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Tetiana V. Zhuravliova [1]

Images of Women in Ukrainian Poetic Cinema: Metamorphoses of Femininity [1]

Abstract: The relevance of the research topic is to address the archetypal foundations of femaleimages in poetic cinema films, to consider the factors that bring the characters of the analysed films out of the depths of the national consciousness. Ukrainian screen culture is currently in search of the main types of screen characters, in the creation of new behavioural traits of heroes and heroines, as well as in the actualisation of symbolic and metaphorical features of the images of Ukrainian poetic cinema. The study object is the female characters in the films of Ukrainian poetic cinema of the 1960s and 1970s. The study aims to identify signs of transformation of archetypal foundations of female characters in the films of Ukrainian poetic cinema. The study analyses the feminine traits of the characters in the films of Ukrainian poetic cinema, identifies similar figurative and metaphorical features of the analysed female characters, and considers the socio-cultural context of the era under which the films were created. The main methods are aimed at understanding the historical process during which the cultural and ideological foundations of Ukrainian poetic cinema were laid. In this regard, the article uses such research approaches as: historical and genetic, cultural, art historical, comparative, and others. Among the researchers of poetic cinema of Ukraine whose works are used in the article are the following: O. Bryukhovetska, I. Zubavina, H. Pohrebniak, O. Musienko, and others. The results of the study focus on the phenomenon of poetic cinema, which included female characters, because through feminine characteristics, directors increasingly boldly promoted the idea of the political and cultural fate of Ukraine, its peculiarities. In these images, the directors encoded their reflections on the colonial past and the colonial present.

Keywords: Ukrainian poetic cinema, female images, femininity, archetypes.

Introduction

Ukrainian poetic cinema of the 1960s–1970s posed a challenge not only to the political system of the then-Soviet Union and its cultural paradigm but also defined new forms of artistic expression. This cinematic movement emerged during the Khrushchev Thaw, a period when public notions of individuality, freedom of choice, and the value of human life were undergoing profound change. Unprecedented attention was paid to the inner world of the individual and to the sphere of emotions. The concept of love began to be associated not only with love for the Motherland or its leaders but also with intimate, deeply personal experiences.

Soviet cinema of the totalitarian era (1930s–1950s) primarily focused on gender distinctions when portraying professional roles (e.g., milkmaid, combine operator, female teacher, steelworker). In war-themed films and those centred on the fight against enemies, masculinity was depicted through traits of militancy and victory, whereas femininity was considered solely as a personalised function for reproduction. Sexual relationships between characters were excluded from the narrative. Even married couples (as positive characters) were rarely shown in an interior with a bed (never in bed), and displays of affection such as hugging and kissing were treated with caution in the Soviet cinematic representation of romantic relationships.

Despite ideological taboos on expressions of sexuality, women on the Soviet screen during this period sometimes still appeared attractive. Actresses of the time attempted to emulate the beauty standards of Hollywood and European stars. However, their characters were subject to

behaviour constraints imposed by ideological censorship, limiting their ability to express attractiveness freely.

In Ukrainian cinema, prohibitions on the expression of female attractiveness often took on the character of taboo. A persistent, predominantly asexual image of the modern Ukrainian woman—both in contemporary and historical settings—prevailed on screen. In poetic cinema, schematic, one-dimensional representations of Ukrainian women frequently replaced more complex portrayals.

The relevance of this research lies in the appeal to the archetypal foundations of female images in poetic cinema and in examining the factors that bring these characters forth from the depths of national consciousness. Today, Ukrainian screen culture is in the process of redefining key character types, shaping new behavioural traits for heroes and heroines, and revitalising the symbolic and metaphorical dimensions of the images found in poetic film.

The study subject is the female characters in Ukrainian poetic films of the 1960s–1970s.

The study aims to identify the signs of transformation in the archetypal foundations of female imagery in Ukrainian poetic cinema.

The objectives of the research include analysis of feminine traits in the female characters of poetic films, identification of recurring symbolic and metaphorical features in these characters, and exploration of the socio-cultural context of the era in which the films were created.

The primary methods applied in the research are aimed at understanding the historical processes that shaped the cultural and ideological foundations of Ukrainian poetic cinema. Accordingly, the article employs a range of research approaches, including historical-genetic, cultural, art-historical, comparative, and others.

Among the key scholars of Ukrainian poetic cinema are L. Briukhovetska, Ya. Hazda, I. Zubavina, I. Kanivets, S. Trymbach, H. Pohrebniak, O. Musiienko, and others. H. Pohrebniak, in her exploration of authorship in Ukrainian poetic cinema, emphasises the important role of cinema in shaping the spiritual space and value orientations of national identity (*2023*). The semantic content of female images in poetic cinema is examined through the archetype of the mother in I. Zubavina's article (*2023*). This same author also stresses the relevance of the warrior-maiden archetype in contemporary cinema (2022), arguing that the image of the Warrior breaks with traditional (i.e., phallocentric/patriarchal) stereotypes portraying femininity as weak and passive (*Zubavina, 2022, p. 19*). The symbolic representation of female characters is analysed in the work of O. Musiienko (*2021*). L. Briukhovetska was the first to draw attention to female sexuality in poetic cinema and to the unique visual representation of the female body (*Briukhovetska, 2015*; *Briukhovetska, 2019*).

The findings of this study are intended to support further scholarly research in Ukrainian cinema and culture at large. The main positions presented in this text may also be of use to third-level art students (Doctor of Arts) in the development of creative projects where the foundational traits of Ukrainian art will be central to the creation of narratives, artistic images, and core messages.

Results

"Shadows of Forgotten Ancestors" by S. Parajanov (1965)

In the article *Two Women: Sexuality in Serhiy Parajanov's Film Shadows of Forgotten Ancestors* (*2015*), O. Briukhovetska emphasises that the Thaw in cinema brought about the emancipation of the discourse of sexuality and the female body—it began to be spoken of, albeit cautiously (*Briukhovetska, 2015, p. 50*). According to the author, the original text by M. Kotsiubynsky, upon which Parajanov based his film, offers fertile ground for a psychological analysis of the characters, particularly the issue of the inability to reconcile two distinct currents—sensuality and tenderness—and to direct them towards a single sexual object: *"In that same year of 1911, as Kotsiubynsky's novella was published, Lesia Ukrainka's play The Forest Song also appeared, exploring the theme of the woman's dual nature…"* (*Briukhovetska, 2015, p. 49*) In *Shadows...*, unlike in Ukrainka's drama, there is no division of female images into categories of spiritual versus earthly love, heavenly versus enigmatic and subconscious versus pragmatic, material affection. In Marichka's image, Ivan finds a synthesis of all feminine hypostases, with an allusion to motherhood (pregnancy) (*Briukhovetska, 2015, p. 49*).

The portrayal of the relationship that begins to form between Ivan and Marichka is rather controversial. Kotsiubynsky's novella states that Marichka began her sexual life at the age of thirteen, while Ivan was slightly older. In a dynamic scene in the film, in which the children run to a mountain lake and gradually undress, the literary meaning is transcribed into the cinematic language: Ivan, playfully, tears a necklace from the naked girl, then picks red berries in the grass and offers them to Marichka. Through play, the children cross the threshold into adult life.

Marichka (played by Larysa Kadochnikova) fulfils all of Ivan's (Ivan Mykolaichuk's) needs, creating a complete cosmos of his existence. Her death robs Ivan's life of all meaning—visually represented by the disappearance of colour, as his further existence is shown in black and white. This continues until Palagna (Tatyana Bestayeva) appears in his life. This woman "breaks the taboo on representing female desire—Palagna takes the initiative, actively seduces Ivan, presenting a completely different type of female sexuality." (*Briukhovetska, 2019, p. 38*) Palagna lacks Marichka's lyrical qualities and childlike innocence. Yet her image is imbued with an unprecedented sensuality on screen. She embodies all earthly pleasures that Ivan once rejected. Here—perhaps, for the first time since the nude scene in Oleksandr Dovzhenko's *Earth* (1930)—a Ukrainian film openly presents a naked woman in order to depict her physical allure.

We never see Marichka working. Palagna, on the contrary, displays her femininity primarily through labour. Her image combines archaic notions of female attractiveness with "the Soviet propaganda-constructed concept of labour libido <…> where strenuous, exhausting work stood as a substitute for the sexual act." (*Briukhovetska, 2019, p. 38*) However, the apex of unrestrained sexual desire is portrayed in the scene where a naked Palagna walks to the river at night to perform a magical ritual. Ivan is unaware of her journey and never sees his wife in such a state. Yet we understand that her desire to attract Ivan is hyperactive in nature—something that repels the man. Ivan begins to think of Marichka more often, mentally retreating into a phantasmagorical world full of unique beauty—a world he has lost, a world where there was Love.

Thus, in Parajanov's film, femininity is presented in both lyrical and hypersexual dimensions. Two women—Marichka and Palagna—at different times construct the existential dimension of the protagonist Ivan's being, a man doomed to death after the loss of Marichka.

The other woman, who was supposed to become a biological replacement for his beloved and a natural way out of loneliness, only deepens Ivan's sorrow, reinforcing his sense of doom.

"Evening on Ivan Kupala" by Y. Illienko (1969)

Sexual desire as a sign of sinfulness is portrayed in Yurii Illienko's film *The Eve of Ivan Kupala*. One particularly bold scene, in terms of its visual expression, takes place in a forest during Kupala Night. This scene—through its dynamic camerawork and mise-en-scène—strongly echoes a similar forest scene from *Shadows of Forgotten Ancestors* by Serhii Parajanov (it is worth recalling that Illienko was the cinematographer for *Shadows*). In Parajanov's film, naked adolescents playing in the forest thicket appear as though in the Garden of Eden, unaware of shame—at least for a time. In contrast, the Gogolian characters—Petro (Borys Khmelnytskyi) and Pydorka (Larysa Kadochnikova)—seduced by an unclean force, find themselves in a state of erotic frenzy, fully aware they are committing a pre-marital transgression. Pydorka is clearly the seductress; she is alluring and tempting. Such an image was unacceptably sensual for its time, especially given its engagement with Ukrainian folk traditions and the adaptation of literary classics.

The dark, nocturnal forest functions as a topos of unconscious desire, of yielding to evil, and in the aforementioned scene, it reveals in the virtuous girl Pydorka the archetype of the fallen woman. Tainted by sin, she will bear no children in marriage to Petro. She is just as potentially sinful as Petro, the murderer of her younger brother. In the end, the now-mad widow Pydorka will cradle a hatchet wrapped in cloth as a substitute for a child. The archetype of the mother, the Madonna, within this segment of the film reflects a deeply ingrained Ukrainian cultural trait—reverence for motherhood. According to archaic beliefs, femininity was realised solely through motherhood.

In an article analysing the cinematic projections of the Mother figure, Ukrainian film scholar Iryna Zubavina notes that the founder of archetypal theory, Carl Jung, identified the Mother archetype as one of the fundamental ones; thus, it can be seen as a prototype of femininity in general (*Zubavina, 2022, p. 52*). She further observes that "the films of the poetic school served as a channel for transmitting the semantic and conceptual foundations of the people's worldview. They represented relationships with kin, native land, its history and mythology." *(Zubavina, 2022, p. 54*) In Illienko's film, the female character carries a significant portion of the symbolic meaning, which the director conveys through a mytho-poetic form: "…Ukraine itself, in its dispossession, is embodied in the image of a woman. Pydorka in *The Eve of Ivan Kupala* becomes the allegorical figure of Ukraine as a 'colonised woman'." (*The 'imperial' image…, 2013*) Thus, the beautiful but childless widow Pydorka—without a home of her own, raped by nomadic invaders—embodies in Illienko's film the pessimistic vision of the Ukrainian 1960s intelligentsia regarding the nation's revival.

It is worth noting that, over time, female figures in poetic cinema, even despite film censorship and bans on public screenings, increasingly advanced the idea of Ukraine's political and cultural fate. The colonial past and the colonial present became a subject that filmmakers encoded, to a large extent, within their female characters. Verbal articulation of the issue of Ukrainian independence was a priori impossible. Therefore, it was deftly masked behind familiar

folkloric types with characteristic ethnic features, rooted in deep-seated archetypes that later took on specific ethnocultural and national significance.

"The White Bird with the Black Mark" by Yu. Illienko (1971)

There has already been mention of the Mother archetype as the foundation for creating recognisable female types in poetic cinema that resonate with the viewer's consciousness. When analysing the socio-philosophical essence of the archetypes in Ukrainian mentality, scholars single out the Mother archetype as "the embodiment of Woman, of Ukraine", and the archetype of the Land, "which is fundamentally based on an age-old trust in the 'kind mother earth', and which significantly shapes the psychological optimism and harmonious worldview of the Ukrainian people due to the land's bountiful natural conditions" (*Hordiichuk, 2018, p. 17*).

An archetypal, almost idealised image of the Absolute Mother was created by N. Naum in Yurii Illienko's film *The White Bird with the Black Mark* (1971). Kateryna Dzvonar loves all her children equally—her sons have grown up, each embracing his own political beliefs, which have become the cause of their hatred towards one another. In one of the film's key scenes—the murder of Orest (Bohdan Stupka)—Kateryna, sensing impending doom, runs to her son with an icon, hoping to avert disaster. The Mother instinctively senses that her protection is needed even by her grown child. To her, there are neither Banderites nor Red Army soldiers—there is only great sorrow: the lack of love between brothers, their enduring hostility, and their inability to coexist on their native land. A shot rings out, the icon slips from the mother's hands into a mountain river, and the camera lingers on the face of the Virgin Mary, her eyes filled with horror and grief.

In Orest's final scene, foreseeing his death, he performs an act of reconciliation—he kisses his younger brother Bohdan's hand. He essentially forgives the one who will kill him, though we never see who fires the shot. The negative figure of Soviet cinema—the "bad Banderite"—is reinterpreted today with a radically different subtext: Orest sought only one thing—to free his homeland from foreign rule. Of course, in the 1970s, such a character had to be loaded with a range of negative traits so that the viewer would feel no sympathy. Only mothers were allowed by Soviet ideology to display "political blindness"—such was the strength of this archetype, so deeply rooted in Ukrainian mentality that it overpowered any ideological framework.

Kateryna Dzvonar is a mother of many children. The family is poor, and one of her sons, a teenager named Heorhii, wants to destroy the stork's nest on their roof to prevent further additions to the family. The stork, as a symbol of motherhood, becomes an essential element of the film's imagery—as well as in others, where women yearn for children (Pidorka in *An Evening on Ivan Kupala*, for instance, builds nests for the storks herself, yet the birds avoid her home). Marriage, motherhood, and having many children have long been considered the principal virtues of women in Ukrainian cultural consciousness. To this list was added diligence—the ability to balance childbearing with fulfilling basic material needs. A woman could attain social legitimacy only by embodying this particular set of feminine qualities. Without them, she was relegated to the margins, facing scorn and condemnation.

In *The White Bird with the Black Mark*, such a marginalised female figure is the village loose woman, Vivdia (D. Firsova). Whereas a married woman with children was perceived as Good from the standpoint of common morality, Evil was embodied by the prostitute. In one scene,

Vivdia appears as a temptress-Eve: young Heorhii Dzvonar sneaks into her apple orchard. In early Christian literature, Eve was often portrayed in a misogynistic light: "These texts place dramatic emphasis on the coexistence of seductive and evil traits within a single woman." (*Skrypnyk, 2022, p. 22*). The alluring beauty enjoys male attention but is regarded by other women as a source of sin. A telling scene shows Vivdia bathing in a pond where local women are rinsing freshly woven linen—her sinful body defiling the labour of decent housewives. As punishment, the community ties her hands above her head with the sleeves of a shirt. Heorhii, who has loved Vivdia since childhood, sees this as a moment to declare himself to her. The wedding ritual and Vivdia's exit from the house in a bridal headdress—a *karabula* decorated with feather grass—equalise her with the other village women, restoring her feminine dignity. Her archetype of the Fallen Woman transforms into a literary and cinematic trope familiar in both European and American traditions—the redeemed prostitute: "a woman who is virtuous at heart but has fallen; she is rescued from her sinful life, usually by a man who risks his own reputation to save her." (*Skrypnyk, 2022, p. 28*) Thus, the male figure becomes the catalyst not only for redemption as a plot device, but also for the transformation of the female character from social pariah to positive heroine. Vivdia had been waiting for her saviour—and he came. She once told young Heorhii, who stole her apples to be like God, to know Good and Evil: "When you've been sold for a crust of bread a few times, then you'll understand." Vivdia consorted with Romanians, Germans, and other men to survive. Only the Ukrainian Heorhii married her and, for a brief moment, allowed her to feel human dignity.

Another female character in *The White Bird…*, Dana (L. Kadochnikova), also longs for a decisive act from a man. The elder Dzvonar brothers are in love with her, but their poverty breeds a certain male inferiority complex—neither dares to marry the priest's daughter. Dana undergoes several stages of feminine transformation. At first, she seems like a typical dramatic archetype—a pure but wilful young lady waiting for her rebel. That rebel is, of course, Orest. However, another facet of Dana's character puzzles the brothers: she herself is unsure which of them she loves—Petro, Orest, or Bohdan. One night, she throws herself into Petro's arms in an attempt at seduction, but he refuses. To Dana, the brothers are one entity, yet none of them can overcome their sense of inferiority—especially national inferiority. Dana is ready to risk her reputation so that one of the Dzvonars will become her husband. Their indecisiveness leads her to agree to marry a Soviet soldier she barely knows (as Bukovyna falls under Soviet rule). This plot element becomes highly symbolic in the context of historical events. In her imagination, Dana performs her wedding dance—a sabbath—passionately with Orest, with whom she will spend her first wedding night.

Ukrainian ethnologist D. Lepkyi noted that the name Dana is associated with Ukrainian water-spirit festivals and appears in songs and folklore (*Lepkyi, 1883*). M. Kostomarov considered Dana to be a female deity of water among the Eastern Slavs (*Kostomarov, 1994*). The recurring refrain "Dana-dana" in folk songs may support these theories across generations. Film scholar O. Musiienko analyses female images through elemental symbolism and notes that "in mythological beliefs, water was seen as the embodiment of femininity, a symbol of purity, truthfulness, and honesty." (*Musiienko, 2021, p. 26*) It is reasonable to assume that this feminine name and its mythologised foundation may invite an association between Dana and Ukraine itself.

Dana undergoes a metamorphosis—from maiden to prostitute and from prostitute to mother. After living in the forest with her lover, the villagers see her as a fallen woman. This stigma is intensified by the fact that Orest is a "traitor, an enemy" (according to Soviet ideological framing, the only acceptable interpretation of UPA fighters). After Orest's death, pregnant Dana returns to the village for good. When her father rebukes her for her sin, she replies: a woman must give birth so that people may live on the earth. With this final statement, Dana is no longer a girl but a woman—"the earth, most often associated with the feminine, with motherhood, with the mature woman" (*Musiienko, 2021, p. 26*).

Thus, Dana will continue the Dzvonar lineage—the lineage of rebellious, defiant Ukrainians who know exactly where their homeland lies, for she bears Orest's child in her womb.

From the above, it is evident that in his film, Yurii Illienko presents a unique triune concept of Ukraine, embodied in the archetypes of the Maiden, the Mother, and the Prostitute—respectively, Dana, Kateryna Dzvonar, and Vivdia. The first and the last exhibit the sexual characteristics of femininity linked to carnal love, while the Mother represents non-sexual qualities—an expression of unconditional spiritual love.

Babylon XX

Let us consider another female figure from poetic cinema, which, like the previous ones, combines the archetypes of the prostitute and the mother. In the film *Babylon XX* by I. Mykolaichuk, the character of Malva (played by L. Polishchuk) presents an allusion to the images of Vivdya or Dana from *The White Bird with the Black Mark*, and we observe the same allegorical dramatic devices: "Once again, we see on screen a woman who embodies the image of Ukrainian soil. And whoever earns her favour will be the one to build the future." (*Babylon…, 2020*)

The archetype of the prostitute, embodied by L. Polishchuk, most fully aligns with its profound foundations. The director spent a long time searching for an actress to play Malva. There are certain traits of an actress's appeal—her psycho-physical factors—that defy straightforward professional classification. Malva's sexuality had to be evident from the moment she appeared on screen. The viewer was meant to believe she was the most attractive, the most desirable woman in Babylon—and yet one who had never experienced the joy of true love. The men who used her body were never able to touch her soul.

M. Romanchenko, analysing the cinematic interpretation of Malva in the screen adaptation of V. Zemliak's novel *The Swan Flock*, compared Malva Kozhushna to the archetype of the "priestess-woman"—a woman to whom others bow, a temptress. He also points out that Malva does not feel ashamed of bodily desires (at least, at the beginning of the narrative) (*Romanchenko, 2016, p. 120*). The author goes on to state: "In I. Mykolaichuk's film, we are shown a slightly different Malva—more self-assured and spiritually stronger." (*Romanchenko, 2016, p. 121*)

Comparing Malva in V. Zemliak's novel and in I. Mykolaichuk's film, researcher N. Kryvoruchko suggests that "the emphasis on Malva's personal traits follows this order: in the novel, she is free, carefree, lustful—the one others fight for—while in the film, she embodies strength, and at times the lack thereof, complete independence from her environment, and becomes the one who fights Circumstance on her own." (*Kryvoruchko, 2014, p. 98*)

In Soviet cinema, such a type of woman could not be portrayed as a positive character. To alter the feminine characteristics of a heroine depicted as a femme fatale, certain events had to take place to suppress her sexual allure and lead her to become a socially active figure. The dramaturgical device of redemption through love in Mykolaichuk's film is introduced at the beginning in a somewhat ironic manner: the young widow Malva, in search of love, arrives at a commune inhabited solely by men. The commune leader (I. Havryliuk) meets the stunning woman with hostility, wishing to expel her lest her appearance tempt the communards.

The scene evokes an analogy with the apostles of Christ and Mary Magdalene, the repentant harlot. The irony lies in the fact that the communard, delivering a fiery communist speech before portraits of Marx and Engels, is doing so in his underwear—having just risen from bed, awakened by Malva's visit. She attracts him, but he believes he must not waste his energy on love and instead offers her a "replacement"—a young, handsome man named Volodia (A. Khostikoyev).

Volodia's meeting with Malva is comical precisely because it defies the commune leader's expectations: the young woman immediately captivates the poet Volodia, who quickly forgets his communist asceticism. However, Malva later sheds the label of a fallen woman. Her relationship with the communard legitimises her behaviour—especially once it becomes clear that she is pregnant with Volodia's child. This signifies that she has become one of the "righteous"; her sexuality, transformed into motherhood, loses its "bourgeois" cultural traits.

Thus, Malva—like the female characters of the previously mentioned films—undergoes a transformation from the archetype of the Prostitute to the archetype of the Mother. Just like Pydorka, Dana, Vivdya, and Kateryna Dzvonar, Malva metaphorically embodies the concept of Ukraine within the socio-cultural paradigm allowed to artists by the ideological doctrine of Soviet poetic cinema.

The research problem of this article lies in identifying the main figurative and metaphorical structures of Ukrainian poetic cinema of the 1960s–1970s associated with female characters. Until now, female characters have not been studied comprehensively in terms of their feminine traits and the processes of transformation (metamorphosis) of those traits.

It can be noted that "the human figure in Ukrainian poetic cinema becomes a representation not so much of their class, as of the people, or more broadly—the land, the homeland." (*Pashchenko, 2015*) Turning to nation-building processes in Ukrainian cinema prompts a reassessment of historical stages, as well as the socio-cultural and political factors that influenced on-screen characters—factors that often dictated the themes and ideas that Ukrainian filmmakers were permitted to explore.

Hence, the female characters of Ukrainian poetic cinema—from the works of O. Dovzhenko to the new poetic visions of contemporary directors such as M. Illienko and O. Sanin—metaphorically represented Ukraine itself, often clashing with the Soviet policy aimed at shaping the notion of a "unified Soviet people".

The current state of Ukrainian culture and political reality dictates new conditions for the representation of Ukrainians on screen, articulating new ideas and the necessity for the emergence of different male and female characters. For this reason, a critical reassessment of Ukrainian cinema in its historical evolution encourages artistic and scholarly reflection on the key concepts of contemporary Ukrainian film art.

Conclusion

A cultural and historical analysis of the 1960s–1970s in the history of Ukrainian cinema reveals a clear regulation in the portrayal of feminine traits on screen. Women more often appeared in roles stripped of sexual appeal. Female characters in poetic cinema largely replaced schematic and one-dimensional screen types of Ukrainian women.

In Serhii Parajanov's *Shadows of Forgotten Ancestors*, two women—Marichka and Palahna—create the existential dimension of the main character Ivan's life, who is doomed to die after losing Marichka. Their opposing feminine traits—tender and sensual—metaphorically reflect two distinct levels of human existence. For Ivan, the loss of a special, sacred level could not be compensated for by the sensual, erotic one.

The phenomenon of poetic cinema gave rise to female figures that, through their feminine features, increasingly embodied the idea of Ukraine's political and cultural fate and uniqueness. In these characters, directors encoded their reflections on both the colonial past and colonial present. The idea of an independent Ukraine was disguised behind familiar folkloric types, marked by distinctive ethnic features grounded in deep-rooted archetypes, which later acquired ethno-cultural and national connotations.

In their films, Parajanov, Illienko, and Mykolaichuk frequently employed the principle of metamorphosis in female images – the transformation of their feminine features or the transfer of such traits from one female character to another. For instance, in *The White Bird with the Black Mark*, Yurii Illienko presents his own triune concept of Ukraine through the archetypes of the Virgin, the Mother, and the Prostitute, embodied in Dany, Kateryna Dzvonar, and Vivdya, respectively. The first and the last display sexual aspects of femininity associated with carnal love, while the Mother reveals non-sexual traits aimed at the spiritual expression of unconditional love. Malva from Mykolaichuk's *Babylon XX*, like the aforementioned characters, also undergoes a transformation from the archetype of the Prostitute to that of the Mother, and in her metaphorical essence embodies the concept of Ukraine within the socio-cultural paradigm permitted to the artists of poetic cinema by the Soviet ideological doctrine.

Conflict of interest

The author declares that there is no conflict of interest.

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Tejmur A. Kasumov [2]

Assessment of the State of Ukraine's Light Industry Market and Possible Paths to Its Recovery [2]

Abstract: Under prolonged economic and political instability, particularly due to the war, Ukraine's light industry market has undergone significant changes and challenges. The study aims to analyse the current state of the light industry market and identify ways for its recovery. The study employs economic and statistical analysis methods, systematisation, induction and deduction, and logical generalisation. The study methodology includes a combination of financial and statistical methods (to determine production capacity utilisation compared to the pre-war period, the proportion of industrial enterprises operating at near-full and full capacity, a systematisation method (to group the identified problems of Ukraine's light industry market) and a method of logical generalisation (to formulate recommendations for the sector's recovery). The study established that Ukraine's light industry market is experiencing a difficult period due to a combination of internal and external challenges: a decline in exports, a disrupted export-import balance (imports exceed exports by a factor of three), increased import levels, a shortage of skilled labour, and difficulties in obtaining state financial assistance. It was found that the main problems of the light industry market include export difficulties due to customs barriers, inequality within the domestic market, economic instability and limited access to credit, a rigid tax system, insufficient state support and localisation, issues in workforce training, a significant share of the shadow economy, and logistical and transportation problems. The study determined that to restore Ukraine's light industry market, a comprehensive set of measures must be implemented: the introduction of a temporary zero VAT rate for imported equipment and the implementation of a mechanism for using tax funds to invest in modernisation and innovation; initiating negotiations with the EU to eliminate import duties on textile products, which would help increase the export of Ukrainian goods to European markets. In addition, it was found that it is significant to support the domestic market through government programmes that ensure access to credit and adapt the tax system to martial law conditions.

Keywords: socio-economic sector, import and export of the light industry, logistical barriers, strict tax policy, financial instability, state support.

Abbreviations:

SMEs are small and medium-sized enterprises,

VAT is value-added tax,

WTO is World Trade Organisation.

Introduction

Amid the prolonged full-scale war that began in Ukraine in 2022, the light industry market, as an essential component of the national economy, has faced unprecedented challenges and problems. Traditionally, light industry has played a key role in the country's industrial structure, contributing a significant share of industrial output and numerous jobs supporting social stability. However, the war has caused large-scale infrastructure destruction, disruptions in resource supply, and a substantial decline in production capacity, all of which have significantly impacted the sector's operations. An analysis of the current state of Ukraine's light industry market under wartime conditions makes it possible to identify the main issues and challenges hindering recovery.

The functioning of the Ukrainian light industry market has attracted the attention of many domestic scholars. For example, L. E. Kasian (*2018*) analysed the industry's current state and identified the main obstacles to its development. Other researchers, such as T. V. Havrylenko and I. V. Brodiuk (*2021*), also examined the industry's challenges in the context of external economic factors. Meanwhile, V. O. Kharchenko and M. O. Sukhomlyn (*2023*) analysed the key factors influencing industry development, highlighting internal and external factors, including the investment climate, resource access, and innovation opportunities. In his study, L. Zinoruk (*2021*) explored the impact of branding on the performance of light industry enterprises, noting that a strong brand can significantly enhance product competitiveness in domestic and international markets. Researchers such as L. M. Hanushchak-Yefymenko, M. S. Shkoda, and T. A. Kasumov (*2023*; *2024*) investigated branding processes in European markets and their significance for Ukrainian manufacturers. In a scientific study by S. I. Serhiychuk, O. A. Ishchenko, and I. I. Dubynska (*2020*), SMEs' current state and development prospects in the light industry were analysed. Thus, recent academic research confirms the need to study the specific features of Ukraine's light industry market's development. Despite the considerable number of studies, the issue of recovery pathways for the light industry market remains underexplored and requires further research.

The study aims to provide a comprehensive assessment of the current state of Ukraine's light industry market by identifying the key problems that have arisen amid the ongoing war and developing recommendations for potential recovery strategies. In line with this aim, the study pursues the following objectives:

- analyse the light industry market in Ukraine under wartime and martial law conditions;
- identify the problems and obstacles to the further development of the light industry market in Ukraine;
- explore possible pathways for its recovery.

The study methodology includes a combination of economic and statistical methods (to determine production capacity utilisation compared to the pre-war period, the proportion of industrial enterprises operating at near-full and full capacity (75–99%, 100% and more), and the volume of the clothing market in Ukraine), a systematisation method (to group the identified problems of Ukraine's light industry market) and a method of logical generalisation (to formulate recommendations for the sector's recovery).

Results

Analysis of the Light Industry Market in Ukraine under Conditions of War and Martial Law

The light industry is one of the most critical socio-economic sectors in Ukraine, significantly impacting the country's economic and social development. Its core characteristic is its focus on the end consumer, making it a vital segment in the production of consumer goods.

The light industry encompasses the production of textiles, clothing, footwear, leather goods, and other everyday essentials for the population. As of 2020, it accounted for 5% of Ukraine's total budget revenues, underlining its importance to the state's financial framework (*Ukraine: Light industry, 2024*).

Moreover, the sector contributes 2.6% to Ukraine's merchandise exports, highlighting its role in international trade and its ability to compete in global markets.

Before the war, developing Ukraine's light industry experienced periods of both growth and decline. In 2008, the production volume in the sector reached almost 60% of the 1990 level. However, the global financial crisis led to a sharp decrease in output. Between 2008 and 2014, processed leather production fell by 68%, sweaters, pullovers, cardigans by 65.5%, and men's suits by 67%. Ukraine's accession to the WTO in 2008 failed to improve the situation, as the reduction in tariff protection of the domestic market further weakened production levels.

In subsequent years, the industry remained unstable: a decline from 2014 to 2016 to 2004 levels, followed by growth in 2017–2018. The sector's response to economic challenges varied: textile and apparel production grew by 3.9% and 2.0%, respectively, in 2014, while tanning, bag production, and other segments dropped by 18.6%. Footwear and weaving production saw a consistent decline.

In 2018, the volume of industrial products sold in the light industry was 93% of the 2006 level, while in 2019–2020, negative trends re-emerged, causing Ukraine to fall behind Poland, Germany, and Italy in production indicators. By the end of 2023, Ukraine had 19,700 registered producers of clothing, footwear, textiles, and leather goods (*Research on textiles…, 2023*).

Analysing the recent dynamics of exports and imports (*Figure 1*) is necessary to better understand Ukraine's light industry market's current state.

