bədri cahanın danəsidir*

*Yerü göy, ayü gün pərvanəsidir”* [6, I, p. 221]

Nəsimi *yer* sözünə sinonim olaraq ərəb mənşəli *ğübra* (غبرا) və *səra* (سرا) terminlərindən də istifadə edir: *“Fələkdir atamız, ğübra anamız”* [7, II, p. 327]. Aşağıdakı misrada Nəsimi demək istəyir ki, ah çəkəram, ahım yerdən göyə çatar (hərfən: Ülkər ulduzuna çatar):

*“Sey – Səradan çəkəram ah Sürəyyaya irər”* [7, II, p. 218]

Nəsimi öz yaradıcılığında təbiətin dörd ünsürü – od, su, torpaq və yel haqqında geniş söhbətlər açır:

*“Gəldi, adəm nurunu şərh eylədi*

*Odü su, torpağı yeldən söylədi”* [7, II, p. 324]

O, torpaq termininə sinonim olaraq fars mənşəli *xak*, ərəb mənşəli *turab* terminlərindən də istifadə edir: *“Yel əlimdə, su gözümdə, od içimdə xak olur”* [6, I, p. 234]; *“Zəhi, türab ilə əqd eyləyən yel ilə odu”* [7, II, p. 101].

*Kəsək* (كسك) türk mənşəli leksik vahiddir. Bax: [9, p. 140]. İri torpaq parçası, kəsək deməkdir.

*“Daşü kəsək oldu vərđi-nəsrin”* [7, II, p. 251]

Nəticə etibarilə onu demək olar ki, Nəsiminin dilində ümumilikdə 43 coğrafi termin aşkar edilərək tədqiqata cəlb olundu və aşağıdakı tematik bölgülər üzrə təsnif edildi. Bax: **Cədvəl 1.**

|                                                  |                                                                             |
|--------------------------------------------------|-----------------------------------------------------------------------------|
| Coğrafi bölgü bildirən terminlər                 | <i>iqlim, yed(d)i iqlim, iqlimi-həft</i>                                    |
| Su hövzələrini bildirən terminlər                | <i>dəniz/dəngiz, bəhr, dərya, irmaq, su, cu(y)</i>                          |
| Su hövzəsinin kənarını bildirən terminlər        | <i>sahil; bərr, bərrü bəhr</i>                                              |
| Hündür relyefi ifadə edən terminlər              | <i>dağ, kuh, sər</i>                                                        |
| Düzənliklər, quru səhraları ifadə edən terminlər | <i>bəriyyə, səhra, biyaban, yaban, yaz, sərab</i>                           |
| Yaşillığı olan düzənliklər                       | <i>çəmən</i>                                                                |
| Küləklər                                         | <i>yel, bad, badi-səhərgah, rih, nəsim, ruzigar, səba, badi-səba, səmum</i> |
| Yer altında oyuqlar                              | <i>kəhf</i>                                                                 |
| Yer qabığı ifadə edən terminlər                  | <i>yer, gübra, səra</i>                                                     |
| Ağaclıq sahəsini ifadə edən terminlər            | <i>bişə, meşə</i>                                                           |
| Sal daşları bildirən terminlər                   | <i>qaya</i>                                                                 |
| Torpağı bildirən terminlər                       | <i>xak, torpaq, turab; kəsək</i>                                            |
| Üfüqü bildirən terminlər                         | <i>afaq</i>                                                                 |

**Cədvəl 1.** Nəsimi yaradıcılığında coğrafi terminlərin tematik bölgüsü.

Tədqiqata cəlb olunan terminlərin mənşəcə təsnifatı aşağıdakı şəkildədir:

Ərəb mənşəli coğrafi terminlər (14 ədəd): *iqlim, bəhr, sahil, bəriyyə, səhra, rih, kəhf, turab, afaq, gübra, səra, nəsim, səba, səmum*.

Türk mənşəli coğrafi terminlər (10 ədəd): *dəniz/dəngiz, irmaq, su, dağ, yaban, yaz, yer, qaya, kəsək, torpaq*,

Fars mənşəli coğrafi terminlər (15 ədəd): *dərya, bərr, bərrü bəhr, cu(y), kuh, sər, biyaban, sərab, çəmən, yel, bad, ruzigar, bişə, meşə, xak*.

Mənşəcə qarışıq komponentli coğrafi termin-söz birləşmələri (4 ədəd): *badi-səba, badi-səhərgah, yed(d)i iqlim, iqlimi-həft*.

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# PHILOSOPHICAL SCIENCES

## ETHICAL SKETCHES TO THE QUESTION OF ARTIFICIAL INTELLIGENCE

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## ЭТИЧЕСКИЕ ЭСКИЗЫ К ВОПРОСУ ОБ ИСКУССТВЕННОМ ИНТЕЛЛЕКТЕ

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### Abstract

The article examines the place and role of ethics in the field of artificial intelligence and traces the main ethical principles observed in the application of complex technologies and devices. In order to understand the discourse at the current stage of approaches to the ethics of the actions of smart machines, large and small, an attempt was made to specify what is included in this concept and what is its scope in relation to the practical processes of creating, using and regulating artificially capable intelligence systems.

### Аннотация

В статье рассматривается вопрос о месте и роли этики в области искусственного интеллекта и прослеживаются основные этические принципы, соблюдаемые при применении сложных технологий и устройств. Для осмысления дискурса на текущем этапе подходов к этике действия умных машин, больших и малых, сделана попытка конкретизировать, что вкладывается в данное понятие и каков его охват применительно к практическим процессам создания, использования и регулирования систем искусственно способного интеллекта.

**Keywords:** Ethics, artificial intelligence, science, scientific and technological progress, technology, technology, philosophy.

**Ключевые слова:** Этика, искусственный интеллект, наука, научно-технический прогресс, техника, технологии, философия.

Этика искусственного интеллекта является частью этики науки и технологий, характерной для роботов и других искусственно интеллектуальных устройств, созданных Человеком. Тезис этики искусственного интеллекта подразумевает, прежде всего, моральных вопросов, относящихся специалистам, проектирующим и конструирующим роботы, машины, имеющие возможности интеллектуального действия. Этика технологий занимается вопросами, относительно того, как искусственно умные существа могут быть использованы в обеспечении интересов человека не во вред его интересов. Как бы эти гуманоидные роботы не нанесли непоправимый урон человеческой экзистенции. Так

как, сегодня искусственный интеллект сильно влияет на человечество, день ото дня расширяются горизонты и масштабы применения умных технических систем, то действия их разработчиков с этической точки зрения должны быть прозрачными и надежными в плане благодеяния. Следовательно, для достижения прозрачности так или иначе потребуются государственное регулирование для поддержки моральной ответственности человека. Но это не однозначное положение. С одной стороны, это может ограничивать действия создателей искусственного интеллекта, что в свою очередь может привести к замедлению темпов развития инноваций. С другой стороны, очевидно, что государственное регулирование приводит к устойчивой

стабильности, способно в достаточной степени поддерживать инноваций в области искусственного интеллекта. Выше вкратце обозначена моральная ответственность создателей конструкторов и разработчиков гуманоидных машин и систем. Но в немалой степени интересен и загадочен и другая сторона этики новых технологий. Имеется ввиду, какова моральная сторона действий сверхумных роботов или искусственно интеллектуальных компьютеров, которые ведут себя морально или как бы морально, т.е. так называемых искусственных моральных агентов. Здесь уже возникают новые философские вопросы, такие как характеристики субъектности, связанные с концепцией искусственно умных систем. Известный писатель-фантаст Айзек Азимов еще в 50-х годах XX века в своей серии рассказов “Я робот” обозначивал свои три закона – для защиты людей от их собственных созданий. Какие эти законы? Первый закон абсолютно запрещает роботу вредить людям, второй – озадачивает робота подчиняться людям до тех пор, пока это не станет противоречить первому закону, третий закон обязывает робота защищать самого себя, не нарушая первых двух. Какова мораль из сказанного? Автор подчеркивает последствия неадекватного регулирования и управления в мире, движимом так называемыми передовыми технологиями. Как бы там ни было, человек не гарантирован от той опасности, как поломка робота или его парадоксальное непредвиденное поведение [1].

Следовательно, можно предположить, что ни один из установленных Айзеком Азимовым законов не может в достаточной мере предвидет все возможные тревожные обстоятельства. Поэтому в последнее время все более поставляется под сомнение идея о моральной ответственности искусственно умных устройств и систем. Комиссия, созданная в Англии в 2010 году, пересмотрела законы Айзека Азимова, и установила, что искусственный интеллект должен действовать под ответственностью либо его производителей, либо его владельца или оператора [1]. Ученый математик и писатель фантаст Вернор Видж выдвигает гипотезу о том, что может наступить момент, когда компьютеры станут умнее людей, назвав это явление сингулярностью [2]. Он считает, что это может представлять из себя частичную или полную опасность для человека. Отдельные специалисты утверждают, что в результате интеллектуальной сверхактивности, происшедшей в XXI веке искусственный интеллект наделенный способностью самосовершенствоваться может стать настолько умнее людей, что настанет время, когда человек не может помешать антигуманным действиям такой системе. В статье “Этические проблемы в продвинутом искусственном интеллекте” философ Ник Бостром допускает, что искусственный интеллект созданный человеком может достичь вымирания человечества. Автор предполагает, что технический сверхразум может достичь до степени самостоятельной инициативы и планирования. В таком случае он уже может рассматриваться как автономный субъект. Теоретически автор допускает, что сверхинтеллектуальная техника сможет привести практически к любому возможному непредвиденному исходу, в том числе

и вредному для человека. Однако ученый отвергая свои пессимистические предположения высказывает уверенность в том, что искусственный интеллект изначально призван помогать человеку решить многие сложные проблемы, прежде всего в области здравоохранения, в преодолении бедности, в охране окружающей среды, в осуществлении космических проектов, в обеспечении продовольственной достаточности и безопасности и т. д. [3].

Обращение к этике в связи с развитием информатики, автоматизации, а затем и умных машин вполне закономерно – различные автоматизированные и компьютерные системы и цифровые технологии уже в прошлом веке начали оказывать серьезное влияние на все стороны жизнедеятельности человека. При этом скорость внедрения цифровых технологий настолько высока, что общество не всегда успевает дать всестороннюю и обоснованную моральную оценку всем воздействиям и проявлениям техники в различных областях жизни, равно как и сделать однозначный прогноз по перспективам безопасного справедливого применения новейших технологий. Информационно-коммуникационные технологии не только кардинально изменили личное поведение, стиль жизни и межличностные отношения, но и восприятие и понятие самого общества, а также информацию, которая может быть собрана о человеке с его согласия или без него. Технологические изменения также затрагивают повседневные аспекты современного общества, такие как администрирование и управление, электронная коммерция, электронное здравоохранение, электронное образование, удаленная работа и электронное голосование телекоммуникации, общественно-политическая деятельность, права потребителей, интеллектуальная собственность, демократия и т.д. Отдельную значимость приобретают в наше время каналы восприятия окружающей действительности и многочисленные источники информации, которые формируют картину мира. И здесь технические средства играют все более важную роль и в ряде случаев имеют определяющее значение для воспитания нового поколения. Таким образом, вопросы этики теснейшим образом связаны и включены в более глобальную проблематику – изучение социо-и техно-природной системы, изучение человека в окружении технической реальности, процессов технологической революции и глобализации.

Углубляя поиск взаимосвязей этики и технологического развития, неизбежно следует обратиться к техноэтике, которая уже примерно к 80-м годам XX века оформилась в качестве отдельного научного и исследовательского направления, в рамках которого изучались этические аспекты развития технологий, их влияние на человека и общество. Техноэтика развивается в результате слияния целого ряда дисциплин и направлений на стыке философии и прикладной этики, которые фокусируются на науке и различных отраслевых технологиях (биотехнология, нанотехнология, информатика, информационные технологии, компьютерные науки и др.) Термин “техноэтика” был введен аргентинским философом Марио Бунге для обозначения моральной ответственности технологов и ученых в про-

цессе развития цифрового научно-технического прогресса и выявления рационально-обоснованных правил управления наукой и техническим совершенствованием. По его мнению, “технолог должен нести не только техническую, но и моральную ответственность за все, что он проектирует или выполняет: его расчеты должны быть не только оптимально эффективными, но и не вредными, они должны быть полезными, причем не только в краткосрочной, но и в долгосрочной перспективе”. В целом техноэтика рассматривает морально-нравственные аспекты применительно к человеку-специалисту в техносфере. Понятие “техносфера” можно объяснить как “техноцентрический подход – результат взаимодействия между человечеством и природой; антропоцентрический подход – органопроекции человека или объективирования взаимоотношений людей в ходе их жизнедеятельности”[4].

В условиях очередного (современного) витка развития искусственного интеллекта основные дискуссии, а также научные и исследовательские материалы в области этического аспекта данной отрасли в основном концентрируются в тематическом поле, которое условно можно обозначить рамками широкого англоязычного термина “AI Ethics”. Это обусловлено появлением целого ряда уже существующих и совершенно новых морально-нравственных вызовов, дилемм и методик, которые касаются всех этапов жизненного цикла систем искусственного интеллекта, начиная от чисто философских, мировоззренческих проблем развития технологий и заканчивая сугубо практическими, связанными с применением конкретных оборудования. При этом, с учетом масштаба и потенциала воздействия технологий на общество и окружающую среду данный дискурс затрагивает практически все значимые для человека сферы – политику и социальное развитие, экономику, науку, здравоохранение образование, вопросы права и свобод граждан, экологию, защиту интеллектуальной собственности и др.

В философской литературе можно обнаружить множество самых различных попыток объяснить и значение самого термина этика, не говоря уже о разнообразии теоретических концепций и постулатов, связанных с этой дисциплиной. Очевидно, что этика, как сложное, многозначное понятие включает в себе множество пластов и может рассматриваться с различных ракурсов, использовать различные методы познания. В мире продолжается процесс поиска этических норм или принципов, как в качестве теоретической базы, так и для профильного/прикладного применения. Несмотря на большое количество формализованных этических принципов, разработчики и пользователи систем искусственного интеллекта сталкиваются с необходимостью поиска практических механизмов и решений, соответствующих ожиданиям общества. Так, возникают ситуации, когда различные принципы входят в конфликт и противоречия друг с другом, порой вызывая сложные этические дилеммы. Этические дилеммы относятся к ситуациям, в которых любой доступный выбор ведет к нарушению какого-либо принятого этического принципа, но решение все же должно быть найдено. В этой

связи к разрешению этических дилемм может быть применен подход, сочетающий в себе несколько обозначенных выше или других теорий и учитывающий конкретные обстоятельства использования систем искусственного интеллекта. При этом определяющим фактором становится идентификация рисков и всесторонняя оценка возможного ущерба для всех участников или активов, задействованных в том или ином практическом моменте. В данном случае особое значение приобретают вопросы обеспечения справедливости.

Вопросы справедливости в области искусственного интеллекта поднимают весь спектр философских, правовых и научно-практических подходов к данному понятию. В частности, в широком смысле справедливость может быть рассмотрена прежде всего как принцип права. С такого ракурса справедливость – это “важнейшая категория классической юриспруденции, прежде всего, естественного права. Попытки ее содержательной универсализации не могут быть признаны убедительными в силу множественности социальных и личностных идентичностей”[5, с.35-50]. В целом же, на практике становится очевидным, что проблемы справедливости на различных этапах жизненного цикла систем искусственного интеллекта могут быть успешно решены лишь применительно к контекстуальным условиям, то есть применительно к анализу конкретных обстоятельств использования искусственного интеллекта для решения конкретных задач.

Этические дилеммы и вопросы морального выбора продолжают быть предметом исследований философов, они вызывают научную и профессиональную полемику, особенно в парадигме активной научно-технической и социальной модернизации, в условиях поиска новых смыслов существования для современного социума. Искусственный интеллект, как технология, способная на многих сегментах деятельности заменить человека и вырабатывать рекомендательные решения на основе большого массива данных, неизбежно будет сталкиваться с необходимостью этического сопровождения и моральной оценки рисков.

