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Military Leadership System in the Armed Forces of Ukraine: Current Issues and Ways to Tackle Them

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Abstract. Despite the fact that in recent years considerable attention has been paid to the development of military leadership, the system of military leadership in the Armed Forces of Ukraine is not yet fully formed. Therefore, research on the formation and development of this system, studying the problematic issues identified in this process and identifying ways to solve them is currently relevant. The majority of scientific publications in this area mainly consider the psychological aspects of the leadership phenomenon. At the same time, the issues related to the formation and development of the military leadership system in the Armed Forces of Ukraine have remained unaddressed by most researchers. Therefore, in this article the authors present the results of the analysis of problematic issues in the system of military leadership in the Armed Forces of Ukraine, identify possible ways of solving them, and provide a model of a promising system of military leadership. The results of the analysis carried out by the authors of the article show that today the Armed Forces of Ukraine have different elements, which are not united into a single system and partially fulfil the task of forming, supporting and developing the leadership qualities of servicemen. The main problems include the following: violation of the principle of unity of command in military leadership; imperfection of the regulatory framework for military leadership; incompatibility of the content of educational components for training military leaders with the requirements for leadership competencies; imperfection of the existing methods for assessing the leadership qualities of military personnel; lack of a fair, stable and transparent system for motivating military leaders, etc. In order to create an effective system of military command in the Armed Forces of Ukraine, the authors propose the following priority measures to create structural units responsible for the organisation and support of military leadership in the Main Personnel Directorate of the General Staff of the Armed Forces of Ukraine, in personnel centres of the Armed Forces of Ukraine and branches of the Armed Forces of Ukraine, as well as in the commands of individual branches of the Armed Forces of Ukraine; to

organise work on the clarification of curricula for the training of officers and non-commissioned officers; to organise scientific research aimed at the development of methods for determining (diagnosing) the level of leadership.

Keywords: leadership, model of military command system, training of military leaders.

Introduction

Given the current situation, in which Ukraine is simultaneously deterring the full-scale armed aggression of the Russian Federation and implementing the strategic commitment to joining the European Community (Strategic Defense Bulletin (2021)), the Armed Forces of Ukraine are in need of competent subject matter experts with strong leadership skills capable of not only effectively defending the country, but also operating together with units and formations of the armed forces of NATO (North Atlantic Treaty Organization) member-states. These principles have become the cornerstones for the implementation of both the Military Leadership Doctrine of the National Guard of Ukraine (2021) and the Doctrine for the Development of Military Leadership of the Armed Forces of Ukraine (2020). In light of the current policy objectives reflected in the Military Security Strategy of Ukraine (2021), the military-political leadership of Ukraine has tasked the Armed Forces of Ukraine with developing a new style of military leadership and transforming the professional culture following the best Euro-Atlantic practices. In his research Kobzar (2020) explores the issues of refining the key definitions and concepts of moral and psychological support and the difficulties in establishing a leadership system in the Armed Forces of Ukraine. Analysis of the Regulation on the General Staff of the Armed Forces of Ukraine (2020) shows that the military leadership system in the Armed Forces of Ukraine has not yet been fully developed and is undergoing a period of imbalance. Therefore, any research that could assist in establishing and advancing the aforementioned system, while also finding ways to tackle issues identified in the process is highly relevant under given circumstances. According to Bilshynskyi (2020) the military leadership system has to be based on both theoretical and practical pillars. Ensuring interoperability between the Armed Forces of Ukraine and other elements of the national defense and security forces, as well as equivalent entities of partner countries, requires implementing a shared vision of military leadership, abiding by the fundamental principles for its development, as well as standards, values, personal qualities, and core competencies of military leaders. The works of Poltieva (2023), Wong (2009), and Mirshuk (2020) define military leadership as the key component of mission success for both individual service members on various levels, and military units (formations), including their commanders and staff. In the armed forces of NATO member-states (for example, as stipulated by the guidelines of the Headquarters of the US Department of the Army (2019) and supported by the findings of analytical research by Loughlin (2007) and Reed (200)) military leadership, among other things, is rooted in values, traditions, ethical behavior, a deep understanding of and strict adherence to military discipline and culture within the military unit. Karpenko (2021) believes that a way to improve the command and control system in the Armed Forces of Ukraine is through the introduction of various education and training programs for leadership development. The aforementioned programs are designed to develop the leadership skills and abilities of military personnel at all levels, from junior officers to senior commanders. The theoretical and methodological principles of change management are also used in the development and implementation of military policy and strategy. They lay out the foundations for a new system of joint command and control of the Armed Forces, emphasizing the importance of cooperation and coordination between the different branches and services. By adopting these methodological frameworks, the military leadership system in Ukraine can effectively guide and support military personnel in their duties, ensuring the state's security. Therefore, taking into account the lessons learned from the existing military leadership systems of NATO member states, Ukraine is presented with a particularly urgent challenge, as the country has to develop its own comprehensive system,

taking into account national and historical factors.

Methodological Framework

The Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine (2020) reflects a system of views on leadership development, basic principles, standards, levels, values, virtues, character traits, and core competencies of military leaders. Military leadership remains a key component of ensuring both the professional growth of individual service members of different categories (as Browne points out there exists a list of possibilities (2009) for its contextual assessment) and the mission success of military command bodies (Hutchison (2018)) and military units (formations) (Snihur (2016)), regardless of the variety of definitions and implementation methods. According to the US Army Leader Development Strategy (2019) and the findings in the publications by Daft (2013) and Zaccaro (2003) military leadership plays a decisive role, in particular, in instilling the values, traditions, behavioral ethics, compliance with military discipline and corporate military culture in the armed forces of NATO member states. C2 (management) in the military allows to ensure stability, control over most processes, and monitoring of mission outcomes, while military leadership drives positive change by focusing on inspiring and engaging with personnel. Thus, the key to effective command and control in the Armed Forces of Ukraine is for commanders to combine management and leadership processes.

Findings

Having carried out a comprehensive analysis, the authors of the paper found that as of today, the Armed Forces of Ukraine have various isolated elements existing outside of a unified system that only partially fulfills the objective of developing, sustaining, and improving leadership skills in service members (Table 1). Simultaneously, it is important to highlight the following key issues (Table 2):

violation of the unity of command principle in military leadership matters;

shortcomings of the existing legislative framework on military leadership;

discrepancies between the contents of the curricula components dedicated to military leader training and the requirements for leadership competencies;

flawed nature of the available methodologies for evaluating leadership skills in service members;

lack of an equitable, sustainable, and transparent incentive system for military leaders, etc.

In order to address these issues, the Armed Forces of Ukraine need to establish an effective and practical military leadership system capable of fostering a new generation of military leaders with critical thinking and providing them with further support throughout their military careers. A model of the aforementioned system is presented in Figure 1. The authors believe that a sustainable system of military leadership in the Armed Forces of Ukraine must comprise:

entities exerting influence:

Commander-in-Chief of the Armed Forces of Ukraine;

Deputy Commander-in-Chief of the Armed Forces of Ukraine (according to the distribution of powers)

Chief of the General Staff of the Armed Forces of Ukraine;

Deputy Chief of the General Staff of the Armed Forces of Ukraine (according to the distribution of powers);

commanders and chiefs of all levels of subordination;

entities subjected to influence:

officers, NCOs, and enlisted personnel identified and selected for leadership development;

other elements (components) of the system:

Main Personnel Directorate (J-1) of the General Staff of the Armed Forces of Ukraine;

Main Directorate of Doctrines and Training (J-7) of the General Staff of the Armed Forces of Ukraine;

Central Military Education Directorate of the General Staff of the Armed Forces of Ukraine;

Central Military Science Directorate of the General Staff of the Armed Forces of Ukraine;

NCO Directorate of the Armed Forces of Ukraine;

Main Directorate of Moral and Psychological Support of the Armed Forces of Ukraine (an organic unit for psychological support);

Personnel Management Center of the Armed Forces of Ukraine and personnel management centers of branches of the Armed Forces of Ukraine;

Command bodies of branches and services of the Armed Forces of Ukraine;

Higher military education institutions and training centers;

interacting elements:

Department of Personnel Policy of the Ministry of Defense of Ukraine;

Department of Military Education and Science of the Ministry of Defense of Ukraine.

There are some critical points that serve as the quality control elements for the military leadership system. These critical points allow to evaluate the effectiveness of the military leader training and education and, if need be, make adjustments to the objectives for military leader development. Distributions of the main objectives between the elements of the military leadership system in the Armed Forces of Ukraine are shown in Figure 1.

In order to establish an efficient and sustainable military leadership system in the Armed Forces of Ukraine the authors suggest to implement the following top priority measures:

first, to create organic units responsible for managing and supervising military leaders:

at the Main Personnel Directorate (J-1) of the General Staff of the Armed Forces of Ukraine - a Directorate for Military Leadership Development;

at the Personnel Management Center of the Armed Forces of Ukraine - a Section for Career Guidance for Military Leaders;

at the personnel management centers of the Land Forces, Air Force, and Navy of the Armed Forces of Ukraine - a Section for Career Guidance for Military Leaders;

at the Special Operations Forces Command, Air Assault Forces Command, Combat Support Command, Logistics Command, Medical Command, Territorial Defense Forces Command, and Communication and Cybersecurity Forces Command of the Armed Forces of Ukraine - sections (detachments) for military leader support;

second, to coordinate efforts to revise the military leadership curricula for officers and NCOs in higher military educational institutions and training centers;

thirdly, to initiate research aimed at developing methods designed to measure the level of leadership qualities of service members of the branches (services) of the Armed Forces of Ukraine, to test these methods and, if proven to be effective, to introduce them into the certification system of the Armed Forces of Ukraine;

fourth, to establish an equitable, sustainable, and transparent incentive system for military leaders in the Armed Forces of Ukraine;

fifth, to draft a new version of the Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine along with a road map to implement it taking into consideration all of the suggestions listed above.

Discussions In recent years, military leadership has garnered a lot of attention from military experts and scholars around the world. Punda (2017) believed strategic leadership development to be an investment in the reform of the military command and control system; Marshall-Mies (2002) focused on the development and assessment of cognitive and metacognitive indicators for predicting leadership potential; Barko's (2010) research focused on the psychology of leadership, while Boiko (2015) perceived transformational leadership as a conceptual framework for the development of leadership competence of future officers of the Armed Forces of Ukraine.

Table 1. Involvement of the organic command and control bodies, higher military education and research institutions of the Ministry of Defense of Ukraine and the Armed Forces of Ukraine in achieving the objectives for the military leadership system