An analysis of export and import dynamics over the past six years shows the sector is going through a difficult period. Export volumes declined from $1.220 billion in 2018 to $951.1 million in 2022, indicating a loss of competitiveness in international markets. The main reason is the full-scale war that began in February 2022. Other factors also impacted the sector. In 2020, the COVID–19 pandemic triggered a global economic crisis that negatively affected Ukraine's light industry. The pandemic led to job losses and disruptions in global supply chains, limiting export and import capabilities.

Imports continued to grow until 2021, reaching $3.538 billion, indicating a high dependence of the domestic market on imported goods. This growth was due to the underdevelopment of domestic production and high demand for foreign products, particularly under the stable economic conditions before the war. However, in 2022, imports dropped to $3.294 billion due to the financial crisis and logistical challenges brought on by the war. Still, import volumes remained significant, suggesting stable domestic demand for imported products.

Examining the capacity utilization of enterprises operating in Ukraine's light industry market (*Figure 2*) is also insightful.

Despite overall resilience during the full-scale war, in 2022, only 7% of enterprises operated at full capacity. This indicates constraints in achieving maximum productivity, primarily due to resource shortages and supply chain issues. A substantial portion of enterprises (32%) operated at 50–74% capacity, underlining the persistent challenges preventing full recovery. On a positive note, only 2% of enterprises ceased operations entirely, showing the sector's relative viability and adaptability even during wartime. Compared to other industrial sectors, light industry performed better in 2022, mainly due to its lower dependency on complex technologies and raw materials.

The situation improved in 2023 and 2024 as the market recovered from the initial shock and resumed operations. The following figure (*Figure 3*) presents the share of industrial enterprises operating at near-full or full capacity (75–99%, 100% or more), based on sectoral surveys, compared to the pre-war period.

Throughout the year, performance indicators improved gradually, especially in the second quarter, where the share of light industry enterprises operating at near or full capacity rose to 55%, reaching 61% by the end of the year. This demonstrates that the sector began to recover from the negative impacts of the conflict, supported by internal market stabilisation and restored production facilities. However, compared to the pre-war period, the sector still shows significant volatility, mainly due to unpredictable external factors and fluctuations in demand.

At the beginning of 2024, the light industry continued to show moderate growth, with 61% of enterprises operating at near or full capacity—an improvement over previous months but still below pre-war levels. The dynamic suggests that businesses continue to implement adaptation strategies but still require further support and investment to ensure stable growth and a return to pre-war production volumes.

Thus, the performance indicators of Ukraine's light industry remain relatively stable, thanks to the sector's flexibility, mainly due to the predominance of SMEs. These SMEs were able to respond swiftly to the outbreak of war, relocating and adapting to wartime realities. Most of the 2,000+ sector-specific enterprises in light industry continued operating under war conditions. Many adapted their production to meet defence needs, fulfilling orders for clothing and gear from local governments, volunteer organisations, and territorial communities (*Ukrainian Business…, 2024*).

Figure 4 presents the dynamics of the clothing market volume in Ukraine in millions of units.

Analysing recent years, clothing sales in Ukraine dropped significantly after 2019. The most substantial decline occurred in 2022 due to the full-scale war and economic hardships, which caused a sharp fall in consumer purchasing power and disrupted supply chains. A modest recovery began in 2023, and forecasts for 2024–2027 point to gradual but steady growth, indicating that the market is adapting to new conditions and consumer demand is rebounding.

Today, Ukraine's light industry market exhibits several defining features that shape its development and adaptation:

- *Resilience to shocks*. Despite significant challenges caused by the full-scale invasion, the sector remains resilient. Experts are confident that the light industry can survive and grow, as it did during the 2014 economic crisis.
- *Strong production capacity*. As of late 2023, 19,702 officially registered operators were in the industry, reflecting substantial industrial capacity.
- *Collaboration with international brands*. A large share of Ukraine's production is outsourced to well-known global brands, reflecting the high quality of Ukrainian goods and the trust of international companies.
- *Rapid specialist training*. Industry professionals, such as technologists and seamstresses, are trained relatively quickly due to effective programmes, allowing prompt adaptation to market needs.

- *Low labour costs*. Labour costs in Ukraine are significantly lower than in the EU, making Ukrainian production more economically attractive than European competitors.
- *Favorable geographic location*. Ukraine borders the EU and is closer to key industry competitors such as China, Vietnam, and India.
- *Production flexibility*. The presence of SMEs allows for small-batch production, which is advantageous for small and niche brands without their facilities.

In conclusion, Ukraine's light industry performance indicators point to a gradual recovery despite difficult economic conditions. The growing share of enterprises operating at or near full capacity shows that businesses are adapting to new challenges.

Problems and Obstacles to the Further Development of the Light Industry Market in Ukraine, as well as Possible Ways of Its Recovery

Based on the information presented (*Table 1*), the author has systematised the main issues hindering the further recovery of the light industry market.

To restore the light industry market in Ukraine, many measures are worth implementing. Firstly, a temporary (10-year) zero VAT rate should be introduced at the legislative level for equipment imported from abroad that is not manufactured in Ukraine. This will help reduce the costs of acquiring modern technologies and equipment for production needs. For example, if a Ukrainian manufacturer wishes to implement advanced technologies to improve the quality of textile products, a VAT exemption on imported equipment will allow them to save a significant amount that can be redirected toward production modernisation and product enhancement (*Internal reserves…, 2023*).

Additionally, a mechanism that allows enterprises to use funds from profit tax for investment in recovery, modernisation, innovation, and energy-saving measures is worth introducing. In particular, companies could allocate part of their profits toward installing energy-efficient equipment, reducing energy costs and lessening environmental impact. For instance, textile factories could implement advanced raw material processing systems that reduce water and energy consumption, which would cut costs and raise environmental production standards.

Another critical step is initiating negotiations with the EU to amend the relevant regulations to eliminate import duties on knitwear and textile products when EUR-1 certificates are obtained. This would enable Ukrainian manufacturers to increase exports to European countries, which is crucial for the industry's growth. For example, if a Ukrainian company produces high-quality knitwear, eliminating duties on exports to the EU would open up new markets and ensure competitiveness in the European market (*Internal reserves…, 2023*).

Moreover, it is crucial to address the issue of insufficient domestic demand. The domestic market for the light industry has a potential volume of about UAH 200 billion annually. Domestically produced goods occupy only 15–25% of this market, resulting from unequal competition conditions. The situation worsened during the war, as imports exceeded exports by three times, while exports declined by 40%. Reviving production and filling the domestic market is essential for stabilising the industry. It is also necessary to support manufacturers through government programs that provide access to credit, adapt the tax system to martial law conditions, and promote participation in public procurement.

Specifically, adjustments to the National Bank of Ukraine's policy to improve access to credit resources and adapt the tax system to wartime conditions will help enterprises overcome financial difficulties. Support for localisation of production through state orders will also promote growth in domestic manufacturing.

Another important aspect is optimising the production structure by considering the industry's innovative potential and prospects for market expansion. In this context, it is recommended to establish industrial technology parks and clusters and develop vertically integrated structures. Involving representatives of small and medium-sized businesses will increase adaptability to changing market conditions (*Hanushchak-Yefymenko et al., 2023*; *Shandrivska & Yunko, 2021*).

Finally, it is significant to strengthen the marketing and logistics departments of light industry enterprises. This will allow for better management of market strategies and effective product distribution, thereby positively influencing the sector's overall competitiveness.

Discussion

Analysing the current state of Ukraine's light industry, it can be stated that the main problem remains the insufficient support from the state and the challenging economic conditions caused by the war. Despite the sector's resilience and ability to adapt, the key challenges continue to be high customs barriers, tax pressure, financial instability, a shortage of skilled personnel, and limited domestic demand. This raises the question: Are the proposed measures sufficient to overcome these difficulties, and can the light industry eventually become an economic driver for the country?

An important aspect for further research is the analysis of the effectiveness of the zero VAT rate on imported equipment and the mechanism for reinvesting corporate income tax into production modernisation. Will such measures truly facilitate a rapid recovery of production and enhance the competitiveness of Ukrainian enterprises? Furthermore, it is necessary to consider the creation of targeted state support programs to stimulate domestic demand and exports and to study the experience of other countries in developing light industries under crisis conditions. Another discussion area is the role of cluster initiatives and industrial technoparks in the market recovery process.

Conclusion

Thus, even under wartime conditions, the sector has demonstrated its viability, adaptability, and capacity to swiftly launch new types of products, carry out relocation and recovery operations in de-occupied territories, and train and retrain workers in production facilities. It can even be argued that the light industry has a real chance of becoming an economic driver.

Based on the information presented, Ukraine's light industry market faces many serious challenges that hinder its recovery and development. The main problems identified during the research include high customs barriers, unequal competition conditions in the domestic market, financial instability, a rigid tax policy, insufficient state support, a lack of qualified personnel, a significant share of the shadow economy, and logistical and transportation difficulties.

To restore the light industry market, it is necessary to implement a comprehensive set of measures, including the introduction of a zero VAT rate on imported equipment, the

development of mechanisms to support investment in modernisation and energy efficiency, and the initiation of negotiations with the EU to eliminate import duties on textile products. In addition, it is important to ensure support for manufacturers through government programmes, adjust National Bank policies to facilitate access to credit, and promote the localisation of production. Optimising the production structure, establishing industrial technology parks and clusters, and strengthening marketing and logistics departments are also key to enhancing the competitiveness and development of the industry.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix

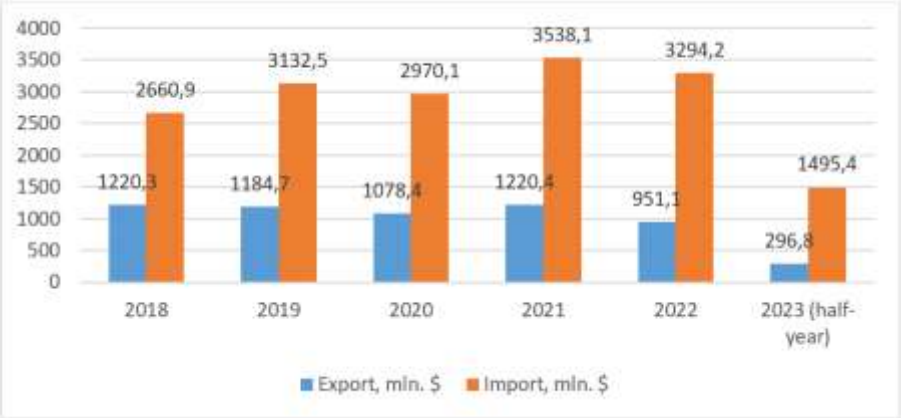

Figure 1. dynamics of light industry exports and imports in Ukraine for 2018–2023 (1st half of the year), mln. doll. USA (*Export of Ukrainian goods…, 2022*)

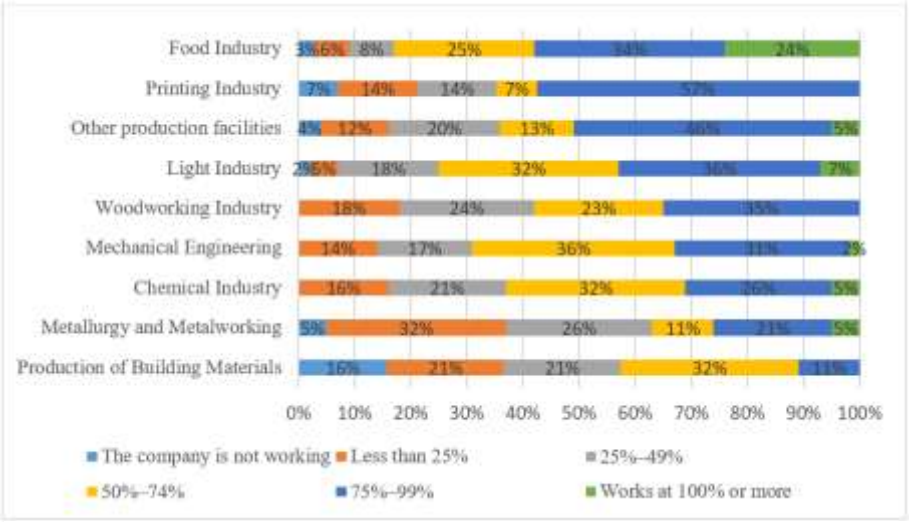

Figure 2. Capacity utilisation, compared to the pre-war period, % of enterprises in 2022 (*Ukrainian business…, 2022*)

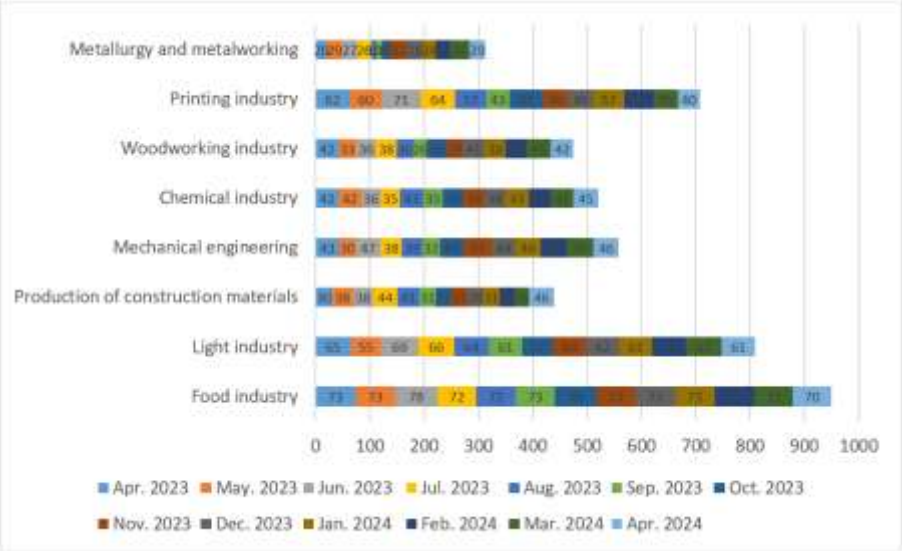

Figure 3. Share of industrial enterprises operating at almost full and full capacity (75-99%, 100% or more) compared to the pre-war period, % of respondents by industry (*Ukrainian business…, 2024*)

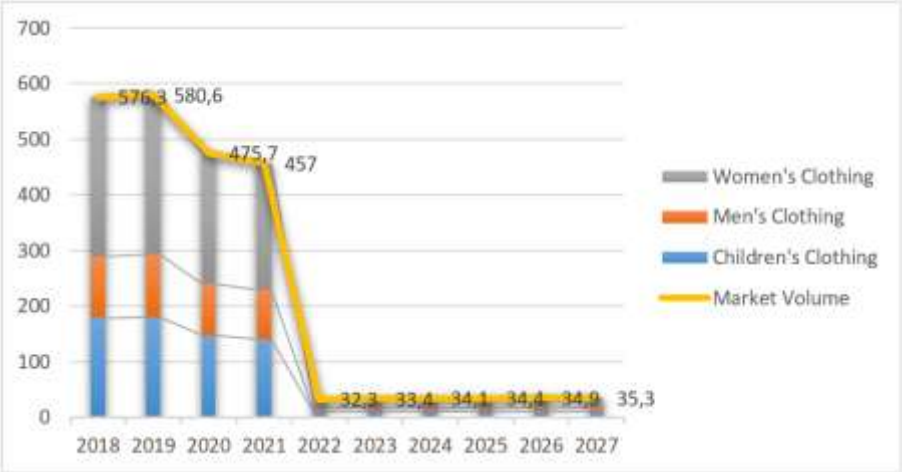

Figure 4. Volume of the clothing market in Ukraine in millions of units. (*Apparel – Ukraine, 2022*)

Table 1. Problems of the Ukrainian light industry market identified (*Internal reserves…, 2023; Shandrivska & Yunko, 2021*)

№	Problem	Description
1	Export difficulties due to customs barriers	The presence of high import duties on knitwear and textile products prevents an increase in exports. Insufficient support in the form of EUR–1 certificates and changes in EU customs regulations make it difficult to enter European markets.
2	Inequality in the domestic market	Low level of domestic products on the domestic market (15–25%) due to unequal competition conditions and a high level of import dependence. Military challenges have exacerbated this problem, in particular, the significant excess of imports over exports.
3	Financial instability and limited access to credit	The unstable economic situation and limited access to credit resources make it difficult to modernize production facilities and implement investment projects.
4	Strict adaptation of the tax system	A strict tax policy under martial law does not contribute to the effective functioning of light industry enterprises, which requires correction.
5	Insufficient government support and localisation	The lack of sufficient participation in government orders and incomplete implementation of product sales mechanisms leads to weak support for domestic producers.
6	Problems with training	The lack of qualified personnel for the light industrial sector, due to the significant migration of women and the mobilisation of men, limits opportunities for modernisation and the introduction of new technologies.
7	A significant share of the shadow sector	Smuggling of goods is a serious problem. According to the reports of the three main importers of finished products to Ukraine—China, Turkey and Poland, in 2017, products worth0 1,079.1 million were imported from their territory, while according to the state Statistics Service of Ukraine—only 4 483.3 million. This means that the Ukrainian market received unaccounted-for imports of knitwear, home textiles, clothing and footwear in the amount of 5 596 million. Budget losses for the year only from these exporting countries amounted to UAH 5.3 billion.
8	Logistics and transport problems, including those related to border closures; transfer of a significant part of logistics operations to an online format	Logistics and transport problems, in particular related to the closure of borders due to political and economic circumstances, as well as the need to transfer a significant part of logistics operations to an online format, significantly hinder the development of light industry. This includes difficulties in obtaining raw materials, delays in the delivery of finished products to consumers, increased transportation costs due to the need to find alternative routes, as well as restrictions on physical access to international markets, which reduces the competitiveness of Ukrainian producers on the world stage.

Andrii I. Korobko [3], *Illia Semenov* [4]

Functional Adaptation of the Grain Carrier with Unstable Weight of the Transported Grain [3]

Abstract: The methodology of functional adaptation of a grain truck by adjusting the speed depending on the density of the transported grain crop is proposed. As a result of studying the functional adaptation of a grain truck with an unstable mass of transported grain, it was found that fluctuations in the grain cargo during transportation significantly affect the stability of the vehicle, especially during maneuvering and braking. When estimating the weight of a grain truck, the density of the transported grain must be taken into account. The volumetric carrying capacity of a grain truck is carefully assessed by establishing a functional dependence on such parameters as nominal carrying capacity, volumetric carrying capacity, body volume, and cargo volume. The dynamic space of grain truck operation is based on a metric state space, each element of which fully determines the state of the system under consideration according to certain functional parameters. If one or more functional parameters of the grain truck are unstable and deviate from their nominal values, the grain truck may lose its functional stability and not perform the functions defined by the regulatory and technical documentation. In such cases, the dynamic operating space is characterised by transfer functions that provide a mathematical basis for analysing the behaviour of the system. During the operation of a grain truck, the task of ensuring its functioning in one of two areas is solved: the area of operation or the area of optimal operation. To ensure that the grain carrier operates in the optimal region, it is necessary to select such nominal values of functional parameters and tolerance fields to ensure the position of the spread and outputs in this region.

Keywords: functional adaptation, grain carrier, grain mass, mass instability, acceleration, equation of motion.

Introduction

Ukraine is rightly considered a grain country due to the efficient transportation of grain from fields to granaries, from elevators to processing plants, and to seaports. Ukraine has created a KrAZ "Karavan–2" grain haulage train consisting of a KrAZ-6511 C4 dump truck and a PCWi-33 dump trailer with technical and economic indicators on par with foreign analogs (*Stehantseva, 2013*).

The KrAZ-6511C4 grain truck is equipped with a 400-hp Weichai Power WP12. 400E40 (Euro 4) with SCR exhaust gas cleaning system, MFZ 430 clutch and Fast Gear 12jS180TA manual transmission. The chassis is equipped with a reinforced rear axle balancer suspension, a front axle with an increased payload of up to 8 tonnes, and an integral steering mechanism. The payload of the vehicle is 20 tonnes and the trailer is 24 tonnes.

The results of factory and operational tests confirm the effectiveness of the KrAZ "Karavan–2" grain truck in agricultural enterprises (*Stehantseva, 2013*).

The applied theory and practice of road train, all-wheel drive vehicle and off-road vehicles are described in several works (*Panchenko et al., 2021*; *Burennikov et al., 2013*; *Zanko et. al., 2019*), on the basis of which the rational values of energy efficiency and parameters of KrAZ grain carriers during grain transportation are substantiated in two works (*Dun & Pavlenko, 2015*; *Dun & Klapan, 2013*). However, these works do not reflect the results of studies on the functional stability of an all-wheel drive truck with instability of the transported cargo weight. In the joint work of S. Dun and V. Klapan (*Dun & Klapan, 2013*), the economic efficiency of using the

KrAZ "Karavan–2" grain truck train for transporting grain over a distance of 400–500 km was determined and it was found that its use for short distances (up to 50 km) is impractical.

The performance of road trains is determined by their average speed and carrying capacity. The possibilities for increasing the average speed of road trains are limited (*Barabash & Kravchenko, 2002*), so the most promising way to increase productivity is to adjust the speed depending on the density of the grain crop (wheat, barley, oats, etc.), i.e., the volumetric carrying capacity (t/m^3).

Functionally, vehicle stabilisation is assessed by its dynamic properties, manifested in the vehicle's response to control influences (*Podrygalo & Sheludchenko, 2015*). This paper proposes using the value of the acceleration (linear or angular) of a car that occurs when creating a controlling influence as a criterion for controllability. It is proposed to use this criterion to evaluate the dynamic properties of a car not only when turning, but also during acceleration and braking, i.e., controllability is characterized by the accuracy of changing the movement parameters according to the driver's desire. Thus, handling is the ability of a vehicle to respond adequately to driving influences. This manifests the dynamic properties of cars while driving, taking into account the applied forces.

The study aims to develop a methodology for the functional adaptation of a grain carrier by adjusting the speed depending on the density of the transported grain crop.

To achieve this goal, it is necessary to solve the following tasks:

– substantiate the functional model of a grain truck;
– develop a methodology for determining the functional stability of a grain carrier when the weight of the transported grain changes;
– develop practical recommendations for ensuring the functional adaptation of a grain carrier.

Results

Mathematical Modeling of Grain Truck Movement

When a grain truck is moving steadily uphill with an angle a (*Figure 1*), the following forces act on it

- gravity G_a, applied at the centre of mass C_a of the vehicle, which can be decomposed into the components $G_a \sin a$ and $G_a \cos a$;
- the air resistance P_w, the point of application of which is at the height of the centre of sail, taken equal to the height h_c;
- reaction P_h applied to the mechanism of coupling of the vehicle with the trailer at the height h_k (it is assumed that P_h is parallel to the bearing surface);
- normal reactions R_1 and R_2, shifted by a value $(n+m)$ from the projection of the wheel axles.

Having compiled the equations of moments of all applied forces relative to the points of applied normal reactions and bearing in mind that the sum of

$$(R_1 + R_2)\frac{n+m}{r_k} = G_a f \cos\alpha ,$$

we obtain the following relations for normal reactions:

$$R_1 = G_a \frac{b}{L}\cos\alpha - P_w \frac{h_c}{L} - G_a f \frac{r_k}{L}\cos\alpha - G_a \frac{h_c}{L}\sin\alpha - P_h \frac{h_k}{L},$$
$$R_2 = G_a \frac{b}{L}\cos\alpha + P_w \frac{h_c}{L} + G_a f \frac{r_k}{L}\cos\alpha + G_a \frac{h_c}{L}\sin\alpha + P_h \frac{h_k}{L}. \quad (1)$$

Neglecting the air resistance (P_w=0) and assuming that the driving wheels of the car are the rear wheels, its traction properties are estimated only by the R_2 reaction. Replacing the reaction P_h of the trailer link in equation (1) with its value:

$$P_h = (l_{fv} - 1)G_a(f\cos\alpha + \sin\alpha) = (l_{fv} - 1)P_a,$$

Where

P_a is the traction force on the driving wheels of the vehicle in the absence of the trailing link,

l_{fv} is the vehicle load factor.

In addition, since.

$$P_a \frac{h_c}{L} = (G_a \sin\alpha + G_a f \cos\alpha)\frac{h_c}{L},$$

then

$$G_a \frac{h_c}{L}\sin\alpha = P_a \frac{h_c}{L} - G_a f \frac{h_c}{L}\cos\alpha.$$

In this case, transforming equation (1), we obtain

$$R_2 = G_a \frac{a}{L}\cos\alpha + P_a \frac{[h_c(l_{ft} - 1)h_k]}{L} - G_a f \frac{h_c - r_k}{L}\cos\alpha. \quad (2)$$

where

l_{ft} is the trailer load factor.

The expression in square brackets in (2) is the reduced height of the centre of gravity of the grain truck, which is greater the higher the load factor and the height of the hitch. For h_k=h_c and the value of the load factor l_{ft} =D_v: D_t=2, where D_v and D_t are the dynamic factors of the vehicle and trailer, respectively. The traction force of the grain truck with the rear drive wheels at the road adhesion coefficient φ is equal to P_c=$R_2\varphi$. For this case, the dynamic factor of the grain truck in terms of traction is written as

$$D_c = \frac{a\varphi\cos\alpha}{l_{ft}L_p - \varphi[h_h + (l_{ft} - 1)h_k]}. \quad (3)$$

Since the last term of equation (2) is negligible (no more than 0.5 % of R_2), the rolling resistance coefficient f is not included in (3).

The variable forces acting on the grain truck are related either to the displacements or to the velocities of the points of application of these forces. The functional relationship that links the magnitude of the force and the kinematic parameters is the characteristic of the force. The force modulus in this relationship can also be a function of the arguments. For ease of calculation, we will assume that the force modulus is a function of the kinetic parameters for given characteristics.

The equations of motion are used to determine the laws of motion of mechanical systems under given forces (*Syvak & Derevenko, 2014*). The number of these equations for grain carriers with holonomic links is equal to the number of degrees of freedom of the grain carrier. The equations of motion of a grain carrier can be represented in various forms based on the theorem

of change of kinematic energy. In the integral form, the equation of motion of a grain truck has the form:

$$\sum_{i=1}^{n} T_i - \sum_{i=1}^{n} T_{i0} = \sum_{i=1}^{m} A_k \,, \tag{4}$$

where

T_{i0}, T_i are the kinetic energy of the link and the grain truck, respectively, at the beginning and end of the time interval under consideration,

A_k is the work of each of the external and internal forces acting on the grain truck during a given time interval,

n is the number of moving links,

m is the number of forces.

Equation (4) is quite cumbersome even for simple traction units, since it is necessary to summarise the forces. For a grain carrier with one degree of freedom, a simpler form of this equation can be obtained, in which all summation operations are performed in advance. For this purpose, equation (4) is replaced by the equation of motion of a single point of the grain truck, which moves so that its generalised coordinate coincides at any time with the generalised coordinate of the grain truck. The dynamic model of a grain truck will be a material point with mass m_p moving under the action of a force F_n so that the generalised coordinate S of this point coincides with the generalised coordinate of the grain truck at any given time.

It is always possible to determine such values of F_n and m_n that the equation of motion of the actuator point is identical to the equation of motion of the grain truck and, therefore, the generalised coordinate of the actuator point will coincide with the generalised coordinate of the grain truck at any time. In this case, the equation of motion of the fulcrum is written in the form of an energy integral for some finite time interval during which the generalised coordinate changes from S_0 to S, and the reduced mass (for the grain truck, this value is variable) changes from m_n to m_{n0}:

$$\frac{m_n v^2}{2} - \frac{m_{n0} v_0^2}{2} = \int_{S_0}^{S} F_n dS \,, \tag{5}$$

where

v is the velocity modulus of the point of reference,

v_0 is the value of v at $S=S_0$.

To ensure the identity of equations (4) and (5), it is necessary and sufficient to fulfil the conditions:

$$\int_{S_0}^{S} F_n dS = \sum_{k=1}^{m} A_k \,; \tag{6}$$

$$\frac{m_a v^2}{2} = \sum_{i=1}^{n} T_i \,. \tag{7}$$

When the condition in dependence (4) is fulfilled, the condition is also satisfied for any moment of time:

$$\frac{m_{n0}v_0^2}{2} = \sum_{i=1}^{n} T_{i0} \cdot \tag{8}$$

The reduced force F_n can be found from (6), and the reduced mass m_n can be found from (4). Thus, the reduced force is a force conditionally applied to the point of reduction and is determined from the equality of the elementary work of this force to the elementary work of forces and pairs of forces acting on the links of the grain truck (car, trailer). The equality of elementary work simultaneously means the equality of powers of the elements of the grain truck:

$$F_n v = \sum_{i=1}^{m} N_k , \tag{9}$$

where

F_k is the power of the force (pairs of forces) acting on the grain truck link.

Given the velocity v_k of the point of application of the force F_k acting on the grain truck link, ω_k of the angular velocity of the grain truck link acted upon by a pair of forces with moment M_k, the reduced force F_n is calculated by the formula:

$$F_n = \sum_{k=1}^{m} \left[F_k \frac{v_k}{v} \cos(F_k, v_k) + M_k \frac{\omega_k}{v} \right]. \tag{10}$$

This sum can be both positive and negative, i.e., the reduced force is a scalar value. The minus sign indicates that the force F_n is directed in the opposite direction to the velocity v of the point of actuation. The reduced force F_n can be considered as a scalar magnitude that coincides with the generalised Lagrange force, which is determined by the ratio of the sum of the possible work of forces applied to the links of the grain truck. From dependence (7) it follows that the reduced mass of the grain truck can be defined as the mass that the point of actuation must have in order for the kinetic energy of this point to be equal to the kinetic energy of the grain truck's links. The kinetic energy of the link

$$T_i = \frac{m_i v_{si}^2}{2} + \frac{J_{si}\omega_i^2}{2} , \tag{11}$$

where

m_i is the mass of the link,

v_{si} is the modulus of the velocity of the centre of mass of the link,

$\omega_i F_i$ is the modulus of the angular velocity of the link,

J_{si} is the moment of inertia of the link relative to the axis passing through the centre of mass perpendicular to the plane of motion.

Considering (11), transforming (7), we obtain the following dependence for estimating the mass of the link

$$m_n = \sum_{i=1}^{n} \left[m_i \left(\frac{v_{si}}{v} \right)^2 + J_{si} \left(\frac{\omega_i}{v} \right)^2 \right]. \tag{12}$$

n general, to build a dynamic model of a grain truck, any point on the grain truck can be chosen as the point of reference, i.e., the point where the mass is concentrated. Therefore, the reduced mass of a grain truck can be defined as the mass that must be concentrated at the point of actuation so that the kinetic energy of this point is equal to the kinetic energy of the truck and

the grain truck trailer.

The reduced force and reduced mass do not depend on the speed of the point of impact, as the formulas for determining them include only the velocity ratios. For example, if the speed modulus of the point of origin v changes by a factor of k, then v_k, v_{si} and ω_i change by the same factor, while their ratios to v remain unchanged. It follows that the determination of the reduced forces and masses can be performed without knowing the velocity of the point of reference, i.e., before solving the equation of motion. This is the main advantage of reduced forces and masses. This conclusion can also be reached by paying attention to the fact that formulas (7) and (8), in addition to the given constants, include only analogues of velocities that do not depend on time.

Let the reduced force F_n be given as a function of the generalised coordinate S (displacement of the point of reference). The reduced mass m_n is a function of the coordinate S. In this case, to determine the law of motion of the actuator, it is convenient to apply the equation of motion in the form of an energy integral with initial conditions $t=0$, $S = S_0^{v=v0}$. The velocity of the point of reference as a function of the generalised coordinate S is written as

$$v = v_p = \sqrt{\frac{2}{m_n}\int_{S_0}^{S} F_n dS + \frac{m_{n0}}{m_n} v_0^2}\ , \tag{13}$$

where v_p is the operating speed of the grain truck.

In some cases, the integral in the root expression of formula (13) can be represented in the final form. Then, after integration, we will obtain the function $v=v(S)$ either in the form of a graph or in the form of a series of eigenvalues for changes in displacement S from S_0 to some value that determines the end of the movement stage under consideration.

When estimating the mass of a grain truck according to dependence (12), it is necessary to take into account the density of the transported grain, which can vary within 300–820 kg/m^3 depending on the moisture content of the grain, temperature and pressure of the medium, as well as the type of grain transported (*Table 1*).

The relationship between the mass and volume of grain is defined by the formula $V=m/Q$, where V is the volume, m is the mass (carrying capacity), and Q is the bulk density of grain.