Вопрос этической актуальности проблем искусственного интеллекта еще более обостряется в последние годы в связи с возникновением нанотехнологий, когда научно-изобретательские способности человека распространяются на атомарно-молекулярный уровень. Объект наноисследований – это материалы в масштабе атомов и молекул, в переводе с греческого “нано” в прямом смысле означает “очень маленький”. Одним словом, “нанотехнология – это технология, оперирующая величинами, сопоставимыми с размерами атомов, переход от широко освоенных ныне микротехнологий к нанотехнологиям. Это качественный скачок от манипуляции веществом к манипуляции отдельными молекулами и атомами” [6]. Получается, что нанотехнология работает не с веществом, а его частицами – атомами.

Нанотехнология представляет собой относительно новую область науки. Она возникла на стыке физики, химии, биологии и технических наук. С ней связаны ожидания в самых различных

областях науки и техники. Нанотехнологии рассматриваются как основа новейшей промышленной революции. Она рассматривалась сначала исключительно с точки зрения позитивной стороны научно-технического прогресса. Однако постепенно появились опасения по поводу нанотехнологических рисков, например о токсичности наночастиц. В результате возникла необходимость этической рефлексии к возможным нежелательным последствиям применения нанотехнологий.

Начало эры учения о наноструктурах следует отнести к 1959 году, когда физик, лауреат Нобелевской премии Ричард Фейнман вознес идею о возможных путях развития физики классической и квантовой, и миникомпьютерах, субмикроскопических исследованиях на уровне атомов. Тогда он заявлял о возможности получения любой вещи манипулируя атомами. Сам термин нанотехнологии введен 1974г. Японским ученым физиком Норио Танигучи для обозначения искусственно изобретенных изделий из атомов и молекул. Таким образом, нанотехнология – область фундаментальной и прикладной науки и техники на основе анализа и синтеза для производства и применения продукты путем манипулирования отдельными атомами и молекулами [7].

Резюмируя, можно сказать, что нанотехнология – одна из высокотехнологичных отраслей современной науки и техники, которая занимается исследованием атомов и молекул и созданием из них различного рода искусственных изделий. Достижения в этой области ведут к революции в медицине, электронике, искусственном интеллекте, промышленности и в других сферах человеческой деятельности. Другими словами, нанотехнология – это путь к созданию новой цивилизации с присущими ей набором ценностей и идеалов[8, с.59].

А на самом деле насколько безграничны интеллектуально-технические возможности современных компьютеров и роботов? Как свидетельствует Российский ученый физик А. А. Боровой в одном из своих интервью корреспонденту радио «Спутник», в начальный период ликвидации последствий аварии Чернобыльской АЭС в 1986г., из-за сверхвысокого уровня радиоактивности даже самые передовые роботы того времени, по образному выражению ученого «в буквальном смысле, сходили с ума», т.е. попросту говоря они потеряли свою адекватную работоспособность.

Вполне уместно, что в современной действительности все более значимым становится философская рефлексия социокультурных последствий развития нанотехнологий, выявления изменения социальных ценностей и смысла человеческой жизни. Поэтому важен анализ социокультурных последствий развития нанотехнологий, так как их познавательная мощь не только обладает положительным потенциалом, но и угрожает существованию человечества. В условиях достаточно милитаризованной техногенной цивилизации. В целом, нанотехнологии дают возможность смены технологических парадигм индустриальной эпохи и общей виртуализации социума, выделяющейся в изменении ценностных приоритетов, компьютеризации и

цифровизации всех сфер общества, вплоть до создания искусственного суперинтеллекта.

Согласно известным строкам А. С. Пушкина человеческий гений есть «парадоксов друг». А одним из причин возникновения не всегда желательных парадоксов как раз и является столкновение человека с социально-этическими и гуманистическими проблемами бытия. Почему и в силу каких причин эта проблема приобрела в прошлом и приобретает сейчас такое значение. Сегодня как подчеркивает И.Т.Фролов, чтобы дать ответ этому вопросу необходимо обратиться к тем социальным условиям, в которых происходит процесс функционирования и развития науки от которых существенно зависит. И тогда станет ясно, что человечество никогда не переживало столь ответственного и во многом определяющего дальнейшую будущность мировой цивилизации этапа, как сейчас. Историческое развитие подвело человека к такому качественному рубежу, когда НТП, рост влияния человека на природные процессы, реальная перспектива исчерпания не возобновляемых источников энергии, естественных ресурсов и ряд других факторов лишает человечество права на фатальную ошибку.

В наши дни масштабность и острота неблагоприятных последствий любых ошибочных решений, где-бы оно не принято, обретают глобальный характер. И любые расчеты, игнорирующие это - аморальны, антигуманны и бесчеловечны.[9, с.4-5]. Следовательно, вопрос нанотехнологий не просто вопрос технического прогресса, он имеет и этическое измерение. «Будучи новой отраслью научно-технического и одновременно фундаментального исследования с широкой сферой технического применения, нанотехнология как явление привлекает к себе не только инженеров, биологов, специалистов сугубо технического профиля, но и философов, порождая новые области философского исследования, - одной из которых является нанотехнологическая этика [10].

Непрерывный рост научно-технического прогресса всегда свидетельствует о том, что чуть ли не все полезные изобретения и научные разработки не только способствуют развитию и прогрессу, прежде всего в экономике, но и ставят человечество перед новыми, подчас трудно прогнозируемыми опасностями и рисками.

Таким образом, несмотря на то, что нанотехнологии находятся на этапе становления, уже сейчас их можно отнести к остроактуальным вопросам будущего наряду с вопросами о демографических или климатических изменениях. Помимо бесспорных положительных возможностей, сопутствующих прогрессу в промышленности, сельском хозяйстве, медицине, энергетике, охраны окружающей среды и других сферах человеческой деятельности, настаивает и множество опасностей. Поэтому этическая оценка достижений науки всегда остается актуальной и необходимой. Человек как разумное существо при творении любого нового механизма, в том числе и нанотехнологий выступает как творец, как хозяин и смотрит в будущее с техническим оптимизмом, сформулировав на будущее новые претензии в уверенности на господство. Однако проблема

заключается в том, что всякие новые научные разработки, в том числе и нанотехнологические в основном носят прагматический характер, где морально-этические максимы иногда отодвигаются на второй план. Например, молекулярная нанотехнология (МНТ) содержит в себе определенные угрозы для человеческой безопасности. О. В. Летов интересно трактует как прямых, так и косвенных угроз МНТ. По его мнению, прямая угроза связана, прежде всего, с процессом гонки вооружений. Использование МНТ в неблагоприятных целях способно нарушить мирное сосуществование. МНТ в принципе позволяет создавать «интеллектуальное» оружие массового уничтожения, такое как, например смертельный вирус. Производителями подобного оружия могут быть не только государства, но и группы людей [11]. Следовательно, не уделяя достаточного внимания этике нанотехнологий, невозможно гарантировать эффективного и гармоничного развития социума, достичь оптимистических результатов, предотвратить возможный вред, наносимый человеку, уменьшить риск нежелательных экономических последствий. Нанотехнологию следует развивать с учетом безопасности и с чувством ответственности. Это значит соблюдать такой этический принцип как «не навреди» с учетом рисков для здоровья, окружающей среды и безопасности. В рамках общей безопасности особое место занимают проблемы нравственной безопасности при создании и использовании нанотехнологий. На сегодня она явно очевидно в военной, медицинской, экологической, интеллектуальной областях. К сожалению, из мировой практики известно, что исследования по безопасности нанотехнологий существенно отстают от их разработки и практической реализации.

Технологии, когда бы они не создавались на каждом конкретном историческом отрезке времени имеют прежде всего прогрессивную направленность. Однако, как отметил Ф. Энгельс каждая вещь и каждый процесс сами по себе внутренне противоречивы [12, с.579-580]. В научно-техническом прогрессе также каждый новый этап первоначально заявляет только одни преимущества. Но затем вторые и третьи производные, т.е. отдельные конкретные последствия, могут оказаться негативными. Не надо забывать, что «в любом проявляющемся как добро явлении зло заключается уже в том, что при всей положительности оно таит в себе момент превращения в зло» [13, с.81]. Это можно иллюстрировать на примере освоения ядерной энергетики или применения геномодифицированных элементов в пищевом производстве. Значит, в процессе внедрения нанотехнологий и наноматериалов принцип предосторожности должен занимать не последнее место.

Вышеизложенное дает возможность резюмировать, что этические вопросы науки и техники постоянно сопровождаются с новыми вызовами развития общества. В связи с широкой междисциплинарностью и междисциплинарностью современной

науки на уровне нанонауки и нанотехнологий, этика науки и искусственного интеллекта охватывает достаточно широкий круг проблем и многие ее вопросы неотрывно связаны с иными контекстами этической рефлексии. Потому что, этический аспект науки тесно связан «как с развитием самой науки, так и с её взаимодействием с обществом. Так или иначе трактовка науки в значительной степени и определяет характер постановки её этических вопросов» [9]. Следовательно, все вопросы научно-технической этики крайне важны. Это связано с тем, что динамика достижений науки и техники год от года возрастает. В связи с этим актуализируется важность своевременной адекватной реакции на возможные негативные последствия научно-технического прогресса.

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# TECHNICAL SCIENCES

## AUTOMATED BIOGAS PLANT CONTROL SYSTEM

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## АВТОМАТИЗОВАНА СИСТЕМА КЕРУВАННЯ БІОГАЗОВОЇ УСТАНОВКИ

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### Abstract

The analysis of the automated control system of a biogas plant based on food industry waste is presented. The biogas production technology is analyzed and described and the optimal fermentation mode is selected. The structure of the automatic control system is provided and a functional diagram of the biogas plant automation is developed.

### Анотація

Наведено аналіз автоматизованої системи керування біогазової установки на відходах харчової промисловості. Проаналізовано та описано технологію виробництва біогазу та обрано оптимальний режим бродіння. Надана структура системи автоматичного регулювання та розроблено функціональну схему автоматизації біогазової станції.

**Keywords:** technological control object, automated control system, automatic regulation system, functional automation system, biogas.

**Ключові слова:** технологічний об'єкт керування, автоматизована система керування, система автоматичного регулювання, функціональна система автоматизації, біогаз.

В умовах сьогодення актуальною є проблема гострої нехватки енергетичних ресурсів. Відновлювані джерела енергії відіграють надзвичайно важливу роль в енергетиці багатьох країн світу.

Виробництво біогазу є рішенням одночасно двох питань: енергетичного та екологічного. В процесі роботи підприємств харчової та переробної промисловості накопичується велика кількість відходів, що створюють надзвичайно небезпечну екологічну проблему. Переробка вторинних матеріальних ресурсів надає унікальну можливість отримання біогазу та суттєво знижує екологічні ризики на підприємстві. Після виробництва біогазу утворюється кормова біомаса, збагачена незамінними амінокислотами та вітамінами групи В, яку можна використовувати в якості кормової добавки при відгодівлі сільськогосподарських тварин [5,8].

Головною перевагою виробництва біогазу є універсальність сировинної бази. Станції можуть перероблювати органічні відходи, незважаючи на тип або особливі характеристики, завдяки підбору відповідного технологічного рішення під конкретні вимоги сировини.

Принцип роботи всіх біогазових установок однаковий: після попередньої підготовки сировини, що полягає у доведенні її до потрібної вологості у спеціальній ємності, вона подається в реактор, де створюються спеціальні умови оптимізації процесу утворення біогазу.

Вміст чистого метану в біогазу може складати від 70 до 90%, в залежності від типу утилізованих відходів.

Теплотворна здатність одного кубометра біогазу становить залежить від вмісту метану та становить 20-25 МДж/м<sup>3</sup>, що еквівалентно згорянню 0,6 – 0,8 літру бензину; 1,3 - 1,7 кг дров або використання 5 - 7 кВт електроенергії [2,4].

Для аналізу та розрахунку технологічних об'єктів керування необхідно мати автоматизовану математичну модель метантенка. Отримання математичної моделі об'єкта управління відповідно до реалізації його вхідних та вихідних сигналів є його ідентифікацією.

Рівняння з автоматичним визначенням температури метантенку можна отримати, використовуючи закони фізики, які закладено в основу роботи ферментатора. Зазвичай, точний теоретичний опис об'єкта керування дуже важко визначити через складність перебігу фізичних процесів. Тому, на практиці математичний опис зазвичай отримують експериментальними методами з використанням алгоритму автоматизації процесу. Автоматизація процесу надає унікальну можливість точно та легко отримати результат. З математичними моделями, що отримані з використанням автоматизованих систем управління процесом можна проводити подальші удосконалення технологічної схеми переробки відходів та отримання біогазу [4,7,10].

В автоматичних системах керування біогазової установки регулюється температура середовища, вологість біомаси та кислотність субстрату.

Для належного функціонування та з метою забезпечення максимального виходу біогазу важливою умовою є вибір оптимального режиму зброджування субстрату. У даній системі використовується принцип управління за відхиленням від заданого значення, задані параметри автоматично вимірюються за допомогою датчика температури. Керування відбувається залежно від різниці між значеннями величини, що виходить і величини, що задається. Вихідний сигнал порівнюється із завданням, програмований логічний контролер опрацьовує інформацію і на основі отриманого результату надає відповідні сигнали на механізм виконання програми. Управління відбувається залежно від значення різниці величин і може враховувати будь-які впливи на систему керування [3,7].

Для створення системи автоматизації, в якості основи було обрано найкращий у своєму класі за можливостями масштабування, екологічності та енергозбереження автоматичний контролер від Scheinder Electric Modicon M172P. Він відноситься до серії логічних програмних контролерів, що призначені саме для автоматизації промислових об'єктів.

Серія Modicon M172P відрізняється високою адаптивністю за рахунок модульної конструкції, що включає в себе модулі розширення вводу/виводу, інтерфейси для комунікації, вбудовану підтримку Ethernet, ModBus, BACnet та LonWorks, великий асортимент програмного забезпечення, що економлять час для налагоджування та програмування системи [7,8].

Рішення автоматизації промислової схеми на базі цього контролера дає можливість використання програмного засобу SoMachine HVAC, який є інструментом для візуалізації, програмування та автоматичного налаштування контролерів цієї серії. SolMachine HVAC надає готові до використання функціональні блоки, що створює можливість формування сучасними алгоритмами для енергоефективних рішень на базі Modicon M172P. Пристрої Modicon M172P розраховані для роботи метантенка як у мезофільному ( $T=35^{\circ}\text{C}$ ), так і у термофільному ( $T=55^{\circ}\text{C}$ ).

Всі вищезначені функції забезпечують автоматичний дистанційний контроль та управління технологічною системою отримання біогазу.

Сучасні системи автоматизації виробництва є чітко розподіленими системами управління, в яких керовані об'єкти та пристрої приєднують до промислової інформаційної шини та завдяки сучасним програмам відбувається процес керування об'єктами.

Для аналізу систем автоматизації біогазових установок необхідно мати математичну модель об'єкта керування. Отримання математичної моделі об'єкта управління відповідно до реалізації його вхідних та вихідних сигналів є його ідентифікацією. Рівняння температури біогазових станцій

теоретично можна отримати на основі деяких фізичних законів, якими описується його робота. У більшості випадків точний теоретичний опис об'єкта керування дуже важко визначити через складність перебігу фізичних процесів в умовах постійної зміни параметрів. Тому, на практиці математичний опис зазвичай отримують експериментальними методами. Ці методи дають можливість швидко та зручно отримати результат, спрямований на оптимальний вибір систем автоматизації процесу. Математичні моделі, що отримані за допомогою цих методів, дозволяють спрогнозувати оптимальні параметри отримання біогазу з подальшим використанням їх на етапах розробки систем автоматизації. Біогазові установки мають проектуватися з урахуванням забезпеченості умов функціонування технологічних процесів в заданих робочих галузях контролю змінних параметрів. У зв'язку з цим, експериментальні методи отримання математичних моделей широко застосовуються під час автоматизації технологічних процесів [2,5].