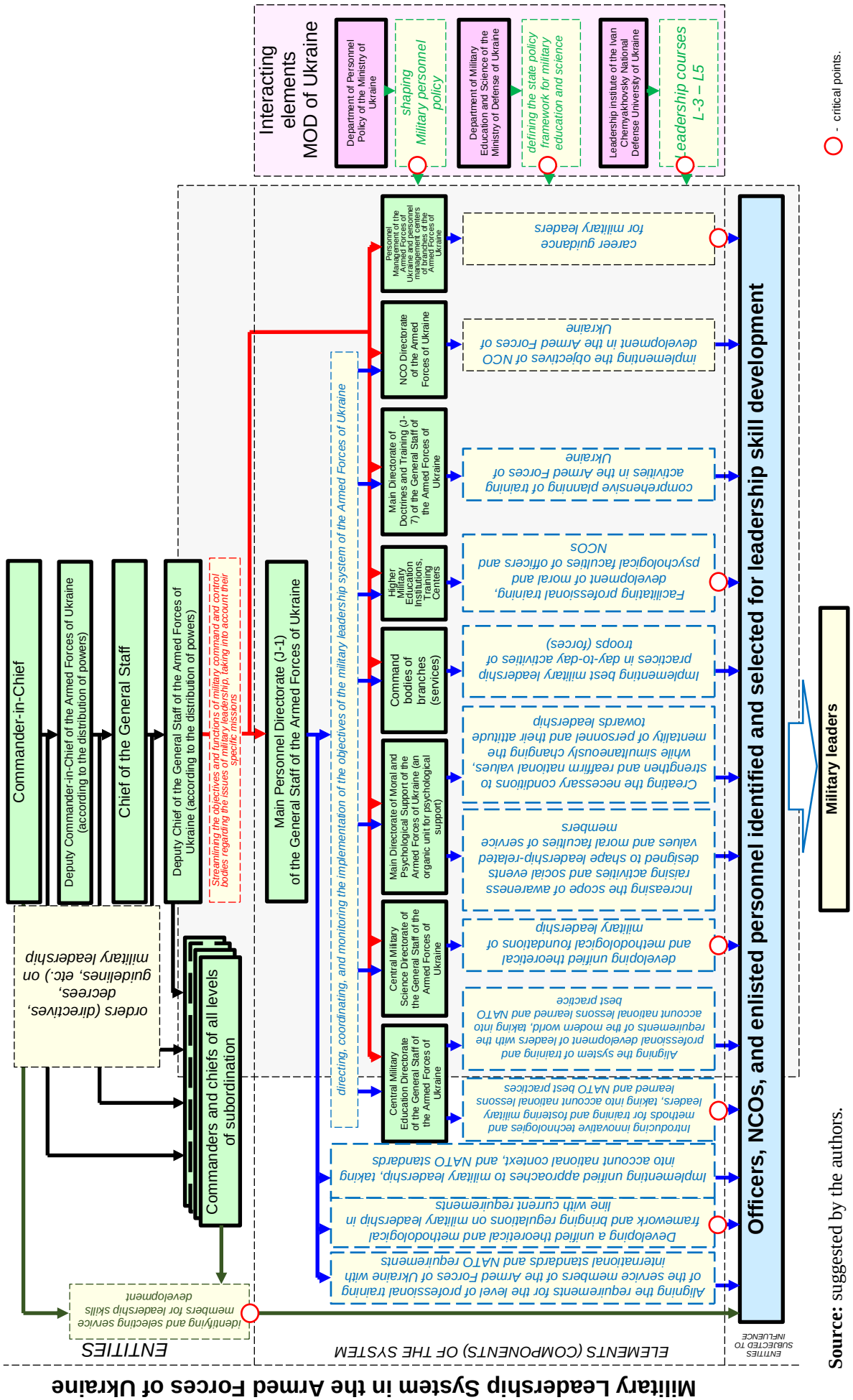
Objectives of the military leadership system	Ministry of Defense of Ukraine				Directly subordinate to the General Staff of the Armed Forces of Ukraine and the Commander-in-Chief of the Armed Forces of Ukraine									Higher Military Education Institutions, Training Centers of branches (services)
	Department of Military Education and Science	Department of Personnel Policy	National Defense University of Ukraine	Personnel Policy Science and Methodology Center	Main Personnel Directorate	Main Directorate of Doctrines and Training	Central Military Science Directorate	Central Military Education Directorate	Main Directorate of Moral and Psychological Support	NCO Directorate of the Armed Forces of Ukraine	Personnel Management Center of the Armed Forces of Ukraine	Central Research and Development Institute of the Armed Forces of Ukraine	Humanitarian Research and Development Center of the Armed Forces of Ukraine	
1. Aligning the requirements for the level of professional training of the service members of the Armed Forces of Ukraine with international standards and NATO requirements	■		■			■		■						■
2. Coordinating efforts and developing common views on military leadership	■	■				■			■	■				
3. Developing a unified theoretical and methodological framework and bringing regulations on military leadership in line with current requirements	■	■	■	■		■	■					■	■	■
4. Streamlining the objectives and functions of military command and control bodies regarding the issues of military leadership, taking into account their specific missions	■	■		■						■				
5. Implementing unified approaches to military leadership, taking into account national context, and NATO standards	■													
6. Introducing innovative technologies and methods for training and fostering military leaders, taking into account national lessons learned and NATO best practices	■			■										
7. Increasing the scope of awareness-raising activities and social events designed to shape leadership-related values and moral faculties of service members									■				■	
8. Implementing best military leadership practices in the day-to-day activities of troops (forces)								■		■				
9. Creating the necessary conditions to strengthen and reaffirm national values, while simultaneously changing the mentality of personnel and their attitude toward leadership			■				■						■	■
10. Aligning the system of training and professional development of leaders with the requirements of the modern world, taking into account national lessons learned and NATO best practice		■			■	■	■	■	■	■	■			
11. Facilitating professional training, development of moral and psychological faculties of officers and NCOs			■											■

Source: developed by the authors based on the analysis of: Military Leadership Doctrine of the National Guard of Ukraine (2021); Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine (2020); Regulation on the General Staff of the Armed Forces of Ukraine (2020); Military Security Strategy of Ukraine (2021).

Table 2. Issues in the Military Leadership Training in the Armed Forces of Ukraine

No.	ISSUES	THEIR DESCRIPTION	WAYS TO TACKLE THEM
1.	**Shortcomings of the existing legislative framework** on military leadership	• The Law of Ukraine "On Education" **does not mention the system for military leader training** as part of military education, instead it only mentions the notion of "professional military education"; • The Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine: ✓ **does not outline a general system** for military leadership training; ✓ **does not specify the leadership-related objectives** for military bodies and institutions; ✓ **does not provide solutions** to the issues of military leadership development; • **there are no relevant guidelines** that elaborate on the general provisions of the Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine.	• **Amend the Law of Ukraine "On Education"** adding a military leader training component to the system of military education; • Amend **the Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine** in the parts detailing the composition of the military leader training system, the objectives for military bodies and institutions and the solutions for the most common issues of military leadership development, **taking into account American FM 6-22 Army Leadership: Competent, Confident, and Agile** as well as best practices of NATO member states (ADP 6-22, Army Leadership and the Profession); • develop relevant guidelines that would elaborate on the general provisions of the Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine.
2.	**Violation of the unity of command principle** in military leadership matters	Entities involved in addressing the aforementioned issues are: • in the **Ministry of Defense of Ukraine** - Department of Personnel Policy and Department of Military Education and Science that **report to different deputies of the Minister of Defense of Ukraine**; • under the **direct subordination to the Commander-in-Chief of the Armed Forces of Ukraine** - Main Directorate of Moral and Psychological Support of the Armed Forces of Ukraine and CO Directorate of the Armed Forces of Ukraine that **report to different deputies of the Commander-in-Chief of the Armed Forces of Ukraine**; • in the **General Staff of the Armed Forces of Ukraine** - Main Personnel Directorate, Main Directorate of Doctrines and Training, Central Military Science Directorate, Central Military Education Directorate that **report to different deputies of the Chief of the General Staff of the Armed Forces of Ukraine**;	• **redistribute powers among deputies of the Minister of Defense of Ukraine, Commander-in-Chief of the Armed Forces of Ukraine, Chief of the General Staff of the Armed Forces of Ukraine**, designating one official at each level to manage (coordinate) military leadership issues; • **clearly define the roles and responsibilities of the relevant organic units** of the Ministry of Defense of Ukraine, General Staff of the Armed Forces of Ukraine and units directly subordinate to the Commander-in-Chief of the Armed Forces of Ukraine on issues related to military leadership.
3.	**Discrepancies between the contents of the curricula components** dedicated to military leader training and the requirements for leadership competencies	The Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine lists the basic values, virtues, character traits, and core competencies related to military leadership and their levels (immediate, organizational, and strategic) that need to be acquired. **At the same time, educational materials on military leadership training for the most part are:** • **lacking clear requirements** for NCO/officer leaders and **criteria for leadership evaluation**; • **focused on the universal scientific and philosophical concepts** of military leadership, the basics of rhetoric and public speaking, psychological aspects of being an officer leader in a team, the basics of strategic communications, and the legal framework of the Armed Forces of Ukraine; • **not fully taking into account** the best international practices and lessons learned by national instructors (with practical experience in the field); • **based on traditional forms** and methods of training.	• with the aim of selecting, evaluating, mentoring, and providing career management and support to best military leaders, **to design a model for acquiring the leadership skills for the officers and NCOs** of the Armed Forces of Ukraine outlining clear requirements for an officer/NCO leader and leadership evaluation criteria taking into account NATO standards (for example, ADP 6-22, Army Leadership and the Profession) and national lessons learned; • envisage training for L2-L5 instructors in educational institutions of **NATO member states** to gain expertise and learn about best educational practices; • introduce the method of **involving instructors with practical experience** (veterans with combat experience) in L-courses; • in addition to traditional forms and methods of training military leaders (lectures, seminars, workshops), **introduce innovative methods, such as**: coaching sessions, master classes, methods of crisis modeling, critical thinking techniques, etc.
4.	**Flawed nature of the available methodologies for evaluating leadership** skills in service members	• Procedure for organizing and conducting certification of military personnel of the Armed Forces of Ukraine: ✓ **fails to explicitly address the assessment of the leadership qualities of officers and NCOs.** Instead, it mentions the assessment of certain individual manifestations of leadership qualities, such as: the effectiveness of command and control, professional growth of subordinates, document management, and the ability to organize and conduct classes; ✓ **procedure envisages the evaluation of leadership skills only for enlisted personnel;** • **currently used psychological tests** for determining the level of leadership skills in service members allow to **only partially identify and measure these skills** (as evidenced by **the track record** of using the tests recommended by the Main Directorate of Moral and Psychological Support of the Armed Forces of Ukraine **in 2012**); • **levels of leadership skills have not been formally implemented** for the purposes of assessing officers and NCOs for further promotions.	• **initiate research on the psychological framework of the leadership qualities** in service members to used as basis for the implementation of the leadership concept in the Armed Forces of Ukraine; • **develop new methodologies for psychological testing** to study a range of leadership traits displayed by service members; • take into account leadership qualities **when assessing officers and NCOs** for further promotion.
5.	Lack of an equitable, sustainable and transparent **incentive system** for military leaders in the Armed Forces of Ukraine	**An imperfect incentive system** for military leaders in the Armed Forces of Ukraine and insufficient remuneration **lead to**: • **loss of talented leaders.** Leaders who do not receive adequate reward and recognition for their work may look for other opportunities where their efforts are better appreciated; • **a decline in motivation and enthusiasm.** Leaders who do not receive adequate financial incentives may lose motivation and enthusiasm for their duties. This can lead to reduced productivity, inefficient problem-solving, and general negligence in the performance of duties; • **decrease in discipline and motivation of subordinates.** Insufficient motivation of leaders can negatively affect the discipline and motivation of subordinates. If leaders do not exhibit personal interest and do not demonstrate effective performance, this can be passed on to the team, which can lead to an overall decrease in productivity and efficiency in the Armed Forces of Ukraine; • **decrease in the combat readiness and combat capability** of the Armed Forces of Ukraine. Leaders who do not feel adequately incentivized and recognized for their work may not show the necessary passion and commitment to their duties. This can affect their ability to make important decisions, particularly when on the battlefield; • **rise of corrupt and unprofessional practices.** Insufficient motivation can lead to corrupt practices among leaders (extortion of bribes, abuse of power, and other unprofessional behavior, etc.); • **loss of confidence of military personnel in their leaders.** When the service members see that their leaders are not properly incentivized and rewarded, it can break discipline, cause dissatisfaction, and reduce trust in leadership.	• **graded system of remuneration and financial compensation**, which includes a base salary, additional payments, bonuses, premiums and other forms of financial incentives; • implementation of **social security packages**, such as: health insurance, retirement benefits, military housing, preferential terms for paying for children's education, etc.; • introduction of a system of **tax incentives and financial packages**: housing loans, mortgages, financial support in case of emergency; • **opportunities for professional development and career growth**, including additional education, advanced training courses, and participation in international exercises and missions; • improvements in **the quality of working conditions and military infrastructure** through modern equipment, improved accommodations on home bases and at military facilities, and the creation of fitness and recreation areas; • implementation of **a recognition and honor system**, which includes awards, honorary titles, distinctions and other forms of public recognition; • ensure **a work-life balance** that allows leaders to have time for family, recreation, and personal growth.
6.	The system of **pre-conscription training** for young people does not address issues of military leadership	• the curricula of general secondary (vocational) education institutions **do not include the topic of military leadership**.	• include in the curricula of general secondary (vocational) education institutions the topic of military leadership **as part of the "Defense of Ukraine"** subject.

Source: suggested by the authors.



Source: suggested by the authors.

Figure 1. Sustainable model of the military leadership system in the Armed Forces of Ukraine

Analyzing the research carried out by Dumenko (2008) it is possible to identify and examine the role and significance of personnel policy in the Armed Forces of Ukraine as part of the overarching reforms. In a number of Ukrainian publications, the authors mainly consider the psychological aspects of the leadership phenomenon but do not provide any ideas on how to establish a military leadership system in Ukraine.

From a practical point of view, it is worth noting that in 2020 Chief of the General Staff of the Armed Forces of Ukraine approved the Doctrine on the Development of Military Leadership in the Armed Forces of Ukraine (2020), and in 2021 a similar publication was produced by the National Guard (2021). Both of the aforementioned documents reflect the system of views on military leadership in their respective organizations, as well as present the basic principles of its development, standards, levels, values, virtues, character traits, and basic competencies of military leaders. In the meantime issues related to the establishment and advancement of the military leadership system in the Armed Forces of Ukraine have been overlooked by most researchers.