The dependence of the volumetric carrying capacity of the KrAZ-6511C4 grain truck is estimated by the following parameters:

Q_n is nominal payload of 15.4 tonnes;

Q_{lc} is volumetric payload of 1.3 m^3;

V_b is body volume of 11.81 m^3;

V_c is cargo volume of 20.53 m^3.

The fuel efficiency of KrAZ grain carriers significantly depends on the volume of transported grain, which was determined during factory tests and by operating organisations using different methods (*Table 2*) (*Dun & Pavlenko, 2015*).

The test methodology is based on the public road network available near the PJSC «AvtoKrAZ» vehicle manufacturing centre, taking into account the location of road facilities, structures, traffic conditions and terrain. The length of the circular route is 37 km, with sections of traffic in highway and urban conditions, with ascents, descents, bridges, railway crossings,

etc. The road surface on the route is asphalt concrete. It is noted that with the increase in the length of the route, the decrease in the density of transported grain crops, fuel consumption decreases (*Table 2*).

Functional Stability of the Grain Carrier

A grain carrier belongs to the class of complex technical systems, the efficiency of which is ensured over a given period of time when performing its general functions within the limits established by regulatory requirements, provided that external destabilising factors are counteracted.

In general, a grain carrier (*Figure 2*) is represented as a system with control function vectors $U(t)$ and disturbance vectors $F(t)$ as input. The output variables characterising the functional parameters of the grain truck are represented by the vector-function $Y(t)$. The dynamic properties of the grain carrier are characterised by the transfer function $W_i=S_o/S_m$, where S_o and S_m are the output and control parameters, respectively.

The grain truck is influenced by both controlled input vectors—control functions ℓ_i ($i(t)$ is transmission gear ratio, $q(t)$ is fuel supply, $k(t)$ is steering gear ratio, $p(t)$ is brake control force) and uncontrolled m_i (R(t) is driving resistance, $C(t)$ is road terrain, $B(t)$ is wind loads, etc). The output variables $Y(t)$ are characterised by the driving speed $v(t)$, the stability of the direction of movement y_d(t) and braking $y_b(t)$, and the stability of the dynamic properties $w(t)$ of the grain truck.

Typically, disturbances $F(t)$ are determined by the instability of the output (functional) parameters $v(t)$, $y_d(t)$, $y_b(t)$, and $w(t)$. When comparing these parameters with their values v^x, y_d^x, y_b^x and w^x, at which the grain carrier operates stably, the controlled input variables $u(t)$ are adjusted at the comparison links ξ_v, ξ_d, ξ_b and ξ_w.

The functional parameter $v(t)$ is characterised mainly by the input control functions $i(t)$ and $q(t)$ and determines the operational properties of the grain truck, the parameters $y_d(t)$ and $y_b(t)$ are determined mainly by $v(t)$, disturbances in the direction of movement $f_d(t)$ and braking $f_b(t)$ and are aimed at ensuring the safety of the grain truck. The dynamic parameter $w(t)$ characterises the movement of a grain truck in the longitudinal, horizontal and vertical planes under the influence of forces in these planes.

The dynamic space of grain truck operation is based on the metric state space, each element of which fully determines the state of the system under consideration by the functional parameters $v(t)$, $y_d(t)$, $y_b(t)$ and $w(t)$. In case of instability of one or more functional parameters of the grain carrier $v(t)$, $y_d(t)$, $y_b(t)$ and $w(t)$, characterised by deviation from the nominal values of y^x, y_d^x, y_b^x and w^x, it is possible that the grain carrier will lose its functional stability, in which case it will not perform the functions defined by the regulatory and technical documentation (R&D). In this case, the dynamic space of grain carrier operation is determined by the transfer functions W_v, W_{yd}, W_{yb} i W_w, characterised by the relationship $v(t)$, $y_d(t)$, $y_b(t)$, $w(t)$ to y^x, y_d^x, y_b^x, w^x.

During the operation of a grain truck, the task of ensuring its functioning in one of two areas is solved:

OA is the area of operation in which the grain carrier operates according to its intended purpose (the required traction force, stability of the direction of movement and braking, etc. are ensured);

AF is the area of optimal operation, for example, according to the energy saving criterion, in which the grain carrier operates at an acceptable change in speed (change in acceleration within acceptable limits) (*Figure 3*).

AF of the grain

In this figure, the points B_y and B_g indicate, respectively, the operation of a grain truck in an unsteady mode of operation without acceleration and the permissible area for energy saving; Δ_v is the margin of optimal operation; V_o, V_f are the vectors of optimal and actual operation, respectively; ΔB is the margin of operation in the AF region.

Each point of the AF characterises a certain mode of operation of a grain truck at a certain point in time and is described by a certain combination of values of functional parameters, disturbing influences, and the initial state (*Figure 2*). The deviation of the point B_g from the point B_y (*Figure 3*) reflects the margin of optimal functioning Δ_v of the grain truck

$$\Delta B_z = \frac{z_{jk} - z_{jn}}{z_{jn}} = \frac{\Delta z_j}{\Delta z_{jn}};\ \Delta B_x = \frac{x_{ik} - x_{in}}{x_{in}} = \frac{\Delta x_i}{\Delta x_{in}}, \quad (14)$$

where

z_{jk}, z_{jn}, x_{ik}, x_{in} are the critical values of the studied and boundary parameters along the x, z coordinates,

Δx_j, Δx_i is the margin of optimal functioning of the grain truck at the value of $\Delta_{z_{jn}}$and $\Delta_{z_{in}}$.

The margin of optimal functioning Δ_v is the deviation of the functioning vector V_f, whose components are the actual values of the functional parameters, from the nominal vector V_o, i.e. $V_f=V_o+\Delta_v$. In this case, to ensure the operation of a grain carrier in the optimal area of the OA according to Figure 3, it is necessary to ensure the selection of such nominal values of the functional parameters and tolerance fields for them that ensure the position of the spread and outputs in this region.

Given the known requirements for the optimal functioning of the grain carrier in the area of OA, which is determined by the parameters: nominal z_{np}, current z and permissible z_{yp} ($z_{np}<z_{yp}$), the density of distribution of the parameter value, taking into account its spread $f°(x)$ and deviation $f'(x)$, should be determined:

- the probability that the parameter value will not go beyond the specified tolerances ($x_{np}<x<x_{vp}$) during a certain time of grain truck operation, taking into account disturbing influences;
- the tolerance limit ($x_{np}<x<x_{vp}$) and the corresponding requirements for the grain carrier not to exceed the probability of the parameter exceeding the tolerance of the specified permissible probability;
- planes $f(x)$ and $f'(x)$, under which the conditions that the probability of going beyond the tolerance will be less than the permissible probability will be fulfilled.

To solve this problem, all the functional parameters of the grain carrier are classified by parameters with specified nominal values X_O^C (Figure 3—$y_1(t)$, $y_2(t)$, ..., $y_n(t)$) and into parameters

whose optimal value must be determined X_O^V (Figure 3—the OO region). They are written in vector form:

$$X_O^C = \begin{bmatrix} X_{oi}^C \\ \dots \\ X_{oj}^C \\ \dots \\ X_{oN}^C \end{bmatrix}; \; X_O^V = \begin{bmatrix} X_{oi}^V \\ \dots \\ X_{oj}^V \\ \dots \\ X_{oM}^V \end{bmatrix} \tag{15}$$

so that any functional parameter of the grain truck is a component of the vectors X_O^C and X_O^V.

Predicting the probability of a grain truck being in the optimal region of functioning of the OA (according to *Figure 3*) at time t is determined by the equations of the Markov process:

$$P_i = \mathrm{v}_i P_i(t) + v_{i-1} P_{i-1}(t) \tag{16}$$

under nominal conditions $i = 0, 1, 2, 3$; $t_o = 0$; $P_i(t) = P_i$.

When assessing the functional stability of a grain truck by only one parameter, for example, by the speed of movement $v(t)$ (*Figure 3*), its functioning can be evaluated by the function $\vec{x}_V = (v_i, \dots v_n)$. The vector $\vec{x}_V$ corresponds to the number $R(\vec{x})$, where $R(\vec{x}) > 0$ and increases to ∞ at $\vec{x}_V \to \vec{v} = (v_i, \dots v_n)$, where $\vec{v}$ is the critical vector. $R(\vec{x}_V) \to \infty$ and at $v_i \to \vec{V}_i = (V_i, \dots, v_n)$. In this case $R(\vec{x}) = [N_i(\vec{x}_V)]^{\pm 1} / [z(\vec{x}_V)]^2$, where i=1.2; a>0 is an arbitrary number; $z(\vec{x}_V) = \prod_{i=1}^{n} |v_i - V_i|^{q_i}$; $N_i(\vec{x}_V) = \sum_{i=1}^{n} \alpha_i |v_i - V_i|$ and a_i >0 is the weighting factor of v_i; q_i >0 is an arbitrary number.

When q=1/(n–1), q>a>1, we can write

$$R(\vec{x}_V) = \sum_{i=1}^{n} \alpha_i |v_i - V_i| \sqrt{\prod_{i=1}^{n} (v_i - V)}. \tag{17}$$

In this case, the functional stability of the grain carrier in terms of the parameter $v(t)$ is estimated using the following dependence

$$H(\vec{x}_V) = 1 / R(\vec{x}_V). \tag{18}$$

This function describes the functioning of the grain truck provided that v_i reaches the value V_i when changing $H(\vec{x}_V)$ within the range from H_{max} to 0 (when v_i=V_i), characterising the functional stability of the grain truck in terms of speed $v(t)$.

Similarly, the functional stability of the grain truck can be assessed by the stability of the direction of movement $y_d(t)$ and braking $y_b(t)$, the stability of the dynamic properties $w(t)$ (*Figure 2*). In this case, the critical values of these parameters, which are in the area of the AF functioning (*Figure 3*), are selected according to experimental data based on the method of partial accelerations (*Artiomov et al., 2025*), which is effectively used in assessing the dynamic properties and stability of vehicles (*Abramov et al., 2014*).

Using the standard form of recording the variable state of a grain truck, we consider its movement as the movement of an autonomous dynamic system when the forces of resistance

to movement and the amount of energy used for movement change. This influence usually causes a change in the speed *v(t)* of translational motion, which is characterised by equation (*Bilokon & Okocha, 2002*)

$$\frac{dv(t)}{dt} = \frac{P_k - \sum R_C}{m_{ag}}, \tag{19}$$

where

Pk is the moving force of the unit (tangential traction force),

ΣR_c is the sum of the forces of resistance to the movement of the unit,

m_{ag} is the reduced mass of the unit.

Discussion

The forces of resistance to the movement of a grain carrier during operation depend on factors, many of which are variable, such as terrain, speed, instability of the mass of transported grain, etc. As the drag forces change, the *dv/dt* changes during grain transport. Measurement of the acceleration *dv/dt* requires the use of appropriate metrological support for measuring and registration complexes that will allow determining its kinematic and dynamic parameters without interfering with the design of the grain truck (*Lebedev et al., 2018*). The basis of this complex is capacitive semiconductor three-axis acceleration sensors—accelerometers, which are installed on the car and trailer of the grain truck to assess longitudinal and lateral accelerations.

The combination of the acceleration sensors with the KrAZ-6511C4 navigation system allows to receive on-line and archive information, the analysis of which provides reliable data on the route and modes of movement of the grain truck, instant and average fuel consumption and direction of movement.

To ensure that the grain carrier operates in the optimal range, it is necessary to select such nominal values of functional parameters and their tolerance fields that ensure the position of the spreading and outlet fields in this range.

Conclusions

The study of the functional adaptation of a grain truck with an unstable mass of transported grain revealed that fluctuations in the grain load during transportation significantly affect the stability of the vehicle, especially during manoeuvring and braking. When estimating the weight of a grain truck, it is necessary to consider the density of the transported grain. The dependence of the volumetric carrying capacity of a grain truck is estimated by the parameters of nominal carrying capacity, volumetric carrying capacity, body volume, and cargo volume.

The dynamic space of grain truck operation is based on the metric state space, each element of which fully determines the state of the system under consideration according to certain functional parameters. If one or more functional parameters of a grain truck are unstable and deviate from their nominal values, the grain truck may lose its functional stability, in which case it will not perform the functions defined by the regulatory and technical documentation. In this case, the dynamic space of grain carrier operation is determined by transfer functions.

During the operation of a grain carrier, the task of ensuring its operation in one of two areas is solved: the area of operation in which the grain carrier operates according to its intended

purpose (ensuring the required traction force, stability of the direction of movement and braking, etc.); the area of optimal operation, e.g., according to the energy saving criterion, in which the grain carrier operates at an acceptable change in speed (change in acceleration within acceptable limits). To ensure that the grain carrier operates in the optimal range, it is necessary to select such nominal values of functional parameters and their tolerance fields that ensure the position of the spreading and outlet fields in this range.

Conflict of interest

The authors declare that there is no conflict of interest.

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Appendix

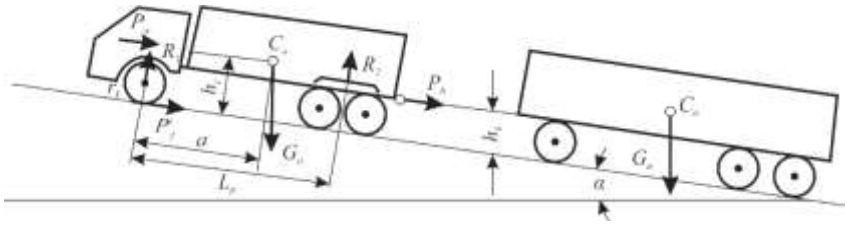

Figure 1. Diagram of the forces acting on a grain truck when driving uphill with an angle α

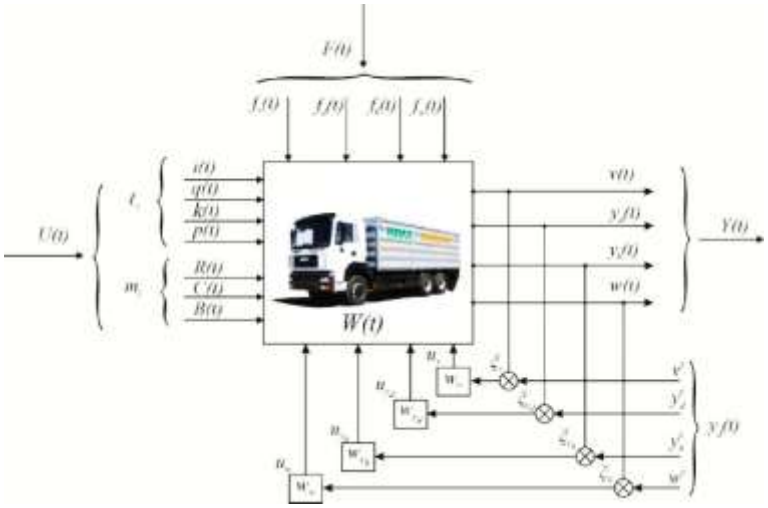

Figure 2. Representation of a grain truck as a multidimensional system in a variable state

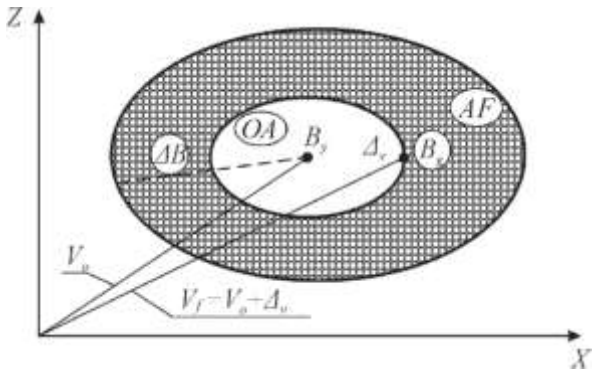

Figure 3. Correlation of the areas of optimal operation OA of the grain carrier and the functioning

Table 1. Bulk density of grain crops

№	Name of grain crop	Density, kg/m^3
1	Wheat	750-850
2	Barley	600-750
3	Oats	400-550
4	Rye	700-750
5	Millet	700-850

Table 2. Results of operational tests of the «Karavan-2» road

Tests	Mileage of the road train during testing, km	Transported cargo, cargo weight, t	«Shoulder» of routes, km	Average fuel consumption, l/10 km	Gear ratio of the main gear
1	Total 2505 With cargo 1250	Corn grain, 48, 83–52, 66 Sunflower seeds, 27, 66	87–89 182–194	53,0–54,6 42,0–42,1	i_{mg} = 6,154
2	Total 2100 With cargo 1050	Corn grain, 41,72–47,01	66–69	48,2–50,1	
3	Total 1737 With cargo 857	Corn grain, 48,7	857	42,0–43,1	i_{mg} = 4,9
4	Total 1340 With cargo 560	Wheat grain, 40,1	280	37,8–38,0	
5	Total 1320 With cargo 225	Organic mix, 35,0 Organic mix, 54,0	115 110	35,0–35,3 40,0–42,3	

Tetiana V. Poharchenko [5]

Legal Consequences of Concluding a Marriage Contract in Ukraine [4]

Abstract: The article studies theoretical and practical issues of the marriage contract in Ukraine. The study object is the legal relations of spouses during the conclusion and execution of a prenuptial agreement in Ukraine. The subject of the study is the legal consequences of entering into a prenuptial agreement in Ukraine. The purpose aims to determine, based on theoretical analysis and considering law enforcement practice, the essence of the prenuptial agreement, the legal consequences of the conclusion of the prenuptial agreement, and the identification and solution of theoretical and practical problems related to the legal implications of the prenuptial agreement under the legislation of Ukraine. The study course used general scientific and unique methods of cognition of legal phenomena: historical, normative-comparative, dialectical method, formal-logical and others. It has been found that the central family law contract is the marriage contract of spouses, which is becoming increasingly widespread in Ukraine. The content of the marriage contract, which has certain legislative restrictions regarding the subject of the contract, is analysed. The features of the marriage contract are outlined, which indicate the difference from other types of family-law contracts that spouses can conclude. The evolution of the development of the legal regulation of the marriage contract in the territory of Ukraine is traced, and a comparative legal characterisation of the marriage contract in Ukraine and foreign countries where such restrictions regarding its content are not provided is performed. The article pays special attention to the study of the legal consequences of concluding a marriage contract in Ukraine: the features of the legal regulation of changing the conditions or termination of the marriage contract are disclosed, the procedure and grounds for recognising the marriage contract as invalid are analysed based on judicial practice, and the procedure for the spouses to refuse the marriage contract is determined.

Keywords: marriage contract, legal regime of marital property, restrictions on the content of the marriage contract, features of non-property legal relations of spouses, legal consequences of concluding a marriage contract, refusal of the marriage contract, changes in the terms of the marriage contract, termination of the marriage contract, recognition of the marriage contract as invalid.

Abbreviations:

CC is the Civil Code of Ukraine,
FC is the Family Code of Ukraine,
SC is the Supreme Court of Ukraine,
SCRA is State Civil Registration Authority.

Introduction

According to the Constitution of Ukraine, the principles of marriage and family regulation are determined exclusively by the laws of Ukraine. Thus, the state ensures the family's protection and guarantees equal rights and responsibilities to each spouse in marriage and family (*Constitution of Ukraine, 1996*). The material foundation of the well-being of any family lies in the spouses' ownership of property, which serves to meet their personal and everyday needs. Therefore, establishing an effective mechanism for legally regulating property relations between spouses is very important. Accordingly, the legislation of many countries, including Ukraine, recognises the institution of the prenuptial (marital) agreement as an alternative way to regulate the relationship between husband and wife. Despite the specific legal regulation of this

institution in different countries, its purpose consistently lies in enabling spouses to settle their relationships according to their individual needs. At the same time, the legislation imposes specific requirements on the content of the prenuptial agreement, which to some extent limits the parties' freedom of will. Nevertheless, this type of agreement remains relatively common in foreign countries.

As for Ukraine, statistics show that the number of concluded prenuptial agreements decreased at the beginning of the full-scale war. However, it subsequently began to increase, despite a general decline in registered marriages. In 2024, 2,762 prenuptial agreements were concluded in Ukraine, which is 7% more than in 2023, although still not as many as before the start of the full-scale war. For comparison, in 2021, Ukrainians concluded 4,099 prenuptial agreements. There is one prenuptial agreement per 54 registered marriages (*Unified web portal…, n.d.*).

The theoretical basis for researching the legal aspects of the prenuptial agreement consisted of the works of scholars such as V.A. Vatras, H.O. Garo, K.A. Kazaryan, O.M. Kalitenko, V.O. Kozhevnikov, O.S. Oliinyk, O.I. Safonchyk, V.I. Truba, Y.V. Fliazhnykova, etc. An analysis of the works by I.V. Zhilinkova was also conducted, as she was one of the first to classify the property agreements between spouses and identify and characterise the prenuptial deal within the system of spousal contracts (i.e., family law rather than civil law agreements) (*Vatras, 2024, p. 20*).

However, the definition and features of the prenuptial agreement, and thus its legal nature, remain a matter of scholarly debate. Some scholars consider the prenuptial agreement to fall strictly under civil law, since it is subject to the general legal provisions concerning transactions. Others, however, regard the prenuptial agreement as part of family law in the part that does not regulate property relations between spouses. This, in turn, leads to contentious issues in the practical application of certain legal norms regarding prenuptial agreements.

Clarifying the content of the prenuptial agreement is also necessary since the proper specification of its terms determines the legal consequences of its conclusion. To avoid invalidating contractual legal relations in the future, it is necessary to strictly adhere to the legal provisions concerning the limitations of the parties' rights under the agreement.

Therefore, the chosen research topic is highly relevant both from the standpoint of family law doctrine and in developing proposals for improving family legislation and its application in practice. This includes clarifying the content of the prenuptial agreement, determining its features and legal nature, regulating changes or termination of the agreement, defining the procedure and grounds for declaring the agreement invalid, and regulating the legal consequences of a couple's refusal of the agreement.

The study object is the legal relationship between spouses during the conclusion and implementation of a prenuptial agreement in Ukraine.

The study subject is the legal consequences of concluding a prenuptial agreement in Ukraine.

The study aims to determine, based on theoretical analysis and considering legal practice, the essence of the prenuptial agreement and the legal consequences of its conclusion, and to identify and resolve theoretical and practical issues related to the legal implications of a prenuptial agreement under Ukrainian law.

To achieve this purpose, specific tasks have been set:

- clarify the role and place of the prenuptial agreement in the system of family law agreements;
- analyse the content of the prenuptial agreement, to define the limitations of its content;
- trace the evolution of legal regulation of prenuptial agreements in Ukraine;
- provide a comparative legal analysis of prenuptial agreements in Ukraine and other countries;
- characterise the legal consequences of concluding such agreements;
- develop proposals and practical recommendations for improving the current legislation concerning the research topic.

The study course used general scientific and unique methods of understanding legal phenomena, such as historical, normative-comparative, dialectical, formal-logical, and others.

Results

Legislative Regulation of the Content of a Prenuptial Agreement

Family and civil legislation generally govern the legal regime of matrimonial property in Ukraine, and in cases involving a foreign element in the marriage relationship, by private international law. Under the so-called statutory legal regime, the following principles apply: the principle of joint ownership of property acquired by the spouses during the marriage, and the principle of separate ownership of property that each spouse possessed before the marriage registration. However, the spouses may change these principles by mutual agreement, in which case a contractual legal regime of property applies to their assets.

The FC allows spouses to enter into any agreements between themselves that are not prohibited by law. These agreements may concern property that is jointly owned as well as property that constitutes the personal private ownership of each spouse. The Ukrainian legislature provides for the following types of agreements through which spouses may alter the statutory legal regime of their property:

- Agreement on the division of matrimonial property (Art. 69 & 70, FC);
- Agreement on the procedure for using property jointly owned by the spouses (Art. 66, FC);
- Agreement on the transfer by one spouse to the other of their share in the joint ownership without allocation of this share (Par. 2 of Art. 64, FC);
- Agreement on the allocation of one spouse's share of real estate from the total matrimonial property (Par. 2 of Art. 69, FC);
- Agreement on maintenance (Art. 78, FC) (this concerns obligations, a type of matrimonial property relationship);
- Agreement on the termination of the right to maintenance in exchange for the acquisition of property ownership (Art. 89, FC);
- Prenuptial (marital) agreement (Art. 92–103, FC) (*Family Code of Ukraine, 2002*).

Special attention should be paid to these agreements, as they may incorporate all the conditions in individual contracts between spouses and additional terms. This makes the prenuptial agreement a more universal instrument for settling matrimonial and family matters,

including future-acquired property. For this reason, legal scholars often classify this type of agreement as a mixed contract (V.O. Kozhevnikova, H.O. Garo, etc.) (*Kozhevnikova, 2016, p. 443*).

However, there is no unified opinion in legal doctrine regarding the legal nature of the prenuptial agreement. Some scholars classify it as a civil-law agreement, others as a family-law agreement, and others as a mixed type. As aptly noted by I.V. Zhilinkova, family legislation lacks general provisions on contracts, unlike civil law, which necessitates constant reference to contractual norms set out in the CC. The scholar suggests a detailed development of specific contractual constructs within the family law domain (*Zhilinkova, 2011, p. 94*).

V.A. Vatras, who researched the place of contracts within the system of family law sources, noted that family-law agreements have their distinctive features that set them apart from civil-law contracts, and that the prenuptial agreement is the principal family-law contract (*Vatras, 2019, p. 117*).

Scholar H.O. Garo explains the prenuptial agreement's mixed nature by stating that it is, on the one hand, a family-law contract with civil-law features and, on the other, a civil-law contract with family-law specifics (*Garo, 2012, p. 14*).

The prenuptial agreement differs from other types of spousal contracts in that it may also be concluded by engaged couples, i.e., from the moment they submit an application for marriage registration to the civil registration authority until the moment of official registration of the marriage (*Family Code of Ukraine, 2002*).

Thus, the parties (spouses or engaged couples) may include in the prenuptial agreement terms regarding: the legal regime of the spouses' property (both existing and future-acquired), the use of property (including housing, by the spouses or other family members), and the provision of maintenance (regardless of disability or need for financial support). Moreover, as noted by O.I. Safonchyk in her research on prenuptial agreements and IT, the parties may also regulate the legal regime of virtual property in the agreement (such as virtual intellectual property objects, electronic money, etc.), by analogy with the regulation of real property owned by the spouses (*Safonchik, 2017, p. 85*).

All of the above should make this type of agreement quite popular among married couples and engaged partners who seek to protect their property rights. However, it should be noted that the legislature has established specific prohibitions (limitations) regarding the content of a prenuptial agreement. For instance, its terms may not place one spouse in a highly unfavorable financial position or diminish a child's legal rights (Par. 4 of Art. 93, FC), and Par. 8 of Art. 7 (FC) states that family relationships must be regulated with the maximum possible consideration of the interests of disabled family members and children (*Family Code of Ukraine, 2002*). In this way, the legislator ensures the protection of the legal rights and freedoms of the most vulnerable family members.

Additionally, unlike other contracts, spouses cannot use a prenuptial agreement to transfer real estate ownership or other property subject to state registration (*Family Code of Ukraine, 2002*). As V.O. Kozhevnikova correctly concluded about the freedom of contract between spouses, the legislator has imposed some limitations on the parties' rights, which underscores both the legal significance and the practical direction of such agreements (*Kozhevnikova, 2016, p. 459*). Moreover, Y.V. Fliazhnikova highlights the following disadvantages of entering into a

prenuptial agreement: the emotional atmosphere of mistrust between partners and the time and financial costs for the parties (*Flyazhnikova, 2024, p. 252*).

Furthermore, under Ukrainian family law, parties to a prenuptial agreement cannot use it to regulate their non-property relations, nor the personal non-property ties between them and their children (*Family Code of Ukraine, 2002*). This restriction remains a subject of debate in family law doctrine. Some scholars argue for the appropriateness of allowing prenuptial agreements to cover the spouses' non-property rights. In particular, O.M. Kalitenko emphasises that it is entirely feasible for a prenuptial agreement to regulate not only property relations but also personal non-property matters, given the substantial legal recognition and regulation of personal non-property spheres in individuals' lives today (*Kalitenko, 2011, p. 307*).

However, the constitutional guarantee of the inviolability of personal non-property rights of spouses must be considered, making the legislative prohibition of contractual regulation of such rights reasonably justified. Nevertheless, this does not prevent spouses from including in the agreement provisions for compensation for moral harm caused by the improper behavior of the other spouse (e.g., infidelity or actions harmful to the family's interests) (*Safonchik, 2017, p. 84*).

At the same time, many foreign legal systems do not impose such prohibitions. This, in turn, may be seen as appropriate, especially in Muslim countries where the legislation does not adequately ensure the principle of gender equality in family relationships. For example, in some Muslim states, a prenuptial agreement may be used to prohibit polygamy (by stating that the husband will not marry other women while in the current marriage), to grant the woman the right to initiate divorce without citing statutory reasons, and to prohibit the husband from restricting the wife's employment or travel outside the country (*Menjul, 2019, p. 72*). Such provisions allow women to establish conditions that promote equality in family relations through a prenuptial agreement. However, women often do not take advantage of these opportunities in these countries due to traditional and religious norms.

In Anglo-Saxon legal systems and European countries following the Romano-Germanic legal tradition, the prenuptial contract is relatively standard. Legislation allows spouses (or fiancés) to include terms not only regarding property relations but also personal non-property matters, such as child-rearing, fidelity in marriage, family behaviour rules, and more (*Kazaryan, 2016, p. 77*).

Therefore, although a prenuptial agreement can address a wide range of family issues important for cohabitation, spouses primarily use this type of contract to regulate property relations in the event of divorce, aiming to avoid lengthy court proceedings and preserve amicable ties.

Development of Ukrainian Legislation on Prenuptial Agreements

As for Ukraine, it can be stated that as early as the 12th century, the practice of concluding a marriage agreement before the wedding was widespread on its territory. However, it was referred to as a "riadna hramota" (or "riadny zapis"), and was concluded by the parents or matchmakers of the future spouses. Later, such agreements came to be called "marriage letters" or "dowry letters", and during the period of the Grand Duchy of Lithuania, these written

agreements were known as a "marriage agreement" or "marriage intercession" (*Kazaryan, 2016, p. 63*).

However, during the Soviet era, the imperative method of regulating marital and family relations prevailed, and as such, the marriage contract was not used to govern the relationship between spouses. Because of the above, it can be said that the history of the institution of the marriage contract in Ukrainian legislation is relatively short. Only after Ukraine gained independence did provisions for the legal regulation of marriage contracts appear in the bill. Thus, in 1992, a provision (Art. 27–1) was added to the then-current Code on Marriage and the Family of the Ukrainian SSR, allowing individuals entering into marriage to agree on resolving family life matters related to the property rights and obligations of the spouses (*On Amendments and Additions…, 1992*). At the same time, the legal consequence of concluding such an agreement was the establishment of a special legal regime for the property of the husband and wife after marriage registration. Although with the adoption in 1993 by the Cabinet of Ministers of Ukraine of a resolution approving the procedure for concluding a marriage contract, its subject matter also included personal non-property rights and obligations (*On the Procedure…, 1993*). Therefore, a legal conflict existed between the regulatory legal acts mentioned above. Only the FC, which came into force in 2004, clearly stated that the subject of a marriage contract may include only the property rights and obligations of the spouses.

Thus, as of now, the main provisions regarding the regulation of the marriage contract (though not the only ones, as Ukrainian family law allows for the subsidiary application of civil law norms) are contained in Art. 92–103 of the FC, where various legal consequences of concluding a marriage contract are also specified (*Family Code of Ukraine, 2002*).

Characteristics of the Legal Consequences of Entering into a Prenuptial Agreement

With the help of Ukrainian legislation and judicial practice, it is necessary to consider the legal consequences of concluding a prenuptial agreement, which takes effect from the moment it comes into force. According to the provisions of Art. 95 of the FC and Clause 2 of Chapter 5, Section II of the Procedure for Notarial Acts by Notaries of Ukraine, approved by the Order of the Ministry of Justice of Ukraine dated February 22, 2012 No. 296/5, the moment a prenuptial agreement comes into force depends on the legal capacity of the parties on the day of its conclusion and notarisation (*Procedure…, 2012*; *Family Code of Ukraine, 2002*).

If spouses agree, it comes into force immediately after being notarised. If fiancés agree, it also requires notarisation but becomes effective from the moment of marriage registration by the SCRA body. If one (or both) of the fiancés is a minor who has received court permission to marry before reaching the age of majority (16–18 years), a written statement from the parents or guardian is additionally required, with the authenticity of their signatures certified by a notary.