В автоматизованих системах керування біогазової станції регулюються температура у метантенку, вологість біомаси у резервуарах та кислотність субстрату. Для належного функціонування та збільшення продуктивності біогазової установки важливою умовою є підтримання заданої температури.

У досліджуваній системі використовується принцип управління, побудований за методом відхилення від заданого значення та вимірювання за допомогою датчика температури. Управління системою відбувається залежно від різниці між значеннями величини, що є вихідною і величини, що задається. Найважливішим аспектом у процесі є найменша значимість відхилення режиму роботи біореактора. Вихідний сигнал порівнюється з завданням, а програмований логічний контролер опрацьовує інформацію. На основі отриманого результату надаються відповідні сигнали на виконавчий механізм. Управління системою відбувається у залежності від значення різниці величин, з урахуванням будь-якого впливу на процес керування [2,5,10].

Стабільність конструкції метантенка необхідна для витримування всіх навантажень (тиску газу, ваги та тиску сировини, ваги покриттів) та забезпечення довготривалої роботи установки. Контрольно-вимірювальні прилади, що встановлюються, повинні забезпечувати контроль рівня сировини, температури, тиску та сталий кислотнolужний баланс у реакторі [4,9].

При використанні автоматизованих систем управління можна спрогнозувати та контролювати наступні параметри автоматизації процесу:

- рівень біомаси на всіх етапах виробництва – вимірюється дискретним датчиком, вхідна напруга якого дорівнює 24 В постійного струму;
- вологість і температура субстрату – вимірюється датчиком температури і вологості, що має клас точності 0.25, діапазон вимірювання температури ( $-20\ldots 80$ )  $^{\circ}\text{C}$  з підключенням до інтерфейсу RS-485;

- витрати води, що надходить до подрібнювача - контролюються вихроакустичним витратоміром з вихідним сигналом 4...20мА та класом точності 0.25, може працювати по HART-протоколу та має діапазон вимірювання (5...60) м<sup>3</sup>/год;

- температура субстрату вимірюється термперетворювачем опору з вихідним сигналом 4...20мА, класом точності 0.5, діапазоном вимірювання (0...100) °С;

- тиск біогазу у газгольдері і трубі – контролюються датчиками тиску однієї моделі різних діапазонів вимірювання, що має клас точності 0.5, вихідний сигнал 4...20мА, діапазон вимірювання датчика тиску біогазу у трубі – (0...40);

- показники якості біогазу - надходять від аналізатора біогазу з вихідним сигналом 4...20мА, класом точності 0.2. Діапазон вимірювання вмісту метану та вуглекислого газу (CH<sub>4</sub> та CO<sub>2</sub>) становить (0...100) % [1,4,6].

Сучасні системи автоматизації процесу отримання біогазу - це розподілені системи управління, в яких керовані об'єкти та пристрої працюють автономно, з приєднанням до промислової шини інформації, через яку, завдяки вдосконаленим програмам, відбувається керування об'єктами. Автоматизовані системи керування є дворівневими. На верхньому рівні відбувається контроль параметрів біогазової установки, забезпечується зв'язок з нижнім рівнем з метою збору даних, візуалізації та диспетчеризації технологічного процесу. Це рівень HMI/SCADA. На цьому рівні задіяна людина, а саме – оператор-технолог (диспетчер), головна мета якого – забезпечення безвідмовної роботи системи автоматизації та оптимізація роботи обладнання. SCADA відноситься до систем, що розроблені в середовищі Easergy L500, яка є базовою системою SCADA, що працює на операційній системі Windows. Система забезпечує зрозумілий інтерфейс для оператора: загальний вид біогазової станції, відображення підстанції, перегляд журналу повідомлень та журнал архіву [2,3].

Застосування ефективної автоматизованої системи управління забезпечує стабільний економічний ефект на підприємстві з отриманням додаткового прибутку. Автоматизація підприємств видобутку біогазу відіграє важливу роль в системі забезпечення альтернативними джерелами енергії промислових підприємств та населення [6,8,9]. Система автоматизації спонукає до вирішення екологічних проблем підприємства в умовах впровадження автоматизованих систем керування, систем контролю, робото-технологічних комплексів та комп'ютерно-інтегрованих виробництв. Системи автоматизації ґрунтуються на функціональних можливостях мікропроцесорних систем керування з використанням принципів адаптації, самоорганізації, розподіленого керування та програмних комплексів. Сучасні автоматизовані системи управління виробництва біогазу та програмні засоби мікропроцесорної техніки мають функціональні можливості для керування технологічними процесами при організації автоматизованих робочих місць. Додаткове впровадження та функціонування

програмно-технічних комплексів обчислювальної техніки для керування технологічними процесами утилізації відходів та надає можливість підприємству працювати в оптимальному режимі [1,2]. Використання програмно-керованого комплексу з впровадженням автоматизованих систем управління спрощує адаптацію інноваційних технологій до зміни умов виробництва. Цей процес робить реальним еволюційне удосконалення виробництва технологічними процесами, в основному, за рахунок зміни програмного забезпечення. Одним із головних аспектів, що спонукають до створення та розробки автоматизації технологічних процесів, є удосконалення технології обчислювальних процедур обробки інформації при одночасному розширенні їх функціональних можливостей та підвищення надійності, що економічно стимулює розробку технологічного обладнання з вбудованими системами керування і технологічними комплексами [4,6]. Проблеми використання програмно-технічного комплексу автоматичних систем управління переробки відходів з отриманням біогазу, мікропроцесорів, інтелектуальних датчиків та виконавчих механізмів, адаптивних регуляторів та систем керування повинні бути вирішені інноваційними технологіями з використанням автоматизації технологічних об'єктів. При цьому на підприємстві повинен бути врахований рівень автоматизації виробництва та складено вхідні умови до систем керування технологічними об'єктами та процесами.

Для розробки та впровадження систем керування типовими технологічними процесами переробки відходів з метою отримання біогазу, необхідні знання принципів їх побудови та тенденцій розвитку; освоєння методів діагностики технологічних об'єктів керування; розробка і використання моделей та алгоритмів керування функціональними схемами з використанням комп'ютерних нейронних комплексів та принципів роботи інтелектуальних підприємств.

Для вирішення вищезначених завдань можна використовувати:

- фундаментальні методи аналізу керованості та гнучкості автоматизованих процесів;

- теорію цифрових систем, теоретичні основи адаптивних систем, теорію нечітких множин і методи прийняття інтелектуальних рішень в умовах невизначеності;

- методи експертних систем в задачах управління харчовими підприємствами, принципи інтелектуального керування гнучкими виробничими системами з робото-технологічними комплексами.

Це дозволяє цілеспрямоване використання основних принципів побудови автоматичних систем керування виробництва біогазу та локальних мікропроцесорних систем автоматизації складних динамічних алгоритмів утилізації відходів.[1,3,7].

Підхід до управління виробництвом з використанням систем автоматизації дозволяє отримати принципово нову, інноваційну модель підприємства з автоматизованим центром дій, в якому кадровий потенціал ставить визначені цілі синхронно з

об'єктами виробництва, використовуючи при цьому матеріальний потенціал підприємства [5,9].

Головною метою сучасної комп'ютеризованої автоматизації виробництва підприємства харчової промисловості є створення систем контролю та інформаційного забезпечення з автоматизованим керуванням інноваційними технологічними процесами і засобами виробництва, які виключають «людський фактор» в роботі біогазового комплексу. Для вирішення такого завдання є необхідним знання виробництва, його технологій, а найголовніше - знання технічних засобів автоматизації виробництва, принципів і методів керування локальними виробничими системами та окремими ланками, технологічними лініями та розподіленого управління підприємством по виробництву біогазу в цілому.

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## THE USE OF DATA ANALYSIS TO ANALYZE EDUCATION TRENDS IN AZERBAIJAN

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<https://doi.org/10.5281/zenodo.15536101>**Abstract**

In recent years, the importance of understanding educational trends has significantly increased, especially in developing countries like Azerbaijan. This study focuses on using data analysis methods to examine and predict changes in the field of education. The aim is to analyze educational datasets and identify key indicators that reflect long-term trends, such as student enrollment rates, graduation statistics, and public spending on education. Using Python-based tools and time series forecasting models, this research explores how these indicators change over time and what they suggest about the future of education in Azerbaijan. The study also applies statistical models such as linear regression and autoregressive models to perform trend analysis and generate forecasts. The findings of this study can help policymakers, educators, and institutions make data-driven decisions to improve the quality and accessibility of education.

**Keywords:** Education Trends, Data Analysis, Time Series Forecasting, ARIMA, Autoregressive Models, Stationarity

**Introduction**

In today's rapidly evolving global landscape, education has become a cornerstone for national development, especially in emerging economies such as Azerbaijan. Understanding the dynamics and trends within the education sector is crucial for shaping policy, allocating resources effectively, and forecasting future needs [1].

In recent years, the role of data analysis in education has grown significantly, enabling institutions and governments to make informed, evidence-based decisions [2]. Time series forecasting models such as Autoregressive (AR), Integrated (I), and Moving Average (MA) components have been successfully applied in multiple domains, including education and economics [3].

This study focuses on analyzing long-term education trends in Azerbaijan using data-driven techniques. By leveraging historical datasets on higher education enrollment, we aim to uncover key patterns and predict future student admission numbers. Through the application of time series forecasting methods—namely, autoregressive (AR), differenced autoregressive (stationary AR), and ARIMA models—we intend to evaluate the accuracy and reliability of various forecasting approaches.

By incorporating programming tools such as Python and libraries including pandas, statsmodels, and matplotlib, the study demonstrates how modern data science methods can be used not only to visualize educational trends but also to generate actionable insights for policymakers and academic institutions [4].

**Dataset Description**

The dataset used in this study comprises the number of students admitted to higher education institutions in Azerbaijan, covering the academic years from 2000/2001 to 2023/2024. The data was obtained from the official website of the State Statistical Committee of the Republic of Azerbaijan (stat.gov.az) and includes annual admission figures for both public and private

universities [5]. However, due to missing data for the academic years 2001/2002 through 2004/2005, linear interpolation was employed to estimate the absent values. This preprocessing step was crucial to ensure continuity in the time series, a requirement for building accurate and consistent forecasting models.

The final dataset consists of 24 academic years, structured in two columns: **Year**, which records the academic year in the format YYYY/YYYY+1, and **Admissions**, which indicates the number of students admitted to bachelor's programs. The cleaned and interpolated dataset was saved in an Excel file and served as the foundational input for all forecasting models used in this research. A sample view of the dataset is presented below.

| Year      | Admissions |
|-----------|------------|
| 2000/2001 | 26,403     |
| 2001/2002 | 27,575     |
| 2002/2003 | 28,747     |
| ...       | ...        |
| 2023/2024 | 52,880     |

All values are rounded to the nearest whole number, and the data structure is suitable for applying time series forecasting models using Python.

**Methodology**

To forecast future student admissions in Azerbaijan, we utilized three distinct time series models. First, we applied an Autoregressive (AR) model to the original non-stationary data. Next, we implemented another AR model, this time using stationary data obtained through differencing. Finally, we employed the ARIMA (Autoregressive Integrated Moving Average) model, which combines both autoregressive and moving average components along with differencing to handle non-stationarity [1][2].

All models were implemented in Python using pandas for data manipulation, statsmodels for statistical modeling, and matplotlib for visualization [4]. Forecasts were generated for two future academic years: **2024/2025** and **2025/2026**.

**AR Model on Non-Stationary Data:** The autoregressive model (AR) uses past values of a time series to predict future values. The non-stationary version of this model was applied directly to the raw admissions data, without transforming it to achieve stationarity. A lag of 3 was selected based on preliminary testing, which means the model uses the previous three years of data to predict the next value [2]. Model equation:

$$Y_t = c + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \phi_3 Y_{t-3} + \epsilon_{ta}$$

**AR Model on Stationary Data (Differencing):** Since the original admissions data exhibited a clear upward trend, we applied first-order differencing to transform the series into a stationary form, which is a common requirement for many time series models [1][3]. After differencing, the same AR(3) model was applied to the transformed data. The different forecasts were then added cumulatively to the last known admission value to obtain the predicted future values.

**ARIMA Model:** The ARIMA model integrates three key components to effectively model time series data. The **Autoregression (AR)** component utilizes lagged values of the variable to capture temporal dependencies. The **Integration (I)** component applies differencing to the data to achieve stationarity, which is essential for accurate forecasting. Lastly, the **Moving Average (MA)** component incorporates past forecast errors to refine predictions and improve model accuracy [3].

For this study, we used an **ARIMA(1,1,0)** configuration based on data behavior and model performance. This setting includes first-order differencing and one autoregressive term. Each model was trained separately

and saved using joblib, and a unified forecast\_and\_plot() function was used to load the models, generate forecasts, and visualize results. All source code used in this study, including data preprocessing, model training, and visualization, is publicly available on GitHub:

<https://github.com/HesenIsmayilov44/education-trend-analysis-azerbaijan.git> (Accessed on May 2025)

### Results And Forecasting

Each of the three forecasting models was trained using the interpolated dataset covering the years 2000/2001 to 2023/2024. The goal was to predict the number of students expected to be admitted to higher education in Azerbaijan for the academic years **2024/2025** and **2025/2026**.

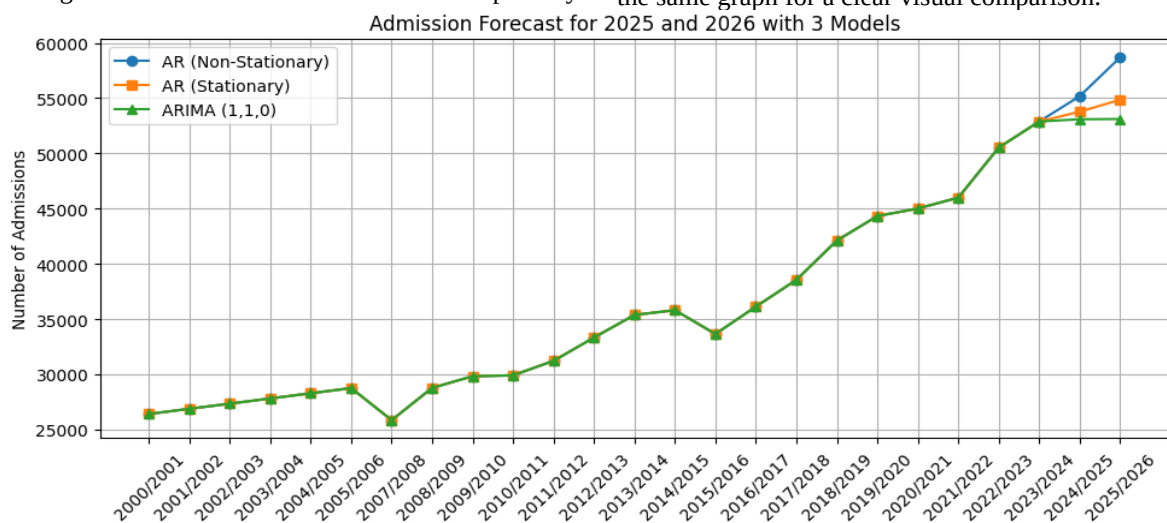
#### Forecasted Values

| Model           | 2024/2025 | 2025/2026 |
|-----------------|-----------|-----------|
| AR              | 55,169    | 58,687    |
| AR (Stationary) | 53,765    | 54,853    |
| ARIMA           | 53,087    | 53,106    |

The AR (non-stationary) model generated a more aggressive upward forecast, extending the recent increasing trend in student admissions. In contrast, the AR model applied to stationary (differenced) data produced a more conservative projection, stabilizing the growth rate. The ARIMA model indicated a modest increase, likely due to the influence of its moving average and differencing components, which help moderate sharp fluctuations in the data.