Conclusions

The article summarizes the results authors obtained while analyzing the current issues in the field of military leadership. In order to tackle said issues, authors suggest to implement a range of measures to improve the organizational structure, regulatory framework, educational components, methodological materials, and incentive factors with the aim of creating an effective military leadership system in the Armed Forces of Ukraine capable of not only raising the new generation of critical thinkers in leadership, but also supporting them throughout their entire career.

Further research should be aimed at elaborating on the general provisions of doctrinal (conceptual) documents in the field of military leadership in the Armed Forces of Ukraine.

Recommendations

The findings presented in this paper, including the suggested sustainable model for the military leadership in the Armed Forces of Ukraine, analysis of issues in military leader training in the Armed Forces of Ukraine, and ways to tackle them, can be used by military command and control bodies involved in the military leadership development process.

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Ірраціональні війни в контексті сучасної світової геополітичної обстановки: український аспект

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Анотація. Актуальність даної статті обумовлена тим, що сучасні теоретичні пізнання в питаннях розвитку війн та воєнних конфліктів постійно трансформуються під впливом динамічної світової геополітичної обстановки, технологічного розвитку зброї та інформаційних систем, розвитку форм і способів ведення воєнних дій, що, в свою чергу, породжує появу нових видів війн та воєнних конфліктів (проксі, гібридні, інформаційні). Одним із таких нових видів є ірраціональні війни, які мають свої певні особливості їх розв'язання та ведення. З метою ефективної протидії їм необхідно чітко розуміти їх природу та вміти їх відрізнити від інших видів війн та воєнних конфліктів. Тому головною метою статті є розкриття теоретичної та практичної сутності ірраціональних війн та особливостей їх розв'язання і ведення через призму історії з урахуванням особливостей сучасності. Основними методами досліджень є методи аналізу та синтезу, дедукції та індукції, а також методи експертного оцінювання. Основними результатами статті є: концентрація уваги вчених на актуальності дослідження теорії і практики розв'язання та ведення ірраціональних війн; визначення ключових аспектів розвитку понятійно-термінологічного апарату теорії ірраціональних війн та воєнних конфліктів; розроблення алгоритму (послідовності) віднесення війн або воєнних конфліктів до класу "ірраціональних"; визначення та оцінювання керованих та некерованих факторів, які впливають на розв'язання та живлення ірраціональних війн; результати аналізу історичного аспекту ірраціональних війни XX та XXI століття з визначенням війн та конфліктів, які мали в історії признаки ірраціональності; формування спільних та відмінних рис гібридних, ірраціональних та проксі війн і конфліктів; визначення причин, генераторів та двигунів ірраціональних війн та воєнних конфліктів; сформовані наслідки впливу ірраціональної російсько-української війни на геополітичну обстановку у світі, а також визначені запобіжники ірраціональних війн та сформовані рекомендації щодо протидії їх розв'язанню у світі. Матеріали статті можуть бути корисними для керівників країни вищої ланки, вищого командного складу сил оборони та безпеки держави, а також науковцям і дослідникам в галузі національної безпеки та розвитку

оборонної сфери держави.

Ключові слова: збройний конфлікт, геополітична обстановка, ірраціональна війна, ірраціональна збройна агресія, проксі та гібридні війни, національна безпека, форми і способи ведення воєнних дій, російсько-українська війна.

“Перша панацея для погано керованої країни – валютна інфляція, друга – війна; обидві приносять тимчасове процвітання, обидві приносять остаточну загибель” – Ернест Гемінгвей

Вступ (Introduction)

Ймовірно, в жодній галузі суспільних знань не було стільки спотворень або, скажімо, відмінностей в уявленнях, як в оцінках причин виникнення воєн і воєнних конфліктів. Багато чого залежить від погляду, з якого дивитися на події. Вплив особистих і групових амбіцій, мабуть, поширений так само широко, як бажання поставити минуле на службу майбутньому або виправдатися минулим, тобто застосування політичним керівництвом держави так званої “політики пам’яті”. Основними елементами, якої є відволікання уваги від дійсності пам’яттю минулих звершень шляхом перекручування історичних фактів та подій в напрямку створення величі в голові народу з метою формування почуттів терпіння щодо існуючих обмежень якості життя. Сьогодні стає зрозуміло, що росія активно та успішно прокачує технології “політики пам’яті” на своєму суспільстві.

Сьогодні головною, безперечною обставиною війн та воєнних конфліктів XXI століття є ірраціональність агресії як такої. Концентрований вираз людських вад, антиінтелектуалізм та відсутність людяності, ненависть та імперські амбіції, терористичні наміри та пихатість цим сьогодні характеризуються завойовницькі війни. Дії ініціаторів і натхненників обох світових воєн, як зазначалося, у своїй основі суперечили логіці у суспільному розвитку їх країн, логіці історії, хоча вони й ставали частиною історії. Тому перед початком агресій у їх ініціаторів виявлялася маса нерозв’язних проблем, які були нерозв’язні не через якісь особливості, наприклад, погано підрахованого співвідношення військових сил або помилок розвідки, а через щось набагато більше.

У більшості війнах XX та XXI століття сторони, які їх розв’язували ніколи не передбачали загальнолюдського резонансу на вчинене ними. Яскравим прикладом цього є триваюча російсько-українська війна. Реалізація загарбницьких намірів, здійснення масових масштабів знищення людей та інфраструктури неминуче викликає величезні соціальні кризи, психологічну, моральну і фізичну контрдію, яка переростає у загальний неперебірний опір проти війни та сил, що викликали її. За історичним досвідом війн у їх більшості незважаючи на приватні військові успіхи агресора, ірраціональність загального визначала йому кінцеву безвихідь. З одного боку, цілі, які ставили собі завойовники напередодні розв’язання воєн, здавалося б, неминуче викликали дії глобальних масштабів, світовий військовий конфлікт. З іншого боку, агресор постійно плекав мрію все-таки уникнути повномасштабної світової війни, бо побоювався перетнути ту червону межу, за якою може все вибухнути, включаючи його самого. Іншими словами, завжди існує певна межа. Навіть найвідчайдушніші авантюристи розуміють, наскільки велика загроза власної загибелі.

Сьогодні можна це бачити як на поведінці політичного керівництва росії, так їх союзників. Тому вони часто вважають за краще діяти так, щоб порівнювати можливості досягнення своєї мети зусиллями, які не викликали б неприйнятних ситуацій та надмірних протидій. Отже, найкраще як ідеальний, але недосяжний варіант світове панування, але без світової війни.

Актуальність дослідження теорії і практики розв'язання та ведення ірраціональних війн становить важливу проблему в сучасному світі, оскільки ми спостерігаємо зростання конфліктів та війн, які надзвичайно складні, не передбачувані і не завжди підпорядковуються звичайним правилам міжнародного права та логіці війни.

Сьогодні в контексті триваючої російсько-української війни та арабо-ізраїльської війни треба зрозуміти, що крім вивчення проксі війн, гібридних війн, також є необхідним розвиток теорії і практики розв'язання та ведення так званих ірраціональних війн, бо збройна агресія за своєю природою приречена на ірраціональність, а хоча б часткове розуміння послідовності цієї ірраціональності є надзвичайно важливим, бо ірраціональні війни впливають не тільки на сторони які їх ведуть, але й трансформують геополітичну обстановку всього світу.

Нерозуміння точки напруги ірраціональності регіонального конфлікту може призвести до глобальних світових геополітичних змін в світі, яскравим прикладом яких є перша та друга світові війни, тому розуміння проблематики розв'язання та ведення ірраціональних війн становлять суттєву складову дослідження в сучасному світі.

Матеріали та методи (Materials and Methods)

Поняття ірраціональності у війні викликає інтерес не лише в контексті наукових досліджень, але й у сфері прийняття рішень політиками, військовими стратегами та аналітиками.

У світі сьогодні, де глобальні конфлікти та геополітичні напруги залишаються актуальними, дослідження теорії ірраціональних війн стає ключовим для сприяння миротворчості, безпеці та стабільності. Розуміння ірраціональності в війні може допомогти уникнути недоцільних конфліктів та розробити ефективні методи їх врегулювання.

Поняття "ірраціональна війна", може бути визначене різними способами, інтерпретація може варіювати в залежності від контексту. У табл. 1 наведено деякі можливі інтерпретації визначення терміну "ірраціональна війна".

Таблиця 1. Погляди щодо формування визначення "ірраціональної війни"

№	Термін	Визначення
1	Ірраціональна війна	це конфлікт або воєнна операція, яка не має стратегічного сенсу або обґрунтування, або ж обумовлена невірними політичними рішеннями. Ця війна може завдати непотрібних збитків і не мати позитивного впливу на національні інтереси країни, яка її розв'язала.
2		це конфлікт, в якому сторони ведуть війну, ігноруючи альтернативні способи вирішення конфлікту, які можуть бути менш насильницькими і менш руйнівними. Ірраціональні війни можуть бути спричинені емоціями, ідеологією або іншими нераціональними факторами.
3		це конфлікт, в якому сторони намагаються досягнути своїх цілей, не враховуючи вартість цих цілей або можливих наслідків війни. Це може призвести до економічного та соціального руйнування як сторін, що приймають участь, так і геополітичного порядку в регіоні чи світі в цілому.
4		це конфлікт, в якому сторони ведуть війну без належного планування і підготовки, що може призвести до недооцінки ворожих сил та стратегічних помилок.

Ці визначення можуть мати різний акцент і деталізацію, але вони загалом вказують на те, що ірраціональна війна – це війна, яка не відповідає раціональним критеріям, таким як стратегічний розрахунок або досягнення конкретних цілей вартістю відомої величини. Якщо розглядати зв'язок між поняттями "ірраціональна війна" і "ірраціональні числа" тоді його можна зазначити в контексті раціональності та логіки, що можна визначити різні способи визначення "ірраціональної війни", поєднуючи їх з ідеєю ірраціональних чисел, наприклад:

ірраціональна війна як війна без обґрунтування, тобто підходячи з точки зору ірраціональних чисел, ірраціональна війна може визначатися як конфлікт, який не має логічного обґрунтування або стратегічного сенсу, подібно до того, як ірраціональні числа не можуть бути виражені в виді простого дробу і не мають логічної послідовності в цілих числах;

ірраціональна війна як нераціональна діяльність, тобто можна вважати ірраціональною війну такою, яка ведеться без врахування наукових, стратегічних та логічних принципів, подібно до того, як ірраціональні числа не можуть бути виражені в простому вигляді та не піддаються логіці раціональних чисел;

ірраціональна війна як нерозуміння наслідків, тобто ірраціональна війна може вважатися тією, в якій сторони не розуміють повністю можливі наслідки і ризики, схоже на те, як ірраціональні числа можуть призводити до несподіваних математичних результатів.

Отже, в усіх цих визначеннях підкреслюється ідея відсутності логічного, розумового або стратегічного обґрунтування в ірраціональний війні, схоже на те, як ірраціональні числа не можуть бути виражені в простий та раціональний спосіб.

Дослідження історичного аспекту воєн та воєнних конфліктів показує, що внутрішня політика керівництва країн, що починали війну, відігравала величезну роль у їхньому прагненні до зовнішньої агресії. Побоювання соціальних змін у своїх країнах, побоювання назріваючих революційних вибухів, втрати влади, бажання відвернути увагу народу від провалів власної політики та внутрішніх криз, що викликають невдоволення мас, все це так чи інакше позначалося на прийнятті агресивних рішень, а іноді й визначало ці рішення, причому обов'язково під прикриттям націоналістичної пропаганди чи ура-патріотизму, або реалізації технологій так званої "політики пам'яті", а також посилань на територіальну обділеність і несправедливість чи щось ще інше. Історичний досвід показує те, що в свідомості цих осіб спліталося в щось єдине – невиразне бажання розв'язання війни та політичних зрушень в країні. Отже, крім прямих загарбницьких планів свою роль грали передчуття і страх політичного керівництва країни щодо насування перетворення як у країні, так і у світі загалом.

Світові війни стали крайнім засобом боротьби проти горизонтів людського духу, що розсуваються в їх свідомості і розуму, проти прагнення перетворити суспільні відносини, що і було основними ознаками ірраціональності цих війн, які вони запускали. Цілком закономірно, що ті, хто починав їх, зробили жахливо-гіпертрофовану ставку на реакційну силу та її носія мілітаризм, вважаючи, що він чудово може вирішити всі проблеми.

Безумство одних і обмеженість інших породжує те, що при пізнанні історії та сучасності навряд чи є щось важливіше, ніж уміння бачити логічний ланцюг подій та його кінцевий результат. У сучасному світі політичним керівникам необхідно ставати ближче до історизму мислення через літописне відтворення фактів чи абстрагування явищ і процесів.