At the same time, the date the prenuptial agreement enters into force must be stated in the agreement itself. It may also specify the general term of its validity, the effect of the agreement or specific clauses after the termination of the marriage, and the duration of particular rights and obligations (*Procedure…, 2012*). Once the prenuptial agreement takes effect, it applies to the property relations of the spouses that exist at that time and those that arise in the future. In addition, other legal consequences of such an agreement may arise. For example, the law allows the parties, during the validity of the agreement, to:

(1) amend its terms;
(2) terminate the agreement;
(3) cancel it; or
(4) declare it invalid (*Family Code of Ukraine, 2002*).

Scholars propose different—and sometimes radically divergent—interpretations of the content of these legal consequences. This, in turn, negatively affects the practical application of these legislative options by spouses. Therefore, it is appropriate to make a comparative analysis of all legal consequences. For instance, the amendment of the agreement, refusal of the agreement, and termination of the contract all share the following features:

First, the law prohibits unilateral action by either party; mutual consent is required. Second, if mutual consent is absent, the agreement can only be amended or terminated through court proceedings (refusal is only possible by mutual consent). Third, only spouses (not fiancés or former spouses) currently in a registered marriage may amend, refuse, or terminate the agreement. Fourth, all such actions must be formalised through a notarised agreement signed by both parties.

The law distinguishes among these legal consequences: according to the law, a court may amend the agreement unilaterally at the request of one party only if the party's interests (or those of children or incapacitated adult sons/daughters) require it. These interests must be significant, and the claimant has the burden of proof (*Family Code of Ukraine, 2002*).

The concepts of "termination" and "refusal" of a prenuptial agreement remain a matter of scholarly debate. Some consider them identical in consequence, while others distinguish between them. O.S. Oliynik notes that in both cases, the agreement ceases to apply in the future while preserving the legal repercussions that arose during its validity, unlike declaring it invalid, which entails bilateral restitution and invalidity from the moment of conclusion (*Oliynik, 2010, p. 120*). However, this cannot be fully agreed with, since Part 2 of Article 101 of the FC allows the parties, when refusing the agreement, to determine whether it should be considered terminated from the date of submission of the refusal to the notary or from the date of the agreement's conclusion. In the latter case, the parties may apply bilateral restitution, as in invalid contracts (i.e., each party returns everything received under the agreement, including financial support received by one spouse). Thus, refusal of a prenuptial agreement is an option for spouses to apply the consequences of an invalid agreement without the grounds for formally declaring it invalid. This is also supported by Part 4 of Article 214 of the Civil Code, which states that "the legal consequences of refusal from a transaction are established by law or by the agreement of the parties." (*Civil Code of Ukraine, 2003*)

Regarding the termination of a prenuptial agreement, it is necessary to understand the relationship between the concepts of "termination" and "cessation" of the agreement. The latter is broader and includes termination as one of the means. The following are grounds for cessation of a prenuptial agreement:

(1) dissolution of marriage (unless the agreement contains clauses that remain in effect afterward, e.g., division of property or financial support);
(2) termination of the marriage due to the death (or declaration of death) of one or both spouses;

(3) termination of the agreement by mutual consent or unilaterally by court order (the latter only in cases of substantial grounds such as impossibility of execution);
(4) expiration of the term stipulated in the agreement.

In all such cases, the moment of cessation coincides with the moment of the underlying cause. However, if the agreement is declared invalid, it is considered terminated from the moment of its conclusion.

The FC refers to civil legislation when regulating invalid prenuptial agreements. According to Art. 103 of the FC, a prenuptial agreement may be declared invalid by the court on the grounds established in the CC. Additionally, a claim for invalidation may be filed by one of the spouses or by another person whose rights or interests are violated by the agreement (*Family Code of Ukraine, 2002*).

When analysing civil law on invalid transactions, the following provisions of the Civil Code (CC) are worth noting: declaring a transaction invalid is one of the means of protecting civil rights and interests through court proceedings. A transaction is presumed valid unless its invalidity is directly established by law (a void transaction) or unless it is declared invalid by a court (avoidable transaction). Grounds for a void transaction include violation of the conditions of validity specified in Art. 203 of the CC and other provisions, including the FC (*Civil Code of Ukraine, 2003*).

Based on the above, the grounds for declaring a prenuptial agreement invalid may include:
(1) the agreement contradicts legislation, public interest, or moral principles;
(2) lack of free will of the parties (fiancés or spouses), including cases of mistake, fraud, coercion, or difficult circumstances;
(3) the agreement is fictitious and not intended to create actual legal consequences;
(4) one or both parties lack the required civil legal capacity;
(5) the agreement, concluded by parents (adoptive parents), violates the rights or interests of minor or incapacitated children;
(6) the agreement contains terms regulating personal non-property relations between spouses or between spouses and their children;
(7) the agreement diminishes the rights of a child or places one spouse in a highly disadvantageous financial position;
(8) the agreement includes provisions transferring real estate or other property subject to state registration into one spouse's ownership.

It is worth noting that the concept of "extremely disadvantageous financial position", as used in the agreement, is considered evaluative in judicial practice and must be proven by the party making the claim. V.I. Truba argues that such legal constructs are unviable and fail to protect the parties' rights effectively, suggesting that evaluative terms are worth avoiding in legal definitions (*Truba, 2014, p. 88*). However, this view is debatable. For example, in case No. 755/5802/20, the SC ruled on May 10, 2022, that both the existence of grounds for invalidating a contested prenuptial agreement and the violation of a subjective private right or interest must be determined at the time of the agreement's conclusion. The court disregarded the plaintiff's argument that the sole marital property was granted to the other party under the agreement, as this property had been acquired in the other party's name after the agreement's execution, and

the plaintiff was fully aware of its terms. Thus, the plaintiff failed to prove grounds for invalidation (*Supreme Court Ruling…, 2022*).

Part 5 of Art 93 also requires clarification of the FC, which prohibits the transfer of ownership of real estate or other registrable property to one spouse under a prenuptial agreement. In case No. 200/1546/19, the SC denied the request to declare the prenuptial agreement invalid, as it did not transfer property ownership but merely outlined how property would be divided in the event of divorce. The court also noted that Part 5 of Art. 93 of the FC applies to personal property already wholly owned by one spouse and transferred to the other under the agreement (*Decision…, 2021*).

As for the failure to notarise a prenuptial agreement results in its invalidity (voidness), which is directly prescribed by law and does not require a court decision. However, under civil law, a court may recognise such an agreement as valid if the parties agreed on all essential terms (confirmed by written evidence), have already fully or partially performed it, and one party avoided notarisation. After such a court decision, notarisation is no longer required.

Discussion

Despite the significant number of scholarly works devoted to the institution of the prenuptial agreement, specific issues remain insufficiently explored within the doctrine of family law. Over time, judicial practice continues to evolve, with courts offering clarifications on the interpretation of family law provisions regarding the legal regulation of prenuptial agreements—provisions that themselves are subject to change.

Further study is needed on the legal nature and content of prenuptial agreements, since the legal consequences of entering into such an agreement depend on the specific terms included. Additional research is also required concerning the spouses' right to withdraw from a prenuptial agreement, particularly concerning the right to terminate such an agreement.

The understanding of the term "extremely disadvantageous financial position" remains a subject of debate, although judicial practice has attempted to provide answers to this issue. Moreover, the grounds for declaring a prenuptial agreement invalid also require deeper examination, especially in cases involving the transfer of real estate or other property subject to state registration to one of the spouses under the agreement.

Conclusion

Thus, the prenuptial agreement is the primary family-law contract between spouses, becoming increasingly widespread in Ukraine. Despite the decline in registered marriages in recent years, statistical data show a growing number of prenuptial agreements being concluded. The mixed nature of the prenuptial agreement indicates that it is a family-law contract with specific characteristics of a civil-law contract. This agreement may regulate only the parties' property relations. The parties may be spouses or engaged couples, distinguishing this agreement from other marriage and family contracts.

Once a prenuptial agreement enters into force, it applies to the spouses' property relations existing at that time and to those that may arise in the future. This includes future maintenance obligations and property to be acquired during the marriage.

An analysis of the legal norms of family and civil law leads to the conclusion that the legal consequences of terminating or withdrawing from a prenuptial agreement are not identical. The parties may withdraw from the prenuptial agreement only by mutual consent, and the date from which the agreement will be considered terminated is determined at their discretion. This allows the parties, upon withdrawal, to apply bilateral restitution as if the contract had been declared invalid.

Analysing judicial practice, it can be concluded that in cases where a prenuptial agreement is declared invalid due to provisions that place one spouse in a highly disadvantageous financial position, the decisive factor is that such a position must exist at the time of the agreement's conclusion—not as a result of the acquisition of property during the marriage.

Courts also point out that under a prenuptial agreement, it is impossible to transfer sole ownership of real estate (or any other property subject to state registration) to one spouse that the other privately owns. In other words, spouses may only establish the procedure for dividing such property in the event of divorce.

Conflict of interest

The author declares that there is no conflict of interest.

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Nataliia M. Obiukh [6]

Concept, Principles and Tasks of Artificial Intelligence in Environmental Law [5]

Abstract: This article examines the legal aspects of using artificial intelligence in environmental law and its areas. The principles and tasks of artificial intelligence for improving the environmental protection system are analysed, as well as the opportunities and benefits that can be obtained with the help of artificial intelligence in climate change, energy, biodiversity protection, waste management, etc. The study object is the social relations connected with using artificial intelligence in environmental protection and sustainable development. The study subject is international and European legislation that regulates the use of artificial intelligence in environmental relations. The study aims to analyse artificial intelligence's concepts, principles and tasks in environmental law. To implement the study, the ideas of foreign scientists were analyzed, namely Nehwal Ch., Piyselman M., Lytvynets V., Gomez Ch., Lhoumeau S., Pinelo J., Borges P., who considered individual aspects of the use of artificial intelligence in environmental protection and agriculture. It was determined that the EU has already developed strategies related to the need to use artificial intelligence, particularly to implement the environmental goals of the EU climate policy. The study concluded that it is necessary to develop legal and ethical principles for using artificial intelligence in environmental law.

Keywords: environmental policy, climate change, emissions monitoring, sustainable development, artificial intelligence.

Abbreviations:

AI is artificial intelligence,

CODES is Coalition for Digital Environmental Sustainability,

GRI is Global Reporting Initiative,

IMEO is International Methane Emissions Observatory,

IoT is Internet of Things.

Introduction

The 21st-century global environmental challenges have highlighted the importance of artificial intelligence as a necessary condition for humanity's continued existence and for finding the most optimal ways to solve ecological problems.

Today, we can observe how artificial intelligence permeates the core spheres of human life: transport, energy, education, construction, and others. With the emergence of AI, human life has become simpler, allowing time and resources to be saved. At the same time, the application of AI in addressing environmental protection issues requires particular attention.

The study object is the social relations connected with using artificial intelligence in environmental protection and sustainable development.

The study subject is international and European legislation that regulates the use of artificial intelligence in environmental relations.

The study aims to analyse artificial intelligence's concepts, principles, and objectives in environmental law based on the analysis of European legal acts and international principles and standards for using AI in key ecological sectors.

In the study, general scientific and specialised legal methods of cognition were applied. The principal method used was the dialectical method, which enabled an analysis of the main aspects of developing artificial intelligence in environmental law. The formal logical method was employed to clarify the content of certain scientific concepts and notions (such as sustainable development, artificial intelligence, and ecological resilience). A comparative legal method was used to analyse the provisions of international treaties and European legal instruments regulating relations in the sphere of AI use in environmental law.

An analysis of recent research indicates the development of artificial intelligence technologies in various areas of environmental protection.

As noted in the works of Indian scholar Chaudhary Nehwal, particularly active research is being conducted into AI-based systems for environmental forecasting and monitoring of climate change, with the aim of adaptation and mitigation.

Foreign publications also discuss the application of AI technologies to address global environmental challenges such as climate change, energy security, and biodiversity conservation. For instance, M. Pieselman and V. Lytvynets have explored the ecological impact of artificial intelligence, legal frameworks, and approaches that support achieving AI's ecological sustainability.

Special mention should be made of the work of international scholars who investigate the use of AI in agricultural activities. For example, Ch. Gomes and J. Matushika examined the potential and benefits of using chatbots and neural networks to improve farm management systems.

Thus, we shall focus specifically on the issue of using artificial intelligence in certain areas of environmental protection that require particular attention.

Results

General Trends in the Use of Artificial Intelligence in Environmental Law

In recent years, AI has become a significant breakthrough across various areas of life, impacting both our daily activities and industry. Its practical application has become essential in many sectors requiring rapid and accurate analysis of large volumes of data, decision-making, and the resolution of complex problems (*Fox, 2024a*).

Climate change is causing various adverse consequences, such as global warming, rising sea levels, and biodiversity loss. In response, national and international authorities are adopting environmental programmes to tackle climate change and adapt to its effects. At the same time, modern technologies, particularly artificial intelligence programmes, are gradually being introduced as part of the strategy to manage climate change.

AI technologies offer considerable potential as tools for informed decision-making. AI can detect insights and patterns in unstructured data (e.g., data generated from videos, images, and social media) and combine computing power to solve complex problems.

AI applications, such as energy forecasting, smart grids, and climate change modelling, hold significant promise for managing adaptation processes. For instance, AI-powered autonomous vehicles could reduce greenhouse gas emissions by 50% by 2050, thanks to their ability to determine the most efficient routes. AI technology can also be used effectively in agriculture to

increase crop yields. For example, farmers growing peanuts in India have improved their harvests by 30% through artificial intelligence (*Newal, 2023, p. 392*).

It is important to note that these technologies raise important legal and ethical questions that must be addressed. AI-driven data analysis can help identify areas affected by deforestation. It can also monitor emissions accurately and assess whether companies meet their primary pollutant emission targets.

Furthermore, AI can be deployed to develop innovative climate policies and address other environmental challenges—e.g., by creating predictive models that forecast the impact of climate change on ecosystems and inform conservation efforts. AI may become a vital tool in environmental monitoring, enabling faster and more accurate environmental data analysis, identifying ecological risks and hazards, and detecting environmental violations.

European companies are actively implementing AI systems and technologies that are required to report greenhouse gas emissions in line with directive requirements. These innovative AI-based programmes assist in analysing and exchanging environmental data, including risk management and strategic planning. Similarly, the GRI provides a standardised framework for reporting on a broad range of topics within environmental reporting—including greenhouse gas emissions, occupational health and safety, human rights, and community impacts—thus improving transparency and governance practices worldwide (*Pijselman & Litvinets, 2024*).

The EU has already adopted the Artificial Intelligence Act (*Regulation EU, 2024*), which addresses sustainability issues related to AI development, training, and use. The methodology for assessing AI's environmental sustainability will be clarified separately by the AI Office and individual Member States through future codes of conduct and harmonised standards.

Meanwhile, the scientific framework of the National Institute of Standards and Technology includes environmental impact assessment and the management of model training practices. It focuses on establishing measurable baseline indicators of sustainability and assessing the reliability of AI systems by documenting key performance indicators such as resource usage and carbon footprint. While the new rules and standards aim to mitigate AI's environmental impact, they lack clarity on how to measure and allocate energy consumption within the complex AI ecosystem involving multiple stakeholders.

Thanks to the integration of AI into satellite systems, it will be possible to track changes in various agricultural sectors such as land use, crop production, and forestry. The use of AI in agriculture will allow for the early detection of plant diseases and associated issues. In our view, AI can be harnessed in agriculture to mitigate environmental risks arising from unsustainable agricultural practices, such as excessive pesticide use or uncontrolled irrigation that leads to fertiliser pollution. Examples of AI use in agriculture include farmer-support chatbots, intelligent systems for monitoring and protecting plant growth, and automated irrigation systems. Modern technologies enable achieving higher yields and transforming farms into environmentally safe and economically viable enterprises (*Gomes & Matushika, 2022, p. 12*).

Features of Using Artificial Intelligence Technologies in Certain Areas of Environmental Law

Artificial Intelligence and Climate Change

Artificial intelligence and emerging technologies are crucial for accelerating the implementation of the *2030 Agenda for Sustainable Development* (General Assembly, 2015), playing a key role in climate action, energy efficiency, green networks, and the circular economy. There is an urgent need for consistent governance of AI and other digital technologies by bringing together diverse stakeholder groups and experts. To address this challenge, the *CODES* is promoting a global movement for digital sustainability and advocating policies such as the *Global Digital Compact*, which is set to be signed by UN Member States at the forthcoming *Summit of the Future*. This event will engage participants in dialogue around the principle of environmental sustainability in the Global Digital Compact, including priorities, next steps for implementation, and actions to promote the environmental sustainability of artificial intelligence (*UN Future Summit, 2024*).

One of the UNEP-led initiatives within the *WESR* digital ecosystem is the *IMEO*, which uses AI to monitor and reduce emissions. This platform functions as a global public database of empirically verified methane emissions. IMEO technology enables the collection and integration of diverse data streams on methane emissions to create a global inventory with high accuracy and detail. Reducing methane emissions in the energy sector is one of the most efficient and cost-effective ways to mitigate climate change and achieve significant emission reductions (*How artificial…, 2022*).

Climate change presents a grave challenge, as it can lead to consequences such as droughts, wildfires, floods, and rising sea levels. These effects may become dangerous for humanity if global temperatures rise by 1.5–2.0°C, as outlined in the *Paris Agreement* (UN, 2015). Should climate change continue or be insufficiently mitigated, the global average temperature may reach 3°C by 2100.

AI-based programmes can support various climate mitigation and adaptation efforts. The EU's climate strategy sets out the goal of achieving climate neutrality by 2050 and reducing emissions by at least 55% by 2030 compared to pre-industrial levels. Accordingly, one of the top priorities of current European climate policy is the shift towards low-carbon development and economic decarbonisation.

In 2021, the European Commission adopted the new EU strategy *Forging a Climate-Resilient Europe* (*Forging…, 2021*), outlining the key directions of EU climate policy in mitigation and adaptation. This strategy aims to realise a vision of a climate-resilient Union by 2050 by making adaptation smarter, more systemic, and faster while intensifying international action. Adaptation measures will extend to every local authority, business, and household, aiming to involve all stakeholders.

It is important to note that science-based solutions can facilitate decision-making and action in climate uncertainty. We must develop effective and inclusive governance mechanisms that foster dialogue between policymakers and scientists, for instance, through the *European Climate Change Adaptation Conference*. We should promote using advanced digital technologies and climate services to support decision-making (e.g., remote sensing, smart weather stations, artificial intelligence). New tools such as *Destination Earth* and *Digital Twins* promise to enhance our understanding of present and future climate impacts at both global and local levels.

Monitoring, reporting, and evaluation are essential for establishing a reliable baseline to track progress in adaptation. Member States are developing climate adaptation plans by integrating them into their energy and climate policy frameworks. A key objective of these plans is to ensure the adaptation of European energy systems to climate change. Special attention must be paid to vulnerable areas, including river basins, mountainous regions, islands, and the most remote regions, which are particularly susceptible to the impacts of climate change.

AI-based adaptation measures should be implemented in energy efficiency, agriculture, and water management programmes. Artificial intelligence enables forecasting weather changes, which in turn allows for improved planning of agricultural activities, including the control and protection of crops from droughts and cold spells.

In conclusion, using AI offers broad opportunities for developing and planning climate change mitigation and adaptation measures through specialised AI-driven programmes and their integration into business operations.

Artificial Intelligence and Biodiversity Conservation

Intelligent systems can assess the environmental sustainability of various projects and develop strategies for biodiversity conservation. They can analyse diverse data on species and ecosystems, which helps to make informed decisions and ensure the preservation of life's diversity on the planet. Artificial intelligence holds great potential for species conservation and for addressing the planet's environmental challenges. Innovative AI-based technologies can assist ecologists and scientists in studying and monitoring various animal and plant species.

Forecasting biodiversity patterns and trends is a highly complex task that fundamentally depends on its variability. Long-term monitoring programmes are indispensable tools for tracking and observing changes in biodiversity over time. They can reveal ecological dynamics such as population cycles or responses to climate change. We believe the information gathered during monitoring is vital for developing effective biodiversity conservation strategies. Artificial intelligence technologies can be applied as a basis for ecological modelling and forecasting (*Lhoumeau et al., 2025*).

Neural networks are a promising modelling tool for studying complex temporal data. Due to the universal approximation theorem, they can approximate—i.e., simplify—any function. This makes it easier to identify species and analyse ecological interactions between them.

Artificial intelligence automates the processes of collecting and analysing data on various species. This significantly speeds up the work of experts and enables the collection of more information on species at risk of extinction. AI technologies can also be used to forecast environmental changes and detect patterns indicating threats to biodiversity. Through machine learning algorithms, AI can identify changes in ecosystems and provide timely alerts.

In addition, artificial intelligence contributes to developing new methods for nature conservation and restoring degraded ecosystems. By analysing vast amounts of data, AI can suggest practical approaches for restoring natural habitats and forests and propose innovative solutions for conserving rare plant and animal species. Thus, artificial intelligence, in combination with ecology, can become a powerful tool for species preservation. This technology will reduce the impact of human activity on the environment and ensure sustainable development (*Fox, 2024b*).

Artificial Intelligence and Waste Management

To regulate legal matters concerning waste management in the European Union, Directive 2008/98/EC is applied (*Directive…, 2008*). According to the Directive, the core principles of European waste management policy include pollution prevention, extended producer responsibility, recycling, and secondary processing. The European policy is focused on reducing waste generation and implementing recycling technologies.

The application of AI in waste management encompasses several modern trends. This involves using machine learning algorithms for waste sorting to classify and separate recyclable materials to reduce pollution during the recycling process. AI technologies are also used to optimise collection routes, resulting in more efficient resource allocation and collection procedures. In addition, AI-based robotics are being introduced to enhance the efficiency of waste processing, particularly during sorting (*Revolutionizing…, 2024*).

AI also plays a vital role in waste recycling by optimising various stages of the recycling process. AI-driven identification and sorting technologies enable the accurate detection and separation of recyclable materials, thereby contributing to resource recovery and reducing pollution from waste. AI-based quality control and inspection systems ensure the production of high-quality recycled materials by detecting defects, contamination, and inconsistencies. Furthermore, robotics and automation of recycling processes guided by AI optimise recycling operations, thus improving their overall efficiency.

Waste monitoring is another area for AI technology applications. Real-time monitoring systems integrated with IoT devices and sensor networks collect and analyse waste generation, collection, and disposal data. AI algorithms analyse and process this data, providing valuable insights for optimising recycling and disposal operations. This enables real-time forecasting of waste generation patterns, optimisation of resource distribution, and data-driven decision-making in waste management.

What AI technologies are used in the waste management sector? The primary AI methods widely applied in waste management include collection, sorting, recycling, and planning. Key methods in the field include linear regression, support vector machines, decision trees, and artificial neural networks (*Olawade et al., 2024, p. 250*).

Recently, supervised machine learning algorithms have gained popularity due to their relevance for analysing large volumes of data. These algorithms identify and sort waste by type, determine bin fill levels, optimise collection routes, and more. These technologies employ advanced sensors, such as X-ray fluorescence, to analyse waste's physical and chemical properties. AI algorithms then process the data obtained to determine the material composition and sort the waste accordingly. Current trends in automated sorting technologies focus on integrating machine learning methods, such as deep learning and neural networks, to identify and sort a wide range of waste, including plastics, metals, paper, glass, and organic matter.

Applying AI technologies in waste management requires ethical considerations and responsible approaches. AI-driven decision-making must be accurate and transparent to avoid errors and unintended outcomes. Efforts are ongoing to establish ethical practices and guidelines for optimal AI-based waste-handling decision-making. Continuous research and

collaboration are crucial for further enhancing AI algorithms and developing ethical principles ensuring fair waste management outcomes.

Developing legal frameworks and industry standards is essential to ensure AI's responsible and ethical use in waste management. Legislation should address key concerns such as data privacy, security, fairness, and transparency. Governments and regulatory bodies should lead the development and adoption of regulations that balance innovation needs with protecting ethical principles and societal values.

The regulatory framework must adapt to evolving AI technologies, ensuring they foster innovation while promoting public welfare and environmental sustainability. As AI advances, governments and regulators must remain proactive in updating legislation and standards to address emerging risks and opportunities in AI-powered waste management.

Discussion

Further areas of research into the application of artificial intelligence in environmental law may include the development and analysis of ethical and legal principles governing the use of AI, which is currently a highly relevant issue. The use of "smart technologies" necessitates the adoption of digital codes of conduct and standards for the safe use of data. Another debated issue is the principle of the environmental sustainability of artificial intelligence, which requires detailed study and analysis in terms of introducing innovations into environmental decision-making processes.

Conclusion

This study has provided an in-depth analysis of how artificial intelligence can significantly contribute to ensuring environmental sustainability in such critical areas as climate change and energy, agriculture, waste management, and biodiversity conservation. As we have seen, monitoring plays a significant role in harnessing the potential of artificial intelligence and advancing environmental sustainability. In particular, we have examined the capabilities of AI in monitoring greenhouse gas emissions to improve environmental reporting and forecasting systems, as well as its application in waste management monitoring, which offers several advantages for waste sorting and recycling.

Future research must focus on specific issues related to AI technologies and the effectiveness of their implementation to achieve environmental sustainability and fully harness artificial intelligence's benefits for present and future generations. The actual value of AI in the environmental field lies in its ability to support more accurate and sustainable environmental decision-making. We can conclude that AI offers benefits such as improved environmental governance, optimisation of environmental performance in production and agriculture, reduction of environmental risks, and a general decrease in pollution.

Conflict of interest

The author declares that there is no conflict of interest.

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Dmytro D. Diachuk [7]

Conceptual Approaches to the Introduction of Compulsory Health Insurance for the Population in Ukraine [6]

Abstract: The critical demographic situation, epidemic challenges, and consequences of the war, which will be observed in the population and the event of its end, require adequate funding for the industry to meet the medical needs of the population. The study aims to research the state and problems of financial support for the healthcare sector and substantiate conceptual approaches to introducing mandatory state health insurance in Ukraine. Materials: data from state and industry statistical reports; regulatory legal acts; draft laws of Ukraine on compulsory health insurance; scientific literary sources. Study methods are analytical, synthesis, comparison, generalisation, and conceptual modelling. For 2022, the funds for the medical guarantee program amounted to 157.3 billion UAH, or 2.9% of gross domestic product (GDP), instead of 5.0% provided for by law. This volume amounted to 142.7 billion UAH (2.3%) in 2023 and 158.8 billion UAH (2.1% of GDP) in 2024. International experience shows that most countries of the world use a mixed form of financing for the healthcare sector to increase the financial access of the population to medical care. We have proposed a conceptual approach to the introduction of compulsory state health insurance in Ukraine through the adoption of the law on mandatory state health insurance, which will determine the sources of financing of medical services—insurance payments to employers, state budget funds and funds from other sources not prohibited by law. The author concludes that the proposed conceptual approaches to the sources of insurance fund formation and their legislative consolidation differ significantly from those proposed in earlier draft laws, and were rejected by the legislative body.

Keywords: insurance, industry financing, healthcare, draft law, medical care.

Abbreviations:

COVID–19 is coronavirus disease 2019,
GDP is gross domestic product,
MH is the Ministry of Health of Ukraine,
PMG is the Programme of Medical Guarantees,
WHO is the World Health Organisation.

Introduction

Since 1991, Ukraine's health status has been unsatisfactory due to a critical demographic situation, high levels of morbidity, prevalence of diseases, disability, and population ageing. Between 1991 and 2021, the proportion of individuals over the age of 60 increased from 18.4% to 24.8%, leading to a rise in the incidence of age-related chronic non-communicable diseases and the number of patients with multiple chronic conditions (*Population…, 2022*; *Annual…, 2023*).

The structure of primary morbidity in Ukraine is composed of respiratory diseases (45.23%), circulatory system diseases (6.69%), injuries and poisonings (6.38%), skin and subcutaneous tissue diseases (5.88%), eye and adnexal diseases (5.13%), and other diseases (30.69%). The structure of disease prevalence includes: circulatory system diseases (30.9%), respiratory diseases (20.1%), digestive system diseases (9.8%), musculoskeletal system and

connective tissue diseases (5.45%), genitourinary system diseases (5.41%), and other diseases (28.34%) (*Annual…, 2017*; *Ringach & Vlasik, 2022*).

The data presented confirm the low level of health among Ukrainians, which has further deteriorated during the period of full-scale war, as Ukrainian citizens, according to WHO experts, are experiencing increased physical and psychological stress, which raises the need for quality healthcare, particularly in terms of its financial accessibility (*1000 days…, 2024*).

This study aims to examine the state and challenges of financial support in the healthcare sector and justify conceptual approaches to implementing mandatory state health insurance in Ukraine.

The research materials included: data from national and sectoral statistical reports; regulatory and legal acts; and academic sources.

Study methods: analytical, synthesis, comparison, generalisation, and conceptual modelling.

Results

The study's results have shown that Ukraine's healthcare system, like those of other countries around the world, came under significant pressure during the COVID–19 pandemic, which exposed gaps in its functioning. According to the Ministry of Health of Ukraine, 5,562,748 confirmed cases of COVID–19 were officially registered during the epidemic period, with 112,478 deaths (*Three years…, 2025*).

In 2021, 11.0% of Ukrainian households became poorer or fell even deeper below the poverty line due to out-of-pocket healthcare expenses, while 17.0% of households (approximately 2.5 million) experienced catastrophic health expenditures—one of the highest rates in Europe (*Self-assessment…, 2021*).

The full-scale invasion by the aggressor state in 2022, which is still ongoing, has increased the population's need for medical care and, as a result, reduced their financial protection. The economic, political, and social challenges exacerbated by the war have further underscored the need to improve healthcare funding mechanisms (*Financing…, 2024*).

Despite introducing a healthcare financing mechanism involving payment for packages of medical services under the PMG, nearly a third of people in need of medical care were unable to access it, primarily due to financial barriers. Catastrophic spending is attributed mainly to the cost of medicines prescribed for outpatient or inpatient treatment and inpatient care.

Legislation allows for the introduction of paid services in public and municipal healthcare facilities providing services under the PMG in the absence of PMG-covered ones, which poses a barrier for low-income groups.

In 2022, funding allocated for the PMG amounted to UAH 157.3 billion, or 2.9% of GDP, instead of the 5.0% stipulated by law. In 2023, this amount was UAH 142.7 billion (2.3% of GDP), and UAH 158.8 billion (2.1% of GDP) in 2024 (*The state budget for 2022…, 2021*; *Expenses, 2024*).

The allocated funding for the Programme of Medical Guarantees in 2025 is UAH 175.5 billion (2.1% of GDP), which also falls significantly short of the required 5.0% (*The state budget for 2025…, 2024*).

According to the MH's forecasts, public healthcare expenditure is expected to reach 3.5% of GDP in the short term and only 7.0% of GDP within the next ten years (*Budget declaration…,*

2024). This will likely negatively affect the healthcare system's ability to deliver services in the coming years and increase the share of private payments, particularly out-of-pocket patient spending.

A conceptual approach is proposed for reforming the healthcare financing model through the introduction of mandatory public health insurance. Under Article 49 of the Constitution of Ukraine, every citizen of Ukraine has the right to health protection, medical care, and medical insurance (*Krylov, 2023*; *The Constitution of Ukraine, 1996*).

Discussion

Ukraine must appropriately prioritise the healthcare sector among competing demands for limited public funds. International experience indicates that healthcare is typically financed through a mixed model. Depending on the dominant form of healthcare funding, systems around the world are categorised as state-funded (e.g., England, Ireland, Italy, Scotland), mandatory health insurance-based (e.g., Austria, Belgium, the Netherlands, Germany, Sweden, Japan), or insurance-budgetary systems (e.g., the United States), where approximately 90% of the population use services provided by private insurance companies (*Kirichenko, 2024*; *Petrushka, 2017*).

The conceptual approach to introducing mandatory state health insurance in Ukraine requires, first and foremost, the adoption of a Law on Mandatory State Health Insurance. This law should define the sources of funding for medical services, which, in our view, ought to include employers' insurance contributions, funds from the state budget, and other sources not prohibited by law.

Insurance funds would be allocated to cover the costs of medical services related to insured events. These insured events would include the treatment of acute illnesses, exacerbations of previously diagnosed chronic conditions, and acute episodes resulting from newly diagnosed chronic diseases.