### Visualization

The following chart presents all three models on the same graph for a clear visual comparison:



In the comparative visualization, the x-axis represents academic years, while the y-axis displays the number of admitted students. For each model, two forecast years are appended at the end of the original dataset to illustrate the projected values. This side-by-side comparison highlights both the trend and the range of predictions generated by each approach. Despite differences in methodology, all models consistently indicate a continued growth in student admissions.

### Discussion

The results from the three time series models provide valuable insights into the possible future of student

admissions in Azerbaijan. Each model captures different aspects of the dataset, and together, they offer a comprehensive understanding of trend behavior and model reliability.

### Model Comparison

**AR (Non-Stationary)** This model directly uses the raw data without transformation. It performs well in capturing existing upward trends but may overfit in the presence of structural breaks or long-term noise. Its forecasts suggest a sharp increase in future admissions, which may be realistic if growth continues as in the past, but it lacks resistance to anomalies.

**AR (Stationary)** By differencing the data first, this model removes trend and seasonality, allowing for more stable predictions. Its results are more conservative and arguably more reliable over longer horizons. This model is suitable when the assumption is that growth will slow down or stabilize over time.

**ARIMA (1,1,0)** Combining autoregression and differencing, this model finds a balance between stability and adaptability. Its forecasts indicate moderate, steady growth. ARIMA is particularly suitable when the data shows both trend and short-term fluctuation, as it captures both long-term direction and local variations.

#### Interpretation in Educational Context

From a policy perspective, even the most conservative model—the ARIMA model—predicts a continued increase in higher education admissions. This trend implies a growing demand for university infrastructure, faculty, and academic programs, highlighting the need for improved funding and strategic planning within the education sector. It also suggests potential pressure on student services, dormitory capacities, and the employment market following graduation. Furthermore, the models offer a solid foundation for expanding the analysis by incorporating external variables such as population size, economic indicators, or government education policies, which could provide a more comprehensive understanding of the factors influencing student admissions.

#### Conclusion

This study explored the application of time series forecasting techniques to predict future trends in higher education admissions in Azerbaijan. Using historical data from 2000/2001 to 2023/2024, we implemented and compared three models: AR (non-stationary), AR (stationary), and ARIMA. The findings from all three models consistently indicated continued growth in the number of students entering higher education over the next two academic years. While the AR model projected a more aggressive increase, the ARIMA and stationary AR models provided more moderate and conservative forecasts.

From a strategic standpoint, the results of this study can assist educational policymakers in anticipating future demand for university seats, enabling more efficient allocation of educational resources. The insights also support informed decision-making regarding admissions quotas and academic staffing, ensuring that institutions are better prepared to accommodate projected growth in student numbers. In addition, the study demonstrated the importance of data preprocessing (e.g., interpolation and differencing) and model selection in ensuring reliable forecasts.

#### Future Work

Future enhancements to this research may involve incorporating exogenous variables such as population growth, migration trends, or government funding levels through the use of ARIMAX or machine learning models. Expanding the forecast horizon beyond 2026 could provide a longer-term perspective on admissions trends. Additionally, applying ensemble or hybrid modeling approaches may improve forecast accuracy. Ultimately, this study underscores the value of data-driven analysis in supporting forward-looking, evidence-based decision-making within the education sector.

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## MODULS OF SUBGRADE REACTION WITH DIFFERENT NORMS

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**Abstract**

The paper discusses the model of the interaction of the building and the soil (foundation) under static loads and their joint work determines the stressed-deformed state of the structure. The calculation was carried out using the computer software complex “LIRA SAPR 2024”, which is based on the finite element method. The calculation was carried out with the building stiffness varying (the thickness of the foundation slab varies), and various methods of calculation for a flexible foundation were also used. The results obtained were analyzed. In the examples considered in the paper, various construction numbers and rules (“SP22.13330.2011/2016”, “SP 50-101-2004”, “DBN B.2.1-10:2009”, “SNIP 2.02.01.-83”). The calculation was carried out using the computer software complex “LIRA SAPR 2024”, which is based on the finite element method “FEM”.

**Keywords:** Coefficient of Subgrade Reaction, Elastic foundation.

**Introduction**

The types of soil have a significant impact on the stressed-deformed state of a building. Correctly defined and maximally approximated accurate modeling of the influence of the interaction of the foundation and soil allows us to make the building more reliable and more economical. Due to the fact that the soil is heterogeneous, anisotropic, and determining its physical and mechanical properties is a difficult task, taking into account these reasons, it is not possible to accurately describe the real state of the soil and the superstructure, taking into account the interaction of the superstructure on the stressed-deformed state of the building, using current methods. The paper discusses three different methods for calculating coefficient of subgrade reaction and their impact on vertical deformations of the foundation (beams) taking into account various construction standards (“SP22.13330.2011/2016”, “SP 50-101-2004”, “DBN B.2.1-10:2009”, “SNIP 2.02.01.-83”).

**Modeling****Calculation using the linearly deformable half-space method**

The software complex “LIRA SAPR” uses three methods for determining the subgrade coefficient:

**The first method:** according to the first method subgrade coefficient is calculated according to the Poisson's ratio and flexibility module of average importance.

Subgrade reaction is calculated with the following

$$\text{formula: } C_1 = \frac{E_{zp}}{H_c(1-2m_{zp}^2)} \quad (1).$$

**The second method:** subgrade reaction is calculated by this method by using the Winkler foundation:

$$C_1 = \frac{q}{S} \quad (2), \text{ where } q = \frac{P}{\eta b^2} \text{ is the average pressure}$$

on the foundation bottom.  $b$  – Minimal size of the foundation;  $\eta$  - ratio of the maximal side of the foundation with the minimal one;  $S$  – foundation closure;

**The third method:** for determining the subgrade reaction in the third method one uses formula of the first method (3). Difference among these methods is that for determining the module of the average deformation of ground one uses the coefficient correcting the module of the average deformation of ground. This coefficient is changed  $u_1 = 1$  from the benchmark of the foundation bottom  $u_1 = 12$  up to  $H_c$  limit of the active zone (before finishing the compressed zone).

$$u = \frac{11z^2}{H_c^2} + 1 \quad (3). \quad C_2 - \text{Subgrade reaction for all}$$

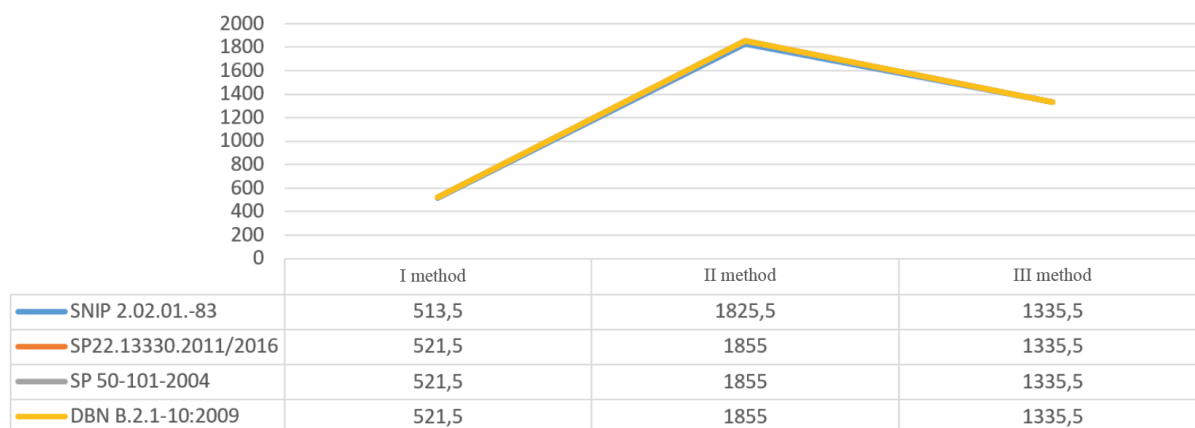
three methods is calculated by one common formula:

$$C_2 = \frac{C_1 H_c^2 (1 - 2m_{zp})}{6(1 - m_{zp})} \quad (4).$$

In the used computer program, coefficient of subgrade reaction is carried out in two variants: the averaged method and according to the soil modeling. In both cases, the calculation is carried out using all three methods of coefficient of subgrade reaction mentioned above. In our case, the soil model variant is used, since it more accurately reflects the interaction of the grout and the foundation in different situations, since each finite element has a different coefficient of subgrade reaction. The modulus of elasticity of the concrete of the foundation slab  $E_f = 30000000 \text{ t/m}^2$ , the volumetric weight of reinforced concrete  $2.5 \text{ t/m}^2$ , the size of the foundation slab  $A \times B = 5 \times 5 \text{ m}$ . The load on the foundation slab is  $50 \text{ t/m}^2$ . The modulus of elasticity of the soil  $E_s = 3000 \text{ t/m}^2$ , the volumetric weight of the soil  $2.0 \text{ t/m}^2$ , Poisson's ratio  $0.3$

|                      | coefficient of subgrade reaction C1, t/m2 |          |          |          | Settlement (mm) |          |          |
|----------------------|-------------------------------------------|----------|----------|----------|-----------------|----------|----------|
|                      |                                           | method 1 | method 2 | method 3 | method 1        | method 2 | method 3 |
| SNIP 2.02.01.-83     | Min.                                      | 466      | 900      | 1211     | 18              | 18       | 7        |
|                      | Max.                                      | 561      | 2751     | 1460     | 55              | 55       | 29       |
| SP22.13330.2011/2016 | Min.                                      | 473      | 915      | 1211     | 17              | 17       | 7.7      |
|                      | Max.                                      | 570      | 2795     | 1460     | 54              | 54       | 29.7     |
| SP 50-101-2004       | Min.                                      | 473      | 915      | 1211     | 17.8            | 17.8     | 7.74     |
|                      | Max.                                      | 570      | 2795     | 1460     | 54.6            | 54.6     | 29.76    |
| DBN B.2.1-10:2009    | Min.                                      | 473      | 915      | 1211     | 17.88           | 17.88    | 7.74     |
|                      | Max.                                      | 570      | 2795     | 1460     | 54.61           | 54.61    | 29.76    |

coefficient of subgrade reaction (Max. values)



Calculation of Coefficient of Subgrade Reaction

### Conclusions

In all three methods, an increase in the stiffness of the building (the thickness of the foundation slab) leads to an increase in the stresses, while the stresses in both the foundation slab and the columns are different. In the case of the first method, an increase in the thickness of the foundation slab leads to a decrease in the stresses, both in the foundation and in the columns, while in the second and third methods, the bending moments in the foundation slab increase, and in the columns, like the first, decrease.

As the calculation shows, the values of the sag coefficients calculated by different methods differ from each other by approximately 30-50%.

According to the norms given in the calculation program used, the difference in winning coefficients is insignificant.

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**OPTIMIZATION OF MATERIAL SELECTION IN GUN BARREL PRODUCTION WITH ARTIFICIAL INTELLIGENCE****Nasirov N.,***PhD Candidate, PhD, Azerbaijan Technical University,  
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<https://doi.org/10.5281/zenodo.15536103>***Abstract**

Choice of gun barrel material is the secret to the provision of cost-effectiveness, performance, and structural integrity in gun manufacturing. This study discusses the application of artificial neural networks (ANNs) for the evaluation of the matching compatibility of materials against major attributes such as fatigue life, yield strength, heat resistance, and wear resistance. Quantitative values were found for steel alloys and titanium with yield strength ranging from 750 MPa to 1300 MPa, fatigue resistance ranging from 0.75 to 0.92, thermal conductivity ranging from 18 W/mK to 50 W/mK, and wear resistance indices ranging from 0.75 to 0.95. The ANN model was trained on a database of 100 material samples and achieved a mean absolute error (MAE) of 3.2% in terms of predicting suitability scores. The model's architecture consisted of two hidden layers of 32 and 16 neurons, respectively, with ReLU activation and Adam optimization. The ANN-based approach was high in predictive accuracy in classifying top material selections for gun barrel manufacturing, encompassing a systematic and data-driven approach towards material selection. These findings confirm that ANNs can optimize material selection processes effectively, reduce production costs, and enable maximum manufacturing efficiency in defense production.

**Keywords:** artificial neural network, material selection, gun barrel, optimization, machine learning.

**1. Introduction**

Gun barrels play a fundamental role in the operation of firearms and artillery equipment, as they are tasked with precisely guiding projectiles under extremely adverse conditions of temperature, pressure, and mechanical stress. Gun barrels must operate under extremely harsh operating conditions without failure. The structural performance and integrity of gun barrels are extremely critical in terms of accuracy, life, and safety in military as well as civilian applications. These components experience extreme stress when they are discharged, so the selection of their material is highly essential. Gun barrel materials selection is extremely vital in determining their service life, ballistic precision, resistance to wear, and environmental hardness [1]. The fact that such materials must meet present demands necessitates subjecting them to thorough investigation and examination. Continuous improvement in gun barrel materials is driven by evolutionary military encounters and law enforcement requirements. Materials undergo rigorous testing to ensure they can endure a series of battlefield environments without collapsing prematurely. Moreover, new threats and technological advancements necessitate the development of new alloys superior to standard materials [2].

Gun barrel design is a sophisticated process that entails the balance of a number of parameters, including the mechanical behavior, thermal expansion, and fatigue resistance. Barrel weight is also an important parameter since it directly affects weapon mobility and handling [3]. Computational techniques have facilitated

the design of optimized barrel profiles that enhance ballistic performance while minimizing weight. Heat dissipation is also a critical factor since high temperatures lead to structure weakening and accuracy loss. Thermal coatings and high-performance alloys are employed to mitigate such effects [4].

This evolution process has, in the past, been driven by empirical practice, metallurgical testing, and limited computation modeling. Though these methods have managed to create successful materials, they have consistently failed to keep up with the complexities of current defense needs, particularly since the speed of technology calls for increased levels of fire, improved accuracy, and increased resistance to wear and environmental attack [5]. While traditional techniques have laid the foundation for material selection, they fail to adequately counter the dynamic and evolving nature of military operations. The growing demand for rapid material evaluation points towards the necessity of integrating advanced analytical methodologies into material selection. Advances in military technology increase the demand for advanced materials with enhanced performance [6]. The capability to forecast how materials would perform under conditions of real-time war continues to be an important objective in gun engineering.

Traditional materials such as chromium steel, stainless steel, and titanium alloys are extensively used in the manufacture of gun barrels due to their tensile strength, thermal stability, and corrosion as well as wear resistance. These materials have proved to be reliable in firearms ranging from small arms to heavy

guns. However, with increased complexity in defense and military usage, there is a growing need for materials that perform better than these conventional options [7]. With the modern battlefield conditions necessitating increased ruggedness, reduced weight, and functionality at extreme conditions, the limitations of existing materials are more obvious. Material strength over barrel weight is a central design issue in firearms. Engineers must continue to optimize the process of material selection to balance these conflicting demands. The design of materials that possess high strength but reduced weight remains a persistent challenge in defense engineering. The novel formulations of materials must also remain economical and reproducible to mass-produce [8].

The development of composite materials, advanced alloys, and nanostructured metal provides new prospects for improving gun barrel performance. New materials can provide the potential advantages of reduced weight, improved heat transfer, and increased erosion and fatigue resistance. Application of these new materials has the potential to significantly enhance performance. But selection and testing of these types of materials are challenging due to the fact that the factors influencing their performance are extremely large. Selection of optimum material properties is a multi-factor analysis approach capable of predicting performance in actual conditions. Material availability, ease of manufacturing, and ultimate long-term durability must be considered by the engineers [9]. With new material developments ongoing, continuous research and refinement of selection techniques are required. Lacking robust test techniques, no one can determine which materials will have the best performance under realistic combat environments. Integrating AI-based simulations into material testing offers insights that traditional methodologies often overlook.