Під час відповідального підходу одне доповнює інше, одне неможливо без іншого. Лише у злитті обох підходів історія відтворюється у всій наочності та повчальності. Розуміння тонусу часу, психологічного настрою людей часом пояснює події вірніше, ніж існуючі офіційні документи. Віднесення війн або воєнних конфліктів до класу ірраціональних може бути складним завданням і може базуватися на різних підходах. Одним із таких підходів щодо віднесення війн або воєнних конфліктів до класу "ірраціональних" наведений на рис. 1.

Існує деяка кількість ознак, які можуть визначати ірраціональність війни, тобто бути їх джерелом (табл. 2). Загалом, аналіз ірраціональності війни або конфлікту вимагає комплексного підходу та розгляду всіх зазначених ознак та характеристик, оскільки вони можуть варіювати в кожному конкретному випадку. Розв'язання та ведення ірраціональних війн є складними процесами, і вплив на них може бути обумовлений різними факторами (табл. 3). Наведені у табл. 2 фактори класифіковані за групами керованих та некерованих факторів. Загальна важливість факторів може змінюватися в залежності від конкретного конфлікту та географічного регіону. Крім того, важливо враховувати, що ірраціональні війни

є складними явищами, і вплив цих факторів може взаємодіяти між собою. На рис. 2 та рис. 3 наведено результати експертного опитування щодо оцінювання важливості впливу керованих та некерованих факторів на розв'язання та живлення ірраціональних війн за кожною із груп окремо. На рис. 4 наведена загальні оцінки важливості факторів за усю групу керованих та некерованих факторів разом. Зазначена оцінка є загальною і показує, наскільки кожен фактор може впливати на розв'язання та ведення ірраціональних війн. Важливість кожного фактору може коливатися залежно від конкретної ситуації і контексту конфлікту.

Ірраціоналізм російсько-української війни полягає в тому, що вона як і ірраціональні числа має ознаки нескінченності та загрози її нового витка можуть тільки затухати та зростати, в залежності як і в ірраціональних числах випадає кожна наступна цифра в продовження. До основних аспектів прояву ірраціональності в російсько-українській війни можна віднести:

політична складність та відсутність раціональної стратегії. Конфлікт виник після анексії Росією Криму і відкидання анексії міжнародним співтовариством. Після цього війна на сході України почалася, але росія негласно визнала свою участь. Конфлікт не мав чіткої стратегії, і його цілі та обґрунтування залишалися до 2022 року розмитими та неявними. Після розв'язання широкомасштабного вторгнення 24 лютого 2022 року цілі та завдання російсько-української війни мали для росії один напрям, але після значного опору з боку України, цілі війни у керівництва росії постійно трансформувалися або можна сказати адаптувалися до умов воєнної та геополітичної обстановки навколо війни, чим і відображали тенденції приналежності до ірраціональної війни. Не треба забувати, що з часом будь-яка війна гібридизується та набуває циклічного характеру, циклічність та довготривалість війни виникає особливо в тих умовах, якщо країна-агресор не перевищує країну на яку вона напала: понад 5-10 за територією, понад 10 разів за людським капіталом (ресурсом); 5-7 разів за бойовою потужністю (озброєння, техніка, особовий склад збройних сил, запаси); понад 10 разів за економічним потенціалом та 2-3 рази союзниками, які підтримують їх агресію. Яскравим прикладом початку Другої Світової є поступове захоплення Німеччиною країн Європи та пошуку союзників з метою нарощування та досягнення балансу у перерахованих вище показниках для нападу на Радянський Союз. Сьогодні російсько-українська війна володіє усіма признаками ірраціональної, довготривалої та циклічної за активністю воєнних дій війни;

гуманітарні наслідки і великі втрати. Війна призвела до великої кількості жертв, значної кількості внутрішньо переміщених осіб та гуманітарної кризи. Це викликало значні страждання для цивільного населення і не має явних позитивних результатів для населення росії також. Гуманітарні та етнічні кризи виникають як на території України так і росії, бо війна усе сильніше набуває рис ірраціональності, тобто нескінченності, а затягування її формує ірраціональну, тобто нескінченну негативну загальну думку населення країн щодо відношення між ними, яка кожного дня та з кожним вбитим зростає і знешкоджує навіть думку сумісного подальшого існування та співпраці;

міжнародна ізоляція і санкції. Росія стала об'єктом міжнародних санкцій і ізоляції через свої дії в Україні. Це суттєво зашкодило російській економіці та міжнародному статусу, але наявність дешевих природних ресурсів змушує нейтральні та полунейтральні країни до співпраці з росією на користь своєї економіки, тобто росія розглядається як сировинна база постачання природних ресурсів без яких більшість країн Євразії не уявляють своє існування, що також є головним аргументом приналежності російсько-української війни до класу ірраціональних, бо відбувається постійне підживлення нестабільної економіки росії, що сприяє розтягуванню війни у часі та приведення її до нескінченності. Значна кількість країн Євразії проти агресивної війни на території України, але вони за стабільне функціонування своєї економіки навіть в таких умовах, бо стабільність економіки є основним індикатором успішного політичного керівництва правлячими партіями чи окремими політичними лідерами;

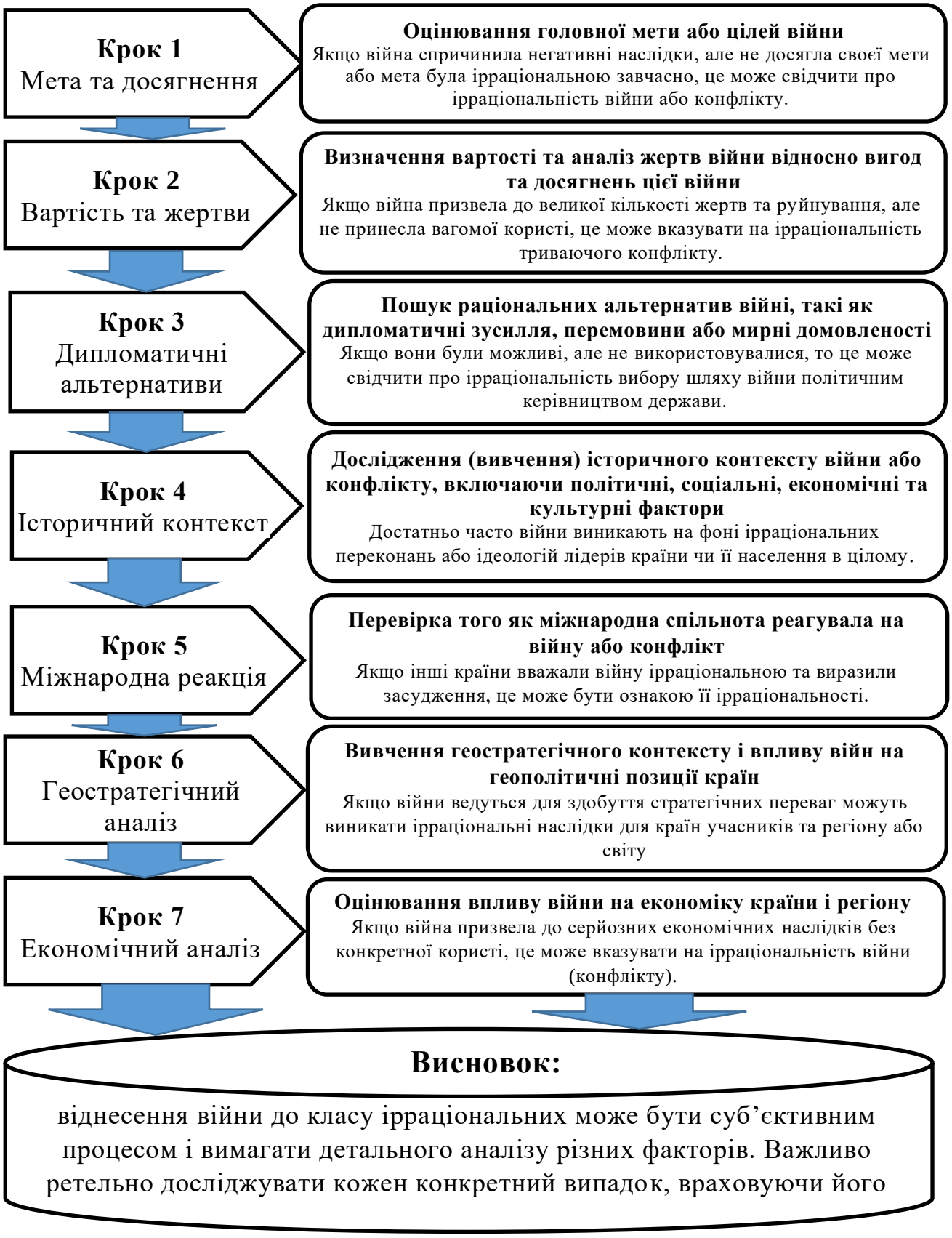


Рисунок 1. Алгоритм (послідовність) віднесення війн або воєнних конфліктів до класу "ірраціональних"

Таблиця 2. Ознаки ірраціональності війни (конфлікту)

Ірраціональність війни ($\sqrt{A \cdot B}$ =ірраціональне число)			
№	Сторона А	№	Сторона В
Критична відмінність релігійних поглядів та напрямів співіснування			
1	Намагання підкорення або насильницька політична співпраця за релігійними принципами, розпалення націоналізму або расизму	1	Інші погляди щодо релігії та центрів віросповідання, розходження політичних інтересів з стороною, наявність власних націоналістичних поглядів
Політичне керівництво			
2	Політичний керівник (керівництво держави), який (і) перебуває довготривалий строк у владі	2	Молодий амбіційний керівник (керівництво держави), який перебуває короткий термін у владі
Підстави війни			
3	Відсутність розумної підстави для війни та прорахунки щодо її кінцевих цілей, недооцінка противника	3	Чітка і зрозуміла ціль щодо захисту країни або звільнення захоплених територій
Співрозмірність країн (території, населення, збройних сил)			
4	території 2-5 разів більше, населення в 3-5 разів більше, збройні сили 2-4 рази більше)	4	території 2-5 разів менше, населення в 3-5 разів менше, збройні сили 2-4 рази менше)
Зброя			
5	Відсутність значної переваги як в кількості (15-20 разів), так і технологічності зброї	5	Програш в кількості зброї противнику, але присутня наявність шляхів її поповнення та наявність технологічної зброї
Дипломатія			
6	Пошук вигідних умов завершення війни	6	Відкидання дипломатичних домовленостей, однобічність бачення умов закінчення війни
Інформаційна обізнаність та моральний потенціал населення			
7	Формування однобічності мислення та низька інформаційна обізнаність населення, розвиток міжетнічної ворожнечі	7	Високий моральний дух нації щодо протистояння ворогу, зростання ненависті до ворога, значні втрати особового складу, героїзм та патріотизм
Співпраця та партнерство			
8	Втрата міжнародної підтримки, зменшення кількості воєнних та економічних партнерів внаслідок незаконних дій, не сприйняття правил міжнародної безпеки	8	Нарощування кількості союзників та партнерів, економічна та воєнна допомога у війні, збільшення міжнародної підтримки передових країн але не введення миротворчих воєнних контингентів
Географічне розташування території країни			
9	Бажання заволодіти вигідними територіями противника (вихід до моря, центральне розташування, заволодіння природними ресурсами тощо)	9	Боротьба за існування держави та її суверенітет, збереження ознак державності та воєнно-політичного керівництва, продовження функціонування економіки
Розмитість та конкретність цілей			
10	Відсутність явної стратегічної вигоди, тобто цілі війни не дозволяють виправдати витрати ресурсів (людських та економічних)	10	Будь-які витрати ресурсів виправдані головною стратегічною ціллю щодо звільнення території держави
Висновок: Наведені ознаки ірраціональності війни підкреслюють складність прийняття розумних, виважених рішень як перед початком війни (конфлікту), так і в умовах її ведення. Наявність значної кількості ознак ірраціональності між двома або декілька країнами сприяють нарощуванню напруги і розв'язанню конфлікту між сторонами, не зводячи до конструктивного вирішення конфлікту. підвищити ризик прийняття невиправданих рішень, які можуть мати серйозні наслідки для всіх сторін конфлікту. Не врахування сторонами А і В ознак ірраціональності створюють середовище невизначеності, яке створює передумови прийняття нерозумних рішень, що приводять до конфлікту без належних обґрунтувань, без розумного підходу до вирішення конфлікту, а також з ознаками нескінченності його тривання.			