Insurance funds would be formed from employers' contributions for employed individuals, contributions made by the Pension Fund of Ukraine for pensioners and persons with disabilities, and the State Social Insurance Fund for Unemployment for children, pregnant women, and the unemployed.

Numerous academic publications are devoted to introducing mandatory health insurance in Ukraine, highlighting the significance and ongoing relevance of this issue. The transition to mandatory state health insurance for citizens has been. It remains one of the main goals of political and civil society actors in Ukraine, as well as existing and potential healthcare service users. Researchers in this area are confident that implementing mandatory state health insurance will help improve population health, reduce mortality, and positively impact the development of the country's human capital (*Brezhneva-Ermolenko & Baiduzhe, 2019*).

Particular attention must be paid to aligning the implementation of mandatory state health insurance with the Ukrainian context, where the constitutional guarantees of free and accessible medical care are not being met, as actual state expenditure on healthcare is significantly lower than what is stipulated by current legislation (*Mishchuk & Vinnichuk, 2019*; *Klymuk, 2021*; *Solovey, 2023a*; *Solovey, 2023b*).

Researchers consider the absence of a law on mandatory state health insurance to be one of the main barriers to the formation of a mandatory state health insurance system in Ukraine (*Barzilovich, 2020*; *Sova, 2018*).

Our proposed conceptual approaches to funding sources for the State Fund of Mandatory State Health Insurance differ significantly from those presented in previous draft laws rejected by the legislature. Notably, our approach foresees citizens being exempt from any additional taxation related to mandatory state health insurance upon the adoption of the relevant legislation.

Conclusion

The insufficient healthcare funding necessitates searching for additional resources to reduce financial barriers to meeting the population's medical needs.

The proposed conceptual approaches to introducing compulsory state health insurance envisage the adoption by the Verkhovna Rada of Ukraine of a Law on Compulsory State Health Insurance, which would define the sources of funding for the State Fund of Compulsory State Health Insurance. These sources would exclude direct contributions from citizens, placing significant emphasis on the use of budgetary contributions for prevention and insurance funds for treating diseases.

Conflict of interest

The author declares that there is no conflict of interest.

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Liliia Ya. Muntian [8]

Virtual and Augmented Reality in the Education of Medical Students [7]

Abstract: Virtual reality (VR) and augmented reality (AR) technologies play an extremely important role in the healthcare sector, where their application allows for better diagnosis, treatment, and rehabilitation of patients. These technologies play a particularly important role in the healthcare sector, where their application allows for better diagnosis, treatment and rehabilitation of patients. The purpose of the study is to analyze scientific data on the use of virtual and augmented reality technologies in the education of medical students and in the practice of doctors. The role of VR and AR technologies in planning complex surgeries is particularly noteworthy, where they allow surgeons to pre-model interventions and receive visual cues in real time, reducing the trauma of operations and increasing their efficiency. In rehabilitation programs, VR and AR are becoming indispensable tools for physical and cognitive rehabilitation of patients, providing effective methods of restoring motor and cognitive functions. The author concludes that the use of VR and AR for mental health deserves special attention. Modern technologies make it possible to create safe and controlled environments for the treatment of anxiety disorders and PTSD, enabling patients to gradually adapt to stressful situations, reducing anxiety and improving their emotional state.

Keywords: virtual technologies, augmented reality technologies, medical students, patient rehabilitation, VR simulators.

Abbreviations:

AR is augmented reality,

$PTSD$ is a post-traumatic stress disorder,

VR is virtual reality

Introduction

VR and AR have become an integral part of the modern digital world. They are changing approaches to education, entertainment, and professional activities. They open up new opportunities for interacting with information, create intuitive tools for analysis, visualization, and training.

These technologies play a particularly important role in the healthcare sector, where their application allows for better diagnosis, treatment and rehabilitation of patients. The relevance of VR and AR in medicine is growing every year. They are becoming key elements of the digital transformation of healthcare systems, helping to overcome traditional barriers to doctor training, communication with patients, and the organization of treatment processes (*Kafes et al., 2024*; *Nelson & Bailey, 2020*; *Ferrari et al., 2019*).

One of the biggest advantages of augmented reality technology is the integration of digital information with data about the user's environment in real time. Using this method, it is possible to visualize physical reality supplemented or enhanced by computer-generated perceptual data, such as images, GPS data, audio or video signals (*Kwon et al., 2018*).

AR and VR technologies are closely related but fundamentally different from each other. Virtual reality provides full immersion with the creation of a three-dimensional world. It completely separates the user from physical reality (blocks signals from the outside world).

Augmented reality allows you to keep in touch with the outside world and improve it (*Kwon et al., 2018*). Compared to it, AR technology allows using less bulky equipment.

AR technology was first used in medicine in the 1990s to preplan surgical interventions and evaluate large amounts of data generated during the intervention (*Williams & Thompson, 2021*). Currently, AR technology is one of the most promising digital health technologies, and interest in it is growing every year.

Thanks to VR and AR, healthcare professionals have access to innovative training methods. They allow to simulate real clinical situations, improving skills and raising the level of professional training of specialists. In turn, patients can receive individualized treatment and rehabilitation that were previously unavailable or ineffective. This makes VR and AR technologies not only useful but also necessary in the context of modern healthcare requirements.

The purpose of this study was to analyze scientific data on the use of virtual and augmented reality technologies in the education of medical students and in the practice of doctors. The use of VR and AR technologies in healthcare covers a wide range of areas, including diagnostics, treatment, rehabilitation, and educational activities (*Table 1*).

Results

One of the major aspects is their use for visualization of the patient's internal organs. This allows doctors to get a three-dimensional view of anatomical structures and pathological changes. Such capabilities significantly improve diagnostic accuracy, reduce the risk of errors, and provide a more detailed analysis of the patient's condition (*Kovalchuk et al., 2020*). Thus, in surgery, VR and AR are becoming indispensable tools for planning and performing complex operations. Thanks to these technologies, surgeons can pre-model surgical interventions, practice them in a virtual environment, and receive visual cues during surgery in real time. This helps to minimize trauma, reduce surgery time and improve treatment outcomes. In addition, these technologies contribute to the improvement of minimally invasive surgery methods, which is especially important in the context of modern requirements for the quality of medical care.

In dentistry, the main application of AR technology is in maxillofacial and oral surgery. In addition, AR software installed on smart glasses helps dentists to form crowns more accurately by overlaying real-time data from a dental scanner (*McGlynn & Asch, 2022*).

In psychiatry, virtual reality is used according to the principle that in order to understand a patient, you need to see the world through their eyes. For this purpose, a special program Mindscape by Viscira has been developed. It is intended not only for professionals but also for the patient's relatives, so that they can better understand how a person with productive symptoms of schizophrenia lives: thinking disorders, auditory hallucinations, and delusions (*Schneider & Sorkin, 2019*).

VR is also used in exposure therapy to create virtual environments that can mimic real-life situations that a patient may fear or find challenging. Exposure therapy is one of the most effective treatments for anxiety disorders, and virtual reality is a safe and controlled way to show patients their fears (*Liu & Zhang, 2020*).

In addition, virtual reality treats phobias. With the help of AR apps, such as Spiderworld by HITlab, patients with arachnophobia can see virtual spiders running on their hands. In a

moment of panic, a person can simply turn off the app and make sure there is no real threat. In turn, the SnowWorld app makes it possible to throw snowballs at penguins in a "winter" environment. This reduces the pain of those who have suffered burns (*Moore & Saito, 2019*; *Pellegrino et al., 2019*).

PTSD is a type of nervous disorder that affects millions of people around the world. This disorder can occur for any reason, such as war. VR allows you to create specially designed environments that simulate real-life situations, helping patients gradually face their fears or traumatic memories in a controlled environment. This approach helps to reduce the intensity of symptoms and develop coping mechanisms.

The process of training medical professionals with VR is extremely important. For example, Weill Cornell Medical College (New York, USA) has a virtual reality room with a simulator for surgeons. The system is equipped not only with a graphic headset but also with tactile feedback. The doctor feels the mechanical impact on the organs of the "patient". With the help of such a simulator, it is possible to acquire the skills necessary for successful operations at a much lower cost (*Petrov et al., 2022*).

Thus, virtual and augmented reality are actively changing the medical field, offering new opportunities to improve the quality of medical services. Their use has led to significant improvements in the diagnosis, treatment, and rehabilitation of patients.

The role of VR and AR technologies in planning complex surgeries should be highlighted, where they allow surgeons to pre-model interventions and receive visual cues in real time, reducing the trauma of operations and increasing their efficiency.

Another important aspect is the use of VR and AR for training medical professionals, which allows them to train in conditions close to real life without risk to patients, thereby improving the level of professional training of doctors.

Conclusion

Thus, in rehabilitation programmes, VR and AR are becoming indispensable tools for physical and cognitive rehabilitation of patients, providing effective methods of restoring motor and cognitive functions.

The use of VR and AR for mental health deserves special attention. Modern technologies make it possible to create safe and controlled environments for the treatment of anxiety disorders and PTSD, enabling patients to gradually adapt to stressful situations, reducing anxiety and improving their emotional state.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. Main areas of VR and AR application in healthcare

Direction	Description
Diagnostics	Using VR and AR to visualize internal organs, improve diagnostic accuracy, and reduce the risk of errors.
Surgery	Simulate operations in a virtual environment and apply real-time prompts during operations.
Personalized treatment	Adapting medical procedures to individual patient needs using VR and AR.
Rehabilitation	Physical and cognitive rehabilitation of patients through interactive games and virtual exercises.
Educational simulations for healthcare professionals	Training of medical professionals in near-real conditions using VR and AR to practice emergency situations.

Source: developed by the author on the basis of research by the group of O.I. Kovalchuk (*Kovalchuk et al., 2020*).

Oleh L. Nazarenko [9], *Serhii O. Hodlevskyi* [10], *Vitalii V. Danko* [11], *Volodymyr O. Fedorenko* [12]

Protecting Ukraine's Critical Infrastructure from Drone Threats: The Role of Security and Defence Forces [8]

Abstract: In the current conditions of the growth of technological threats, the problem of protecting critical infrastructure (CI) facilities from UAVs is gaining particular importance. The growing use of UAVs in various fields, namely, military conflicts, intelligence activities, terrorist attacks and sabotage, creates new challenges for the national security systems of Ukraine. In the context of the ongoing aggression against Ukraine, uncrewed aerial vehicles have become one of the key means of conducting combat operations, reconnaissance, and sabotage activities. The study examines the growing threat of uncrewed aerial vehicles (UAVs) to Ukraine's critical infrastructure (energy, transport, defence) amid ongoing hybrid warfare. UAVs are increasingly used for strikes, reconnaissance, and sabotage, demanding urgent improvements in detection, neutralisation, and legal frameworks. The research analyses technical solutions (electronic warfare, AI-driven systems), regulatory gaps, and interagency coordination challenges. Findings highlight the need for a multi-layered defence combining electronic countermeasures, air defence, and cyber capabilities, alongside updated laws to regulate UAV use. International cooperation and advanced technologies (swarm interceptors, sensor networks) are identified as critical for resilience. The study proposes legislative reforms, enhanced interagency synergy, and adoption of global best practices to fortify Ukraine's infrastructure against evolving drone threats.

Keywords: critical infrastructure protection, drone strikes, regulatory gaps, interagency coordination.

Abbreviations:

CI is critical infrastructure

UAV is an uncrewed aerial vehicles.

Introduction

In the current conditions of the growth of technological threats, the problem of protecting CI facilities from UAVs is gaining particular importance. The growing use of UAVs in various fields, namely, military conflicts, intelligence activities, terrorist attacks and sabotage, creates new challenges for the national security systems of Ukraine. In the context of the ongoing aggression against Ukraine, uncrewed aerial vehicles have become one of the key means of conducting combat operations, reconnaissance, and sabotage activities. They are designed to strike CI, which can lead to significant destruction and disruption of the functioning of strategic facilities, creating a substantial threat to the civilian population.

Today, measures are actively being implemented in Ukraine's security and defence sector to detect and neutralise UAVs. However, existing systems require further improvement by integrating the latest technologies (electronic warfare, laser destruction, cyber defence, etc.) and increasing the efficiency of interaction between Ukraine's security and defence forces. Another pressing issue is improving the modern regulatory framework, which regulates measures to protect CI from UAV attacks, namely, the Law of Ukraine "On Critical Infrastructure".

Recent decades have seen the rapid development of UAVs, which have been used for civilian and military purposes (*Nashivochnikov, 2024*). In the context of modern military conflicts

and hybrid threats, the use of UAVs has become one of the most effective means of conducting combat operations, reconnaissance, sabotage, and terrorist attacks.

Continuing to resist military aggression, Ukraine faces a significant threat to the CI facilities (*Gerasymenko, 2024*). Hostile UAVs are actively used to strike at energy, transport, communications, and defence industry facilities, which have serious consequences.

Despite Ukraine's efforts to counter UAVs, key challenges remain, namely (*Nashivochnikov, 2024*): limited effectiveness of traditional air defence against small, agile drones; lack of a unified national strategy for UAV threats, requiring better coordination among security agencies; need for advanced detection/neutralisation tech (electronic warfare means, lasers, cyber defences, automated systems); insufficient laws regulating UAV use and countermeasures; gaps in interagency coordination in protecting CI from drone threats.

Thus, the problem of increasing the effectiveness of protecting CI from threats posed using UAVs is multifaceted and requires a comprehensive solution. It includes technical and organisational legal aspects and requires coordinated interaction of all components of Ukraine's security and defence sectors. Analysing the growing threat of strike UAVs to troops and CI (*Lenkov et al., 2023*), propose increasing the effectiveness of active defence using fragmentation engineering munitions, in particular MON–50, MON–90, MON–100, MON–200, to destroy low-flying targets.

The study (*Krivtsun et al., 2024*) covers technical solutions for countering drones, including electronic means of neutralisation, laser technologies, and mechanisms for physical destruction of drones.

Havrys et al. (*2024*) describes protecting Ukraine's CI facilities during a military conflict, emphasising the complexity of modern threats and the need for an integrated approach. The authors examine the features of information analysis of security systems of strategic facilities during martial law and justify the need to integrate advanced threat monitoring methods.

Thus, the study of measures to counter the threats posed by UAVs to the CI of Ukraine is relevant, allowing: to assess the real threats posed by uncrewed aerial vehicles to the CI of Ukraine; to determine effective methods and means of protecting the CI from UAV attacks, including technical, organisational and legal mechanisms; to develop recommendations for improving the security system of the CI, considering international experience and the specifics of military threats in Ukraine. Given these factors, the study's topic has theoretical and practical significance for ensuring national security and the effective functioning of critical state facilities.

Results

UAVs have become an important element of modern military and terrorist strategies, posing serious threats to CI such as power plants, transportation hubs, military facilities, government buildings, etc. Threats from UAVs can be divided into three main categories: reconnaissance operations, strike impact, and sabotage-terrorist attacks.

Uncrewed aerial vehicles are actively used for reconnaissance due to their ability to penetrate controlled areas while remaining invisible to traditional detection systems. The main threats to reconnaissance UAVs include aerial reconnaissance during which UAVs can photograph strategical facilities in high resolution; radio reconnaissance, carried out by UAVs equipped with devices for intercepting radio signals and collecting information about the

operation of communication systems; cyber threats, during which UAVs can be used to hack wireless networks and obtain confidential information.

Modern UAVs can carry various weapons: missiles, explosive devices, unguided munitions and even chemicals. They are used for pinpoint strikes on CI, which can have catastrophic consequences. The main threats from strike-type UAVs include attacks on energy facilities to damage power plants, substations, oil refineries, which can cause massive power outages; destruction of transport infrastructure, attacks on railway junctions, bridges and airports are carried out, which can paralyse logistics; pinpoint strikes on military facilities carried out Kamikaze drones can be used to eliminate important targets.

Due to UAVs' availability and relative cheapness, even small terrorist or sabotage groups can use them to perform illegal actions. Risks of using UAVs by enemy sabotage and reconnaissance groups are as follows (*Yerylkin et al., 2022*):

- using UAVs equipped with explosive devices to attack civilian objects, mass events, government institutions, industrial enterprises, etc.;
- using UAVs to spray biological or chemical weapons;
- using UAVs for sabotage operations (undermining of CI).

Reconnaissance UAVs allow the enemy to obtain precise coordinates of objects. Strike UAVs can destroy strategic objects, causing severe damage. Terrorists can use UAVs to attack civilians.

Protecting CI from UAVs requires a comprehensive approach that includes technical means of detecting and neutralising UAVs, organisational and strategic measures, and electronic counter-UAV systems.

Technical means of combating UAVs are divided into detection systems (*Table 1*) (radars, sensors) and neutralisation means (*Table 2*) (anti-drone guns, laser systems, signal interception).

Unmanned aerial vehicle detection systems include radar systems, which detect drones using radio waves; acoustic sensors, which detect the sound of a drone's engine running; optical and thermal imaging cameras, which identify drones visually; and radio frequency detectors, which analyse drone control signals.

The UAV neutralisation system includes anti-drone guns that create radio interference for drones, causing them to lose contact with the operator; laser installations that physically destroy drones at a long distance (*Shaptala et al., 2023*); interceptor drones equipped with nets to capture enemy UAVs; and cybernetic interception, which is the hacking of drone control channels.

The main security measures for combating UAVs include delimitation of airspace, which is carried out by establishing zones prohibited for UAV flights; increased patrolling, namely, involving the military, police, and private security companies; personnel training, namely, training employees of critical facilities to recognise and respond to threats; cooperation with international partners, exchange of experience and implementation of the latest technologies (*Table 3*).

In addition to physical combat methods, electronic means allow jamming control signals or even intercepting the control of enemy drones (*Table 4*).

The main types of electronic warfare with UAVs include (*Shumygai et al., 2020*) radio-electronic jamming to block communication between the drone and the operator; GPS

spoofing, which creates false GPS coordinates for the drone, forcing it to change course; and cybernetic interception, which allows one to take control of an enemy drone.

Adequate protection against UAVs requires a combination of technical, organisational, and electronic measures. The most effective approach combines radar, radio frequency jamming, laser weapons, and territory patrolling. Organisational measures help reduce the risk of attacks but are ineffective without modern technologies. Electronic warfare is a key area, as it allows blocking or capturing drones without physically destroying them (*Tsapura, 2023*).

Protection of CI facilities from UAVs is one of the key tasks of Ukraine's security and defence sector, especially in military conflict and hybrid threats. Legislative regulation of this issue remains relevant, as the use of UAVs for reconnaissance, sabotage, and attacks on strategic facilities is becoming increasingly widespread (*Morkvin et al., 2022*).

Legal regulation in this area should ensure a clear definition of entities responsible for protecting the CI from UAVs, coordination of actions of various structures of Ukraine's security and defence sector, definition of legal mechanisms for neutralizing flights of unauthorized UAVs, and establishment of liability for airspace violation.

Ukraine's regulatory and legal framework regarding the protection of CI from UAVs is based on several main legislative acts (*Table 5*). The shortcomings of the current legislation include an insufficiently developed single mechanism of interdepartmental coordination for combating UAVs, insufficiently defined legal grounds for destroying drones in peacetime, an insufficiently developed mechanism for financing UAV countermeasure systems at the CI, and limited access of law enforcement agencies to technologies for neutralizing UAVs.

Studying the experience of leading countries in legal regulation of the protection of CI from UAVs allows identifying effective legal models for combating drones. In the USA (FAA Part 107, National Defense Authorization Act)—all UAVs weighing more than 250 g are subject to mandatory registration, law enforcement agencies have the right to shoot them down; EU (Regulation 2019/947, 2021/664)—regulates the use of UAVs in general airspace, defines "drone-free zones: over critical infrastructure; Israel—a strict system of control over UAV flights, active use of electronic warfare (EW) systems to neutralise them; Great Britain (Air Navigation Order 2016)—provides for hefty fines and criminal liability for violating the rules for using UAVs (*Yerylkin et al., 2022*).

To increase the effectiveness of the protection of the CI from UAVs, it is necessary to determine the legal grounds for the destruction of UAVs by law enforcement agencies; introduce a single state register of UAVs to which all civilian and commercial UAVs should be entered; develop a system of "drone-free zones" over military, energy, and transport facilities; strengthen criminal liability for the use of UAVs for illegal purposes; implement a state program for the development of anti-drone systems, finance the creation of technologies to neutralise them. Amendments to the legislation will allow for a more effective response to threats and increase CI facilities' security level.

Protecting CI facilities from threats posed by UAVs requires a comprehensive approach and coordinated interaction between all components of Ukraine's security and defence sector (*Plahotniuk, 2023*). The subjects of the National Critical Infrastructure Protection System are Armed Forces of Ukraine (AFU), Security Service of Ukraine (SBU). National Guard of Ukraine (NGU), National Police of Ukraine (NPU), State Emergency Service (SES), State Border Service

of Ukraine (SBSU), local government bodies, private sector and CI operators, international partners, allies and others.

Adequate protection of CI depends on a well-established communication mechanism, joint threat analysis, information exchange, and coordinated response to threats from hostile unmanned aerial vehicles.

The Armed Forces of Ukraine are the main force protecting strategic facilities, military bases, and government institutions from air threats. The main functions of the Armed Forces of Ukraine in the fight against UAVs are their detection and identification. For this purpose, modern air defence and radar surveillance systems are used. Electronic warfare means are used to suppress the communication of enemy UAVs.

Air defence systems, such as surface-to-air missile systems and automated drone destruction systems, are used to physically neutralise UAVS. Mobile teams use small arms and specialized systems (e.g., anti-drone rifles) to neutralise UAVS.

To protect military facilities, special networks and barriers are being established to physically block enemy UAVs. In addition to the above, the latest technologies, such as laser weapons and kinetic weapons, are being considered.

Strategies and exercises are being developed to improve the quality of training, namely conducting joint exercises with NATO allies to improve tactics for combating UAVs while protecting the CI, and developing and implementing new anti-drone technologies and tactical solutions.

The joint work of the SBU, NGU, NPU, and SES is a key element in ensuring critical infrastructure security (*Table 6*). This table lists the main public security sector agencies involved in protecting CI from threats posed by unmanned aerial vehicles and their main functions in countering UAVs. It can be used to analyse the effectiveness of interagency cooperation and further improve the CI protection system.

Key measures to improve cooperation: To respond quickly to UAV threats, an operational headquarters (single coordination center) must be created; intelligence must be exchanged to ensure effective situation analysis and coordination between state bodies; and regular training and joint exercises with practicing drone attack scenarios must be conducted to increase the level of readiness.

The areas of international cooperation are aimed at: obtaining information about the latest threats and methods of countering UAVs; transferring technologies for the supply of modern electronic warfare systems, anti-drone complexes and drone detection means; joint training—participation in international military training on tactics for combating UAVs; financial support—attracting grants and assistance from Western partners to strengthen the protection of critical infrastructure.

The growing threat from UAVs requires continuous improvement of the critical infrastructure protection system. The future development of this system is based on implementing innovative technologies, strengthening the regulatory framework, international cooperation, and increasing the level of coordination between government agencies.

One key development area is the introduction of modern technologies in UAV detection and neutralisation (*Yarosh, 2021*). Promising solutions include modern technologies for protecting CI from UAVs (*Table 7*).

To ensure adequate protection of the CI, significant financial investments are required. The main areas of investment include development and production of domestic UAV countermeasure systems (*Azarenko et al, 2024*); purchase of advanced foreign drone protection technologies; equipping law enforcement agencies with modern electronic warfare and air defence equipment; creation of specialised training centres for operators to combat unmanned threats.

Protecting CI from UAVs requires close cooperation between the military, law enforcement, and other government agencies. The main steps in this direction are creating a unified airspace monitoring system that would combine data from radars, electronic warfare, and observation posts; developing joint protocols for actions in case of detection of a threat from UAVs; conducting joint exercises and training to practice tactics to combat drones; and exchanging intelligence data.

Given the dynamics of UAV technology development, future research and implementation in their neutralisation will focus on the following further development areas:

- improvement autonomous drone interceptors capable of destroying enemy UAVs in the air;
- improvement of the laser drone destruction system, which allows for effective counteraction to UAV swarms;
- integration of electromagnetic pulse systems for deactivating drones;
- expansion of cyber defence capabilities to counter attacks on UAV control systems;
- implementation of intelligent threat analysis systems based on artificial intelligence (*Kazmiruk et al, 2024*).

Discussion

The article's analysis showed that UAVs are becoming one of the key threats to the Ukrainian security forces (*Krivtsun et al., 2024*). They are used both for reconnaissance purposes and for strike action, terrorist acts, and sabotage. Of particular danger are advanced drones with artificial intelligence systems, the ability to operate autonomously, and circumvention algorithms to counteract detection means.

Analysis of the regulatory framework for protecting CI from UAVs showed that Ukraine's current legislation contains separate provisions on this topic. However, it requires updating and detailing regarding countering UAVs (*Slobodska et al., 2023*). There is a need to create a single integrated system of legal regulation to coordinate the actions of state bodies responsible for protecting strategic objects.

The most effective methods of combating UAVs are multi-level protection, namely, electronic warfare (*Tsapura, 2023*), short-range air defence, laser and electromagnetic means, and the development of swarm systems of drone interceptors. Successful protection of critical facilities depends on implementing automated management systems and artificial intelligence for early detection of threats and rapid response (*Kazmiruk et al., 2024*).

An important factor in countering threats from UAVs is effective interaction between the SBU, the Armed Forces of Ukraine, the National Security Service, the State Emergency Service and other security sector structures. Establishing cooperation with international partners,

integrating advanced world experience, and adapting modern technologies are key to increasing the country's defence capabilities.

The recommendations were developed on developing the legislative framework, namely, the need to adopt the Law of Ukraine on Combating Unmanned Aerial Vehicles and update existing regulatory legal acts according to international standards; regulation of the use of both civil and military UAVs; definition of restricted airspace zones and legal mechanisms for the forced neutralisation of drones in the event of a threat.

It is necessary to introduce modern technologies, namely, the creation of a multi-level system for detecting and combating UAVs, which will include combined methods of electronic warfare, air defence, laser installations, anti-drone nets, and cyber defence; and the integration of artificial intelligence and automated threat analysis systems to increase the speed of decision-making in the event of an attack.

To increase the effectiveness of the protection of the CI, it is necessary to strengthen international cooperation constantly: exchange of experience with NATO countries in combating UAVs, joint exercises in countering unmanned threats; involvement of international technical assistance and cooperation with companies developing counter-UAV systems.

Protection of the CI requires increased coordination between state structures. This includes a clear definition of the areas of responsibility of various law enforcement agencies in the event of UAV threats and the development of interdepartmental centres for analysis and coordination of measures to counter drone attacks.

Further research directions in this area may include studying promising technologies for combating UAVs, developing effective methods for combining electronic warfare, air defence, laser, and electromagnetic weapons, and implementing distributed airspace monitoring systems based on a network of sensors and analytical centres.

Conclusion

Protection of CI from threats associated with using UAVs is one of the priority tasks of Ukraine's security and defence sector. Modern UAVs are capable of performing reconnaissance operations, carrying out strikes on strategic objects, and also being used in terrorist and sabotage acts. Therefore, the issues of their detection, neutralization, and prevention of attacks are critically important for national security.

The study showed that despite Ukraine's already some experience in countering UAVs, many issues need to be urgently addressed.

First, the current regulatory framework does not yet fully meet modern challenges. The legislation should be supplemented with provisions that regulate the use of drones, establish restrictions on their operation in CI areas, and determine mechanisms for their forced neutralisation. Studying international experience in the legal regulation of UAVs and adapting it to Ukrainian realities is also important.

Secondly, adequate protection of UAVs is possible only if an integrated approach is used, which includes technical means of detection, electronic countermeasures, short-range air defence, and cyber defence. The development of automated control systems and artificial intelligence will increase the speed and accuracy of response to threats from UAVs.

Thirdly, an important aspect is coordination between state structures responsible for protecting critical infrastructure. Interagency coordination is a key factor in ensuring an effective response to drone threats. In addition, international cooperation, the exchange of experience with NATO countries, and the introduction of the latest technologies will also contribute to increasing the level of protection of critical infrastructure.

The prospects for developing the CI protection system as a comprehensive approach include improving legislation, expanding technical capabilities in combating UAVs, and increasing the level of training of personnel responsible for the security of strategic facilities. Further research should focus on developing new methods of combating unmanned threats, integrating artificial intelligence into security systems, and creating effective mechanisms for interagency cooperation.

Conflict of interest

The authors declare that there is no conflict of interest.

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Appendix

Table 1. Main UAV detection systems

System name	Working principle	Range (km)	Advantages
AN/TPQ-53	radar detection	20	large radius of action
DroneShield DroneSentry	combined approach (radar + acoustics)	10	high accuracy
Dedrone RF-100	radio frequency analysis	5	affordable price

Table 2. Means of UAVs neutralisation

Weapon type	Principle of operation	Range (km)	Advantages
DroneGun Tactical	Radio electronic jamming	1	Compactness, mobility
Thor C-UAS	Electromagnetic pulse	5	Mass destruction
High Energy Laser	Laser radiation	10	Instant destruction of UAVs

Table 3. Organisational measures to combat UAVs

Action (mesure)	The essence of the event	Expected effect
Flight zone control	Introducing restrictions on the use of drones close to the strategic facilities	Reducing the likelihood of unauthorized flights
Protection of critical facilities	Organization of physical security using modern technologies	Rapid response to threats
Staff training	Conducting training on UAV identification and neutralization	Increasing readiness

Table 4. Electronic systems for combating UAVs

System name	Principle of operation	Efficiency (%)	Range (km)
SkySafe	Radio frequency jamming	85	3
DroneDefender	GPS spoofing	90	1
MESMER	Cyber Interception	95	5

Table 5. Legal regulation of combating UAVs in the field of protecting CI

Document	Main provisions	Importance for the protection of CI
Constitution of Ukraine	Defines the sovereignty and security of the state as a priority	Guarantees the state's right to protect critical infrastructure facilities
On National Security, Law of Ukraine	Determines the structure of the security and defence sector, coordination between agencies	Establishes those responsible for protecting CI from air threats
Air Code of Ukraine	Regulates the use of airspace, determines the order of UAV flights	Sets restrictions for flights over critical infrastructure
On Combating Terrorism, Law of Ukraine	Allows special units to eliminate threats, including from UAVs	Used to neutralise drones in the event of a terrorist attack
On Critical Infrastructure, Law of Ukraine	Identifies critical infrastructure facilities and measures to protect them	Provides for the implementation of counter-UAV technologies
On Approval of the Regulations on the Use of the Airspace of Ukraine, Resolution of the Cabinet of Ministers No. 954 from December 6, 2017	Defines a list of no-fly zones	Prohibits UAV flights over CI

Table 6. Functions of government structures in the field of countering UAVs

Authority	Functions in countering UAVs
Main Intelligence Directorate of the Ministry of Defence of Ukraine (GUR MO)	Identifying sources of enemy UAV launches, collecting and analysing intelligence on unmanned threats. Coordinating actions with international partners to obtain the latest UAV defence technologies.
Armed Forces of Ukraine (AFU)	Using electronic warfare (EW) to neutralise enemy UAVs, deploying air defence (AD) systems to protect strategic targets. Conducting special operations to destroy enemy drone operators.
Security Service of Ukraine (SBU)	Counterintelligence activities, counterterrorism, detection and elimination of sabotage groups using UAVs. Threat analysis and development of response measures.
National Guard of Ukraine (NGU)	Protection of strategic critical infrastructure facilities, protection of industrial and energy enterprises. Implementation of special measures to identify and neutralise threats associated with UAVs.
State Border Service of Ukraine (SBSU)	Detection of illegal UAV airspace crossings, protection of border facilities, surveillance and threat analysis. Use of specialised electronic warfare systems to combat drones at borders.
National Police of Ukraine (NPU)	Public order protection, response to incidents involving the use of drones in urban environments, combating the illegal use of UAVs. Conducting operational measures to detect illegal drones.

State Emergency Service (SES)	Elimination of the consequences of UAV attacks on critical infrastructure, conducting evacuation measures, training personnel of critical facilities. Demining and disposal of dangerous facilities after drone attacks.
State Enterprise "Ukroboronprom"	Development and implementation of the latest UAV detection and neutralisation systems. Production of electronic warfare (EW) and air defence systems.