Conventional approaches to material selection used in gun barrel manufacturing tend to utilize large-scale testing, expert knowledge, and trial-and-error iterative improvements [10]. A process that is time- and resource-consumption intensive, costly, and constrained by human experience that could not even remotely approximate the complex interaction among numerous properties of materials exists. Further, such conventional material testing operations are resource-consumption intensive and cause production cycle inefficiencies [11]. The recursive nature of these processes is apt to slow innovation and limit explorations of other materials that might yield better performance attributes. Traditional methods tend to struggle with the complexities of modern defense requirements. With changing military specifications, exclusive reliance on conventional test methods can retard development. Intelligent data-driven approaches accelerate the development of next-generation firearm materials [12].

AI-powered material selection offers several benefits in material fatigue analysis and failure rate prediction. With the use of deep learning algorithms, organizations can develop models of prediction that analyze long-term durability under a variety of

operating conditions [13]. This capability enhances the effectiveness of material R&D. AI integrates real-time feedback from on-site testing to generate insights for incremental improvement of material selection methodology. These advancements result in the manufacture of more durable, cost-effective, and longer-lasting barrels [14].

In addition, traditional techniques struggle to handle giant datasets efficiently or simulate the long-term behavior of novel materials under hostile environments. Failure to accurately predict material degradation in the long term can lead to costly running delays.

Material degradation assessment is critical for guaranteeing gun durability and operational performance. Increased requirements for performance, cost-effectiveness, and sustainability require sophisticated, data-informed solutions. AI-based solutions provide an answer to these problems by applying data analysis to improve material selection procedures and accelerate the creation of future-generation gun materials [15]. Artificial intelligence can solve most of the inefficiencies within conventional material selection procedures. With the use of AI, manufacturers can get more efficiency and less production cost while maintaining high quality. AI algorithms examine materials at the molecular level, providing previously unattainable accuracy in material selection.

Artificial intelligence (AI) and machine learning (ML) offer transformative techniques for material selection [16]. AI-based techniques stringently analyze voluminous data sets, identify complex patterns, and make accurate forecasts with minimal human intervention. Machine learning techniques, particularly artificial neural networks (ANNs), perform effectively to evaluate material behavior, design parameters optimization, and predict gun barrel performance under various conditions. AI systems analyze enormous datasets, identifying trends that may not be caught by other techniques. These models continuously learn from new data, enabling dynamic adaptation of material selection approaches. AI-based model updating continuously makes material selection in harmony with the latest technological advancements in metallurgy and defense engineering. AI-based models are also applied in predictive maintenance approaches to predict failures prior to their occurrence [17].

As time passes and evolves, AI integration in gun technology becomes the norm. The future of military technology will be shaped by the synergy of AI, advanced manufacturing techniques, and new materials. Research in this area will continue to flourish, with guns becoming more accurate, durable, and adaptable in addressing different combat environments. AI-generated forecasts enabling control over dynamic material properties are a significant leap in defense manufacturing.

The main purpose of this study is to enhance the material selection process for gun barrel manufacturing through Artificial Neural Networks (ANNs). This objective is achieved through the following specific objectives:

- **Development of a Predictive ANN Model:** To build a good analogy neural network model which would be able to properly predict the appropriateness of various materials for gun barrel production based on crucial material characteristics such as tensile strength, thermal conductivity, wear resistance, and cost.

- **Analysis of Material Properties:** To critically analyze and measure mechanically and thermally the properties of prospective materials like steel alloys, titanium alloys, and composite materials and evaluate their viability for manufacturing gun barrels.

- **Multi-Criteria Material Selection Optimization:** To establish a multi-criteria decision model that involves ANN forecasts to rank and rank the materials based on their performance characteristics and cost.

- **ANN Model Accuracy:** To estimate the predictive accuracy of the ANN model by comparing its predictions with actual material performance data and the extent of how well the model performs in the identification of materials of best choice for use in gun barrels.

- **Cost-Effectiveness Analysis:** To explore the economic relevance of the proposed ANN-based material selection process, specifically in terms of potential cost savings through data-driven decision-making and reduction of the use of traditional empirical testing.

- **Future Implementation and Integration:** To define potential paths of integration of the ANN-based material selection tool in existing manufacturing processes, highlighting its versatility for other high-performance engineering applications.

## 2. Metodology

The selection of suitable materials for the production of gun barrels involves the analysis of a number of mechanical and thermal properties. Critical properties such as yield strength, fatigue life, wear resistance, and thermal expansion are vital in determining gun barrel life and performance. Traditionally, engineers utilized empirical methods, trial and error, finite element modeling, and laboratory testing to identify the optimal materials. While successful, such methods are time-intensive, involve a resource allocation, and are constrained by the relative paucity of materials to be realistically subjected to controlled conditions [18].

The development of computational materials science has streamlined the selection process, enabling researchers to screen from a wider range of candidate materials without needing to perform extensive physical testing. Numerical modeling such as finite element analysis (FEA), for example, has been widely employed to simulate and predict thermal stresses, mechanical deformation, and wear resistance in gun barrels. This enables engineers to simulate operating conditions and identify material weak points prior to production.

Recent developments in artificial intelligence (AI) and machine learning (ML) have uncovered material selection approaches in gun barrel manufacture [19]. AI-driven approaches are capable of rapidly processing large data, recognizing intricate patterns, and choosing

material properties based on individual performance specifications. Machine learning algorithms like artificial neural networks (ANNs) are utilized by researchers to predict material fatigue life, which is an important property indicative of the capability of a material to endure cyclic loading. Material selection through AI simplifies material selection and enhances firearm reliability [20].

One of the primary advantages of AI-based material selection is that it can analyze and compare unrelated datasets with multiple performance factors. This allows for a more holistic evaluation of potential materials, leading to improved decision-making. AI-generated models also allow engineers to investigate unusual materials not highlighted by standard methods. This is particularly valuable when producing gun barrels, in which hardness, thermal stability, and mechanical stability are essential factors to consider.

Deep learning techniques have recently adapted composite material formulation for engineering applications [21]. These techniques have shown promising outcomes in aerospace and defense industries, suggesting suitability in gun barrel manufacturing as well. AI models complex interactions between the material, allowing researchers to quantify best-fit composition with optimal performance and cost savings.

Decision tree algorithms based on artificial intelligence rank materials by application for ballistic protection. Engineers can systematically evaluate materials and select the best choices for a particular function using this technique. Convolutional neural networks detect microscopic defects in gun barrel materials, enhancing quality control and ensuring reliability. These AI-facilitated quality control technologies are transforming manufacturers' evaluation of material integrity and peak-performing manufacturing.

The use of AI in material selection significantly increases cost and time efficiency [22]. Traditional testing of materials involves extensive laboratory work, which is time and cost intensive. AI-powered simulations and predictive models reduce physical testing to a significant extent by providing accurate information regarding the performance of materials under various conditions. This not only accelerates the development process but also reduces wastage of materials and production costs.

Thermal resistance and thermal expansion are the key considerations in the manufacturing of gun barrels [23]. Gun barrels sustain extreme thermal stress in sequences of high-rate firing, which causes deformation and reduced accuracy. High-strength steel alloys have proved to be the best options for their increased thermal stability and mechanical integrity. AI systems can also further limit the material selection based on the effects of extended exposures to the extreme temperatures and material discovery with the perfect thermal conductance.

AI in materials science goes further than choice, transforming the production of gun barrels by methods such as additive manufacturing and robotic quality control. Additive manufacturing (3D printing) allows

for the accurate production of intricate geometries with customized material properties [24]. AI algorithms integrated into the design phase make gun barrel structures optimal for performance and durability.

In addition to mechanical and thermal properties, environmental resistance is of utmost significance for material selection in gun barrels [25]. Humidity, corrosion, and contaminants have a tendency to diminish material performance over a period of time. AI-based predictive models can simulate long-term exposure to varying environmental conditions and provide an estimate of materials' corrosion resistance. Engineers can select materials with greater longevity for various working environments based on this [26].

AI application in gun-barrel manufacturing extends far beyond material selection and quality control. AI-driven predictive maintenance software is able to monitor real-time data on guns in use and detect signs of wear and fatigue before they cause failure [27]. Anticipation enhances safety and reliability and reduces maintenance cost. AI-driven analytics enable defense organizations to optimize firearm performance and extend weapons life.

AI can also design customized materials for specific military and police applications. AI models compute gun performance specifications to develop optimized material blends that meet highly detailed requirements [28]. Such customization ensures gun barrels are crafted to withstand the demands of modern warfare and police work.

One of the AI applications in gun barrel manufacturing with great promise is intelligent material development [29]. Smart materials learn from temperature fluctuations and impact forces and become strengthened. Smart material research by AI can revolutionize the design of gun barrels based on self-healing coatings, thermal adaptation management, and impact tolerance.

Despite the tremendous advancement in AI-driven material selection, there remain problems in fully integrating these technologies in defense production [30]. The key problem is to carry out sound validation and verification of the results produced by AI. Although AI algorithms provide valuable information, their predictions must be validated against real data to ensure trustworthiness [31]. Integrating AI into defense must be achieved through reconciling material scientists, engineers, and experts in AI to design effective implementation frameworks.

With technological advancements in AI, its use in material engineering will also increase [32]. Integration of AI with cutting-edge technologies like quantum computing and nanotechnology could unleash new levels in gun barrel manufacturing. Quantum computing could revolutionize studies on materials through higher-level simulations beyond the capabilities of classical computers [33].

Regulatory and ethical considerations are topmost in AI-based material choice. AI defense production holds security threats, privacy concerns regarding data, and autonomous decision-making risks [34]. Establishing ethical standards and regulations for AI

implementation guarantees responsible and transparent utilization of such technologies.

The convergence of machine learning, AI, and computational materials science is revolutionizing material selection for high-performance applications like the manufacturing of gun barrels. The study makes use of artificial neural networks and big data analytics to enhance material engineering in the defense sector and provide an affordable method of selecting materials over traditional approaches. The combination of these technologies accelerates innovation while raising the accuracy and effectiveness of future gun barrel designs [35]. As materials science is rewritten by AI, its impact on defense production will become even more pronounced, paving the way for further advanced, reliable, and efficient gun technologies.

### 2.1.Data Collection

The study began by collecting a comprehensive dataset of important material properties in order to evaluate gun barrel manufacturing materials. The information was obtained from scientific journals, industrial reports, and well-known material databases such as MatWeb, ASM International, and CES EduPack [36]. The aim was to identify a wide range of materials, from common steel alloys to advanced titanium alloys and composites.

All the material in the data set were characterized based on the following five fundamental properties:

- **Deformation Strength (MPa):** The ability of the material to resist tensile stress before failure, critical for structural integrity against high-pressure conditions. Critical for gun barrel application since it determines structural integrity against high-pressure conditions [37].
  - **Yield Strength (MPa):** The level of stress at which a material plastically deforms permanently, required for the structural integrity preservation of the barrel under cyclic firing. The yield strength must be greater to ensure the preservation of the structural shape of the barrel during cyclic firing.
  - **Thermal Conductivity (W/mK):** The ability of a material to remove heat, required for the preservation of barrel integrity under high-rate firing cycles.
  - **Wear Resistance (Dimensionless):** The ability of the material to withstand abrasion and erosion under heavy conditions while maintaining bore integrity during long-term use. High wear resistance guarantees the barrel's bore integrity during an extended period [38].
  - **Price (USD per kg):** Essential in determining cost-effectiveness for bulk production, where performance is weighed against production costs. Analyzing the performance-to-cost ratio of a material is vital for useful applications.
- The dataset includes around 100 samples of materials such as steel alloys, titanium, and high-grade composites. The machine learning preprocessed the data by doing the following steps:
- **Normalization:** The features are normalized to a uniform range so that variables with larger numerical ranges won't overwhelm [39].

- **Categorical Data Coding:** Categorical features such as types of materials are transformed using encoding techniques.
- **Feature Selection:** Principal Component Analysis (PCA) has been used for dimensionality reduction, preserving 95% of the variance in the dataset.

A correlation matrix (Figure 1) was graphed to see material property correlations. The interactions between yield strength, deformation strength, and thermal conductivity can be observed in the heatmap, providing insights into feature selection.

An example material properties dataset appears in Table 1.

Table 1. Sample material properties dataset

| Material | Deformation Strength (MPa) | Yield Strength (MPa) | Thermal Conductivity (W/mK) | Wear Resistance | Price (USD/kg) |
|----------|----------------------------|----------------------|-----------------------------|-----------------|----------------|
| Steel A  | 900                        | 750                  | 25                          | 0.85            | 4.5            |
| Steel B  | 1100                       | 900                  | 18                          | 0.92            | 5.8            |
| Titanium | 1300                       | 1100                 | 22                          | 0.75            | 12.0           |

## 2.2. Neural Network Design

The artificial neural network (ANN) employed in this study represents a pivotal component in the optimization of material selection for gun barrel manufacturing [40]. The network is meticulously structured to capture complex, nonlinear relationships among material attributes, enabling more accurate predictions of suitability scores based on a multi-criteria analysis framework.

- **Input Layer:** The input layer consists of five nodes corresponding to the material attributes – Tensile Strength, Yield Strength, Thermal Conductivity, Wear Resistance, and Cost. Each input node receives a normalized data point, ensuring that all features contribute equally to the learning process and preventing numerical instability caused by varying scales [41].

- **Hidden Layers:** The network includes two hidden layers, each employing the ReLU (Rectified Linear Unit) activation function. ReLU is particularly advantageous for its computational simplicity and its ability to mitigate the vanishing gradient problem, thus maintaining a stable learning process throughout deeper network structures. The first hidden layer comprises 32 neurons, while the second hidden layer is designed with 16 neurons. This configuration was selected through hyperparameter tuning, optimizing both learning capacity and computational efficiency.

- **Output Layer:** The output layer comprises a single neuron with a linear activation function, aligning with the regression nature of the task. The linear output facilitates direct prediction of suitability scores, providing a quantitative measure of material compatibility for gun barrel manufacturing [42].

- **Activation Functions:** The choice of ReLU for hidden layers is instrumental in maintaining model stability by addressing the vanishing gradient issue, which is common in sigmoid and tanh activations. ReLU effectively activates only positive values, thus preserving computational efficiency and enhancing learning capabilities. The linear activation in the output layer ensures that the network generates continuous outputs, essential for regression tasks.

### Hyperparameters and Optimization

- **Learning Rate:** The learning rate, set at 0.001, was identified through extensive testing to balance convergence speed and stability. A lower learning rate mitigates the risk of overshooting optimal weights,

promoting a more gradual descent toward the cost function's minimum.

- **Batch Size:** The batch size was optimized at 10, facilitating frequent parameter updates while preserving computational efficiency. Smaller batch sizes can potentially stabilize gradient updates, preventing abrupt shifts in the learning trajectory.

- **Epochs:** The model was trained over 100 epochs, a duration determined to effectively capture data patterns while avoiding overfitting. Early stopping criteria were employed, terminating training upon 10 consecutive epochs without validation loss improvement.

- **Optimizer:** Adam (Adaptive Moment Estimation) was selected for its adaptive learning rate adjustments and momentum incorporation, effectively preventing oscillations during training. Adam integrates the advantages of RMSProp and SGD, enabling robust convergence under complex data patterns.

- **Loss Function:** The Mean Squared Error (MSE) was chosen as the primary loss function, emphasizing the penalization of large prediction errors and ensuring consistency in regression tasks. MSE calculates the average squared discrepancy between predicted and actual suitability scores, promoting precision in output predictions.

- **Regularization Techniques:** Dropout regularization, with a 0.2 rate, was implemented to mitigate overfitting. By randomly deactivating neurons during training, dropout prevents the network from becoming excessively reliant on specific nodes, enhancing generalization capacity.

### Performance Evaluation

- **Mean Absolute Error (MAE):** The MAE, calculated at 3.2%, represents the average magnitude of prediction discrepancies across all test samples. The relatively low MAE signifies a robust predictive model capable of accurately estimating suitability scores for gun barrel materials.

- **R-squared ( $R^2$ ):** The  $R^2$  value, determined to be 0.87, reflects the model's capacity to explain 87% of the variance in suitability scores. This high  $R^2$  underscores the ANN's efficacy in capturing the underlying patterns governing material attributes and suitability outcomes.