Таблиця 3. Керовані та некеровані фактори, які впливають на розв'язання та живлення ірраціональних війн

№	Фактори	Характеристика	Оцінка важливості
Керовані фактори			
1	Політичні рішення	Політичні лідери та уряди можуть приймати рішення, що сприяють ірраціональним війнам, наприклад, через амбіції, релігійні переконання або геополітичні інтереси.	Важливість: висока 0,9
2	Економічні інтереси	Захист економічних інтересів може бути мотивом для ірраціональних війн. Наприклад, контроль над ресурсами або ринками.	Важливість: висока. 0,8
3	Соціокультурні та релігійні фактори	Ідеологія, релігійні погляди та культурні розбіжності можуть призвести до конфліктів.	Важливість: висока. 0,85
4	Збройні сили та військова готовність	Наявність потужних збройних сил та можливість ведення війни впливають на рішення про втручання у конфлікт.	Важливість: висока. 0,75
5	Масові медіа	Засоби масової інформації можуть впливати на публічну думку та допомагати у формуванні військових рішень, але їх роль може варіювати.	Важливість: середня. 0,5
6	Технологічний розвиток	Технологія може впливати на ведення війн, але її роль залежить від контексту конфлікту.	Важливість: середня. 0,6
Некеровані фактори			
1	Етнічні та культурні конфлікти	Наявність етнічних або культурних розбіжностей може сприяти народженню ірраціональних конфліктів.	Важливість: висока. 0,85
2	Соціальна нестабільність	Соціальні проблеми, такі як безробіття, бідність та нерівність, можуть створювати атмосферу нестабільності, що сприяє конфліктам.	Важливість: висока. 0,8
3	Історичні конфлікти	Попередні конфлікти та нерозв'язані справи можуть мати довгостроковий вплив на відносини між країнами або групами.	Важливість: висока. 0,75
4	Геополітичне оточення	Геополітичний контекст, такий як розташування країни в регіоні, може впливати на рішення військових дій.	Важливість: висока. 0,95
5	Екологічні проблеми	Екологічні проблеми, такі як боротьба за доступ до природних ресурсів, можуть викликати ірраціональні війни.	Важливість: середня.0,5
6	Міжнародна співпраця і дипломатія	Міжнародні зусилля з метою запобігання конфліктам та дипломатичні ініціативи можуть зменшувати ірраціональні війни.	Важливість: середня. 0,45

тривалість і загостреність конфлікту. Російсько-український конфлікт (війна) триває вже багато років без чіткого вирішення. Він спричинив значну дестабілізацію та економічний збиток для обох сторін, а також не відновлено відбився на взаємовідносинах росії та України як мінімум на декілька десятиріч, а також безповоротно вплинув на геополітичну обстановку в світі в цілому. Цей історичний факт є застереженням, уроком недбалого ставлення до власної безпеки країни для більшості країн як пострадянського простору, так і країн НАТО. Значна тривалість та загостреність конфлікту завдає безповоротної шкоди екосистемі не тільки України але й світу в цілому, але нажаль поки не відбулося масштабної глобальної екологічної катастрофи світ реагує на війну та її екологічні наслідки дуже кволо. Також тривалість російсько-української війни є позитивною для країн, у яких в економіці мілітаризація є однією

із ключових галузей, але значна тривалість цієї війни є вбивчою для економік більш слабких країн, які не мають своєї сировинної бази та залежні від дотацій країн-донорів.

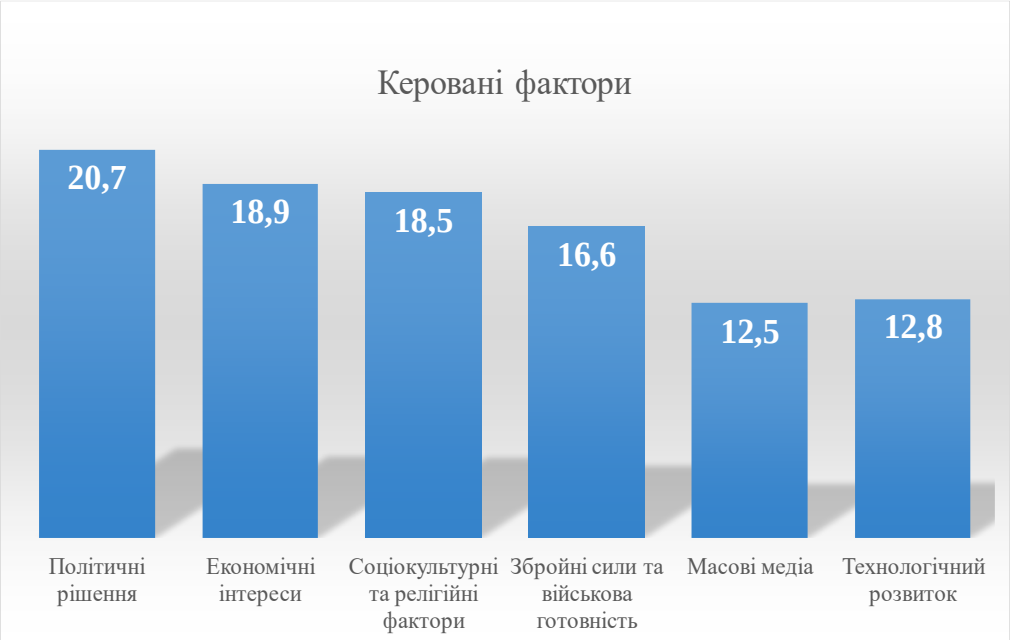


Рисунок 2. Результати оцінювання важливості впливу керованих факторів на розв'язання та живлення ірраціональних війн



Рисунок 3. Результати оцінювання важливості впливу некерованих факторів на розв'язання та живлення ірраціональних війн

Як і ірраціональні числа, які не мають кінцевого знаменника в десятковому представленні, російсько-український конфлікт може продовжуватися на довгострокову

перспективу без чіткого вирішення, що призводить до невизначеності та тривалої нестабільності. Неможливість досягнення сталого миру та стратегічних вигод для будь-якої із ведучих сторін робить цей конфлікт ірраціональним на довгострокову перспективу.

Основними складовими ірраціональних війн є генератори та двигуни таких війн та конфліктів (рис. 5), але запуск генераторів можливий тільки за умови появи основних причин формування підґрунтя для запуску генераторів, які змушують почати працювати основні двигуни ірраціональних війн.

До основних генераторів ірраціональної російсько-української війни можна віднести:

історичне геополітичне становище України, бо її географічне розташування історично викликає погляди інших країн щодо володіння або контролю за цими територіями;

територіальні питання є однією з ключових генеруючих причин конфлікту, бо питання території, зокрема анексія росією Криму і війна проти України – це намагання володіти силою територіями України;

ідеологічні розбіжності, між різними регіонами України щодо подальшого її розвитку та співпраці з іншими країнами;

амбіції російського уряду відносно впливу на своє сусідство та стратегічну позицію в регіоні також відіграли важливу роль у розв'язанні триваючої російсько-української війни;

зовнішні впливи факторів, такі як роль США, Європейського Союзу та інших країн у підтримці України та введення санкцій проти росії, створили генеруючі умови її тривалого продовження.

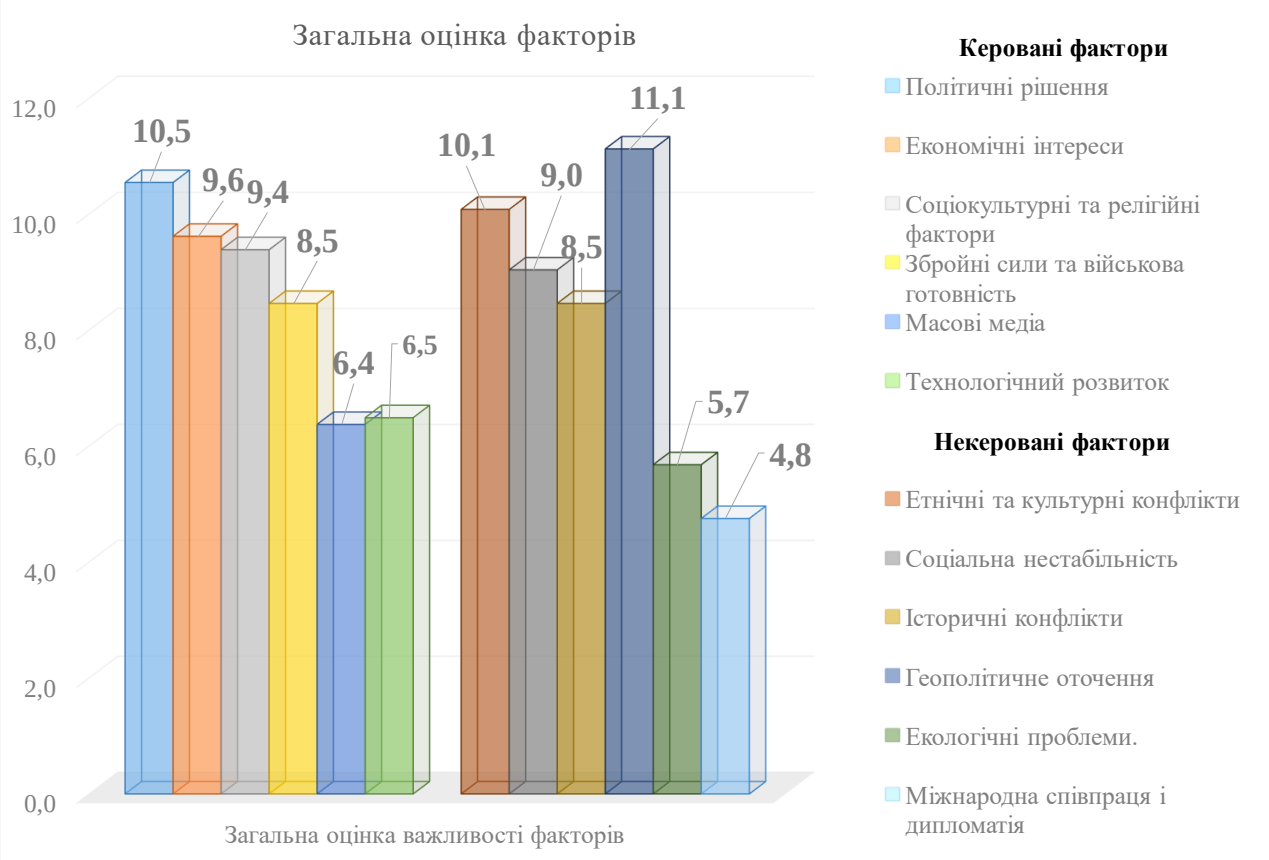


Рисунок 4. Результати оцінювання важливості впливу групи керованих та некерованих факторів на розв'язання та живлення ірраціональних війн (за усю групу факторів в цілому)