Table 7. Modern technologies for protecting CI from UAVs

Technology	Principle of operation	Expected effect
Electronic warfare (EW)	Suppression of communication channels between the UAV and the operator, blocking of navigation signals (GPS, GLONASS).	Loss of control of drones, their forced landing or departure in an unspecified direction.
UAV detection systems	Optical, acoustic and radar sensors for real-time drone tracking.	Early detection of threats, increased response time, increased defence effectiveness.
Short-range air defence	The use of portable air defence systems, C-RAM-type systems, and anti-aircraft artillery to destroy enemy drones.	Physical destruction of attacking UAVs, reducing damage to critical infrastructure.
Automated security management systems	Using artificial intelligence to analyse threats, make decisions, and coordinate security forces.	Increasing the efficiency of CI security management, rapid response to UAV attacks.
Cybersecurity	Implementation of technologies to protect against cyberattacks on infrastructure related to UAV control.	Minimising the risks of hacking control and navigation systems, protecting critical digital networks.
Anti-drone nets and mechanical devices	Using special nets and UAV interceptors to capture enemy drones physically.	Safe neutralisation of drones without the use of weapons, minimising collateral damage.
Laser weapon	The use of high-energy lasers for pinpoint destruction of UAVs at close and medium distances.	Destruction of drones without ammunition, high accuracy of destruction.
Drone swarm systems	Using groups of interceptor drones to counter enemy UAVs in automatic mode.	Collective fight against massive drone attacks, creating an effective defence barrier.
Electromagnetic weapons (microwave guns)	Generating a powerful pulse of electromagnetic radiation to disable drone electronics.	Mass disabling of UAVs in the affected area without physical destruction of objects.

Ihor V. Pylypenko [13]

Adsorbents Based on Modified Clay Minerals for Heavy Metals Removal [9]

Abstract: The escalating global issue of heavy metal contamination in water resources necessitates the development of efficient and sustainable remediation technologies. Adsorption using modified clay minerals has emerged as a promising approach due to the natural abundance, low cost, and inherent adsorption capacity of clays, which can be significantly enhanced through various modification techniques. This review explores the fundamentals of clay minerals as adsorbents, detailing their structure, properties, and natural adsorption capabilities. It synthesizes current research on the mechanisms of heavy metal adsorption onto modified clay minerals, including ion exchange, surface complexation, and electrostatic attraction, highlighting the influence of modification on these processes. Various methods for enhancing adsorption, such as chemical (acid activation, pillaring, organic modification, metal oxide functionalization, polymer modification), physical (thermal treatment), biogenic, and mechano-chemical treatments, are discussed. The investigation examines the efficacy of modified clay minerals in removing various heavy metals, including lead, cadmium, mercury, and arsenic, along with the principal elements affecting adsorption effectiveness, such as pH, temperature, adsorbent dosage, and contact time. The review also addresses the challenges, limitations, and future directions in the application of these materials for heavy metal removal, emphasizing the ongoing need for cost-effective, selective, and environmentally friendly solutions. Key researchers whose works are utilized in this review include Lamrani et al., Adekeye et al., Sarkar et al., Bhatnagar et al., and Pylypenko et al., whose contributions have significantly advanced the understanding and application of modified clay minerals in wastewater treatment. The results of this study are intended for environmental scientists, engineers, researchers, and policymakers seeking sustainable solutions for heavy metal pollution remediation.

Keywords: modified clay minerals, heavy metals, adsorption, wastewater treatment, environmental remediation, clay modification.

Abbreviations:

CEC is cation exchange capacity.

Introduction

The increasing contamination of water resources by heavy metals poses a significant global environmental and health crisis, demanding urgent and effective remediation strategies (*Hu et al., 2024*; *Bhatnagar et al., 2010*; *Fu & Wang, 2010*; *Rafique et al., 2022*). Industrial activities, agricultural practices, and urbanization are primary sources of pollutants like lead, cadmium, mercury, arsenic, chromium, and copper, which are toxic and non-degradable, leading to bioaccumulation and adverse health effects (*Fu & Wang, 2010*; *Lamrani et al., 2025*; *Rafique et al., 2022*). Existing wastewater treatment methods often have limitations in terms of cost, efficiency at low contaminant levels, and the generation of toxic by-products. Adsorption using modified clay minerals has emerged as a promising alternative due to the abundance, low cost, and modifiable adsorption capacity of clay materials (*Adekeye et al., 2019*; *Sarkar et al., 2018*). This review aims to explore the potential of modified clay minerals for heavy metal removal, discussing their fundamentals, modification techniques, adsorption mechanisms, performance, influencing factors, challenges, and future directions. The findings are intended for

environmental scientists, engineers, researchers, and policymakers involved in developing sustainable water treatment solutions.

Results

Fundamentals of Clay Minerals as Adsorbents

Clay minerals, composed mainly of silica, alumina, and iron, possess layered structures that contribute to their high surface area and cation exchange capacity (CEC) (*Adekeye et al., 2019*; *Sarkar et al., 2018*). These phyllosilicates, such as kaolinite, montmorillonite, and bentonite, exhibit a net negative surface charge due to isomorphic substitution, attracting positively charged heavy metal ions. Key properties like high surface area, significant CEC, porosity, and surface reactivity enable natural clay minerals to adsorb pollutants through mechanisms including ion exchange, surface complexation, electrostatic attraction, and direct bonding (*Adekeye et al., 2019*; *Sarkar et al., 2018*; *Bhatnagar et al., 2010*). Thus, the inherent structural and chemical characteristics of clay minerals make them effective natural adsorbents for heavy metals.

Mechanisms of Heavy Metal Adsorption onto Modified Clay Minerals

Modifying clay minerals enhances their heavy metal removal capabilities by augmenting natural adsorption mechanisms and introducing new interaction processes (*Adekeye et al., 2019*; *Sarkar et al., 2018*). The introduction of functional groups like -OH, -COOH, and -NH_2 through modification facilitates hydrogen bonding with contaminants (*Hu et al., 2024*). Modification can also increase the CEC and enhance the negative surface charge, leading to stronger electrostatic attraction for heavy metal ions. Surface complexation is significantly influenced by modification, allowing heavy metal ions to form stable complexes with introduced functional groups. Furthermore, modifications can create mesoporous structures, increasing surface area and binding sites. Certain techniques can introduce functional groups that form strong covalent bonds or chelating complexes with heavy metals. Modifications using nZVI can facilitate redox reactions for heavy metal removal, while cationic surfactants can enable the adsorption of anionic heavy metal species (*Adekeye et al., 2019*; *Sarkar et al., 2018*). Thus, the diverse modification strategies significantly improve the efficiency of heavy metal adsorption by clay minerals.

Methods for enhancing adsorption: modifying clay minerals

Various techniques are employed to modify clay minerals for enhanced heavy metal adsorption. Chemical modification includes acid activation to increase surface area and porosity, pillaring and intercalation to enhance structural properties, modification with organic compounds to alter surface properties (*Bhatnagar et al., 2010*), salt modification to introduce specific functional groups (*Adekeye et al., 2019*), metal oxide functionalization to increase surface area and introduce reactive sites (*Sarkar et al., 2018*), and polymer modification to create hybrid composites. Physical modification primarily involves thermal treatment like calcination to alter clay structure and increase porosity. Biogenic modification uses organic biomass to enhance adsorption (*Adekeye et al., 2019*), while mechano-chemical treatment employs mechanical force

to alter clay properties (*Sarkar et al., 2018*). Thus, a wide array of chemical and physical methods can be used to tailor clay mineral properties for improved heavy metal adsorption.

Performance Analysis of Modified Clay Minerals in Heavy Metal Removal

Modified clay minerals have shown significant effectiveness in removing various heavy metals. For lead (Pb), carbon-modified montmorillonite and activated bentonite–alginate composite beads have demonstrated high adsorption capacities and removal rates (*Hu et al., 2024*). For cadmium (Cd), MgO-modified biochar composites and MoS_2/bentonite composites have shown enhanced adsorption. In removing mercury (Hg), montmorillonite with thiol groups and (chitosan-polyvinyl alcohol)/bentonite composites have shown strong ability to adsorb it (*Hu et al., 2024*; *Adekeye et al., 2019*; *Sarkar et al., 2018*). Montmorillonite and nZVI-supported smectite composites have been effective for arsenic (As) removal (*Hu et al., 2024*). Research by Pylypenko and colleagues has further demonstrated the effectiveness of Fe/Ti-pillared montmorillonite for cobalt, chromium, and uranium removal (*Pylypenko et al., 2014a*), Al- and Al/Fe-pillared clays for chromium and uranium removal (*Pylypenko et al., 2014b*), and Zr/Al-pillared montmorillonite for uranium and chromium removal (*Pylypenko et al., 2014a*). Composites of montmorillonite with iron oxide are effective for chromium (VI) removal (*Pylypenko & Spasonova, 2020*), and nanoscale iron composites show sorption of Cu(II), Cd(II), Co(II), Zn(II), and Cr(VI) ions (*Kovalchuk et al., 2021*). Granular composites based on laponite have also been developed for the removal of methylene blue and uranium (VI) (*Pylypenko, 2023a*; *Pylypenko et al., 2023b*; *Pylypenko, 2024*). Thus, modified clay minerals exhibit promising performance across a range of heavy metal contaminants (*Table 1*).

Factors Influencing Adsorption Efficiency

The efficiency of heavy metal adsorption by modified clay minerals is influenced by several environmental parameters. pH is a critical factor affecting both the surface charge of the adsorbent and the speciation of heavy metals, with optimal adsorption often occurring at moderate pH levels (*Lamrani et al., 2025*). Temperature can also influence adsorption, with its effect varying depending on whether the process is endothermic or exothermic (*Adekeye et al., 2019*). Adsorbent dosage generally shows a positive correlation with removal efficiency up to an optimal point. Contact time is crucial for reaching adsorption equilibrium. Initial heavy metal concentration affects the adsorption capacity and removal efficiency. Ionic strength and the presence of competing ions can also impact adsorption by affecting surface charge and competition for binding sites (*Bhatnagar et al., 2010*). Thus, optimizing these environmental parameters is essential for maximizing the effectiveness of modified clay adsorbents.

Discussion

The research on modified clay minerals for heavy metal removal has shown significant advancements, yet several challenges remain. The cost-effectiveness and environmental impact of different modification techniques vary, and achieving high selectivity for specific heavy metals in complex wastewater is still a hurdle. The regeneration and disposal of spent adsorbents loaded with heavy metals also present economic and environmental considerations. Variability in the properties of natural clay sources can lead to inconsistencies in adsorbent performance

(*Adekeye et al., 2019*; *Sarkar et al., 2018*). Therefore, the central research problem revolves around optimizing modification techniques to enhance the efficiency, selectivity, and sustainability of clay-based adsorbents for heavy metal removal from diverse wastewater sources. Key questions for further discussion include: How can modification methods be made more cost-effective and environmentally benign? What strategies can be employed to improve the selectivity of modified clays for specific heavy metals in complex matrices? What are the most efficient and sustainable methods for the regeneration and disposal of heavy metal-laden clay adsorbents? Addressing these questions will be crucial for the broader application of modified clay minerals in environmental remediation.

Conclusion

The analysis of existing studies underscores the considerable potential of modified clay minerals as adsorbents for the extraction of heavy metals from aqueous solutions. Various modification techniques enhance the natural adsorption capabilities of clays, leading to improved performance in removing pollutants like lead, cadmium, mercury, and arsenic. The effectiveness of these adsorbents is influenced by factors such as pH, temperature, adsorbent dosage, and contact time, necessitating careful optimization for practical applications. While challenges related to cost, selectivity, and regeneration remain, ongoing research focuses on developing more sustainable and efficient modification methods, exploring novel materials, and investigating hybrid treatment systems. Furthermore, modified clay mineral adsorbents offer a long-term and effective option for heavy metal removal from aqueous solutions. Continued research and development in this area are expected to yield even more efficient and environmentally friendly materials and processes, contributing significantly to the global efforts in combating water pollution and protecting human health and ecosystems.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. Performance of modified clay mineral adsorbents for heavy metal removal

Clay Mineral	Modification Method	Target Metal	Max Adsorption Capacity (mg/g)	Removal Efficiency (%)	Key Conditions	Reference
Montmorillonite	Carbon modification	Pb(II)	263.83	–	–	(*Sarkar et al., 2018*)
Bentonite	Activated, alginate composite beads	Pb(II)	250.5	High	Acidic conditions	(*Hu et al., 2024*)
Montmorillonite /Carbon	Carboxylation (-COOH)	Pb(II)	247.85	–	Langmuir model fit	(*Adekeye et al., 2019*)
Bentonite	MgO-modified biochar	Cd(II)	Significantly higher than pristine biochar	–	Ion exchange, chemical bonding	(*Hu et al., 2024*)
Bentonite	MoS_2 composite	Cd(II)	89.45	–	Hydrothermal method	
Attapulgite	Magnetic composite (ATPCFS-CSEs)	Cd(II)	127.79	>88% (after 5 cycles)	–	
Montmorillonite	AEPE grafting	Hg(II)	46.1	–	pH 4	
Hectorite			54.7	–	pH 4	
Montmorillonite	Thiol-functionalization (ISH)	Hg(II)	141.55	–	–	
Bentonite	(Chitosan–polyvinyl alcohol) composite	Hg(II)	460.18	–	–	(*Adekeye et al., 2019*; *Sarkar et al., 2018*)
Montmorillonite	Untreated	As(V)	–	99.5%	River water	(*Hu et al., 2024*)
Montmorillonite	Untreated	As(III)	–	68.2%	River water	
Smectite	nZVI-supported	As(V)	23.12	–	Wide pH range, negligible iron release	
Halloysite Nanotubes	Zirconia-loaded	As(III)	36.08	–	Hydroxyl groups, large surface area	
Montmorillonite	Ti-pillared	As(III)/As(V)	–	Effective	–	(*Adekeye et al., 2019*)
Fe/Ti-pillared Montmorillonite	Pillaring	Co(II)	4.42	–	pH 6	(*Pylypenko et al., 2014a*)
		Cr(VI)	5.8	–	pH 6	
		U(VI)	70.2	Effective	pH 6	
Al-pillared Clay	Pillaring	Cr(VI)	1.35	–	pH 6	(*Pylypenko et al., 2014b*)
Al/Fe-pillared Clay	Pillaring	Cr(VI)	23.5	–	pH 6	
Al-pillared Clay	Pillaring	U(VI)	38.08	–	pH 6	(*Pylypenko et*

Al/Fe-pillared Clay	Pillaring	U(VI)	71.65	–	pH 6	*al., 2014a*)
Zr/Al-pillared Montmorillonite	Pillaring	U(VI)	67.6	–	pH 6	(*Pylypenko et al., 2014b*)
		Cr (VI)	10.87		pH 6	
Montmorillonite /Iron Oxide	Composite	Cr(VI)	3.28	–	pH 6	(*Pylypenko & Spasonova, 2020*)
Nanoscale Iron Composite	Composite	Cu(II)	16.01	–	pH 6	(*Kovalchuk et al., 2021*)
		Cd(II)	10.34	–	pH 6	
		Co(II)	6.13	–	pH 6	
		Zn(II)	12.62	–	pH 6	
		Cr(VI)	2.44	–	pH 6	
Laponite/Sodium Alginate	Composite	Methylene Blue	7.04	–	pH 6	(*Pylypenko, 2023a*)
Laponite/Zr/Fe -Alginate	Composite	U(VI)	75.8	–	Sulfate solutions	(*Pylypenko et al., 2023b*)
		Cr(VI)	1.54	–	pH 6	(*Pylypenko, 2024*)

Roman V. Gakh [14]

Process Motivation as a Factor of Sports Activity Self-Regulation [10]

Abstract: In the modern sports environment, athletes' motivation is a key factor that affects their performance, stress resistance, and ability to self-regulate. Of particular importance is procedural motivation, which focuses on the enjoyment of the process of sports activity and not only on achieving the final result or external rewards. At the same time, the study of its specificity and mechanisms of influence on self-regulation and performance of athletes remains insufficiently developed. The purpose is to analyse current approaches to the definition of procedural motivation, investigate the relationship between procedural motivation, self-regulation and performance in sport, and develop recommendations for increasing the level of procedural motivation as a tool for supporting self-regulation in athletes. The paper applies theoretical analysis of scientific sources, generalising modern approaches to studying motivation in sports activities. A systematic approach was also used to establish the relationship between procedural motivation, self-regulation and performance. The study confirmed that procedural motivation is an essential component of sports activity, which contributes to forming self-regulation skills, such as emotion control, concentration and adaptability to external conditions. Procedural motivation has been found to form athletes' sustained interest in the training process, providing them with psychological stability in stressful situations and high involvement in sports activities. It has been determined that the effectiveness of procedural motivation depends on integrating personal and situational factors, including the coach's style of work, training conditions and social interaction. The article substantiates the importance of procedural motivation in supporting self-regulation in athletes. Recommendations for coaches and psychologists are developed, which include the creation of a favourable emotional climate, the use of methods to stimulate intrinsic motivation, the provision of social support and the introduction of psychological training.

Keywords: physical fitness, psychological stability, maintaining internal balance, emotional stress, goal achievement.

Abbreviations:
SDT is the self-determination theory.

Introduction

Modern sports activities are characterised by high competition, requiring athletes to be physically prepared and maintain psychological resilience and effective self-regulation. One of the key factors influencing success in sports is motivation. However, research in this field has predominantly focused on analysing external and substantive motivation, while processual motivation—defined as the orientation toward deriving enjoyment from the activity itself—remains insufficiently studied.

Processual motivation is important because it can support internal balance and help athletes overcome emotional, physical, and psychological challenges during training and competitions. At the same time, its impact on athletes' capacity for self-regulation, which is fundamental to achieving sports goals, requires more profound analysis. The lack of theoretical and empirical data on this issue complicates the development of practical approaches to enhancing athletes' motivational background and self-regulation levels.

Thus, the relevance of studying processual motivation as a factor in self-regulation in sports activities is driven by the need for a deeper theoretical understanding of this phenomenon and

the development of practical recommendations for coaches, psychologists, and athletes striving for high achievements in their sports careers.

The issue of athlete motivation and its influence on self-regulation in sports activities is a significant topic in modern sports psychology. A substantial body of research has focused on analysing external and substantive motivation, including the works of Roztorhui et al. (*2022*) and Diachenko and Tishchenko (*2023*). These studies have substantiated the importance of internal and external motivational factors and have contributed to the development of self-determination and expectancy theories, which explain the relationship between motivation and success.

Some authors, including Zhdaniuk, Lukova (*2019*) and Kuzikova (*2021*), emphasise the impact of intrinsic motivation in promoting athletes' psychological well-being, overcoming stress, and maintaining consistent engagement in the training process. Other studies, such as those by Skybytskyi et al. (*2016*) and Khurtenko and Bortun (*2019*), describe motivational profiles that influence athletic performance based on athletes' goals.

However, processual motivation, which is centered on the enjoyment derived from the activity itself, remains insufficiently explored. Only a few authors, such as Tyshchenko (*2013*) and Rochniak (*2018*), have examined the phenomenon of "flow" as a processual aspect. Still, their work mainly focuses on general psychological factors rather than the specifics of sports activities.

As a result, contemporary academic literature lacks comprehensive studies on the role of processual motivation as a factor of self-regulation in athletes. The scarcity of empirical data on the relationship between processual motivation, self-regulation strategies, and performance outcomes creates research gaps that require further investigation.

The purpose aims to determine the role of processual motivation in self-regulation in sports activities and justify its impact on athletes' emotional states, stress resistance levels, and effectiveness in achieving sports results.

Based on the purpose, the following tasks were:

- analyse modern approaches to defining processual motivation and its differences from other types of motivation (substantive and external);
- identify specific mechanisms linking processual motivation, self-regulation, and performance in sports activities;
- develop recommendations for coaches and psychologists on enhancing processual motivation to support self-regulation in athletes.

Results

Motivation is one of the central concepts in psychology, which defines a person's drive to action, shapes their behaviour, and determines the goals and direction of their activity (*Tyshchenko, 2013, p. 214*). In psychological literature, motivation is considered a multidimensional phenomenon encompassing internal and external stimuli that trigger an individual's activity and form motives that underlie their actions (*Ivanenko & Oksa, 2021, pp. 156-157*). This concept explains the mechanisms of purposeful human behaviour, which is fundamental to understanding their life activity.

In psychology, motivation is viewed as a process that integrates various mental phenomena: needs, instincts, motives, emotions, and attitudes (*Panchuk et al., 2024, p. 124*). It has three key functions: activating, directing, and regulating, which determine its impact on human behaviour.

Motivation is unique in sports, requiring significant physical and psychological effort, self-discipline, and stress resistance (*Rochniak, 2018, p. 77*). Psychologists note that motivation is one of the key conditions for achieving high results in sports (*Perepelytsia et al., 2022, p. 91*). A. Maslow believed that understanding the ways of forming achievement motivation is a prerequisite for the effective organisation of training and competitive processes (*Panchuk et al., 2024, p. 124*). In particular, achievement motivation is considered a personal factor that contributes to increasing the effectiveness of sports activities and achieving high results.

According to V. Antonets and Y. Kozak, sports motivation is an athlete's psychological state, which reflects their attitude to various sports activities: goals, expected results, successes and failures, partners and coach (*Antonets & Kozak, 2016*). Thus, motivation, as a fundamental psychological process, manifests in various forms and types, reflecting the diversity of motivating factors that determine human activity (*Lukova & Fomenko, 2021, p. 162*). Two approaches to understanding motivation are fundamental in sports activities: procedural and content-related. These types of motivation have different effects on an athlete's behaviour, their ability to overcome difficulties, maintain high performance, and retain interest in the training process.

Procedural motivation is an important aspect of sports activity that defines an athlete's driving forces for self-realisation through training or competition, not just the final result. It focuses on the satisfaction of the action process, performing physical exercises, improving technique, and developing personal qualities. This type of motivation is oriented towards internal satisfaction from the activity, towards achieving internal goals, such as increasing self-confidence, improving skills, or maintaining physical condition. Procedural motivation contributes to resilience and self-regulation, as the athlete does not focus only on results, but receives emotional and psychological satisfaction from the training process or participation in competitions. It is an important factor that helps maintain a high level of motivation even in difficult moments when external incentives (such as victories or awards) may be absent.

Unlike procedural motivation, content-related motivation is focused on the final result or achieving a specific goal. It motivates those who strive to achieve specific, external results, such as victories, medals, recognition, or material rewards. A person motivated by content usually works to achieve a specific final result, which may be less important or exhausting. It is more dependent on external factors that ensure the achievement of this goal. Thus, the main difference between procedural and content-related motivation is that procedural motivation focuses on the satisfaction of the activity itself, and content-related motivation focuses on the final result of this activity. The Appendix (*Table 1*) provides more detailed information on this.

These two types of motivation are not mutually exclusive. They can complement each other, but procedural motivation is often considered more stable, as it does not depend on external factors and helps maintain interest even in difficult situations.

Procedural motivation of athletes of different levels and age groups has unique features that affect their involvement in the training process and the desire to achieve their goals. It is based on the satisfaction of the activity process, not just its final result. This satisfaction can

manifest in sports through the joy of movement, enthusiasm for the training process, or even a sense of unity with the team. For coaches and educators, understanding the specifics of procedural motivation is key to creating a harmonious environment where every athlete feels valued and inspired.

For novice athletes, procedural motivation is often the primary driving force. It is based on curiosity about the new and the joy of performing physical exercises. At this stage, the foundations of attitude towards sports are laid. The coach or teacher must maintain this interest using game elements, positive reinforcement, and task variety. When children or beginners enjoy the process, they are more likely to return to training, maintaining enthusiasm and a desire to develop.

For mid-level athletes, procedural motivation takes on new meaning. They begin to understand their goals and capabilities better. At this stage, it is important to maintain interest in the training process while complicating tasks and focusing on self-improvement. Coaches can stimulate such athletes by emphasising their progress, new techniques, or the opportunity to participate in competitions. The main task is to ensure that each training session is perceived as a step towards achieving more, but without losing the pleasure of the process itself.

For professional athletes, procedural motivation retains its importance but becomes part of a more complex motivation system. At this level, athletes often enjoy the details: improving technique, overcoming their limitations, and working together with a team or coach. However, the risk of burnout is relatively high here, especially if the training process becomes monotonous or the focus shifts exclusively to achieving results. Therefore, it is important to introduce variety into training, maintain psychological comfort, and remind athletes of the joy that sports bring.

The age of athletes also plays an important role in forming procedural motivation. It is most associated with children and adolescents' natural desire to play and interact. For them, training should be fun, exciting, and socially engaging. Young people on the threshold of adulthood begin to focus more on their achievements, but also appreciate the process that allows them to feel stronger and more confident.

Adult athletes often find a balance in procedural motivation between striving for results and the pleasure of movement. For them, sports become a way to achieve goals and a source of harmony, stress relief, and physical fitness maintenance. At the same time, elderly athletes perceive procedural motivation as a way to stay active, maintain health, and preserve the joy of life.

The relationship between procedural motivation and the ability to self-regulate in a sports context is one of the key aspects that determines the effectiveness of the training process and the achievement of athletes' goals (*Piankivska, 2020*). Procedural motivation, which is based on satisfaction from the process of sports activity itself, serves as an important foundation for the formation and maintenance of an athlete's ability to self-regulate.

Self-regulation in sports involves the athlete's ability to independently control their emotions, behaviour, and efforts, adapting them to the demands of the training process or competitions. Procedural motivation, which focuses on the positive perception of the activity itself, creates conditions for deeper immersion in training and increases the athlete's internal discipline. As a result, athletes become more responsible and motivated to control their actions and effectively manage their energy.

The interaction of external and internal factors also plays a significant role in forming self-regulation. External conditions, such as the organisation of the training process, support from the coach, and stimulation, create a foundation for meeting the athlete's needs. At the same time, internal factors, including personal characteristics such as self-confidence and a tendency towards positive motivation, affect how the athlete responds to these conditions.

An athlete who finds satisfaction in procedural motivation is more likely to use effective self-regulation strategies. For example, they are more inclined to plan their training, analyse results, and independently adjust actions to achieve their goals. This allows them to balance tension and rest, which is key to maintaining high athletic performance and avoiding burnout.

In addition, procedural motivation stimulates the athlete to overcome challenges and develop adaptive self-regulation mechanisms. Completing complex tasks and the satisfaction of overcoming difficulties contribute to strengthening self-confidence and increasing stress resistance. This, in turn, helps the athlete effectively manage their attention and resources in competitions or intense training.

It is also important to note that the ability for self-regulation is enhanced by motivational stimuli that create a favorable environment for developing self-control skills. For example, positive reinforcement, praise from a coach, or even success in completing a training task increase interest in sports activities. This fosters a sense of internal control, where an athlete follows the coach's instructions and makes independent decisions regarding personal progress.

The relationship between procedural motivation and self-regulation in sports can be better understood by analysing existing procedural motivation theories, which have practical applications in sports activities (*Table 2*). Understanding these concepts allows us to identify how different aspects of motivation influence an athlete's ability to effectively regulate their behaviour, adapt to changes, and maintain consistent engagement in training and competition.

One of the most well-known theories is Vroom's expectancy theory, which explains how motivation is formed through the relationship between an athlete's expectations, achievement of results, and rewards (*Slobodianiuk, 2020*). Self-regulation in this context is expressed through conscious planning and effort allocation. For example, an athlete who believes that regular training will improve their performance demonstrates higher self-discipline and the ability to overcome obstacles. Significantly, coaches can deliberately shape these expectations by emphasising specific results that can be achieved through dedicated effort.

Another theory worth considering is Adams' equity theory, which highlights the importance of an athlete's perception of fairness in conditions and rewards (*Slobodianiuk, 2020*). When athletes feel that their efforts are undervalued, their ability to self-regulate may decline due to a loss of motivation. This is particularly relevant in team sports, where success depends on coordinated group efforts, and perceived inequality can cause conflicts. Ensuring fairness helps harmonise internal processes and allows athletes to focus on self-improvement.

Locke's goal-setting theory also deserves attention, emphasising the importance of clear and challenging goals. This concept relates to self-regulation because achieving ambitious goals requires athletes to concentrate, be patient, and control their emotions. For example, improving the execution of a complex gymnastics' element necessitates step-by-step planning and continuous analysis of personal progress. For coaches, goal formulation should be as specific as possible and consider each athlete's characteristics.

The SDT also plays a key role in understanding the relationship between motivation and self-regulation. This theory underscores the significance of intrinsic motivation, which arises when three basic psychological needs are satisfied: autonomy, competence, and social involvement. Self-regulation manifests in athletes' ability to make independent decisions, set priorities, and solve problems. For instance, when athletes can choose their training style or schedule, it increases their responsibility for personal development and strengthens intrinsic motivation.

Finally, Weiner's attributional motivation model explains how athletes interpret their successes and failures (*Slobodianiuk, 2020*). If an athlete attributes victory to their efforts, it reinforces their self-belief and promotes self-regulation skills. Conversely, attributing failures to external factors (e.g., unfair judging) can reduce motivation and weaken emotional control. In this context, coaches and psychologists must help athletes develop an optimistic attributional style that fosters self-confidence.

To enhance procedural motivation as a tool for supporting self-regulation in athletes, coaches and sports psychologists should implement comprehensive approaches that consider individual athlete characteristics, the specifics of the sport, and age, social, and psychological factors.

First, it is essential to create conditions that foster intrinsic motivation. This can be achieved by granting athletes autonomy in choosing how to achieve their goals, formulating tasks that align with their abilities and skill level, and fostering a sense of belonging to a team. Coaches should encourage athletes to take an active role in planning the training process and making decisions regarding tactics and preparation strategies, creating an environment where they feel valued and significant.

Second, special attention should be given to setting clear, specific, and achievable goals. Goal-setting theory suggests that ambitious yet realistic tasks stimulate athletes to mobilise internal resources, develop self-regulation skills, and improve focus on training tasks. Coaches are advised to periodically adjust goals in line with an athlete's progress, which helps maintain high motivation and prevent disappointment in case of setbacks.

Third, emotional support and creating a positive emotional climate during training play a crucial role. Praise for achievements, even minor ones, and constructive criticism aimed at development rather than punishment help athletes form a positive attribution of success and failure. Psychologists should conduct training sessions to build self-confidence, reduce pre-competition anxiety, and strengthen intrinsic motivation.

Additionally, fostering social interaction within a team is an important tool. Group tasks, team-building exercises, and collaborative problem-solving contribute to developing a sense of responsibility for personal results and the team's success. This positively influences the formation of values centred on support and cooperation and enhances motivation through social engagement.

Finally, psychological training techniques should teach athletes self-regulation methods, such as autogenic training, success visualisation, attention control, and emotional management. These methods help athletes better understand their internal states, respond more effectively to stressful situations, and develop stable behavioural patterns that contribute to achieving high results.

Conclusion

The article analyses modern approaches to defining procedural motivation, its essence, and its role in sports activities. It has been established that procedural motivation is unique, distinct from intrinsic and extrinsic motivation. It focuses on the process of performing activities itself, fostering satisfaction from training and competition, which enables athletes to maintain stable engagement and effectiveness even in the absence of external rewards or final results. Intrinsic motivation, oriented toward goal achievement, and extrinsic motivation, dependent on incentives or sanctions, play a supplementary role but cannot fully replace the impact of procedural motivation.

The article also identifies mechanisms linking procedural motivation, self-regulation, and sports performance. Procedural motivation has been proven to be a fundamental factor in shaping athletes' self-regulation abilities. By focusing on the process of activity, athletes develop skills in self-awareness, emotional control, maintaining concentration, and resilience to stress. These aspects significantly determine their performance in sports competitions. Furthermore, self-regulation in the context of high procedural motivation enhances athletes' adaptability to changing training and competition conditions.

Based on the obtained results, practical recommendations have been developed for coaches and sports psychologists to enhance the level of procedural motivation in athletes as a tool for supporting their self-regulation. In particular, the importance of creating conditions that ensure athletes' autonomy in decision-making, setting clear and achievable goals, fostering a positive emotional climate, and promoting social interaction within teams has been emphasised. Implementing psychological training to develop self-regulation skills and actively using methods to stimulate intrinsic motivation through praise, encouragement, and constructive feedback is recommended.

Thus, the study results highlight the significance of procedural motivation in ensuring high sports performance and contribute to a better understanding of its role in developing self-regulation skills. Implementing the proposed recommendations in coaching and psychological practice will facilitate the harmonious development of athletes, providing them with sports success and psychological well-being.