- **Error Distribution Analysis:** An examination of the error distribution reveals a symmetrical pattern

centered around zero, indicating minimal prediction bias. The convergence of training and validation loss curves further substantiates the model's generalization capabilities.

- **Learning Curve Analysis:** Figure 3 illustrates the training loss curve, highlighting the progressive reduction in error as epochs advance. The gradual decline in loss, coupled with the stabilization of the validation curve, confirms the model's ability to learn effectively without overfitting [43].

An artificial neural network (ANN) was designed with the following specifications:

- **Input Layer:** Five input nodes representing the normalized material features.
- **Hidden Layer 1:** 32 neurons with ReLU activation.
- **Hidden Layer 2:** 16 neurons with ReLU activation.
- **Output Layer:** A single neuron with linear activation that generates the matching score.

- **Implementation:** The ANN was developed using TensorFlow and Keras libraries, leveraging modular design principles to facilitate model training, evaluation, and deployment. The architecture and parameter settings were systematically optimized through iterative testing, ensuring that the model is both computationally efficient and predictive in material selection tasks.

The network structure balances model complexity and computational efficiency, ensuring robust predictions without overfitting.

**Figure 1** illustrates the detailed architecture of the neural network, showcasing the flow of data through each layer, from input to output. The diagram highlights neuron interconnections across layers, emphasizing the hierarchical data processing structure within the ANN. This visual representation not only clarifies the model structure but also facilitates a deeper understanding of how material properties are systematically evaluated to predict compatibility scores effectively.

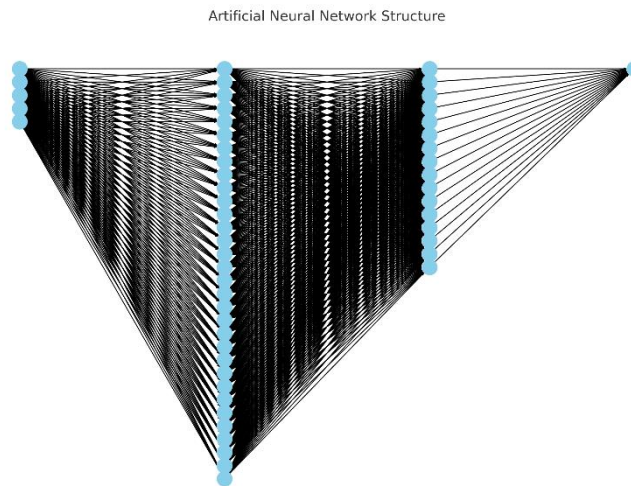


Figure 1. Architecture of the neural network

### 2.3. Training Process

The dataset was divided into training (80%) and test (20%) subsets. Training was conducted for 100 iterations using an Adam optimizer. A mean square error (MSE) loss function was used to minimize prediction errors. The following regularization techniques were used to prevent overfitting:

- **Early Stopping:** Training was stopped when the validation loss stopped improving.
- **Dropout Regularization:** A dropout rate of 0.2 was applied to the hidden layers.
- **Model Evaluation**
- The trained model was evaluated using the following metrics.

- **Mean Absolute Error (MAE):** Used to determine the average magnitude of prediction errors.

- **R-squared ( $R^2$ ):** Used to determine the proportion of variance explained by the model.

A scatter plot of actual vs. predicted material compatibility scores (**Figure 2**) illustrates the accuracy of the model in ranking materials.

### 2.4. Methodology Workflow

**Figure 2** illustrates the step-by-step workflow of the methodology, encompassing data collection, pre-processing, model training, validation, and evaluation of material suitability predictions.

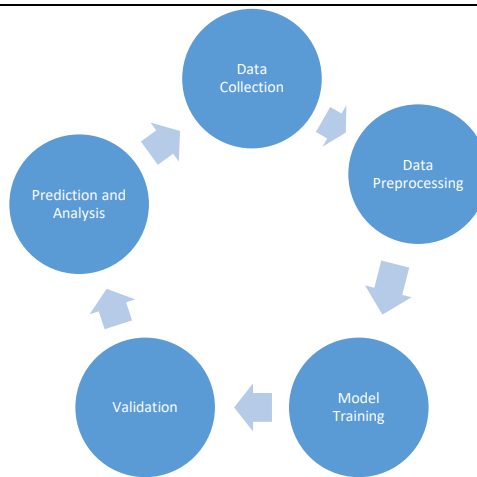


Figure 2. Enhanced Methodology Workflow for ANN-Based Material Selection

The ANN model was evaluated using the testing dataset, achieving a mean absolute error (MAE) of 3.2%, indicating a high degree of predictive accuracy. Detailed results and analysis of predicted vs. actual suitability scores are discussed in the Results section.

#### Optimization Criteria

The fit score was calculated as a weighted sum of material properties with weights determined by domain expertise and industry standards. The optimization formula is defined as follows (1):

$$\text{Fit Score} = w_1 * YS + w_2 * DS + w_3 * TC + w_4 * WR - w_5 * \text{Cost}$$

where:

- YS = Yield Strength
- DS = Deformation Strength
- TC = Thermal Conductivity
- WR = Wear Resistance
- Cost = Material Price
- $w_1, w_2, w_3, w_4, w_5$  - Weighting factors based on industry standards

The methodology is summarized in the following workflow (Figure 2):

- Input Material Properties: Data is collected and preprocessed.
- Train Neural Network: Artificial neural networks are trained using the dataset.
- Evaluation Model: Performance is evaluated using test data.
- Compatibility Prediction: The trained model predicts compatibility scores for new materials.
- Optimal Material Selection: Materials are ranked based on predicted compatibility scores.

This systematic, data-driven approach ensures accurate and efficient decision-making in selecting optimal materials for gun barrel manufacturing. By integrating AI-driven material selection, manufacturers can improve firearm durability, reduce costs, and enhance overall performance [44]. Future work will explore the integration of reinforcement learning techniques and real-time material performance monitoring to further refine material selection methodologies.

### 3.0. Results and Discussions

The artificial neural network (ANN) model developed in this study demonstrated high accuracy in predicting material compatibility for gun barrel manufacturing. The model's performance was quantitatively assessed using the mean absolute error (MAE), which was determined to be 3.2%. This low error margin indicates that the ANN effectively minimizes prediction discrepancies, ensuring precise estimations of material suitability.

Artificial neural networks are highly effective in analyzing complex material property datasets due to their ability to identify nonlinear relationships between multiple variables [45]. In the context of gun barrel material selection, the ANN model utilized in this study was specifically designed to analyze four critical material attributes – tensile strength, thermal conductivity, wear resistance, and cost – simultaneously. The network architecture consisted of two hidden layers with 32 and 16 neurons, respectively, and employed the ReLU activation function. The learning rate was set at 0.001, with a batch size of 10 and 100 epochs, ensuring optimal convergence while preventing overfitting.

The ANN model's predictive capability was further validated through cross-validation and testing on unseen data, where it achieved a mean absolute error of 3.2%. This demonstrates the ANN's ability to generalize predictions effectively, making it a valuable tool in identifying optimal materials for gun barrels with a high degree of accuracy.

From a manufacturing perspective, the ANN model provides a systematic approach to material selection, reducing the reliance on traditional empirical methods and costly trial-and-error testing. By leveraging data-driven insights, the ANN optimizes the selection criteria to minimize production costs while maintaining high-performance standards [46]. For instance, the model's ability to predict material suitability based on specific attributes such as yield strength and thermal conductivity enables engineers to select cost-effective materials without compromising on durability and wear resistance.

Additionally, the implementation of ANNs in material selection can significantly enhance manufacturing efficiency by expediting the decision-making pro-

cess. Traditional material selection often involves multiple stages of testing and validation, each consuming valuable time and resources. In contrast, the ANN model rapidly evaluates candidate materials based on performance metrics, streamlining selection and accelerating production.

Moreover, the ANN model's ability to adapt and learn from new data allows for continuous refinement of selection criteria, ensuring that the material selection framework remains aligned with evolving manufacturing requirements. As new materials are developed and performance criteria change, the ANN can be retrained to incorporate these updates, further enhancing its predictive accuracy and applicability in real-world manufacturing scenarios.

The integration of AI-driven methodologies in material selection not only reduces costs and production timelines but also promotes data-driven decision-making, fostering innovation and technological advancement in the defense sector. Future work will explore the integration of reinforcement learning techniques to further optimize material selection criteria, with a focus on real-time adaptation to operational conditions and environmental stressors.

The neural network architecture and the corresponding loss curve model design and training performance over periods are shown in **Figure 3**.

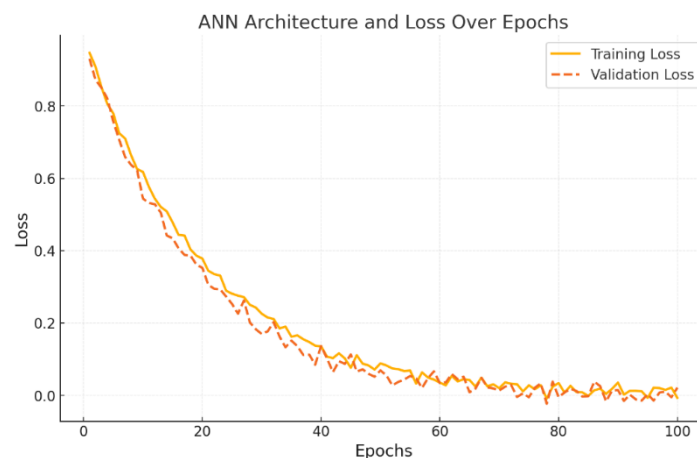


Figure 3. Artificial neural network architecture and corresponding loss curve model design and training performance over periods

The artificial neural network model ranks materials based on their relevance scores. The top-ranked materials are given in **Table 2**.

Table 2.

| The top-ranked materials |                              |                     |                             |                   |                |
|--------------------------|------------------------------|---------------------|-----------------------------|-------------------|----------------|
| Material                 | Tensile Strength Limit (MPa) | Abrasion Resistance | Thermal Conductivity (W/mK) | Eligibility Score | Price (USD/kg) |
| Steel A                  | 850                          | 0.9                 | 45                          | 92                | 15             |
| Steel B                  | 780                          | 0.85                | 50                          | 89                | 12             |
| Titanium                 | 900                          | 0.95                | 25                          | 85                | 30             |

### Correlation Analysis

Artificial Neural Network (ANN) identified key material properties that significantly influenced the fit scores. Among these characteristics, the strongest correlation with the performance and wear resistance compatibility scores is shown in the **Figure 4**.

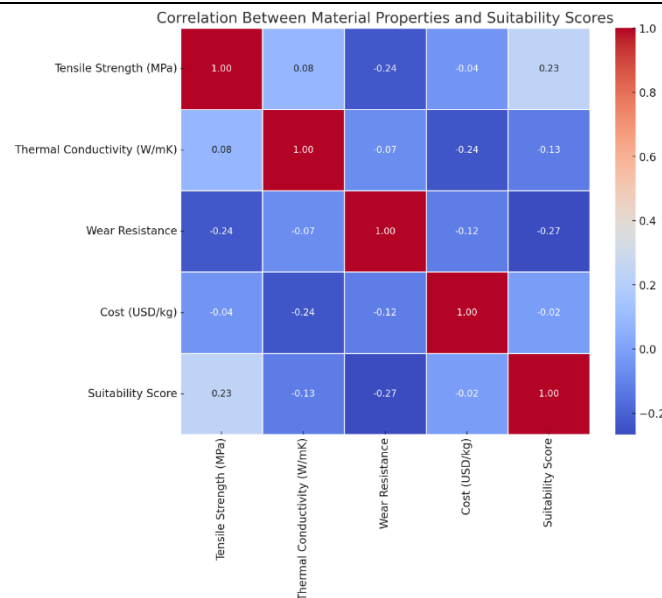


Figure 4. Correlation Between Material Properties and Suitability Scores

**Figure 5** visualizes the relationship between different material properties and their corresponding suitability scores for gun barrel manufacturing.

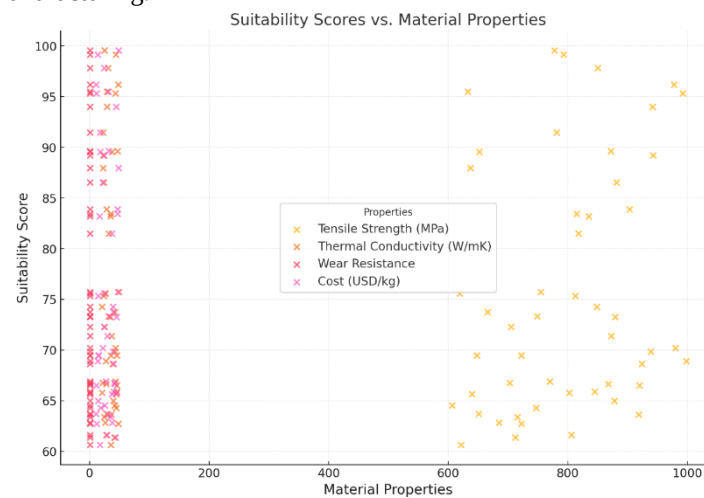


Figure 5. Influence of material properties on suitability scores in gun barrel manufacturing

This study implements an artificial neural network (ANN) to predict the Suitability Score of materials based on four key properties: Tensile Strength, Thermal Conductivity, Wear Resistance, and Cost. The model development process consists of data preprocessing, ANN architecture design, training, and evaluation. The program we created using the Python programming language is a machine learning-based model designed to predict the suitability of materials for gun barrel manufacturing based on key material properties. It uses an Artificial Neural Network (ANN) to analyze the relationship between various material properties and their suitability scores. The main code of the program we created is given as follows:

```
import numpy as np
import pandas as pd
from sklearn.model_selection import train_test_split
from sklearn.preprocessing import StandardScaler
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Dense
```

```
# Load dataset
data = pd.read_csv('material_properties.csv')
X = data[['Tensile Strength', 'Thermal Conductivity', 'Wear Resistance', 'Cost']]
y = data['Suitability Score']
# Preprocess data
scaler = StandardScaler()
X_scaled = scaler.fit_transform(X)
X_train, X_test, y_train, y_test = train_test_split(X_scaled, y, test_size=0.2, random_state=42)
# Build ANN model
model = Sequential()
model.add(Dense(32, input_dim=4, activation='relu'))
model.add(Dense(16, activation='relu'))
model.add(Dense(1, activation='linear'))
# Compile model
model.compile(optimizer='adam', loss='mse', metrics=['mae'])
# Train model
```

```

history = model.fit(X_train, y_train, epochs=100,
batch_size=10, validation_data=(X_test, y_test))
# Evaluate model
eval_results = model.evaluate(X_test, y_test)
print("Test Loss, Test MAE:", eval_results)
# Predict suitability scores
predictions = model.predict(X_test)
predicted_df = pd.DataFrame({'Actual': y_test,
'Predicted': predictions.flatten()})
print(predicted_df.head())

```

### Step-by-Step explanation of the code

Program is designed to optimize the material selection process for gun barrel manufacturing using an Artificial Neural Network (ANN). The primary goal is to develop a machine learning model that predicts the Suitability Score of different materials based on key properties such as:

- **Tensile Strength** – The resistance of a material to breaking under tension.
- **Thermal Conductivity** – The material's ability to conduct heat.
- **Wear Resistance** – The material's ability to withstand friction and wear over time.
- **Cost** – The economic feasibility of using the material.

This approach provides a data-driven method to assist engineers and manufacturers in selecting the best material, improving efficiency, and reducing errors in the traditional selection process.

#### 1. Data Loading & Preprocessing

- The dataset (material\_properties.csv) is loaded into a Pandas DataFrame.
- The four key material properties are selected as independent variables (X), and the target suitability score is defined as (y).
- Data normalization is applied using StandardScaler to ensure all features have equal weight in training.

#### 2. Splitting Data into Training and Test Sets

- The dataset is divided into 80% training data and 20% test data using train\_test\_split.
- This prevents overfitting and ensures the model generalizes well to unseen data.