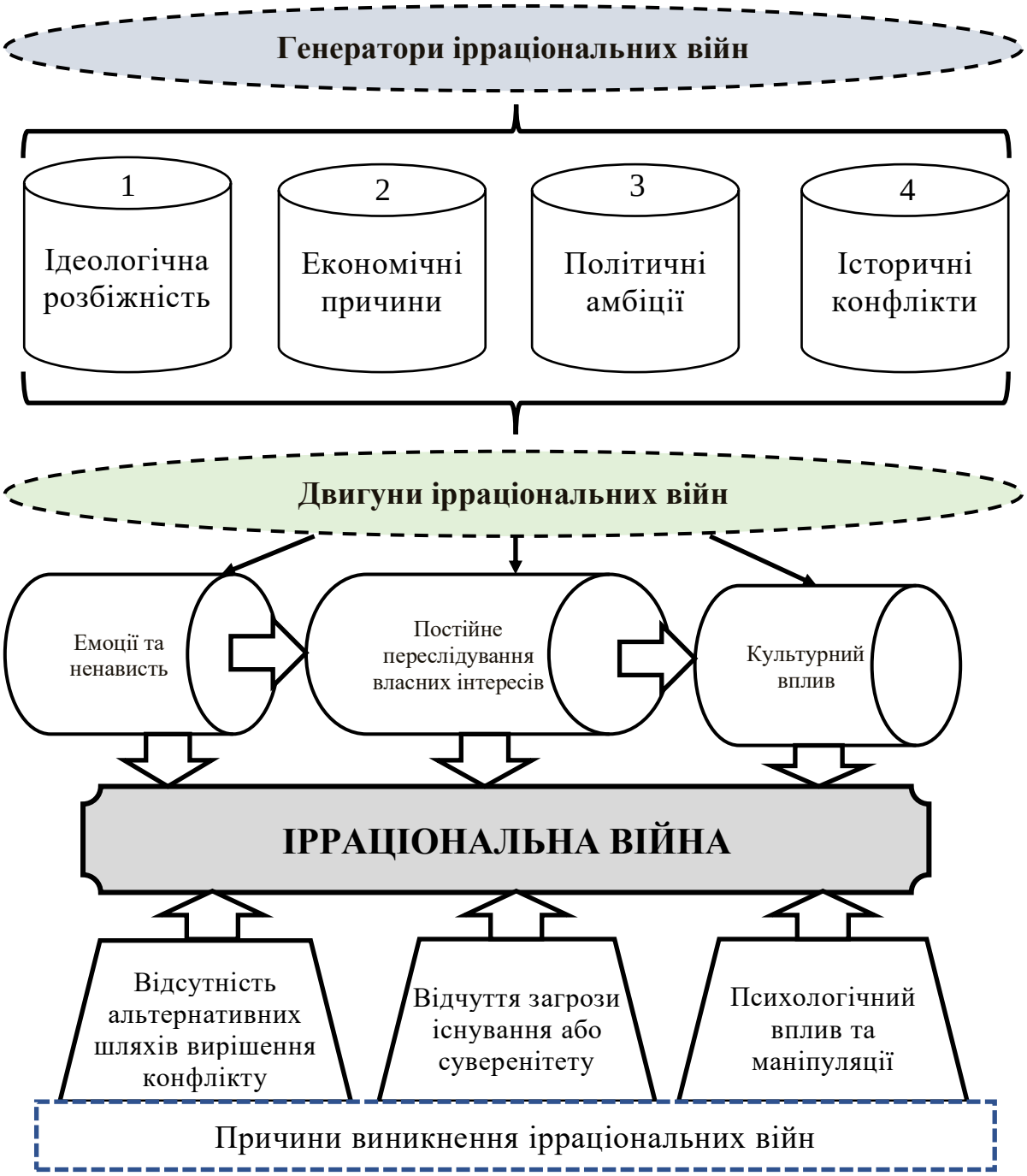


Рисунок 5. Причини, генератори та двигуни ірраціональних війн та воєнних конфліктів

До основних двигунів ірраціональної російсько-української війни можна віднести:

емоційний заряд патріотизму та націоналізму в обох країнах стимулював рухи та дії, які можуть бути ірраціональними та слугуватимуть збудниками щодо нескінченності триваючої війни;.

довготривалі стереотипи, ворожнеча та ненависть, які були вирощені впродовж років, вплинули на психологічний настрій та рішення учасників конфлікту, особливого нарощування ці настрої мали з боку росії до України;

економічні причини, такі як контроль над ресурсами чи економічні санкції, можуть підштовхнути до ірраціональних дій.

Основними елементами ірраціональної російсько-української війни є:

військові операції;

інформаційна війна шляхом застосування дезінформації та пропаганди для маніпулювання суспільною думкою;

гібридна війна, включаючи кібератаки, які відіграють важливу роль у триваючій війні;

гуманітарна криза пов'язана із масовими переселенцями, втратами серед цивільного населення та порушення прав людини;

дипломатичні спроби вирішення конфлікту та співпраця із міжнародними організаціями, яка стала частиною реагування на війну.

Російсько-українська війна є складною ірраціональною війною, яка має численні фактори та виміри. Розуміння причин, генераторів, двигунів та складових цієї війни є важливим для аналізу та розробки стратегій розв'язання триваючого конфлікту та попередження подібних ситуацій у майбутньому.

До основних наслідків ірраціональної російсько-української війни для України та світу можна віднести:

економічні та соціальні наслідки. Війна призвела до серйозних економічних та соціальних втрат для України, включаючи зниження ВВП, руйнування інфраструктури та внутрішнього переміщення населення;

геополітичні впливи. Російсько-українська криза має великий вплив на геополітичну ситуацію в регіоні та міжнародні відносини, відновлення яких сьогодні за більшістю напрямів практично не можливе;

гуманітарна криза, яка обумовлена тим, що російсько-українська війна призвела до гуманітарної кризи з мільйонами внутрішньо переміщених осіб та біженців як по території України, так і усьому світі;

психологічні наслідки. Війна на довгий термін залишить слід на психіці населення, особливо серед дітей та молоді, і чим довше вона триватиме, тим глибше слід і невідворотність глибокого протистояння;

співпраця та реконструкція. У майбутньому важливо співпрацювати з міжнародними партнерами для реконструкції та відновлення України, а також для зміцнення миру та стабільності в регіоні.

Зупинення ірраціональної російсько-української війни вимагає від світових лідерів та керівництва України і її лідерів рішучості, дипломатичної спритності та співпраці з міжнародним співтовариством для досягнення миру та розв'язання конфлікту в інтересах світу в цілому.

У табл. 4 наведено погляди щодо основних наслідків російсько-української війни як для росії так і для України на короткостроковий (1-2 роки), середньостроковий (2-4 роки) та довгостроковий (4-6 років) період.

Загальною тенденцією є те, що тривалість конфлікту підвищує ризики та збитки для обох сторін, які можуть бути економічними, соціальними та політичними. Довгостроковий конфлікт може також призвести до глибших змін у геополітичному ландшафті Європи та світу в цілому, а також створити виклики для міжнародних відносин, які можуть створювати військову напруженість в світі та перерости у війну більш глобального (світового) масштабу.

Результати (Results)

Сучасний світ стикається з ірраціональними війнами, які характеризуються несистемним та хаотичним характером. Ірраціональні війни загрожують світовій стабільності та безпеці. Генератори ірраціональних війн включають територіальні, ідеологічні, економічні та політичні фактори. Двигуни включають націоналістичні та патріотичні настрої, стереотипи та емоції, а також економічні та геополітичні інтереси. Особистості, зокрема політики та лідери, можуть впливати на генерацію та рух конфлікту. Їхні ідеологічні переконання, амбіції та стилі

керівництва важливі для розуміння ірраціональних війн. Ірраціональні війни можуть включати в себе військові операції, інформаційну війну, гуманітарну кризу та дипломатичні зусилля.

Таблиця 4. Ймовірні наслідки російсько-української війни

росія	**Україна**
1-2 роки (короткострокова перспектива)	
збільшення витрат на підтримку війни та санкції можуть продовжити економічний спад; можливий більший внутрішній тиск на владу з боку громадян через втрати та економічні труднощі; погіршення міжнародного іміджу та ізоляція можуть зростати.	додаткові людські та територіальні втрати; економічні та фінансові виклики внаслідок продовження війни; збереження політичної нестабільності та корупції.
2-4 роки (середньострокова перспектива)	
подовження економічних та фінансових труднощів, можливий спад ВВП; посилення міжнародної ізоляції та санкцій; підвищення громадського невдоволення і можливий внутрішній тиск на владу.	збільшення загальних втрат і руйнування; гірша економічна ситуація та вищі соціальні виклики; спроба зміни стратегій та підходів у вирішенні конфлікту.
4-6 років (довгострокова перспектива)	
суттєве погіршення економічного становища та збільшення втрат; збільшення політичного тиску на владу з боку громадян; можливість подальшої повної ізоляції та непереборних санкцій.	глибокі та тривалі втрати, особливо в людях та інфраструктурі; серйозні виклики для економіки та соціальних служб; потреба усилити дипломатичні та миротворчі зусилля для розв'язання конфлікту.
Висновок: У всіх сценаріях тривалості війни, обидві сторони та цивільне населення можуть стикатися зі складнощами, але подовження тривалості війни підвищує загрози та створює серйозні виклики для майбутнього росії та України, а також геополітичної стабільності в цілому.	

Ефективне управління ірраціональною війною або конфліктом, а також їх локалізація та розв'язання вимагають інноваційних підходів, включаючи активну дипломатію, гуманітарну допомогу та співпрацю між міжнародними організаціями. Розуміння генераторів, двигунів та складових ірраціональних війн є ключовим для попередження подібних конфліктів у майбутньому.

Ірраціональні війни визначаються хаотичністю та несистемністю, є справжньою загрозою для глобальної стабільності та миру. Російсько-українська війна служить прикладом складності та тривалості ірраціональних конфліктів. Аналіз цієї війни та інших подібних конфліктів надає можливість зробити наступні висновки:

генератори та двигуни ірраціональних війн включають територіальні, ідеологічні, економічні та політичні фактори. Сильний вплив особистостей, їхні ідеологічні переконання та амбіції поглиблюють ірраціональні війни та конфлікти;

ірраціональні війни включають в себе військові операції, інформаційну війну, гуманітарну кризу та дипломатичні зусилля. Ці конфлікти мають глибокий і багатогранний вплив;

вирішення та управління ірраціональними війнами вимагають комплексних стратегій та інноваційних підходів. Дипломатія, гуманітарна допомога, спостереження, миротворчі операції та міжнародна співпраця є важливими компонентами;

глобальні конфлікти потребують спільних зусиль та співпраці між країнами та міжнародними організаціями. Міжнародна система та правила гри важливі для управління ірраціональними конфліктами;

запобігання ірраціональним війнам передбачає використання дипломатії, міжнародних договорів, гуманітарної допомоги, освіти та демократизації. Важливо попереджати конфлікти замість їхнього розв'язання;

зміни в політичних системах, боротьба з корупцією та розвиток демократії можуть сприяти стабільності та запобіганню конфліктів.

Російсько-українська війна є складним прикладом ірраціонального конфлікту, який вимагає пошуку рішень та спільних дій в міжнародному співтоваристві. Зрозуміння природи та причин ірраціональних війн допомагає розробити стратегії для їх запобігання та розв'язання, а також підтримати світовий мир та стабільність.

Обговорення (Discussions)

Чим сильнішою стає зброя і чим глибші соціальні, економічні та інші наслідки, які здатна викликати світова війна, тим більше побоюється агресор загального апокаліпсису. Ірраціоналізм політичного та військового мислення та дій лідерів країн-агресорів – це не лише властивість особистостей, а й результат усіх зчеплень їх між собою, що логічно випливають одна з одної багатьох подій та обставин. Ставка на світову війну як засіб вирішення політичних проблем програшна сама по собі. Приватне може бути чимось іншим, ніж загальне.

Сьогодні також стає зрозумілим, що свідоме розв'язання завчасно визначеної ірраціональної війни, недооцінка російським лідером можливостей України, її політичного та психологічного настрою, допомоги країн-партнерів також призведе росію та її лідерів до політичної та економічної кризи, наслідки якої будуть довгий час вона долати, а також буде просити про допомогу навіть країни, які зараз стоять на боці України.

Чи можна говорити про логіку війни? У агресорів, які визнають раціональність світової війни, це абсурдна логіка. Вихідні хибні рішення породжують інші, так само хибні. Йде невблаганна ескалація абсурду. Коло ірраціоналізму ширяться до того часу, поки його скріплення не рвуться. Логічною є лише боротьба з агресором.

Висновок (Conclusion)

У статті розкрито основні теоретичні та практичні аспекти ірраціональних війн та визначено особливості їх розв'язання та ведення через призму історії з урахуванням особливостей сучасності. Основними результатами статті є: концентрація уваги вчених на актуальності дослідження теорії і практики розв'язання та ведення ірраціональних війн; визначення ключових аспектів розвитку понятійно-термінологічного апарату теорії "ірраціональних війн" та воєнних конфліктів; розроблення алгоритму (послідовності) віднесення війн або воєнних конфліктів до класу "ірраціональних"; визначення та оцінювання керованих та некерованих факторів, які впливають на розв'язання та живлення ірраціональних війн; формування спільних та відмінних рис гібридних, ірраціональних та проксі війн і конфліктів; визначення причин, генераторів та двигунів ірраціональних війн та воєнних конфліктів; сформовані наслідки впливу ірраціональної російсько-української війни на геополітичну обстановку у світі. Отримані теоретичні та практичні результати проведеного дослідження дозволяють визначити основні та додаткові заходи протидії розв'язанню та призупиненню ірраціональних війн та воєнних конфліктів (табл. 5).

Матеріали статті можуть бути корисними для вищого політичного керівництва держав, їх вищого командного складу, а також науковцям та дослідникам в галузі національної безпеки та розвитку оборонної сфери держави.

Рекомендації (Recommendations)

Ірраціональні війни і конфлікти залишатимуться складними викликами для міжнародної безпеки на довготривалу перспективу. Зростаюча роль кібернетичної безпеки, тероризму,

гібридних конфліктів та релігійних або етнічних напружень вимагатиме надалі вдосконалювати теорію та практику протистояння таким конфліктам.

Перемога у ірраціональній війні вимагає від політичного керівництва країни (Президента), Головнокомандувача збройних сил та військових керівників вищого рівня вжиття різноманітних заходів і дій на декількох рівнях (табл. 5).