Future research prospects include an in-depth study of the mechanisms linking procedural motivation with other psychophysiological aspects of athletes' self-regulation, an analysis of the effectiveness of the proposed recommendations in different sports, and the development of differentiated approaches to motivation based on age, gender, and level of sports mastery.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. Comparison of Procedural and Content Motivation by Main Characteristics

Procedural Motivation	Meaningful Motivation
Main Focus	

In the process of activity, enjoying the performance of an action	On the final result (goals, achievements)
Source of Pleasure	
Pleasure from the process itself, improvement	Satisfaction from achieving a goal (e.g., winning, rewarding)
Motivating Factor	
Internal experiences, well-being, and emotional connection with activities.	External incentives (material rewards, recognition, competition)
Emotional Component	
Positive emotions that arise during the process.	Emotions associated with the result (joy from winning, disappointment from losing)
Dependence on External Factors	
Independent of external factors, focused on the internal process.	Depending on external factors, such as awards or performance evaluation
Degree of Motivation Stability	
High stability, because it does not depend on the result.	May be less resilient without a clear goal or external reward
Type of activity	
Assessment of the process of performing activities (training, technique).	Assessment of the final goal achievement (Victory, Records)
Impact on Self-Regulation	
Maintaining motivation through inner pleasures reduces stress and exhaustion.	Can lead to stress and burnout without achieving the goal

Source: author's development

Table 2. Fundamental Theories of Procedural Motivation and Their Relationship with Self-Regulation in Sports

The Main Idea	Connection with Self-Regulation	Practical Application in Sports
Motivation depends on the athlete's expectations of results and rewards.	Form conscious planning, distribution of efforts, and increased self-discipline.	Create realistic expectations and set achievable goals.
The importance of a sense of equality in terms of conditions and rewards	A sense of Justice supports motivation and harmonises the inner state of the athlete	Ensuring transparency of remuneration and equal treatment of all athletes in the team.
Clear and ambitious goals help increase motivation.	Promotes the development of concentration, patience, and emotional control when achieving complex tasks	Formulation of specific goals according to athletes' abilities
Motivation arises when basic needs are met: autonomy, competence, and social engagement.	Develops responsibility, increases engagement and internal motivation.	Providing athletes with the opportunity to choose and be independent in training
Motivation depends on how athletes explain their successes or failures	Positive attribution (success through your efforts) builds confidence and the ability to control your emotions	Teaching athletes an upbeat attribution style by analysing their successes and failures

Source: Compiled by the author based on (*Slobodyanyuk, 2020*)

Serhiy S. Danylyuk [15]

Digital Transformation in Higher Education: A Comparative Analysis of Ukraine and the Czech Republic [11]

Abstract: This article explores the digital transformation in higher education, offering a comparative analysis of Ukraine and the Czech Republic. Over the past decade, digitalization has become a pivotal component of educational reform, with universities striving to adapt to the rapid evolution of digital technologies. The COVID-19 pandemic further accelerated this transformation, forcing institutions to shift to online modes of learning, teaching, and research. This study investigates how both Ukraine and the Czech Republic have responded to these challenges through national strategies, institutional innovations, and international cooperation. In particular, the paper examines five core dimensions of digital transformation: national digitalization policies, digital infrastructure, faculty development, student access, and institutional autonomy. While the Czech Republic benefits from strong integration with European Union frameworks and funding programs such as Erasmus+ and Horizon Europe, Ukraine faces considerable structural and geopolitical obstacles, especially during the ongoing military conflict. Despite these challenges, Ukrainian universities have demonstrated notable resilience and creativity in implementing digital tools, often relying on international partnerships and external support. The study reveals both convergences and divergences between the two national systems. Czech universities typically enjoy more autonomy and stable infrastructure, enabling them to design sustainable digital strategies and participate in international research initiatives. Ukrainian universities, meanwhile, navigate resource constraints but show strong adaptability and motivation to align with European educational trends. The findings suggest that successful digital transformation depends not only on technological infrastructure but also on policy consistency, institutional leadership, and inclusive access for all stakeholders. The article concludes with strategic recommendations to foster long-term digital capacity, including strengthening faculty digital competencies, supporting students in rural areas, and promoting cross-border academic collaboration. This comparative study contributes to the growing body of literature on digital transformation by highlighting context-specific responses and offering insights for policy-makers and educational leaders in similarly positioned countries.

Keywords: digital transformation, higher education, Ukraine, Czech Republic, digital infrastructure, international collaboration, student access, digital pedagogy.

Introduction

The rapid integration of digital technologies into all spheres of public life has fundamentally transformed the landscape of higher education around the world. The concept of digital transformation in education encompasses the restructuring of pedagogical approaches, the redesign of administrative processes, and the enhancement of research capabilities through digital tools and platforms. In this context, higher education institutions (HEIs) are required not only to adopt new technologies but also to cultivate a digital culture that permeates all levels of academic and institutional life.

In recent years, digital transformation has become especially relevant for countries undergoing structural transitions, such as Ukraine, and for countries within the European Union, such as the Czech Republic. Both nations have embarked on ambitious paths to modernize their education systems, albeit under different socio-economic and political circumstances. Ukraine's digital education reforms have intensified due to the dual pressures of

globalization and military conflict, while the Czech Republic has taken advantage of EU digitalization programs and a relatively stable institutional environment.

The relevance of the study lies in its comparative nature, aiming to explore how two countries with varying levels of economic development, political stability, and digital infrastructure are approaching the same global trend—the digital transformation of higher education. As universities worldwide are redefining their missions and operational models, understanding these national experiences provides valuable lessons for policy makers, educators, and academic leaders.

The object of the study is the process of digital transformation in Ukrainian and Czech higher education institutions.

The study aims to conduct a comparative analysis of the strategies, tools, and practices used by HEIs in both countries to implement digital technologies. It also aims to evaluate the effectiveness of these practices in terms of student access, quality of education, research productivity, and international integration.

To achieve these goals, the following objectives were established:

- analyze national digitalization strategies affecting higher education in Ukraine and the Czech Republic;
- identify institutional innovations that have emerged as a result of digital transformation;
- assess the digital competencies of faculty and administrative staff;
- evaluate students' access to digital resources;
- compare the outcomes and challenges in each country.

The study employs a mixed-methods approach, combining policy analysis, institutional case studies, and review of relevant academic literature. This methodology allows for both a macro-level understanding of national policies and a micro-level exploration of institutional practices. Special attention is given to data published by the European Commission, UNESCO, and national ministries of education.

The study is informed by the works of leading scholars in digital education, including H. Andrushchak and O. Burov (*2022*), M. Černý and J. Malach (*2021*), R. Kvasnička and M. Štěpánek (*2020*), L. Lisnycha (*2023*), U. Schmid, L. Goertz and J. Behrens (*2020*), I. Sokolovska and I. Datsyuk (*2022*), O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur (*2020*), who emphasize the importance of contextual factors in shaping the outcomes of digital transformation. By examining Ukraine and the Czech Republic, this article contributes to the ongoing scholarly discussion on how regional and institutional differences influence the digitalization of higher education.

The results of this study are intended for a broad academic audience, including education researchers, policy-makers, university administrators, and faculty members involved in digital strategy development. The insights presented here are particularly relevant for countries that are striving to modernize their education systems under challenging conditions.

Results

The digital transformation of higher education in Ukraine and the Czech Republic is largely influenced by their respective national policies. Ukraine's initiatives such as the Digital Agenda

for Ukraine (2020) and the National Strategy for Digital Transformation of Education and Science until 2030 aim to modernize the educational environment through the integration of ICT. Meanwhile, the Czech Republic has implemented the Digital Czech Republic strategy, emphasizing digital education and skills development across all levels of education. These national frameworks have encouraged universities to align their strategies with state-level digitalization goals and provided funding for relevant initiatives (*Molnár & Puklus, 2019*).

So, national strategies play a crucial role in setting the direction and enabling conditions for digital transformation in higher education institutions.

Digital infrastructure forms the backbone of educational digitalization. In Ukraine, significant investments have been made to improve internet connectivity, equip institutions with digital tools, and implement national platforms like EDEBO (Unified State Electronic Database on Education). The Czech Republic's universities benefit from strong IT infrastructure and systems like IS/STAG, providing integrated digital environments for administration and learning. Both countries have expanded the use of learning management systems (e.g., Moodle, Google Classroom) and virtual labs, particularly during the COVID-19 pandemic, which accelerated the shift to blended and online learning models (*Budnyk & Mazorchuk, 2021*).

Thus, the development of robust digital infrastructure and e-learning platforms is essential for scalable, resilient, and accessible digital education.

The successful implementation of digital technologies in higher education relies heavily on the digital competencies of academic staff. Ukraine has promoted digital literacy through national training programs such as "Digital Teacher" and local university-based workshops. In the Czech Republic, educators receive ongoing support through programs like DigiEduHack and institutional centers for teaching and learning. In both countries, professional development efforts have increased, focusing on pedagogy, the use of digital tools, and adapting to hybrid teaching formats (*European Commission, 2021*).

Consequently, continuous professional development and institutional support are key to empowering faculty members to adopt and integrate digital technologies effectively.

Digitalization can both alleviate and exacerbate educational inequalities. In Ukraine, disparities in access to devices and high-speed internet remain a challenge, particularly in rural areas. Efforts to mitigate these include governmental subsidies and university-led initiatives to lend equipment (*Ponomarenko & Kushnir, 2020*). Czech universities generally report higher digital access, though attention is still paid to supporting students with disabilities or socio-economic disadvantages. Accessibility features and inclusive e-learning design are increasingly prioritized in both systems.

So, addressing equity in digital access is fundamental to ensuring inclusive digital transformation in higher education.

Autonomous institutions are more agile in implementing innovative digital practices. In Ukraine, higher education institutions have used their autonomy to introduce digital services, such as electronic student records and remote admissions. Czech universities, benefiting from stable governance structures, have launched numerous digital initiatives, including AI-supported advising and blockchain-based credentialing. However, institutional digital maturity varies widely and is influenced by leadership vision, funding, and collaboration networks (*Mashtalir & Trofymenko, 2022*).

Thus, institutional autonomy combined with visionary leadership enhances innovation capacity and the pace of digital transformation.

Digitalization facilitates international cooperation in education. Ukrainian and Czech universities have expanded participation in European projects like Erasmus+, Horizon Europe, and Digital Europe. Joint virtual courses, online conferences, and mobility programs exemplify the benefits of cross-border digital initiatives. Nonetheless, challenges such as language barriers,

platform compatibility, and legal frameworks remain. Strengthening digital interoperability and common standards is essential for sustainable cooperation (*Lisnycha, 2023*).

Consequently, cross-border digital collaboration enriches academic exchange but requires coordinated efforts to overcome structural and technological barriers.

Discussion

Despite substantial progress in the digital transformation of higher education in Ukraine and the Czech Republic, several important challenges and open questions remain. One of the core research problems concerns the sustainable integration of digital innovations in pedagogical practice. While both countries have implemented strategic frameworks and infrastructure projects, the actual usage of digital tools by faculty and students varies significantly across institutions (*Radkovets, 2023*).

A critical issue for further examination is how national policies translate into localized, institution-specific practices. To what extent are universities able to maintain the momentum of digital innovation without external funding or crisis-induced incentives such as those caused by the COVID-19 pandemic? Moreover, the development of digital competencies among faculty remains uneven, suggesting a need for longitudinal studies on the effectiveness of current training programs and their impact on teaching quality (*Farnell et al., 2021*).

Another area warranting further discussion is the role of institutional autonomy and leadership in fostering innovation. The Czech model shows that stable governance and long-term investment can accelerate digital maturity. In Ukraine, however, the political and economic instability poses risks to the consistency of digital reforms, raising the question of how institutions can build resilience and continuity in their transformation journeys.

Furthermore, digital equity and inclusion emerge as pivotal themes. Despite efforts to expand access, rural areas and disadvantaged groups still face significant barriers. What mechanisms can be established to ensure that digitalization does not deepen existing inequalities?

Finally, cross-border digital collaboration opens new frontiers but also introduces complexity. Future research could explore the impact of interoperable systems and multilingual platforms on international academic cooperation, especially in joint degree programs and research initiatives.

In light of these unresolved questions, the discussion underscores the necessity for ongoing comparative research, policy dialogue, and institutional self-assessment to support effective and inclusive digital transformation in higher education.

Conclusion

The comparative analysis of digital transformation in higher education institutions in Ukraine and the Czech Republic reveals a complex but promising landscape. Both countries have made notable progress in integrating digital technologies into educational practices, though at different paces and with varying systemic support. National strategies have played a foundational role in setting the vision for digital advancement, while institutional efforts have determined the pace and quality of implementation.

Improvements in digital infrastructure and the adoption of e-learning systems have significantly increased the accessibility and flexibility of education. However, the sustainability of these innovations' hinges on consistent investment and long-term planning. The upskilling of academic staff through professional development initiatives remains crucial to ensuring meaningful pedagogical change. At the same time, issues of digital equity continue to pose challenges, especially in underserved regions.

Institutional autonomy, when supported by visionary leadership, emerges as a critical factor in fostering innovation. Czech institutions demonstrate how stable governance can accelerate digital maturity, whereas Ukrainian institutions must navigate additional external pressures that affect continuity and planning.

Cross-border collaboration represents a key opportunity, enabling the sharing of knowledge and technologies across borders. Yet it also demands greater interoperability, policy alignment, and inclusive design to ensure equitable benefits.

Thus, digital transformation is not a finite goal but an ongoing process that requires systemic coordination, adaptability, and inclusive practices. The findings of this study underscore the need for further comparative research, particularly on the long-term impacts of digital reforms, the effectiveness of training initiatives, and the resilience of higher education institutions in the face of political and economic uncertainties.

Conflict of interest

The author declares that there is no conflict of interest.

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Nataliia I. Zaichenko [16]

Two Paradigms in the History of Pedagogy [12]

Abstract: The study aims to analyse pedagogical teachings from various historical periods and to compare the classical (philosophical-theological) and non-classical (socialisation) paradigms in the history of pedagogy. The article is devoted to the problem of paradigm comprehension of pedagogical doctrines from the 17th to the 20th century. It is shown that in the history of pedagogy, the classical (philosophical-theological) and non-classical (socialisational) paradigms were distinguished, and at the turn of the 20th and 21st centuries, pedagogical thinking began to gravitate towards the post-non-classical (informational) paradigm. It is explained that the classical (philosophical-theological) paradigm is part of the history of pedagogy. It is explained that the classical (philosophical-theological) paradigm in the history of pedagogy was marked by the centralisation of pedagogical teachings on issues of spiritual education and the nature-conformity of schooling. Within this paradigm, education was understood exclusively as a gradual path of bringing out the individual abilities of the human soul and improving them with the aim of a person's knowledge of his fateful destiny and its realisation in earthly life. It is noted that the intensive movement of reformist pedagogy at the turn of the 19th and 20th centuries, despite not being unified, caused a large-scale socio-pedagogical turn from the classical (philosophical-theological) paradigm to the non-classical (socialisational) one. It is also noted that within the socialisation paradigm, education was conceived as a creative organisational force to create an environment favourable for developing the human personality. It illustrates the pedagogical works of Jan Comenius, Konstantin Ushinsky, Pedro de Alcantara, Anton Makarenko, and other prominent teachers of the world, who reflected the most expressive ideas of the era.

Keywords: history of pedagogy, classical (philosophical-theological) paradigm, non-classical (socialisation) paradigm, post-non-classical (informational) paradigm, pedagogical doctrine, reformist pedagogy.

Introduction

The application of the paradigmatic approach in the history of pedagogy enables the representation of the development of global pedagogical thought within the framework of three paradigms: the classical (philosophical-theological), the non-classical (socialisation), and the post-non-classical (informational). A paradigm in the history of pedagogy allows for the establishment of a coordinate system to navigate the diversity of pedagogical theories, doctrines, and teachings, to identify them with traditions of education and upbringing, and to study pedagogical reality by distinguishing typical ways of formulating and solving problems related to human education and learning.

The task of paradigmatic reflection in the history of pedagogy is to construct generalised models of the ideological platforms on which various pedagogical teachings were based at different historical times.

The study aims to analyse pedagogical teachings from various historical periods and to compare the classical (philosophical-theological) and non-classical (socialisation) paradigms in the history of pedagogy.

In studying the pedagogical legacy and teachings of prominent educators of the past, both general scientific methodological approaches—such as the systemic and problem-based approaches—and specifically scientific ones were employed: the paradigmatic, comparative, problem-historical, biographical, and hermeneutic approaches.

The most important research methods were the pedagogical-retrospective method, which made it possible to comprehend the conceptual sphere of various pedagogical teachings throughout history; the comparative-contrastive method, which enabled the identification of the originality of a particular educator's views and their similarity to the pedagogical thinking of contemporaries; and the hermeneutic method, which allowed for the interpretation, analysis, and commentary of historical-pedagogical sources, considering both the author's subjective traits and the objective historical context.

The distinction between classical and non-classical paradigms in the history of pedagogy contributes to a more accurate perception of a particular pedagogical teaching as belonging to a specific historical period and a more comprehensive understanding of the significance of a given pedagogical doctrine in the history of global pedagogical thought—its scope, influence, and innovativeness.

Results

Since the 17th century, pedagogy has been understood as an independent science. The towering figure of John Amos Comenius (1592–1670) became symbolic in the formation of pedagogical science. His works, The Great Didactic and General Consultation on the Improvement of Human Affairs, held unprecedented significance in global pedagogy.

Until the mid-19th century, pedagogy remained largely speculative and philosophical; pedagogical thought was confined within the framework of a philosophical-theological paradigm. The roots of this paradigm reach back to antiquity, but the "classical" worldview in pedagogy was established during the medieval period. The human being was understood as created according to God's design, with a destined purpose that could be fulfilled in earthly life through the soul. The physical body was seen as sinful and had to be subordinated to the spiritual. The soul, granted by God, was meant to comprehend earthly life's mysteries, accumulate spiritual experience, and achieve spiritual refinement. Through the righteous conduct of worldly existence, the soul must earn the right to eternal happiness—God's grace, which would come to a person after the body's death.

With its unique intellectual, moral, and aesthetic capacities, the individual soul requires timely nurturing to fully unfold and ascend toward its destined goals. The soul must understand that divine revelation manifests in the earthly world's truth, goodness, and beauty and that its entire journey leads toward God. Human relationships will encounter many contradictions and difficulties, yet they will never feel unhappy if they remember their individual, destined purpose and unwaveringly follow God's commandments.

In *The School of Infancy*, Comenius wrote: "People train the ox for plowing, the dog for hunting, the horse for riding and carrying loads, because they are created for such purposes and cannot be adapted to other ends. Man—a being higher than all these animals—must be led to the highest goal. Therefore, parents do not fully fulfil their duty if they teach their children merely to eat, drink, walk, speak, or dress, for all this serves only the body, which is not the person but rather a house for the child. The master of this house (the rational soul) dwells within; it is this master who must be cared for more than the outer shell… Thus, the soul, as the main part of the person, must be given the greatest care so that it may emerge from the

body as beautifully adorned as possible. And the body should be cared for to become a dwelling suitable and worthy for the immortal soul…" (*Comenius…, 1893, pp. 8–9*)

In pedagogical treatises, a person's education was viewed as consisting of two components: the education of the body (physical education) and the education of the soul (spiritual education). Unlike the physical body, the human soul is governed by its unique laws of development. The human soul possesses three higher faculties—sensation, will, and reason—which enable the individual to act consciously and freely. These faculties—sensation, reason, and will—are the three most important sources of human individuality.

The main path of education is exagogical. It allows for the external unfolding of the individual abilities hidden deep within the soul—intellectual, moral, aesthetic, and religious. Therefore, all pedagogy within the framework of the philosophical-theological paradigm is understood as being according to human nature: it does not aim to change human nature, it does not possess creative power; rather, it is a means of revealing and perfecting (ennobling) the spiritual potentials of a person.

The essence of this pedagogical approach is aptly described in the *Compendium of Theoretical and Practical Pedagogy* (Madrid, 1891) by the renowned Spanish educator Pedro de Alcántara García (1842–1906): "The soul of a child is not a *vast vacio* or a *tabula rasa* that must be filled or layered upon over time. The education of the soul does not consist in giving it talent or imposing virtues; education is a task that does nothing more than develop what has already been given to a person by nature." (*Alcantara Garcia, 1891, p. 3*)

In Spanish pedagogical treatises at the end of the 19th century, it was emphasised that pedagogy is a philosophical science, as it is "an integral part of the system of philosophy" (*Alcantara Garcia, 1896, p. 5*).

"Metaphysics, natural or real philosophy, the general study of the nature of things, encompasses four branches: ontology (the doctrine of being or existence), theodicy or natural theology (about God), cosmology (about the world), and anthropology (about the human being)," according to Elementary Philosophy (Barcelona, 1896) by Juan Arolas (*Arolas Juani, 1896, p. 4*). Anthropology, in turn, is divided into psychology (the study of the human soul) and physiology (the study of the body) since the human being consists of two parts—soul and body. It is precisely psychology, as a philosophical-anthropological science with its numerous independent branches, that served as the theoretical foundation of pedagogy aimed at studying the spiritual and physical education of the individual.

The theoretical pedagogy of the mid-19th century represents the culmination of the classical philosophical-theological paradigm, initially established by medieval scholastics. Concepts concerning the education of the human soul remained dominant despite large-scale efforts to "anthropologise" and "scientify" pedagogy. In his book Man as the Subject of Education, the renowned Ukrainian educator Konstantin Ushynsky (1823–1870). An Attempt at Pedagogical Anthropology (1868–1869) formulated the leading slogan of the era: "If pedagogy wants to educate a person in all respects, it must first know that person in all respects as well." (*Ushynsky, 1983b, p. 199*)

Reflecting on the significance of a comprehensive understanding of the human being, the educator further explained: "The educator must strive to know the human being as they truly are, with all their weaknesses and all their greatness, with all their mundane petty needs and lofty

spiritual aspirations. The educator must know the person in the family, in society, among the people, among humanity, and alone with their conscience; at every age, in all social classes, in every situation, in joy and sorrow, in grandeur and humiliation, in the prime of strength and illness, amid boundless hopes and on the deathbed, when words of human consolation are already powerless. They must understand the driving forces behind the basest and the noblest deeds, the origins of criminal and great thoughts, and the development of every passion and character. Only then will they be able to draw, from the very nature of the human being, the means of educational influence—and these means are immense!" (*Ushynsky, 1983a, p. 207*)

At the same time, in the same pedagogical work, Konstantin Ushynskyi identified one of the principal aims of all education as "to continually involve new generations in the common cause of humanity in its endless striving towards absolute good" (*Ushynsky, 1983a, pp. 469–470*).

Earlier, in his article *On National Character in Public Education* (1857), the educator emphasised: "There is only one ideal of perfection before which all nations bow—the ideal given to us by Christianity. Everything that a human being, as a human being, can and should be is fully expressed in the divine teaching, and the primary task of education is to root the eternal truths of Christianity as its foundation. It gives life and indicates the highest aim of all education; it must serve as the source of all enlightenment and eternal truth for the education of every Christian nation. It is an inextinguishable beacon, moving eternally like a pillar of fire in the desert, leading individuals and nations; the development of every nationality and all true education that goes hand in hand with national identity must follow it." (*Ushynsky, 1983a, pp. 101–102*)

The prominent Ukrainian educator Pamfil Yurkevych (1826–1874), in his *Course in General Pedagogy* (1869), asserted: "There is no doubt that an educator who not only understands Christianity as a doctrine and a discipline but also embraces it as spirit and life, would grasp the ultimate aims of life and education with clarity and would not become lost in the endless variety of human aspirations, needs, wills, abilities, conditions and ways of life." (*Yurkevych, 1869, p. 11*)

Explaining what constitutes the "individual principle of humanity", the educator stated: "The whole person stands in fear of God and observance of God's commandments: this is the source of law and freedom, culture and happiness; everything human, however diverse, is concealed and preserved in the spirit that fears God and serves Him. The essential task of education lies precisely in imparting to the pupil a clear perspective on life, strengthening the heart with sobriety and courage, and preparing them for life's struggle, engraving in them an indelible faith in goodness and in God; and this can only be achieved in the days of youth when the heart is still receptive to all that is noble and beautiful." (*Yurkevych, 1869, p. 27*)

The emergence of reformist pedagogy ("new education", "free education", "learning by doing", experimental pedagogy, social pedagogy, and so forth) and its culmination at the turn of the 19th and 20th centuries serves as vivid evidence of the exhaustion of the philosophical-theological paradigm in pedagogical thought and educational practice. The methodology of educational classicism, rote learning, and the messianic role of the teacher could no longer meet the challenges of the "industrial age". Reformist (alternative) pedagogy became a distinctive milestone in the history of global education—a bridge from the philosophical-theological to the socialisation paradigm in pedagogical thinking. The leading historical significance of reformist pedagogy lay in the fact that, for the first time on such a scale, the ideologemes of the educational

process were being rethought—and the "pedagogy of fear" was decisively opposed by the "pedagogy of freedom". (*Zaichenko, 2024, p. 50–51*)

Precisely because the socio-pedagogical discourse of that time was imbued with powerful socio-political and civilisational reformist intentions (not merely social-oriented ones, as seen among the Enlighteners of the 18th to the first half of the 19th century), the further development of global pedagogical thought unfolded within the framework of a socio-pedagogical turn. From the 1920s onwards, pedagogical thinking rapidly shifted towards a new worldview paradigm—the socialisation paradigm—which accepted the determinative influence of the environment on the individual, as opposed to the nature-aligned exagogy of the human soul.

The essence of the socio-pedagogical turn as a reformist inspiration was aptly defined by the Swiss educator Robert Seidel (1850–1933) in his discourse *The Aim of Education from the Perspective of Social Pedagogy* (Zurich, 1915): "The higher standpoint from which the goals of education can and must be considered is that of social pedagogy. By this, I mean social pedagogy, which might be more accurately referred to as a socio-pedagogical philosophy. I have repeatedly defended this viewpoint before the pedagogical world in public speeches and print. For quite some time, I have predicted that the true socio-pedagogical perspective would become dominant, for this is demanded by the natural course of development of social and pedagogical ideas and dictated by social conditions and the requirements of education." (*Seidel, 1915, p. 58*)

In his work *Education and Sociology* (Paris, 1922; written in 1917), the French sociologist Émile Durkheim (1858–1917), explaining the limitations of the philosophical-theological paradigm in pedagogy, emphasised: "Thus, education does not have the individual and their interests as its sole or even primary aim; it is above all a means by which society perpetuates the conditions of its existence. A society can only survive if there is a sufficient degree of homogeneity among its members. Education reinforces this homogeneity by implanting the essential similarities required for collective life in the child's mind. On the other hand, without a certain diversity, no cooperation would be possible. Education also preserves this necessary diversity; in doing so, it differentiates and specialises. Hence, in both aspects, it is essentially a process of deliberate socialisation of the younger generation." (*Durkheim, 1922, p. 6*)

The most vivid advocate of the socialisation paradigm in pedagogy, Anton Makarenko (1888–1939), wrote in his *Pedagogical Poem* (1933–1935): "I asserted that it is impossible to build all of education upon interest alone, that the cultivation of a sense of duty often contradicts the child's interest, especially as the child understands it. I called for the education of a resilient, strong individual capable of performing unpleasant and tedious work when the interests of the collective demand it. Ultimately, I championed the creation of a strong and, if necessary, strict and inspired collective, placing all hopes on it alone. My opponents confronted me with axioms of pedology and focused exclusively on the 'child'." (*Makarenko, 1977, p. 98*)

In *A Book for Parents* (1937), the educator stressed: "Education is a social process in the broadest sense. Everything educates: people, objects, phenomena, but first and foremost—people. And among them, above all—parents and teachers. A child enters into countless interactions with the complex world of surrounding reality, each of which inevitably evolves, intertwines with other relationships, and becomes more complex as the child develops physically and morally. This whole 'chaos' seems impossible to quantify, yet it produces certain changes

in the child's personality at every given moment. Guiding and managing this development is the task of the educator." (*Makarenko, 1973, p. 10*)

Within the socialisation paradigm, education is directed at instilling in individuals the qualities necessary for social life and creating an environment conducive to the comprehensive development of the personality.

Discussion

The correlation of pedagogical thought in the history of pedagogy with the two established paradigms (classical and non-classical) proves insufficient. At the turn of the 20th and 21st centuries, pedagogical thinking gradually shifts towards a new—post-non-classical (informational) paradigm. Numerous innovations are progressively entering the educational reality, including distance learning, digital didactics, and artificial intelligence, which significantly transform the academic environment and human development. Pedagogical approaches and ideas developed within the non-classical (socialisation-based) paradigm are being considerably reinterpreted in the first quarter of the 21st century. The current pedagogical discourse is focused on the issues of information and communication technologies in the educational process. It explains and interprets the aims of education based on the principles of the information society, signalling a departure from the core tenets of the socialisation paradigm.

Conclusion

A paradigmatic interpretation of pedagogical doctrines throughout the history of pedagogy enables the distinction between classical and non-classical pedagogy. The face of pedagogical science changed significantly at the beginning of the 20th century. Within the framework of the classical (philosophical-theological) paradigm, pedagogical science was speculative and aimed at pursuing absolute truth. It was understood as a form of humanistic knowledge, with its subject being the upbringing (education) of the human being as a dual entity (both corporeal and spiritual), centred on cultivating the individual soul.

Within the framework of the non-classical (socialisation) paradigm, pedagogical science primarily transformed into a social (socio-behavioural) discipline, focusing on the laws and regularities of personality development (as a social being) under the purposeful influence of upbringing, teaching, and education. The vector of the educational process shifted from the "exagogical" (drawing out a person's spiritual potential) to the "organisational" (creating environmental conditions conducive to the holistic development of the individual). While in the philosophical-theological pedagogical paradigm, the subjugation of human will to the will of God and the natural alignment with the Divine plan was paramount, in the socialisation paradigm, what is given to a person by nature (heredity) is viewed as the least significant precondition for upbringing; the most influential factors in personality formation are external (environmental) influences and internal factors (self-activity of the individual).

It is also crucial that, in the socialisation paradigm of pedagogy, "absolutes" were replaced by "multiplicities". This refers to the multifactorial nature of the conditions, methods, forms, and means of upbringing and education.

Thus, the paradigmatic approach makes it possible to define the most general worldview foundations embodied in the pedagogical doctrines of different historical periods, to identify

both the specific historical features of a particular pedagogical doctrine and its epochal originality, the author's innovation, and the progressive development of pedagogical thought over historical time.

Conflict of interest

The author declares that there is no conflict of interest.

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Vsevolod V. Zelenin [17]

Professional Self-Realisation of Ukrainians in Time of Crisis: Psychological Strategies for Overcoming and Achieving Success [13]

Abstract: The relevance of this work is due to the complex socio-psychological conditions of the Ukrainian present, caused by various challenges in the context of modern crises. Prolonged war, pandemics COVID-19, economic instability, and natural disasters have a negative impact on physical and psychological health. In such conditions, people experience stress, anxiety, depression and emotional vulnerability, which affects the possibilities of self-development and professional self-realisation. The study of professional self-realisation of Ukrainians in times of crisis focuses on the psychological aspects of overcoming difficulties and achieving success. The paper examines the crises and challenges faced by modern Ukrainians, identifies effective strategies for self-realisation, factors that influence this process, and mechanisms that contribute to the successful overcoming of crisis situations. During crisis situations, a special role belongs to individual adaptation resources, which act as personal potential and allow learning, changing and developing in adverse circumstances. An important role is played by the resources of psychological resilience that arise as a result of certain dynamics of life situations and affect the further success and efficiency of life. One of these resources is resilience, which ensures rapid adaptation to change, the ability to cope with stress and difficulties and the ability to return to normal life after a crisis without harm to mental and physical health. The positive impact of coaching on increasing motivation, improving well-being, increasing work efficiency and professional development was noted. Coaching contributes to the development of personal anti-stress skills, the ability to control one's emotions, the ability to manage stress and adapt to crisis conditions, self-efficacy and resilience. Thus, coaching in the context of professional self-realization, especially in times of crisis, is an effective tool for developing personal characteristics, improving motivation and achieving success.

Keywords: professional self-realization, success, coaching, psychology, crisis.