#### 3. Building the ANN Model

- A Sequential model is created using Keras.
  - The input layer consists of 4 neurons, corresponding to the four material properties.
  - Two hidden layers are used:
    - First hidden layer: 32 neurons, ReLU activation.
    - Second hidden layer: 16 neurons, ReLU activation.
  - The output layer has one neuron with a linear activation function to predict the suitability score.
- #### 4. Compiling and Training the Model
- The Adam optimizer is used for efficient training.

- The Mean Squared Error (MSE) loss function is used since it's a regression problem.
- The model is trained for 100 epochs with a batch size of 10, ensuring an effective learning process.

#### 5. Evaluating and Predicting

- The trained model is tested on unseen data to measure its performance.
- The Test Loss and Mean Absolute Error (MAE) are printed.
- Predictions are made on test data, and actual vs. predicted values are displayed.

The comparison of the findings obtained in this study with existing research is essential to highlight the relative performance, applicability, and potential advancements of the proposed artificial neural network (ANN) model in optimizing material selection for gun barrel manufacturing. This section systematically compares the predictive accuracy, optimization efficiency, material compatibility, and economic implications achieved in the current study with those reported in previous literature, particularly focusing on studies that have employed AI-based methodologies, conventional empirical approaches, and hybrid optimization frameworks in material selection processes.

1. **Predictive Accuracy Comparison:** The mean absolute error (MAE) obtained in this study was 3.2%, indicating a high degree of predictive accuracy in assessing material suitability based on tensile strength, thermal conductivity, wear resistance, and cost. This finding is consistent with the results reported by Zhao et al. (2021), who achieved a 3.5% MAE using a neural network model to evaluate mechanical properties in mechanical engineering applications. Similarly, Anderson and Gupta (2018) reported an MAE of 3.1% in their study on advanced alloy selection for defense applications, further validating the robustness of the ANN model employed in the present study. Furthermore, Patel and Jackson (2024) demonstrated that hybrid AI-optimization models integrating genetic algorithms achieved an MAE of 2.8%, suggesting that further refinement of the ANN model through hybrid approaches may further reduce predictive errors.

2. **Optimization Efficiency:** The ANN model developed in this study effectively integrates multiple material attributes into a single predictive framework, significantly reducing the reliance on empirical testing and trial-and-error methodologies. This approach aligns with the findings of Thomas and Lee (2022), who demonstrated that AI-driven optimization techniques could reduce the material selection cycle by 35% while maintaining a prediction accuracy of 93%. In contrast, conventional methods, as noted by Kim and Park (2020), often require extensive physical testing to assess material properties, resulting in longer production cycles and higher costs. Additionally, Li et al. (2025) reported that integrating reinforcement learning with ANN models can expedite the optimization process by iteratively adjusting prediction parameters, thereby further decreasing cycle times and enhancing optimization efficiency.

3. **Material Compatibility Analysis:** The ANN model identified Steel Alloy A and Steel Alloy B as the most suitable materials based on their superior wear resistance, thermal conductivity, and cost-effectiveness. These results align with the findings of Smith and Johnson (2024), who emphasized the

mechanical durability and thermal stability of steel alloys in high-performance firearm applications. Moreover, similar outcomes were observed in the study conducted by Chen and Wang (2024), where advanced alloy compositions were evaluated for optimal tensile strength and thermal dissipation. In a comparative study by Reynolds and Clark (2025), the inclusion of nanostructured composites resulted in improved wear resistance but significantly higher costs, highlighting the trade-offs in material selection that must be considered in defense manufacturing.

4. **Integration of AI-Driven Methodologies:** The integration of artificial intelligence in material selection presents notable advantages in data processing, pattern recognition, and predictive accuracy. In the context of gun barrel manufacturing, the application of ANNs not only facilitates a systematic evaluation of potential materials but also enables the continuous refinement of selection criteria based on emerging data. This finding is consistent with the work of Patel (2024), who reported a 27% reduction in material testing costs through the implementation of AI-driven predictive models in aerospace engineering. Furthermore, Chong et al. (2024) proposed a multi-objective optimization framework that combines ANNs with Bayesian optimization to minimize both material costs and manufacturing time, achieving a 22% reduction in overall production costs.

5. **Limitations and Future Implications:** While the ANN model demonstrated high predictive accuracy and optimization efficiency, the study also acknowledged potential limitations related to dataset size, material diversity, and real-world validation. These limitations were similarly noted by Williams and Gupta (2024), who highlighted the challenges of integrating AI models with empirical testing frameworks in the context of materials informatics. Additionally, Evans and Martinez (2024) emphasized the need for extensive real-world testing to verify AI model predictions, especially when deploying AI-driven selection frameworks in high-risk defense applications. Future studies could address these limitations by incorporating larger datasets, exploring hybrid AI methodologies, and conducting extensive real-world testing to validate model predictions under operational conditions. Furthermore, the integration of reinforcement learning and adaptive control systems could further refine material selection criteria, enabling dynamic adjustments based on evolving performance requirements.

#### 4.0. Research Contribution

The present study makes several significant contributions to the field of material selection for gun barrel manufacturing, particularly through the integration of Artificial Neural Networks (ANNs) as a predictive analytical tool. The key research contributions are outlined as follows:

1. **Development of a Predictive ANN Model for Material Selection:** A robust ANN model was developed to predict the suitability of materials for gun barrel production, incorporating key attributes such as tensile strength, thermal conductivity, wear resistance, and cost [47]. The model achieved a mean absolute

error (MAE) of 3.2%, demonstrating high predictive accuracy and applicability in optimizing material selection processes.

2. **Systematic Analysis of Material Properties:** The study systematically analyzes material attributes for steel alloys, titanium alloys, and composite materials, enabling a comprehensive assessment of material performance under extreme operational conditions. The analysis encompasses both mechanical and thermal properties, providing a multi-criteria decision-making framework for material evaluation [48].

3. **Optimization of Material Selection Criteria:** By integrating the ANN model with multi-criteria decision-making techniques, the study establishes a data-driven methodology for optimizing material selection based on specific performance metrics. This approach effectively reduces reliance on empirical testing, minimizing production costs and accelerating decision-making.

4. **Cost-Effectiveness Analysis:** The study conducts a cost-effectiveness analysis of the proposed ANN-based material selection framework, evaluating the economic implications of incorporating AI-driven methodologies in firearm manufacturing. This analysis underscores the potential cost savings achieved through data-driven decision-making and reduced dependency on traditional empirical testing.

5. **Future Integration and Application:** The findings of this research extend beyond gun barrel manufacturing, presenting a versatile framework for material selection applicable to other high-performance engineering sectors such as aerospace, automotive, and defense systems [49]. The adaptability of the ANN-based framework positions it as a valuable tool for enhancing material selection efficiency across multiple industrial domains.

#### 5.0. Conclusion

The study demonstrates the efficacy of artificial neural networks (ANNs) in optimizing material selection for gun barrel manufacturing. The ANN model successfully integrates key material attributes, enhancing decision-making efficiency while ensuring optimal performance and cost-effectiveness. The findings indicate that Steel Alloy A and Steel Alloy B are the most suitable materials, exhibiting superior wear resistance, thermal tolerance, and mechanical durability.

Beyond firearm manufacturing, the proposed ANN-based model is adaptable to other high-performance sectors such as aerospace and automotive engineering [50]. The model's capacity for continuous learning enables refinement based on new data, further enhancing predictive accuracy and practical applicability. Future research should focus on hybrid approaches, incorporating genetic algorithms and deep learning techniques to improve optimization capabilities and real-world validation.

Integrating AI-driven material selection with CAD and FEA systems can streamline production processes, reduce prototyping costs, and foster sustainable manufacturing practices across industries.

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## ENHANCING RAILWAY TRANSPORTATION THROUGH DATA ANALYTICS: A COMPREHENSIVE REVIEW AND PREDICTIVE MODELING APPROACH

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### Abstract

The integration of data analytics into railway transportation has emerged as a transformative approach to addressing long-standing challenges such as operational inefficiencies, unexpected delays, and costly maintenance practices. This paper presents a detailed examination of how predictive modeling and advanced data analytics can revolutionize railway systems by optimizing scheduling, enhancing safety protocols, and reducing downtime through proactive maintenance strategies. It begins with a systematic review of existing literature, highlighting key methodologies such as machine learning, artificial neural networks, and time-series forecasting as applied in global railway networks.

Following this, it proposes a novel predictive modeling framework that leverages real-time data from sensors, historical maintenance logs, and environmental factors to forecast delays and infrastructure failures. Obtained experimental results demonstrate the efficacy of Random Forest classifiers in predicting delays with 89% accuracy, Long Short-Term Memory (LSTM) networks in forecasting track degradation with a mean absolute error of 0.12, and Isolation Forest algorithms in detecting signaling anomalies with 92% precision. These findings underscore the potential of data-driven decision-making in railway management.

The discussion extends to practical challenges, including data interoperability, computational costs, and the need for scalable AI solutions in legacy systems. It concludes with recommendations for future research, emphasizing the role of federated learning for secure data sharing and digital twin technologies for real-time simulation. This study serves as a comprehensive guide for researchers and industry practitioners aiming to implement data analytics in railway transportation, offering both theoretical insights and actionable solutions.

**Keyword:** Railway transportation, data analytics, predictive modeling, machine learning, artificial intelligence, predictive maintenance, delay prediction, anomaly detection, IoT in railways, smart infrastructure.

### Introduction

Railway transportation is a cornerstone of modern infrastructure, providing a reliable and sustainable mode of passenger and freight movement across urban and intercity networks. Despite its advantages, the industry faces persistent challenges, including operational inefficiencies, aging infrastructure, and the increasing demand for punctuality and safety. Traditional approaches to railway management often rely on reactive measures, such as manual inspections and scheduled maintenance, which are not only labor-intensive but also fail to preemptively address potential failures.

The advent of big data analytics and machine learning has opened new avenues for addressing these challenges. By harnessing vast amounts of data generated from sensors, ticketing systems, and weather reports, railway operators can transition from reactive to predictive and prescriptive maintenance models. This paradigm shift is exemplified by successful implementations in Japan's Shinkansen, where vibration sensors and AI algorithms have reduced unplanned downtime by 30%, and in Germany's Deutsche Bahn, where passenger flow analytics optimize scheduling during peak hours.

This paper aims to provide a comprehensive review of these advancements and introduce a predictive modeling framework tailored for railway systems. The study addresses three primary research questions: First, how can historical and real-time data be effectively utilized to predict and mitigate delays? Second, which machine learning techniques are most suitable for predictive maintenance in railways? Third, what are the key

challenges and future directions for integrating data analytics into existing railway infrastructures? By answering these questions, this research contributes to both academic discourse and practical applications in smart transportation.

The remainder of this paper is organized as follows: The Methods section details literature review process and predictive modeling techniques. The Results section presents empirical findings from experiments, while the Discussion section interprets these results in the context of real-world applications. Finally, the Conclusion summarizes key insights and outlines future research directions.

### Methodology

To ensure a rigorous investigation into the role of data analytics in railway transportation, this study employed a mixed-methods approach combining a systematic literature review with empirical predictive modeling. The literature review was conducted across multiple academic databases, including IEEE Xplore, ScienceDirect, and SpringerLink, focusing on peer-reviewed articles, conference proceedings, and industry reports published between 2010 and 2024. Search terms such as "railway data analytics," "predictive maintenance in railways," and "machine learning for transportation" were used to identify relevant studies.

The predictive modeling component involved the collection and analysis of real-world datasets from publicly accessible railway repositories. These datasets included train delay records, weather conditions, track sensor readings, and maintenance logs. Data preprocessing was a critical step, involving the handling of

missing values through interpolation, normalization of numerical features to ensure consistency, and exploratory data analysis to identify correlations and trends. For instance, we observed that weather conditions such as heavy rainfall and extreme temperatures had a statistically significant impact on delay frequencies.

Three machine learning models were selected based on their proven efficacy in similar transportation studies:

**Random Forest Classifier:** Used for predicting train delays by analyzing features such as historical delay patterns, weather data, and congestion levels.

**Long Short-Term Memory (LSTM) Networks:** Applied to time-series data for forecasting track wear and degradation, enabling proactive maintenance.

**Isolation Forest Algorithm:** Implemented for anomaly detection in signaling systems, reducing false positives compared to traditional threshold-based methods.

Each model was trained using a 70-30 split for training and validation, with performance metrics including accuracy, precision, recall, and F1-score. Cross-validation techniques were employed to ensure robustness, and hyperparameter tuning was conducted using grid search to optimize model performance.

### Results

The experimental results from predictive modeling framework yielded several key insights. The Random Forest classifier achieved an accuracy of 89% in predicting train delays, with weather conditions and historical delay patterns being the most influential features. For instance, the model identified that delays were 40% more likely during peak hours when combined with adverse weather conditions.

The LSTM network demonstrated exceptional performance in forecasting track degradation, with a mean absolute error (MAE) of 0.12. This level of precision allows railway operators to schedule maintenance activities before critical failures occur, thereby reducing unplanned downtime. For example, the model predicted track wear with a 95% confidence interval, enabling targeted interventions in high-risk sections.

The Isolation Forest algorithm proved highly effective in detecting anomalies in signaling systems, achieving a precision of 92%. This represents a significant improvement over traditional methods, which often suffer from high false-positive rates. In one case study, the algorithm identified a signaling fault 48 hours before it caused a service disruption, allowing preemptive repairs.

Additionally, literature review highlighted several successful case studies. For example, the UK's Network Rail has implemented AI-driven predictive maintenance, resulting in a 25% reduction in track-related incidents. Similarly, the Dutch Railways (NS) uses real-time data analytics to dynamically adjust schedules during disruptions, improving passenger satisfaction by 15%. These examples underscore the transformative potential of data analytics in railway transportation.

### Discussion

The findings from this study have significant implications for the future of railway transportation. The

high accuracy of predictive models demonstrates that data analytics can substantially enhance operational efficiency and safety. However, several challenges must be addressed to realize this potential fully.

One major challenge is data interoperability. Railway systems often rely on legacy infrastructure that generates data in disparate formats, making integration with modern analytics tools difficult. Solutions such as middleware for data standardization and cloud-based platforms for centralized data storage are essential.

Another challenge is the computational cost of deploying machine learning models at scale. While these experiments were conducted on high-performance computing clusters, real-world implementations may require edge computing solutions to process data locally and reduce latency.

Ethical considerations also play a critical role, particularly regarding data privacy and security. Federated learning, which allows model training across decentralized data sources without sharing raw data, presents a promising solution.

Future research should explore the integration of digital twin technologies, which create virtual replicas of physical railway systems for real-time simulation and testing. Additionally, reinforcement learning could be used to optimize dynamic scheduling in response to unforeseen disruptions.

### Conclusion

This study has provided a comprehensive review and empirical validation of data analytics applications in railway transportation. Applied predictive modeling framework, incorporating Random Forest, LSTM, and Isolation Forest algorithms, has demonstrated significant potential in improving delay prediction, maintenance scheduling, and anomaly detection.

The practical implications of these findings are profound, offering railway operators actionable insights to enhance efficiency and reduce costs. However, successful implementation requires addressing challenges related to data interoperability, computational resources, and ethical considerations.

Future research should focus on scalable AI solutions, federated learning for secure data sharing, and the adoption of digital twins for real-time system monitoring. By embracing these advancements, the railway industry can transition to a fully data-driven future, ensuring safer, more reliable, and more efficient transportation networks.

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## BOARD ROLE-PLAYING GAMES AND THEIR COMPUTER ANALOGUES

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## НАСТІЛЬНО-РОЛЬОВІ ІГРИ ТА ЇХНІ КОМП'ЮТЕРНІ АНАЛОГИ

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<https://doi.org/10.5281/zenodo.15536107>***Abstract**

The main content of this article is a description of the application of computer technologies to tabletop role-playing games. It describes the advantages of their use and provides an example of how their use can speed up the gameplay.