Важливість цих заходів залежить від конкретних обставин та характеру конфлікту. Головний принцип полягає в тому, щоб гармонійно поєднувати політичні, військові та дипломатичні зусилля для досягнення перемоги в ірраціональній війні. Також важливо забезпечити ефективне ведення війни, не забуваючи про гідне ставлення до прав людини і міжнародних норм.

Таблиця 5. Заходи щодо досягнення перемоги або призупинення у ірраціональній війні

Рівень управління	Заходи та їх напрями	Їх зміст
Політичне керівництво (Президент, Парламент)	Створення та адаптація стратегічного плану	повинен (повинні) розробити або мати, і усіма способами впроваджувати чіткий стратегічний план ведення війни, включаючи цілі, завдання та пріоритети
	Дипломатія	здійснювати активну дипломатичну роботу для залучення міжнародної підтримки, залучення миротворчих контингентів з метою можливості досягнення мирного розв'язання конфлікту та виходу із війни
	Ефективне управління ресурсами	забезпечувати ефективне використання усіх видів ресурсів (людських, шляхом раціонального розподілу людей за напрямами їх ефективного використання; фінансових шляхом належного фінансування воєнних потреб та забезпечення військовослужбовців; матеріальних шляхом ефективного їх використання як для потреб армії, так і забезпечення життєдіяльності держави в цілому).
	Публічна підтримка	збереження високого рівня підтримки населення для військових дій через ефективну комунікацію та інформаційну кампанію
Головнокомандувач Збройних Сил	Розроблення військової стратегії	визначення основних стратегічних завдань та розробка докладних планів для їх виконання
	Керівництво військами	організація та координація військових операцій, забезпечення надійного командування
	Технічне озброєння та підготовка	забезпечення армії сучасним озброєнням і технікою та надання високоякісної підготовки військових
	Забезпечення безпеки військового персоналу	заходи для збереження життя військовослужбовців, включаючи медичну допомогу та захист
Військові керівники вищого рівня	Розвідка та аналіз інформації	Збір та аналіз інформації про дії противника для прийняття обґрунтованих військових рішень
	Психологічна війна	Використання психологічних та інформаційних методів для впливу на противника та місцеве населення
	Забезпечення логістики	Забезпечення постачання та технічного обслуговування військових підрозділів
	Співпраця з союзниками	Робота з іншими країнами або міжнародними організаціями для спільної боротьби з загрозою

Російсько-українська війна, на жаль, є прикладом ірраціональної війни, і перемога в такому конфлікті або його зупинення на довготривалий період вимагає дуже специфічних заходів та дій. Політичне керівництво країни (Президент), Головнокомандувач ЗС України та військові керівники вищого рівня повинні розглядати в своїй діяльності та вживати таких заходів:

активна дипломатична робота для залучення міжнародної підтримки і відкриття каналів міжнародного тиску на Росію для припинення агресії проти України;

створення ефективної військової стратегії, спрямованої на відстоювання та відсіч російських агресорів;

максимальна мобілізація внутрішніх ресурсів та підтримка населення для забезпечення сил оборони;

реалізація заходів для забезпечення безпеки громадян, включаючи евакуацію із зони конфлікту та захист цивільного населення;

забезпечення гуманітарної допомоги тим, хто потребує, і створення умов для гуманітарних організацій;

максимізація робота з міжнародними союзниками та організаціями для підтримки України та встановлення санкцій проти Росії.

ефективна інформаційна кампанія для відображення істинного стану справ та розкриття російської пропаганди.

У випадку ірраціональних конфліктів, як російсько-українська війна, важливо приймати рішення, які б зменшували людські страждання і сприяли досягненню мирного розв'язання конфлікту. Розвиток дипломатії та міжнародного співробітництва має велике значення для здійснення подібних заходів. Російсько-українська ірраціональна війна є складною ситуацією у сучасному геополітичному середовищі, тому для перемоги у такому конфлікті, або його зупинення на вигідних для України умовах потрібні комплексні дії на всіх рівнях управління державою та її збройних сил. У табл. 6 наведено основні заходи та їх характеристику з оцінкою важливості.

Таблиця 6. Основні заходи наближення перемоги або зупинення російсько-української війни

Рівень управління	Заходи	Їх характеристики	Оцінка важливості заходів
Політичне керівництво (Президент)	Дипломатія та міжнародна підтримка	Активна робота на міжнародній арені для залучення підтримки з інших країн та міжнародних організацій для тиску на росію та пошуку мирного вирішення конфлікту. Спроба укладення перемир'я для зниження насилля та створення умов для переговорів. Робота з міжнародними союзниками та організаціями для підтримки України та залучення міжнародного тиску на росію	Висока. Політичне керівництво повинно координувати всі аспекти державного управління для досягнення перемоги та забезпечення майбутньої стійкості України.
	Політичні реформи	Реформування уряду, боротьба з корупцією та зміцнення демократії для підвищення легітимності та підтримки українського населення	
	Економічна підтримка	Залучення міжнародних інвестицій та розвиток економіки для забезпечення фінансових ресурсів для армії та населення	

Таблиця 6 (закінчення). Основні заходи наближення перемоги або зупинення російсько-української війни

Рівень управління	Заходи	Їх характеристики	Оцінка важливості заходів
Головнокомандувач Збройних Сил	Військова стратегія	Розробка та впровадження ефективної військової стратегії для відстоювання та відсічі російським силам	Критично важливо. Головнокомандувач повинен забезпечити ефективне керівництво та високу готовність військ.
	Військовий координаційний центр	Створення центру для ефективної координації дій українських військ	
	Мобілізація та підготовка	Забезпечення максимальної мобілізації резервів та підготовки військових до ведення бойових операцій	
Військові керівники вищого рівня	Розвідка та аналіз	Збір та аналіз інформації про російські дії та стратегію для прийняття обґрунтованих військових рішень	Висока. Військові керівники повинні забезпечити інтелектуальну підтримку та максимальний ефект в інформаційному полі
	Гуманітарна допомога	Забезпечення гуманітарної допомоги пораненим та переселенцям, а також розміщення громадян в безпеці	
	Інформаційна війна	Ефективна інформаційна кампанія для впливу на громадську думку та підвищення морального духу військових	

Загалом, перемога в російсько-українській ірраціональній війні вимагає комплексу дій, які об'єднують політичну, військову, гуманітарну та інформаційну складові. Важливо також залишати пріоритетом збереження життя та підтримку громадян у надзвичайних обставинах. Зупинення російсько-української ірраціональної війни – це складне завдання, але деякі заходи та дії можуть сприяти зменшенню насилля та пошуку шляхів до мирного врегулювання конфлікту. Однак важливо розуміти, що успіх цих заходів залежатиме від багатьох факторів, і можливо не відбудеться зупинка війни назавжди, бо запущені ірраціональні війни в більшості випадків можуть мати циклічність.

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Irrational wars in the context of the modern world geopolitical situation: the Ukrainian aspect

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Abstract. The relevance of this article is due to the fact that modern theoretical knowledge on the development of wars and military conflicts is constantly transformed under the influence of the dynamic world geopolitical situation, technological development of weapons and information systems, forms and methods of conducting military operations, which in turn gives rise to the emergence of new types of wars and military conflicts (proxy, hybrid, informational). One of these new types is irrational wars, which have their own specific features of their resolution and conduct. In order to effectively counter them, it is necessary to clearly understand their nature and be able to distinguish them from other types of wars and military conflicts. Therefore, the main goal of the article is to reveal the theoretical and practical essence of irrational wars and the peculiarities of their resolution and conduct through the prism of history, taking into account the peculiarities of modernity. The main methods of research are methods of analysis and synthesis, deduction and induction, as well as methods of expert evaluation. The main results of the article are: the concentration of scientists' attention on the relevance of studying the theory and practice of solving and conducting irrational wars; definition of the key aspects of the development of the conceptual and terminological apparatus of the theory of "irrational wars" and military conflicts; development of an algorithm (sequence) for assigning wars or military conflicts to the class of "irrational"; identification and assessment of controllable and uncontrollable factors that influence the resolution and fueling of irrational wars; analysis of the historical aspect of irrational wars of the 20th and 21st centuries with the definition of wars and conflicts that had signs of irrationality in history; formation of common and distinctive features of hybrid, irrational and proxy wars and conflicts; determining the causes, generators and engines of irrational wars and military conflicts; formed the consequences of the impact of the irrational Russian-Ukrainian war on the geopolitical situation in the world, as well as identified safeguards of irrational wars and formed recommendations on countering their outbreak in the world. The materials of the article can be useful for the country's top leaders, the top command staff of the defense and security forces of the state, as well as scientists and researchers in the field of national security and the development of the defense sphere of the state.

Keywords: armed conflict, geopolitical situation, irrational war, irrational armed aggression, proxy and hybrid wars, National security, forms and methods of conducting military operations, russian-Ukrainian war.

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Основні положення когнітивно-динамічного підходу до прогнозування воєнно-політичної обстановки в регіоні

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Анотація. Актуальність дослідження обумовлена необхідністю здійснення оцінювання та прогнозування воєнно-політичної обстановки з метою своєчасного реагування на її можливі зміни.

У статті розкриваються основні положення когнітивно-динамічного підходу до прогнозування воєнно-політичної обстановки в регіоні. Він базується на комплексному застосуванні когнітивного моделювання, системної динаміки, теорії планування експерименту, методу групового урахування аргументів та методів аналізу часових рядів. У ньому реалізується новий підхід до когнітивного моделювання складних воєнно-політичних процесів, що дозволяє будувати ієрархічні моделі з функціональними зв'язками замість знако-вагових. Запропонований підхід дає можливість врахувати під час моделювання максимальну кількість суттєвих зв'язків між показниками (факторами), а також зв'язків між сферами (зрізами), які описують функціонування елементів досліджуваної системи, при цьому вперше запропоновано порядок визначення впливу показників (факторів) один на одного, який враховує весь можливий спектр таких впливів, у тому числі опосередковані та автовпливи, а також можливий час затримки реалізації стратегії протидії, що більш точно відбиває реальні процеси, коли реакція системи на збудження не може бути миттєвою.

Основу підходу становить комплексне використання теорії планування експериментів та методу групового урахування аргументів для побудови функцій, які описують апріорно невідомі залежності між значеннями параметрів побудованої когнітивної моделі системи воєнно-політичних відносин та результатами її функціонування, а також систем диференціальних рівнянь, які будуються з використанням теорії графів і системної динаміки.

За допомогою когнітивно-динамічного підходу можуть бути розроблені комплекси прогнозів: пошуковий експрес- та ієрархічний, а також нормативний прогноз із наступним обчисленням та аналізом характеристик динаміки отриманих часових рядів для розроблення заходів із забезпечення потрібного рівня воєнної безпеки держави.

Ключові слова: когнітивно-динамічний підхід, воєнно-політична обстановка, прогнозування, часові ряди.

Вступ (Introduction)

Останні роки XX та початку XXI сторіччя характеризуються різкими змінами у політичному житті як усієї планети загалом, так і окремих її регіонів. У ході сучасних міждержавних стосунків виявляється чимало політичних, економічних та інших суперечностей.

Сьогодні жодна держава не в змозі захистити себе, використовуючи лише військово-технічні засоби. Забезпечення безпеки дедалі більше стає комплексним завданням, яке включає політичні, економічні, інформаційні та інші заходи. Успішно виконувати це завдання вдається завдяки широкому використанню економічних, дипломатичних та інших несилових засобів, а також інформаційних технологій. Для організації успішної протидії необхідно розуміти геополітичні та воєнно-політичні процеси, що відбуваються навколо та за участі України.

У зв'язку з цим актуальним є питання про воєнно-політичну обстановку (ВПО) у регіоні навколо України, про спектр небезпек та загроз воєнного характеру, їх масштаб та динаміку змін у часі. Однак до теперішнього часу питання розроблення методологічного апарату оцінювання, моніторингу та прогнозування воєнно-політичної обстановки, а також прийняття рішень із забезпечення національної безпеки досліджені недостатньо.

Питанням оцінювання ВПО присвячено багато робіт як в Україні, так і в інших країнах. Так В. Богданович (2019) пропонує загальний підхід до оцінювання комплексного впливу військових та невійськових засобів на стан воєнної безпеки та воєнну-політичну обстановку. Семенюк Ю. (2020) визначає основні складові суспільно-політичної обстановки та їх вплив на воєнну безпеку держави. Стичинська А. (2022) наголошує на важливості військово-політичного прогнозування для підвищення ґрунтовності прийняття політичних рішень. У монографіях (Romanchenko, 2023) та (Романченко, 2021) досліджуються різні аспекти національної та воєнної безпеки, пропонуються методичні підходи щодо їх аналізу та прогнозування. В своїх роботах Бочарніков В. (2019) визначає головні тенденції, які визначатимуть стан майбутнього світового середовища безпеки та його проекцію на безпеку у регіоні довкола України, а також робить прогноз розвитку воєнно-політичної обстановки.