Introduction

Across the globe, the challenges of our time—wars, pandemics, hunger and natural disasters, socio-economic crises—are having a significant impact on the physical and psychological well-being of the population. The global COVID-19 pandemic and military aggression have fundamentally altered not only the everyday lives of millions of people in Ukraine, but also their professional activities. In times of crisis, the disruption of the regulation of negative emotions such as fear, anger, hatred, disappointment, sadness, humiliation, uncertainty, and hopelessness affects an individual's mental state and their professional self-realisation. Specialists across various fields are faced with questions regarding the possibility of continuing career development and professional skills, and the challenges and obstacles they may encounter in their professional paths (*Cosic, et al., 2024*; *Lass-Hennemann, et al., 2024*; *Quintero, et al., 2024*).

Self-realisation is a process of self-awareness and self-improvement, reflecting personal growth, which involves an endless series of situations requiring free choice and responsibility for that choice. The relevance of the issue of personal self-realisation is determined, on the one hand, by significant economic and, consequently, professional changes occurring in today's world, and on the other—by an individual's subjective perceptions of the specifics of self-

development and self-realisation within a particular profession (*Lass-Hennemann, et al., 2024*; *Bedan, et al., 2021*).

An analysis of scientific studies indicates that the gradual mastering of professional skills encourages individuals to utilise not only their psychophysiological resources but also their potential personal capacities—self-realisation, self-development, self-actualisation, and the purposeful application of professional knowledge, skills, and abilities necessary for further personal development within their profession and the achievement of success (*Zhuravleva, et al., 2024*; *Nerubasska, et al., 2020*; *Zelenin, 2024*).

Self-realisation remains a vital process for a fulfilling life in Ukraine during times of crisis, but it requires targeted psychological support to address individual problems and to develop emotional and interpersonal skills (*Chayka & Zelenin, 2024*; *Garay-Rondero, et al., 2022*; *Quintero, et al., 2024*).

The study aims to identify the characteristics of self-realisation among Ukrainians in times of crisis and to establish effective psychological strategies for overcoming adversity and achieving success.

Materials and Methods

The work was performed using scientific methods of theoretical generalisation, classification, analysis, synthesis, and summarisation. The provided literature review is intended to consolidate data from literary sources concerning the specifics of self-realisation among Ukrainians in times of crisis and to identify effective psychological strategies for overcoming challenges and achieving success. Scientific publications were selected through scientometric databases such as Google Scholar and Scopus. The search was conducted using the following key terms: "professional self-realisation", "success", "coaching", "psychology", and "crisis."

Results

Self-realisation is an integral part of the social dimension of sustainable development, as it enables individuals to strengthen their mental health and well-being through the achievement and enhancement of their potential, life goals, and success (*Milyutina, 2008*; *Stoliarchuk et al., 2024*). For the process of self-realisation to be effective, it is essential for a person to form and continuously develop both personal and professional skills. This is particularly important in light of numerous contemporary challenges and constraints. Circumstances such as economic crises, rapid technological advancement, pandemics, and wars require individuals to possess flexible thinking, the ability to adapt quickly to new conditions, motivation, high personal values, and a commitment to ongoing self-development (*Kandiuk-Lebid et al., 2024*; *Weierstall-Pust et al., 2022*; *Mirza & Mahboob, 2021*).

The war in Ukraine has triggered negative processes within the economic sphere, leading to an economic crisis, financial system instability, accelerated inflation, and the intensification of destructive processes in various sectors. As a result, people experience stress and depression, feelings of fear and anxiety, negative emotions, and uncertainty about the future (*Cosic et al., 2024*; *Lass-Hennemann et al., 2024*; *Quintero et al., 2024*).

In terms of professional self-realisation, self-improvement, the search for new opportunities to realise one's abilities and personal potential, plays a significant role.

Additionally, personal anti-stress skills, the ability to control one's emotions, manage stress, adapt to crisis conditions, self-actualisation, self-fulfilment, self-efficacy, and resilience are of great importance (*Table 1*). Self-efficacy refers to an individual's belief in their ability to cope with new situations, difficulties, and challenges, and is particularly important in responding to global crises. A negative correlation has been identified between levels of anxiety and self-efficacy (*Lass-Hennemann et al., 2024*).

Modern academic literature identifies a range of factors influencing a person's professional self-realisation. These can be conditionally divided into personality-dependent factors (such as values, goals, willpower, a desire for self-improvement, and cognitive flexibility) and personality-independent factors (such as social conditions, material status, and media influence). In times of crisis, professional fulfilment is driven by personality-dependent factors (*Kulichenko & Boichenko, 2021*; *Filonenko et al., 2022*).

Psychological resilience resources play a crucial role in influencing an individual's success and effectiveness in life. Resilience determines one's ability to adapt to crises. Internal resources support swift adaptation to changes, aid in overcoming stress and difficulties. Thanks to psychological resilience, individuals are capable of confronting crisis events (such as warfare, pandemics) while maintaining and even enhancing their personal resources. This leads to personal strengthening and positive reorganisation, thereby facilitating the process of adaptation. By harnessing resilience, a person can construct and reconstruct their life path, restore balance, transform themselves, and view challenges positively, using them as catalysts for growth (*Quintero et al., 2024*; *Kulichenko & Boichenko, 2021*; *Filonenko et al., 2022*).

It is now well established that motivation, as a combination of driving forces, plays a key role in the process of self-realisation. V. Bedan et al. (*2021*) assert that individuals with higher levels of self-realisation are primarily guided by intrinsic motivators, such as creativity and self-improvement, whereas those with lower levels of self-realisation tend to seek external rewards. This distinction underscores the importance of a balanced combination of intrinsic and extrinsic motivational factors for comprehensive professional growth and the realisation of personal potential.

Motivation may be both intrinsic and extrinsic, prompting individuals to carry out certain professional tasks. Intrinsic motivation is influenced by a stable commitment to a goal, which determines the prioritisation of a particular profession. This type of motivation activates behaviour in a specific direction and fosters the creation of favourable conditions within the social environment. Extrinsic motivation, on the other hand, represents a process that shapes the adjustment of self-management and self-regulation mechanisms. The characteristics of motivation suggest that it reflects the internal structure of an individual engaged in professional activity. This is facilitated by a person's desire and readiness to undertake actions aimed at satisfying specific professional needs.

As individuals develop their professional skills and competencies, they gradually come to recognise their own significance and value within the profession. They begin to treat themselves as individuals, identify and become aware of key motivations, and develop initiative and responsibility. A combination of internal qualities—such as needs, interests, and values—contributes to a person's motivation for professional self-realisation. Under the influence of a

hierarchically structured set of motives, an individual's attitude towards professional activity gradually takes shape (*Zhuravleva, et al., 2024*).

In their work, E. Monderna and N. Voinarovska identify personal motives for self-development, among which self-realisation, self-assertion, self-expression, and self-actualisation play a significant role. Equally important is the relationship between an individual's professional and personal activity, as well as the transformation of goals for professional development (*Monderna & Voinarovska, 2019*).

Psychological conditions are of great importance for professional self-realisation. Addressing professional challenges allows individuals to satisfy the need for self-realisation and self-actualisation, to fully utilise their personal potential, thereby enhancing the prospects for professional fulfilment (*Zhuravleva, et al., 2024*).

Among the most common strategies for overcoming the challenges of modernity and achieving self-realisation are coaching, cognitive behavioural therapy, emotional regulation, social support, adaptive coping mechanisms, personal growth, and others.

Effective strategies for coping and achieving success in professional self-realisation among the Ukrainian population amid contemporary crises include individual and group coaching. This approach is aimed at identifying and maximising the deep potential of the individual or group in the current social context. Coaching may take the form of individual or group sessions with a coach, or self-coaching—using coaching techniques to support oneself.

Utilising coaching is advisable for preventing psychological instability in active individuals. Through coaching, a person can address a range of issues related to the development of psychological resilience and the elimination of professional instability. Such tasks include as developing a strategy for professional growth; overcoming behavioural traits that cause passivity and demotivation; enhancing professional flexibility and mobility; acquiring skills for handling critical situations; focusing on positive outcomes; and learning to manage one's emotions and feelings (*Lee, et al., 2018*).

The research findings of M. Hryshchenko and V. Zelenin (*2025*) have identified self-realisation as a factor that affects quality of life and the level of satisfaction with one's professionalism. Self-realisation strategies help optimise and develop various individual abilities. They include personal involvement in professional development programmes, coaching, and more. It has been shown that coaching provides emotional support and helps individuals overcome difficulties, has a positive impact on motivation, enhances well-being, and improves overall work performance. In his study, V. Zelenin (*2023*) highlights the significant role of coaching models—especially in wartime conditions—in developing managerial and leadership qualities among managers of business organisations.

According to researchers A. Kulichenko and M. Boichenko (*2021*), coaching enables individuals to gain a better understanding of their strengths and weaknesses, as well as to recognise the impact of stress and distress on their behaviour and decision-making. Coaching provides emotional support and helps overcome difficulties, facilitating both professional and personal self-fulfilment. An awareness of one's strengths and weaknesses allows a person to assess their capabilities more accurately and choose the right direction in their career and life in general. Meanwhile, the ability to recognise and manage one's own emotions, as well as those of others, contributes to effective communication and the building of relationships within a

team. The drive for self-fulfilment, achieving personal goals, and deriving satisfaction from work, along with motivation, enhances productivity and resilience in stressful situations. Active engagement in career development, the pursuit of new opportunities, fresh ideas, and initiatives are essential for both personal and professional growth. Therefore, seeking support in the form of coaching practice can aid in the development of these essential skills and offer valuable assistance in times of crisis, which, thanks to coaching, can become challenges and new opportunities for professional self-fulfilment.

Conclusion

In the context of the current challenges posed by military aggression and restrictions, an individual's capacity for self-development and self-realisation becomes crucial. It is the correct choice of direction for personal growth and the identification of available opportunities that serve as key factors for success and can enhance the effective use of accessible resources to develop professional skills and increase the level of self-realisation. During times of crisis, individual resources and adaptation strategies play a particularly important role, as they support learning and development under crisis conditions. These resources include personal anti-stress skills, the ability to control one's emotions, stress management and adaptation to crisis situations, self-efficacy, and resilience.

Professional self-realisation remains a vital process for a fulfilling life in Ukraine during wartime, yet it requires targeted psychological support to address individual challenges. Coaching may serve as an effective tool for developing personal and motivational characteristics, which in turn contribute to productive professional self-realisation. When a person becomes aware of their responsibility for shaping their own life, they are better able to adapt quickly to change and fulfil their potential in both personal and professional domains.

Prospects for further research in this area may focus on exploring the specific features of professional self-realisation among representatives of different professions, investigating gender aspects of professional self-realisation among Ukrainians during times of crisis, and identifying psychological strategies for achieving success.

Conflict of interest

The author declares that there is no conflict of interest.

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Appendix

Table 1. Comparative analysis of the terms: Professional self-fulfilment, professional self-realisation, and professional self-actualisation

Term	Definition	Purpose	Result
Professional self-fulfilment	This is the process of applying one's abilities and skills in professional activity, characterised by a high level of personal potential being realised within the chosen profession, along with the development of one's abilities and professionalism. It is associated with intrinsic motivation and a sense of fulfilment in carrying out professional tasks, and may involve a creative approach to work and the pursuit of personal ambitions.	Job satisfaction and achievement of professional goals	Integration of personal interests into one's professional activity. A sense of satisfaction, achievement, and growing confidence
Professional self-realisation	The process of harmonious personal development and acquisition of professional-practical skills, which combines personal growth with professional advancement. In this context, the social aspect is of great importance, meaning that self-realisation occurs within the framework of society and the professional environment.	Identification and development of a person's potential and abilities	Applying one's skills in professional practice. Attaining a high level of competence and career development
Professional self-actualisation	The process of achieving an individual's highest potential in the professional sphere. It is an activity aimed at attaining maximum efficiency in the professional field, realising one's potential, and the capacity for creativity and innovation	Full realisation of personal and professional potential	Combining knowledge, abilities, and talents to fully express one's identity. The opportunity to influence others and reach the heights in the professional field

Source: Created by the author

Oxana I. Hevko [18]

The Use of Information and Computer Technologies in Preschool, Secondary and Higher Education Pedagogy [14]

Abstract: The article examines the relevance and versatility of information and computer technologies in the educational process at different stages: preschool education, general secondary school, and higher education. The study subject is digitalising the educational process in preschool, general secondary, and higher education institutions. The study aims to identify the forms and methods of intensifying various levels of education through information and computer technologies. The potential of information and computer technologies for enriching the learning environment, increasing students' motivation, individualising learning, and developing key competencies is analysed. The specifics of the use of various digital tools and resources at each level of education are revealed, and their role in improving teaching methods, organising knowledge control, and stimulating the creative activity of children, pupils, and students is emphasised. Special attention is paid to the benefits of integrating information and computer technologies for developing the future generation's independence, critical thinking, and digital literacy.

Keywords: information computer technologies, preschool children, preschoolers, pupils, schoolchildren, students, preschool educational institutions, general secondary educational institutions, higher educational institutions, competencies, educators, teachers, lecturers, scientists.

Abbreviations:

ICT is information and computer technologies.

Introduction

Modern processes of globalisation, digital transformation, the formation of a market economy, and the gradual integration of Ukraine's educational system into the European educational area necessitate the modernisation of the content and structure of professional higher, pre-tertiary, and preschool education. This highlights the need to improve the quality of teaching in the subject area and to develop learners' intellectual and psychological readiness to process large volumes of information and to continuously update their knowledge and competencies, particularly in the use of information and computer technologies to enhance the quality and effectiveness of the educational process.

The study subject is digitalising the educational process in preschool, general secondary, and higher education institutions.

The study aims to identify the forms and methods of intensifying various levels of education through information and computer technologies.

The study objectives are:

- examine how the informatisation of the educational process is addressed in academic literature;
- identify the main areas of application of information and computer technologies;
- outline the specific features of using online services, particularly the tools of Google Workspace;
- detail the potential for using tools such as Canvas Apps and Canva in the educational process for fostering learners' creative development;

– identify the multimedia opportunities available for the educational process across different levels of education.

Educators, psychologists, and researchers have explored key aspects of information and computer technologies, their structural components, and their significance for the educational process and personal development. This includes a historical overview of implementing digital technologies (O. Humennyi, V. Kapustnyk, N. Kiyanovska, V. Kovalenko, P. Kostiurulina, A. Sukhikh); the application of information and computer technologies in the educational process (S. Verezomska, O. Hevko, Yu. Zinkovskyi, M. Kademiya, L. Krukevych, T. Kuzmych, O. Pashchenko, V. Tatarintseva, O. Chaikovska, N. Shvadchak); the development of digital competence and the use of digital services and tools for various forms of learning (H. Henseruk, Yu. Zaporozhchenko, Z. Zvynyatskivska, I. Kobernyk, S. Martyniuk, I. Fursov); and the use and significance of information and communication technologies in the formation of the educator (O. Hritchenko, V. Kuzmenko, O. Mekhed, V. Nazarenko, O. Ovcharuk, etc.).

This study will be of interest to educators, learners, and parents involved in preschool, general secondary, and higher education, as well as researchers and all those interested in current trends in education development.

Results

Content, Forms, Methods, Means, Tools, and Significance of the Use of Information and Computer Technologies in the Educational Process

ICT encompass a set of tools, methods, and approaches that facilitate data collection, processing, storage, and transmission through computer equipment and telecommunications. These technologies cover the key areas of their application, including:

- working with internet networks and utilising online resources (such as web platforms and cloud services) (*Sukhikh, 2021, pp. 157–160*) for data retrieval and communication;
- developing creative tasks (such as project-based research, interactive reports, educational sessions, and collaborative creative work involving two to several dozen participants, including students, lecturers, educators, parents of preschoolers, researchers, etc.), as well as the creation of presentation materials;
- employing multimedia tools of computer equipment as an effective means of problem-oriented visualisation.

ICT is being actively integrated into the educational process (*Krukevych, 2023, pp. 411–414*) at higher education institutions, as well as in general secondary and preschool education, and is regarded as one of the most promising innovations in this field. ICT engages the auditory and visual analysers of the individual, thereby enhancing emotional perception and the visualisation of educational content. The combination of images, illustrative examples, and text, along with the use of animation, sound effects, video clips, and other visual media, contributes to greater interest, improved comprehension, and better assimilation of educational material, making it more accessible and engaging for preschool children, school pupils, and university students alike.

An essential advantage of integrating information and computer technologies into the educational process lies in the development of educational resources in higher preschool education institutions and the effective use of online services (*Verezomska, 2022, pp. 165–167*), particularly the tools provided by Google Workspace:

- Document-oriented solutions (real-time collaborative editing of presentations by preschool education staff, as well as students and lecturers);
- Interactive assessment formats (creating tests for preschool children, school pupils, and students via Google Forms);
- Use of Google Sheets for data collection (among students, parents of preschoolers, and educators in both preschool and higher education institutions);
- Use of Google Classroom for course management (appropriate for creating and managing academic subjects in higher education institutions and for use in the methodological work of preschools);
- Use of Google Meet to organise online communication within the educational environment across various institutional levels (the platform's adaptability to higher education needs, including lectures, seminars, consultations, departmental scientific, methodological, and technological meetings and events; in preschool and general secondary education institutions it serves to optimise interaction among teachers, administrators, and parents through various video conferences for pedagogical-methodological and administrative-organisational tasks);
- Use of Google Drive for cloud storage of educational information, documents and other textual content, photos, videos, audio materials, images, and archived materials relevant to both preschool and higher education institutions;
- Availability of modern educational resources such as e-books, repositories, and online libraries accessible in real-time from any classroom, group, or home setting, including assembly and sports halls. These resources engage users by offering quick access to books, journals, and other publications, as well as to articles, scientific and archival materials, and research—both domestic and international—thereby enhancing the productivity of the educational process;
- Use of Jamboard as an interactive virtual whiteboard in the educational process—allowing for the display of diverse visual materials tailored to various age groups, including children and preschool pupils; the uploading and display of visual content in formats such as photographs, text notes, graphic images, as well as Word and PDF documents, Excel spreadsheets, and presentations created in Canva and PowerPoint; the organisation of group work among students or within a classroom (e.g., brainstorming sessions, projects, collaborative discussion of strategies, textual analysis, commenting) using various tools such as pens, handwriting recognition, and other functions; the creation of a "shared interactive banner (drawing/poster)" which enables a large number of participants (lecturers, educators, researchers, pupils, preschoolers) to simultaneously collaborate, draw, refine materials, and share creative ideas and solutions; accessibility not only via desktop computers and laptops, but also via mobile devices, smartphones, and tablets; the use of real-time adjustable visuals (drawings, sketches, tables, and diagrams) by educators through

uploading various files from Google Drive to Jamboard; centralised collection of diverse information (personal data, individual work, tests, responses, suggestions) from all participants in one place;

- Use of the Skillshop platform, which offers an extensive collection of specialised learning materials focused on mastering the process of creating digital tools;
- Use of the Moodle distance learning system for students, lecturers, and educators (facilitating modular, individualised, and social learning, academic courses, professional development, programming, and testing; allowing lecturers, teachers, or institutional heads to configure moderation settings, access permissions, or participant access via password; enabling the publication of educational content in text, audio, and visual formats);
- Use of services for creating comics, such as Storyboard, and puzzle generators like Rebus1, which open new horizons for education at all levels—from preschool to higher education;
- Use of modern, interactive, and highly adaptive tools such as Canvas Apps and Canva, tailored to the needs of students, pupils, educators, teachers, and lecturers, to enhance the interactivity and visualisation of the educational process and automate procedures.

Let us examine in more detail the potential of creatively using Canvas Apps and Canva tools to foster the creative development of preschoolers, pupils, students, educators, teachers, lecturers, and researchers, to organise collaboration among educational process participants, and to improve learning efficiency at all levels of education.

In the early years of educational institutions, the use of Canvas Apps and Canva enables the organisation of:

1. Interactive games and exercises through the creation of simple applications with tasks focused on recognising colours, shapes, numbers, and letters. Children can interact with on-screen elements, which supports the development of fine motor skills and logical thinking.
2. Virtual albums and portfolios to store children's creative works and photos from events, educational activities, excursions, celebrations, performances, competitions, and recreational activities. These collections also document children's achievements and can be viewed by their parents and educators.
3. Electronic mood diaries that record a child's emotional state throughout the day help educators better understand children's feelings, desires, and needs.

In general, in secondary education institutions, the use of Canvas Apps and Canva can support:

1. Visualise educational content by creating interactive diagrams, infographics, and presentations to explain complex topics (e.g., cell structure, human anatomy, historical events and facts, or mathematical, physical, and chemical formulas, algorithms and processes).
2. Organisation of group projects and posters, allowing pupils from one or more classes and teachers to collaboratively create posters, flyers, and presentations for performances, competitions, or school events.
3. Create and administer tests and surveys, enabling teachers to collect student responses in real time and automatically assess their knowledge.

4. Improved and faster organisation of school events, including developing apps for event registration, participant list management, timetable planning, and conducting surveys regarding celebration arrangements.
5. The setup of "virtual laboratories", where dedicated apps simulate physical, chemical or biological experiments. Pupils can independently adjust specific parameters and observe the outcomes.

In higher education institutions, the application of Canvas Apps and Canva also has a wide range of uses:

1. Management of student projects, where Canvas Apps provides a convenient platform for planning, tracking progress, and sharing files and comments within a study group or academic department.
2. Automation of administrative processes, such as creating apps for submitting applications, course registration, booking rooms for educational or leisure purposes, and maintaining electronic records.
3. Visualisation of research: This allows the creation of interactive graphs, charts, and presentations of scientific findings using built-in or custom tools.
4. Student portfolio development, including dissertations, bachelor's and master's theses, coursework, diplomas, and certificates of participation in conferences and seminars—facilitating future employment opportunities.

Key advantages of using Canvas Apps and Canva across all levels of education include:

- User-friendly drag-and-drop interface, offering an intuitive and accessible design that enables users to create apps and learning materials without requiring in-depth programming knowledge;
- Interactivity for participants, engaging educators across early years, secondary, and higher education, as well as researchers, parents, pupils, and students in active interaction with the material, thus enhancing motivation to learn;
- Visualisation of informational content, making complex topics taught in nurseries and primary and secondary schools more comprehensible through the use of diagrams, charts, and infographics—particularly beneficial for STEM education;
- Collaborative work, enabling shared editing by all participants, group discussions, and results presentations.

A significant advantage of these web-based applications is their accessibility via any web browser without additional software installation, which supports their reliability provided a stable internet connection is available.

Traditional methods of delivering educational material from early childhood to higher education—such as storytelling, discussion, lectures, and static presentations—often limit engagement and opportunities for the practical application of knowledge. Interactive presentations offer a significantly broader pedagogical possibility, highlighting active audience involvement. Integrating multimedia components, such as dynamic video clips, visually rich imagery, and audio accompaniment, diversifies the learning process and enables deeper immersion into educational content. Moreover, the possibility of direct interaction with the

material through interactive elements stimulates active learner participation, transforming them from passive listeners into co-creators of the educational experience.

Interactive presentations in group settings also serve as a powerful tool for developing social skills, fostering effective collaboration, and nurturing a sense of teamwork among children, pupils, and students. The educational process becomes more dynamic and informative with the inclusion of multimedia tools—videos, clips, illustrations, graphs, tables, sound effects, and animations. A key advantage of such presentations lies in their interactive nature, which allows learners in early years, primary and secondary schools, and higher education to observe and actively explore the presented material, thereby reinforcing their acquired knowledge.

In addition to individual benefits, interactive presentations prove to be an effective means of organising group work for acquiring new information and applying it practically. They encourage the exchange of ideas, development of communication and cooperation skills, mutual support, teamwork, and collective achievement of set goals.

An engaging, interactive learning tool for preschoolers, schoolchildren, and university students is the use of comics, which aid in visualising knowledge and developing creativity. *Storyboard* comic creation platforms provide a captivating and effective way of conveying information to learners. These platforms are powerful didactic tools, offering an intuitive interface for creating visual stories that combine imagery and text. Their application in the educational process is highly versatile and suitable for all age groups—preschoolers, schoolchildren, and university students.

For preschool children, comics can be an excellent means of illustrating fairy tales, learning letters and numbers, and introducing behavioural norms. Visual representations help young learners better retain information and develop their imagination and creativity.

For schoolchildren, creating comics can be used to visualise historical events, scientific concepts, literary plots, and more. This approach contributes to a deeper understanding of the material, developing retelling skills and creative thinking. Pupils can create comics individually or collaboratively, thereby enhancing their teamwork skills.

In higher education, comics can be employed to visualise complex theoretical concepts, present research findings, and create educational resources. This can make learning more engaging and facilitate better information retention.

Using Storyboard and similar services enables educators to design unique teaching materials tailored to the needs of specific audiences. Learners, in turn, gain the opportunity to comprehend information and actively contribute to its creation, which significantly increases their interest and motivation to learn.

The use of *rebus puzzles* in education also promotes the development of logical thinking and attentiveness and reinforces and revises learned material. Rebus puzzles are brainteasers that use drawings, letters, numbers, and other symbols to encode words or phrases. The *Rebus1* platform is a convenient tool for generating a variety of rebuses that can be effectively employed at different stages of the educational process.

In early years education, simple rebuses with bright illustrations can be used to develop phonemic awareness, attention to detail, and early reading skills among young learners. Solving rebuses in a playful context makes learning enjoyable and unobtrusive.

In secondary education institutions, rebuses can be used to reinforce material studied across various subjects, develop logical thinking, and expand pupils' vocabulary. Creating their rebuses can be an engaging creative task for pupils, allowing them to reveal their abilities across different fields.

Even in higher education, rebuses may find application, e.g., to activate prior knowledge before introducing a new topic, to stimulate mental activity at the beginning of a lesson, or as a component of interactive assessment. More complex rebuses can foster the development of non-standard thinking.

Rebus1 and similar platforms allow educators to easily generate rebuses of varying complexity, tailoring tasks to suit the proficiency level of preschool children, school pupils, and university students. Solving rebuses provides entertainment and promotes the development of key cognitive skills such as analysis, synthesis, deduction, and attention to detail.

The use of platforms such as *Storyboard* and *Rebus1*, along with the integration of comics and rebuses into the educational process, presents significant advantages and prospects:

- Increased engagement among children, pupils, and students, as the visual appeal of comics and the intellectually stimulating nature of rebuses help to capture learners' attention and maintain their interest in studying.
- Enhanced cognitive activity, as both the creation and solving of comics and rebuses require active mental effort, information analysis, and knowledge application.
- Development of creativity and imagination, with the process of creating one's visual stories and encoded messages encouraging imaginative and creative thinking.
- Improved understanding and retention since visual imagery and interactive tasks help learners absorb and memorise educational material more effectively.
- The creation of a positive learning atmosphere, as the use of unconventional teaching methods makes the learning process more engaging and emotionally enriched.

Thus, integrating computer technologies with multimedia capabilities opens up unprecedented opportunities for educators and learners at various levels, elevating lessons to a qualitatively new standard. The application of multimedia does not merely enrich lessons with visual and audio effects but fundamentally transforms approaches to learning, knowledge assessment, and the development of creative potential. It enables illustrative support throughout the learning process—from static images to dynamic content.

One of the key benefits of using computer-based information technologies with multimedia is the considerable expansion of options for illustrative support during lessons. Instead of static posters or chalkboard drawings, teachers can utilise dynamic presentations, interactive diagrams, video clips, animations, and virtual tours. This diversity of visual content helps explain complex concepts more effectively, retains audience attention, and activates multiple channels of information perception. For instance, the study of historical events or plant growth can be accompanied by chronological videos, while understanding cell structure can be aided by interactive 3D models.

Multimedia technologies offer flexibility in organising the learning process, enabling the effective combination of different forms of learning and types of activity within a single lesson. Lecture material can seamlessly transition into interactive exercises, discussions, thematic video

viewings, practical assignments, virtual research, experimental, and laboratory work. This approach supports high levels of engagement among children, school pupils, and university students, considers their characteristics and abilities, learning styles, preferences, and inclinations, and facilitates deeper assimilation of material. For example, to help preschoolers pronounce sounds correctly in words, audio recordings of speech therapists or teachers may be used; in foreign language learning, students can benefit from listening to audio recordings, watching context-relevant videos, taking interactive grammar tests, and using online platforms to communicate with native speakers.

Using computers with multimedia significantly expands the tools available for assessing pupils' and students' knowledge, skills, and competencies. Instead of traditional written tests and oral questioning, educators can use interactive quizzes with automated feedback, online competitions, multimedia presentations as a form of reporting, simulations of real-life situations, and other innovative assessment methods. This makes the assessment process more objective, efficient, and engaging for students and also provides immediate feedback, helping learners better understand their strengths and areas for improvement.

Multimedia technologies are crucial in facilitating and enhancing the development of creative works, projects, and essays. Pupils and students gain access to a wide range of tools for creating multimedia presentations, videos, podcasts, interactive posters, and other creative products. This makes the task completion process more engaging and fosters the development of their digital skills, creativity, and ability to work with information and present the outcomes of their work in innovative ways. For instance, a literature project may be offered as a book trailer, while research on environmental topics can take the shape of an interactive infographic.

Computer-assisted learning is an integral component of modern, quality education. It makes the learning process more engaging and visual and enables effective differentiation. It also supports the development of independence and creativity in children and students, intensifies the educational process, and strengthens cross-curricular connections. Collectively, these aspects open new opportunities for improving the quality of education and preparing competent and competitive professionals.

One key advantage of computer-supported lessons is their ability to spark and sustain a high level of interest among preschoolers, pupils, and students. Interactive programmes, multimedia presentations, educational games, virtual laboratories, and online resources transform the learning process from passive observation into exciting interactive engagement. The novelty of technologies, the visual appeal of the content, and the opportunity for direct involvement in the educational process stimulate intellectual curiosity and motivate learners to delve deeper into the subject matter.

Information and communication technologies provide unique tools for effectively implementing a differentiated approach in the educational process. Software can be adapted to the individual learning pace of each preschool or school-aged child or student, offering tasks of varying complexity, additional support materials for those who need them, and advanced challenges for more gifted learners. This enables educators to account for different learning styles, levels of preparedness, and individual needs, ensuring the most effective knowledge acquisition and skill development.

Information and communication technologies in education are essential in fostering independence and creativity in children and students. Providing access to diverse informational resources, tools for creating multimedia projects, platforms for collaborative work, and online services encourages individuals to seek information independently, think critically, experiment, and express themselves creatively. They are empowered to determine the pace and direction of their learning, explore topics of personal interest, and present the outcomes of their efforts in original and imaginative ways.

Information and communication technologies do not merely complement traditional teaching methods but enable a qualitative transformation of the educational delivery model. Lessons and lectures become more illustrative through visualisations, animations, video materials, and interactive models. Interactive exercises and games—including board games (*Bokarieva & Shypov, 2024, p. 56*), online tests, virtual excursions, and simulations—promote active participation from children, pupils, and students alike. Furthermore, computer technologies broaden access to education by enabling remote learning, facilitating online resources, and fostering collaboration among participants in the educational process regardless of their geographical location.

The application of information technologies intensifies the activities of educators, children, pupils, and students. Educators have powerful tools for planning and conducting lessons, automating routine tasks, organising knowledge assessments, and ensuring feedback. In turn, learners benefit from the ability to interact with information more dynamically and effectively, utilising various educational resources and tools to complete assignments. Additionally, computer technologies enhance interdisciplinary links by integrating knowledge from multiple subjects within a single educational project or task.

Conclusion

Thus, all the aforementioned advantages of computer-assisted learning ultimately contribute to developing an individual's overall giftedness. Engagement in active learning, the opportunity for independent inquiry, the development of creative abilities, individualised instruction, and the intensification of the educational process create favourable conditions for unlocking the potential of every participant in the learning environment. As a result, integrating information and computer technologies into the educational process is a powerful driver for improving the quality of education at all levels.

Hence, implementing information technologies, particularly using computers with multimedia, is not merely a trend but a necessary condition for ensuring high-quality and competitive education at every level. It allows the learning process to become more dynamic, interactive, personalised, and focused on developing an individual's key competencies (*Henseruk & Martyniuk, 2019, pp. 158–162*). Multimedia tools are becoming a powerful catalyst for transformation within the educational environment, opening up new horizons for effective learning and the holistic development of individuals. The successful use of these technologies requires educators to be technically literate and open to experimentation, creative approaches, and continuous self-improvement. Consequently, integrating multimedia into education is an investment in the future, ensuring the intellectual development of the younger generation from

early childhood to higher education and preparing highly qualified professionals capable of acting effectively in an information-driven society.

Conflict of interest

The author declares that there is no conflict of interest.

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