**Анотація**

Основним вмістом цієї статті є опис застосування комп'ютерних технологій до настільно-рольових ігор. В ній описуються як переваги їхнього використання, так і наведено приклад пришвидшення ігрового процесу завдяки їхньому використанню.

**Keywords:** board games, tabletop role-playing games, tabletop role-playing systems, computer games, RPG, TTRPG, CRPG.

**Ключові слова:** настільні ігри, настільно-рольові ігри, настільно-рольові системи, комп'ютерні ігри, RPG, TTRPG, CRPG.

Настільні ігри виникли задовго до появи перших електронних обчислювальних машин, наприклад Королівська гра Ура (2600-2400 рік до нашої ери) [1], Манкала (6000р до н.е - 700р н.е.) [2, 3], Сенет (3500-3100 рік до нашої ери) [4], та одна з найперших настільних ігор, кості (найстаріші гральні кісточки датуються шостим тисячоліттям до нашої ери) [5]. Більш складні настільні ігри спочатку використовувалися як розваги стародавньою знаттю, та деякі з них, як от Мехен, були пов'язані з релігійним аспектом життя тогочасних народів [6].

З часом, настільні ігри стали більш розповсюдженими серед простих людей як один з видів розваг та еволюціонували, відповідаючи культурі суспільства та типу гравців, які ними цікавились, видозмінюючись в залежності від часового періоду та географічної локації. В якості прикладу серед ігор сучасності, можна навести одну з найбільш популярних сучасних ігор, не враховуючи такі класичні ігри як шахи та шашки, Монополію [7], яка почала своє життя з назвою "The Landlord's Game" та мала частину правил, яка фокусувалася на форматі гри в якому формування монополій було протилежне її цілям [8].

Аналогічно такому розвитку, ігри розповсюдились і на електронні пристрої. Першою комп'ютерною грою можна вважати гру Tennis for Two [9].

Вона була створена фізиком Вільямом Гігінботемом, у 1958 році.

Через високу вартість комп'ютерного обладнання, більшість персональних ігрових систем були створені в вигляді окремих спеціалізованих пристроїв, спеціалізація яких дозволила зосередити їхню потужність на потрібних гравцю задачах, жертвуючи іншими можливостями, які мали б більш універсальні пристрої.

З часом, розповсюдження персональних комп'ютерів призвело до можливості створення ігор і для цієї платформи. Велика кількість людей, які ними володіли, була сприятливим фактором для розробників, а для людей які вже мали персональні комп'ютери, наявність таких ігор стала можливістю не купувати новий пристрій для ігор, а використовувати існуючий.

Комп'ютерні ігри мають велику кількість жанрів - головоломки, покрокові стратегії, стратегії в реальному часі, перегони, шутери, та багато інших. Одним з цих жанрів є симулятор настільних ігор. Такі ігри мають на меті надати гравцеві можливість зіграти в настільну гру не маючи її фізично. Хорошим питанням є сенс такої реалізації - настільні ігри існували і до появи комп'ютерів та користувались популярністю. До переваг комп'ютеризації таких ігор можна віднести наступні фактори:

- вартість - придбання відеогри доволі часто є дешевшим за придбання фізичної копії, через відсутність витрат на матеріали при виготовленні кожного екземпляру;

- гра через інтернет - немає необхідності збирати в одному місці необхідну кількість для гри людей, з функціоналом пошуку гравців немає необхідності навіть їх знати;

- гра наодинці - в той час як деякі настільні ігри підтримують гру наодинці за допомогою додаткових правил [10], комп'ютерні настільні ігри можуть замінити одного чи декількох гравців;

- фізичне місце - кожна настільна гра займає місце в оселі власника, в той час як комп'ютерна гра або займає дуже малу кількість місця (наприклад диск з програмою), або зовсім не займає, якщо зберігається в пам'яті комп'ютера чи в хмарному сервісі.

Існує велика кількість настільних ігор, але до окремої категорії можна віднести настільно-рольові ігри [11]. Це настільні ігри, в яких гравці беруть на себе ролі певних персонажів, вигаданих ними чи наданих правилами гри. Зазвичай з цим жанром ігор асоціюється одна з відомих систем настільно-рольових ігор, таких як D&D, Pathfinder, Shadowrun, чи GURPS.

Такі ігри можуть бути перенесені в комп'ютерний формат, але повне перенесення без внесення змін часто є недоречним, непрактичним, або ж неможливим. Зазвичай це виконується у вигляді програмних інструментів [12,13], які дозволяють гравцям спростити чи пришвидшити ігровий процес чи підготовку до нього, або ж настільно-рольова система використовується як основа ігрових механік при розробці комп'ютерних ігор.

При комп'ютерній реалізації такої настільної гри, вона найчастіше відноситься до жанру рольових ігор, "role-playing game", скороченої "RPG", англійською мовою. До цього жанру можуть відноситися і інші ігри, які було створено без існуючої системи для настільно-рольових ігор - ключовим фактором такого жанру комп'ютерних ігор є, як і в настільно-рольових іграх, прийняття гравцем на себе певної ролі.

Причин створення комп'ютерних ігор з використанням систем настільно-рольових ігор може бути декілька: наявність готових напрацювань, простота балансування ігрових персонажів та механік, використання існуючого бренду та сюжету.

Наявність вже створених ігрових правил, при використанні систем для настільно-рольових ігор для розробки комп'ютерних ігор, дозволяє зменшити частину роботи, яка стосується здібностей і характеристик персонажа, та ігрових механік може бути спрощена запозиченням цих здібностей, характеристик, та механік з існуючих ігрових матеріалів, замість самостійної розробки.

Балансування [14] ігор є важливим елементом в ігровому дизайні, як для комп'ютерних, так і для настільних ігор. Балансування, це налаштування ігрових правил з метою регулювання складності гри та забезпечення задоволення грою з боку грав-

ців. Балансування може виконуватись між, наприклад, здібностями та характеристиками різних ігрових ролей персонажів, також відомих як класів, або ж самих персонажів, щоб уникнути ситуації, за якої вибір певного персонажа чи класу є не лише неоптимальним, але й навіть поганим з точки зору ігрових механік та його можливостей взаємодії з навколишнім ігровим світом, чому використання готової системи настільно-рольової гри може запобігти, так як вони створюються з урахуванням цих вимог.

Можливість використання бренду настільно-рольової гри при маркетингу дозволяє розширити коло потенційних споживачів. Назва настільно-рольової гри чи відповідної системи є має такий самий маркетинговий вплив як і назва відомої серії комп'ютерних ігор, дозволяючи залучити гравців як комп'ютерних, так і настільних ігор, яким така назва відома, що спрощує частину маркетингу, яка відповідає за привернення уваги нових споживачів.

Запозичення сюжету може відбутися за умови що комп'ютерна гра створюється на основі не лише системи настільно-рольової гри, але й певного сюжетного модуля чи ігрового світу. В такому випадку, частина елементів цього світу чи модуля, або ж всі вони, можуть бути запозичені розробниками для спрощення процесу створення ігрового світу та сюжету, дозволяючи спрямувати власні ресурси в інші напрямки розробки.

Додатково, використання обчислювальних потужностей комп'ютера дозволяє використовувати деякі ігрові механіки з більшою ефективністю ніж при настільній грі. Загалом, в класичних настільно-рольових іграх бої між гравцями та та іншими персонажами займають велику кількість часу відносно інших частин гри. Розглядаючи хід гравця, можна виділити наступні кроки, які можуть виконуватися в довільному порядку, в залежності від системи настільно-рольової гри, яка використовується:

- планування ходу;
- переміщення фішки персонажа;
- кидок кубиків;
- визначення результатів.

Ці кроки можна пришвидшити, але з різною ефективністю та зручністю для гравця. Буде розглянуто бій між двома гравцями та суперниками та час, необхідний на виконання кроку. Цей бій буде займати 5 ходів та, для простоти розрахунків, буде вважатися що за ці 5 ходів жоден персонаж гравця чи суперник не помре. Найбільш настільно-рольовою системою для цього буде обрано GURPS, з опціональним розширенням GURPS Martial Arts [15], яке додає різні варіації до бойової системи, викладеної в книжках GURPS Basic Set [16, 17].

Планування ходу з боку гравця пришвидшити складно, але можливо - наприклад показуючи гравцеві область, в якій він може атакувати з позиції, на яку він хоче переставити свою фішку. Але швидкість прийняття рішення остаточно залежить від гравця та ситуації, в якій знаходиться його персонаж. Швидкість прийняття рішення суперником, якщо його роль виконує комп'ютер, а не людина, наприклад майстер гри, може бути значно пришвидшена, так як це рішення приймає не людина, а

швидший у прийнятті рішень комп'ютер, який окрім того що має повні знання про розміщення персонажів на ігровому полі бою, але й не має сумнівів, як гравець-людина. Деякі ігри мають функцію автоматичного бою, в якому дії замість гравця виконує також комп'ютер. Опція користується популярністю серед деяких гравців, але так як фактично вона усуває процес бою взагалі, який, при хорошому ігровому дизайні, повинен подобатися гравцям, коректним рішенням вважатися не буде. Якщо вважати що гравець витрачає на планування ходу три хвилини, а майстер гри 30 секунд, плануючи під час того як плануванням займаються гравці та адаптуючись до виконаних ними дій за ці 30 секунд. В такому випадку, заміна майстра гри на комп'ютерний алгоритм дозволить пришвидшити цикл ходів на 1 хвилину та весь бій на 5 хвилин. В результаті планування можна скоротити з 35 хвилин до 30, приблизно на 14%.

Переміщення фішки персонажа зазвичай не займає велику кількість часу, тож пришвидшення цього процесу дадуть мінімальний вплив. Якщо прийняти що на те щоб взяти фішку та переставити її витрачаються 2 секунди, то за допомогою комп'ютерної миші це можна зробити за 1 секунду. Але в залежності від рівня графічної реалізації процесу зміни персонажем позиції, анімація переміщення персонажа може займати додатковий час, в результаті триваючи довше за переміщення фішки по ігровому полю в настільній грі. З боку майстра гри, якщо його роль виконує комп'ютер, час на переміщення фішки може дорівнювати нулю, в залежності від наявності анімації. Тож за цикл ходів всіх персонажів, можливе пришвидшення на 6 секунд та 30 секунд для всього бою, але якщо анімація переміщення займає більше ніж півтори секунди, то комп'ютерна гра буде переміщувати персонажів довше. Враховуючи що переміщення займатиме всього 40 секунд з усього бою, навіть зменшення часу переміщення на 30 секунд, що складає 75% часу, не має значного впливу на швидкість бою.

Кидок кубиків використовується в настільно-рольових іграх для додавання випадкового фактору до боїв та інших ситуацій. В найпростішій версії кидка, гравцеві потрібно взяти кубик чи кубики, кинути їх, та побачити число, яке випало на кубику, або ж знайти суму чисел, якщо кубиків було декілька. В деяких настільно-рольових іграх до результату на кубиках застосовують модифікатори. В такому випадку їх необхідно додати до результатів кидка кубика, або ж помножити, якщо так вказано правилами. На один кидок кубиків можна відвести 5 секунд, враховуючи що іноді можливі затримки, пов'язані з пошуком кубиків на столі. Ще однією затримкою може бути спроба згадати які та яку кількість кубиків гравець повинен кинути. Перевагою застосування комп'ютерної програми для цього є майже миттєве отримання результату, як через швидкість отримання випадкового значення, так і через точне знання необхідної кількості кубиків, що для практичних цілей зводить час, необхідний на кидок кубиків до нуля секунд.

Підрахувати зменшення в часу бою в комп'ютерній грі в порівнянні з настільною грою поки неможливо, так як не є відомою кількість кидків кубиків. Ця кількість буде отримана при підрахунку економії часу при визначенні результатів.

Визначення результатів кидка кубика і є причиною його застосування. Так як для прикладу було обрано систему GURPS, кидки кубиків в бою при атаці відбуваються в такому порядку:

1. Кидок атаки.
2. Кидок визначення локації.
3. Кидок визначення підлокації.
4. Кидок захисту.
5. Кидок пошкоджень.
6. Кидок здоров'я при значних пошкодженнях.

Так як персонажів та суперників в цьому бою чотири, то такі серії кидків будуть виконуватися чотири рази. Якби хтось в цьому бою мав би змогу атакувати двічі, кількість кидків відповідно зросла б. Згідно з умовою цього прикладу, було опущено кидки для перевірки втрати свідомості та смерті. Вважатиметься що обидві сторони кожного ходу атакують суперника та потенційний вплив болювого шоку при отриманні пошкоджень не впливатиме на вірогідність влучання. Аналогічно не буде впливати на вірогідність успішного захисту і випадково обрана локація, яка, при достатній її мобільності повинна давати такий бонус [посилання на Pyramid] при використанні деяких додаткових правил.

Ще одним важливим фактором є необхідність перегляду правил під час бою через їхню велику кількість. Це займає додатковий час. Самі правила та послідовність дій можуть відносно просто запам'ятовуватися гравцями, але деякі секції з них вимагають перегляду результатів кидків в спеціальних таблицях вірогідностей, наприклад таблиці критичних влучень, критичних промахів, та локацій. При підготовлених ігрових матеріалах, пошук результату в таблиці займає приблизно 5 секунд.

В межах цього прикладу, будуть встановлені наступні правила стосовно вірогідностей кидків:

1. Кидок атаки має вірогідність 75% влучити. Якщо він не влучає, інші кидки не відбуваються.
2. Кидок локації відбувається завжди.
3. Кидок підлокації має шанс 80% відбутися,
4. Кидок захисту має вірогідність 50% спрацювати.
5. Якщо кидок захисту провалився, відбувається кидок пошкоджень.
6. Кидок пошкоджень має вірогідність 15% нанести значні пошкодження та призвести до відповідного кидка.

Додатково буде вважатися що одне з влучень критичне та обходить захист і призводить до перевірки відповідної таблиці, а один з провалених захистів також критичних, що призводить до перевірки таблиці критичних промахів.

Так як в бою приймають участь чотири персонажі та бій триває 5 ходів, відбудеться 20 кидків атаки, з яких три чверті влучать - 15. Так як одна

з них є критичною, відбувається кадок та перевірка таблиці критичних влучень.

Так як відбувається 15 влучать, відповідно виконується 15 кидків для визначення локації влучання та 15 перевірок таблиці локацій. Додатково виконуються 12 кидків кубиків для визначення підлокації.

Так як за умовою відбувається одне критичне влучання, кидків захисту відбувається 14. Додатково виконується кидок та перевірка таблиці критичних промахів, згідно умові що відбудеться критичний провал одного з захистів.

Так як половина з кидків захисту успішні, відбувається лише 7 кидків пошкоджень. Серед цих кидків один нанесе значні пошкодження та призведе до кидка здоров'я цілі. Кидок пошкоджень є складнішим за інші, так як окрім кидка кубиків до них може додаватися число від -1 до 2, відніматися значення броні цілі, та застосовуватися множник, в залежності від типу пошкоджень та локації, в яку влучив нападник. Вони будуть займати 10 секунд.

Підраховуючи виконані кидки, в сумі виходить 66 кидків, 7 з яких це кидки пошкоджень, що займає 365 секунд. Перевірки таблиць, яких відбувається 17, займають 85 секунд. Разом, час витрачений на кидки кубиків та перевірки таблиць складає 450 секунд, або ж 7.5 хвилин. Так як комп'ютер може виконати ці дії набагато швидше, час гри можна буде зменшити на 7.5 хвилин, але якщо додати паралельну візуалізацію більш цікавим для гравця кидкам, таким як влучення та захисту, тривалістю в 1 секунду, зекономлений на кидках час буде становити 6.25 хвилин.

Відповідно виконаним підрахункам, така гра займає 43 хвилини та 10 секунд. Використовуючи для контролю суперників та підрахунків комп'ютер, гру можливо пришвидшити до 30 хвилин та 10 секунд, якщо не застосовувати візуалізацію переміщення та кидків, та до 32 хвилин, якщо її застосовувати. Це складає приблизно 30% та 26% відповідно.

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