Однак ці роботи здебільшого мають загальнотеоретичний характер та не дають відповіді, яким саме чином можна спрогнозувати можливе загострення ВПО, що може призвести до збройного конфлікту, та забезпечити підґрунтя для розроблення рекомендацій щодо її стабілізації. Значним недоліком у цьому плані є відсутність досконалого підходу, який би гарантував виявлення небезпек та загроз на ранніх стадіях їх виникнення, оцінювання та прогнозування динаміки їх рівня з урахуванням специфіки регіону, конфлікту геополітичних, економічних, воєнних та інших інтересів як держав – членів регіону, так і провідних держав світу, інтереси яких проектуються на цей регіон, з тим, щоб завчасно адаптувати систему забезпечення національної (воєнної) безпеки України до виявлених прогресуючих загроз воєнного характеру, що й обумовлює актуальність статті.

Методологічна основа (Methodological Framework)

Традиційні підходи до оцінювання ВПО зазвичай оперують відносно невеликою кількістю факторів та спрямовані на формування її якісного опису, при цьому важко дати чітку оцінку – наскільки загострилась ВПО, в якій сфері найбільші загрози та куди спрямувати ресурси для запобігання виникненню конфлікту. Тому для усунення зазначених недоліків пропонується когнітивно-динамічний підхід прогнозування ВПО, який ґрунтується на когнітивному моделюванні та системній динаміці, а також теорії планування експериментів і методі групового урахування аргументів.

Під ВПО розуміється історично конкретна сукупність умов і факторів, пов'язаних з розміщенням воєнно-політичних сил, характером їх дій і станом відносин між ними, використанням військової сили в політичних цілях (Піча, 2020).

Зазвичай ВПО оцінюється в якісних показниках – *звичайна*, *загострена*, *кризова*, *збройного конфлікту* або *кооперaційна* чи *конфронтаційна* (Богданович, 2019). За такого підходу важко дати відповідь щодо тенденцій розвитку ВПО та моменту переходу з одного стану до іншого.

Тому пропонується використовувати поняття *стан ВПО*, який є числовим еквівалентом відповідного якісного показника та характеризує сукупність обставин існування ВПО (Соломицький, 2020). Такий показник дозволить формалізувати оцінювання ВПО та здійснювати прогнозування тенденцій її розвитку.

Результати і обговорення (Results and Discussions)

Оцінювання та прогнозування воєнно-політичної обстановки доцільно проводити в межах геополітичного регіону, який включає власне державу та її оточення, з урахуванням впливу позарегіональних центрів сили, організацій та недержавних акторів.

Загальну схему запропонованого підходу наведено на рис. 1.

На першому етапі відбувається побудова когнітивної моделі воєнно-політичних відносин у регіоні, що досліджується (Соломицький, 2020).

Процес побудови когнітивної карти складається з таких етапів:

1. Виокремлення факторів, що характеризують проблемну ситуацію.

1.1. Виокремлення базисних факторів (концептів), що описують суть проблеми. Виокремлення із сукупності базисних цільових факторів, стан яких бажано змінити.

1.2. Визначення факторів впливу, які в моделі будуть потенційно можливими важелями впливу на ситуацію (параметрами управління).

1.3. Визначення індикаторів (параметрів) факторів та процесів, що відображають і пояснюють динаміку розвитку проблемної ситуації. Групування в окремі блоки факторів, що характеризують певну сферу проблеми (геополітичну, макро- і мікроекономічну, соціальну, екологічну, демографічну, галузеву, регіональну тощо).

2. Групування факторів за блоками.

2.1. Виділення для кожного блоку часткових показників, які детально характеризують тенденції та процеси, що досліджуються.

2.2. Побудова для кожного блоку групи інтегральних показників, за якими можна судити про загальні тенденції у певній сфері.

2.3. Визначення шкал вимірювання для побудованих показників.

3. Визначення зв'язків між факторами.

3.1. Визначення напряму впливів і взаємовпливу між факторами.

3.2. Визначення характеру впливу (позитивний, негативний).

3.3. Визначення сили впливу і взаємовпливу факторів (зокрема, у термінах лінгвістичних змінних).

3.4. Визначення зв'язків між факторами різних блоків.

При виборі досліджуваних факторів доцільно обрати тільки ті, що мають значний вплив на систему в цілому.

При цьому, на відміну від існуючих підходів до побудови когнітивних моделей:

– для опису структури воєнно-політичних відносин застосуємо ієрархічні когнітивні карти (кількість ієрархічних рівнів може визначатися потрібним рівнем деталізації під час досліджень), в результаті чого отримаємо складний багаторівневий орієнтований граф;

– для опису зв'язків у моделі будемо використовувати когнітивну модель типу "векторний функціональний граф", де кожен зі зв'язків (дуг) отриманого графа описується функцією;

– для відображення динаміки функціонування системи під впливом факторів у модель уводиться час.

– для визначення вагових коефіцієнтів здійснюється розширений аналіз зв'язків між вершинами (можливі впливи трьох видів, для яких визначаються відповідні вагові коефіцієнти: автовплив (вплив фактору (зрізу, сфери) самого на себе), характеризує зусилля національного уряду, спрямовані на підтримання (розвиток) цього фактору; вплив фактору самого на себе через вплив на інший фактор, характеризує можливі зміни фактору через спробу вплинути на інший фактор; вплив фактору на інший фактор, відповідно до класичного підходу характеризує вплив одного фактору на інший);

– під час опису зв'язків передбачимо можливу часову затримку у реакції однієї сторони на дії іншої – *час реалізації стратегій протидії*. Урахування цього часу дозволить більш точно описувати реальні процеси, що відбуваються, та пояснювати, чому навіть за наявності потрібних сил, засобів та ресурсів одна сторона воєнно-політичних відносин не здатна адекватно реагувати на дії іншої держави;

– під час побудови ієрархічної когнітивної карти будемо враховувати не тільки зв'язки всередині одного зрізу (сфери), а й вплив між зрізами як у межах однієї держави, так і між різними зрізами (одно- та різнойменними) різних держав (Shebanin, 2022) та (Forrester, 1961).

На відміну від існуючих підходів до побудови когнітивних карт пропонується новий підхід щодо визначення вагових коефіцієнтів ω_{ij}.

Він полягає у розширеному аналізі зв'язків між вершинами, за якого оцінюється не тільки прямий вплив одного фактору на інший, але й зворотній вплив першого фактору самого на себе внаслідок цього. Тобто кожний зі зв'язків буде характеризуватися двома ваговими коефіцієнтами. При цьому, ці коефіцієнти можуть змінюватися в часі дискретно або за певним законом.

Однак, воєнно-політичним процесам притаманні багатовимірність, тому пропонується, за необхідності, для кожного з елементів побудувати древо цілей. Тобто значення кожного з визначених елементів може бути функцією від певного набору показників нижчого рівня.

Для врахування цього пропонується перейти до ієрархічної (багаторівневої) когнітивної карти. Тобто для кожного з елементів визначається перелік показників, від яких залежить його значення. Така процедура може повторюватися до досягнення потрібного рівня деталізації.

Важливим елементом перевірки працездатності побудованої когнітивної карти є її статичний аналіз, який у загальному випадку складається з таких етапів:

1. Визначення підсумкового (сукупного) взаємовпливу факторів один на одного, враховуючи як прямий вплив, так і опосередкований, коли один фактор впливає на інший через ланцюжок проміжних факторів. На цій основі будується матриця взаємовпливу.

2. Розрахунок системних показників когнітивної карти за побудованою матрицею підсумкового взаємовпливу, таких як вплив фактора на систему та вплив системи на фактор.

3. Аналіз взаємовпливу факторів один на одного.

Побудована когнітивна модель має бути перевірена на структурну стійкість та стійкість по збудженню (Grzesik, 2020). Тобто пропонується розглядати два аспекти поняття "стійкість": стійкість системи під впливом зовнішніх збурювань при фіксованій структурі системи (це ситуація, коли змінюється тільки зовнішнє середовище), і стійкість поведінки системи при змінах структури системи – структурна стійкість (це коли малі зміни в структурі системи викликають малі зміни в її динаміці). Якщо вона відповідає вимогам якості то модель може розглядатися як початкова для подальших досліджень, формалізації та обчислень.

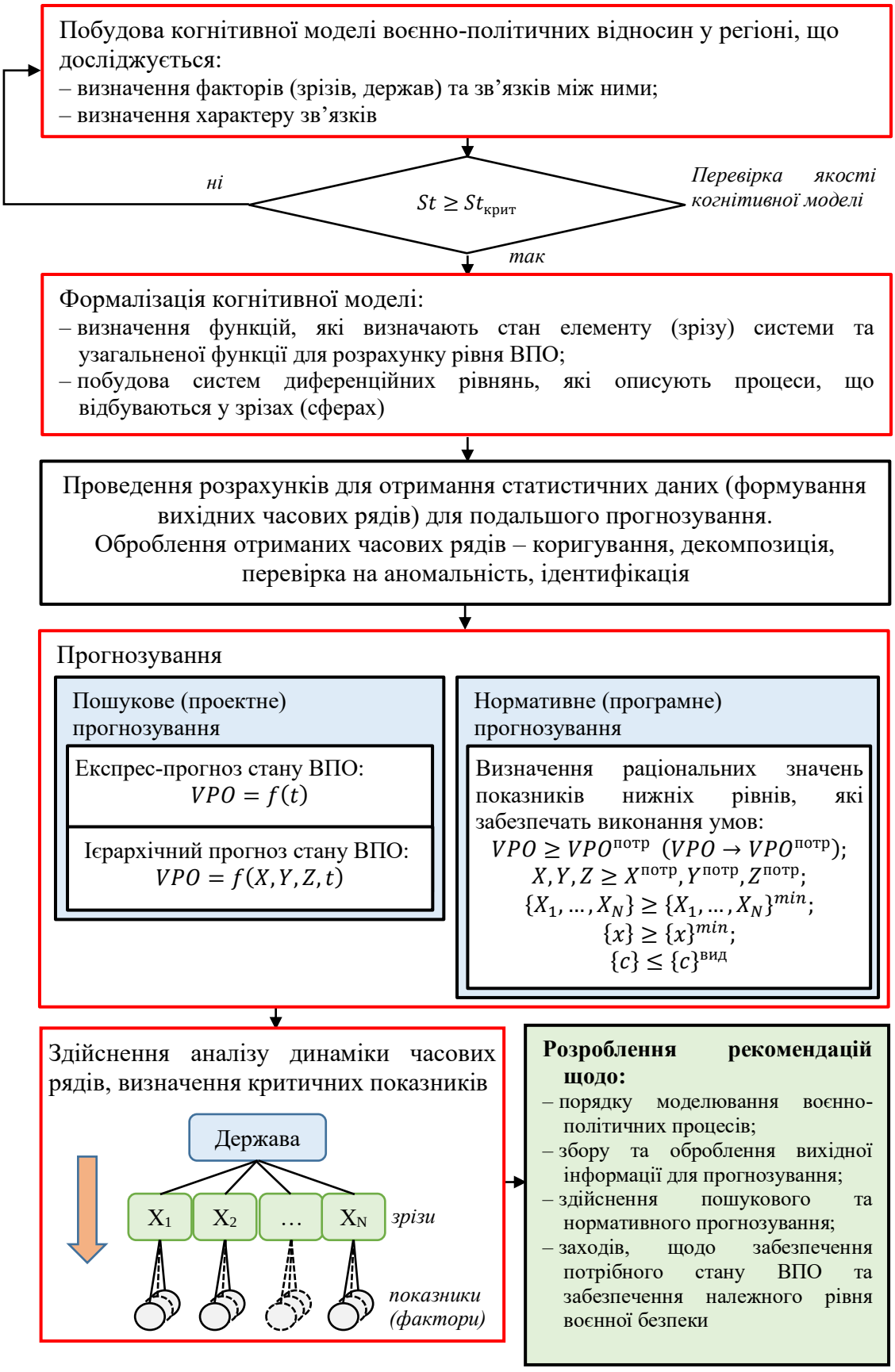


Рисунок 1. Загальна схема когнітивно-динамічного методу прогнозування ВПО в регіоні

Наступним етапом є формалізація побудованої когнітивної моделі та визначення вигляду функціональних зв'язків між елементами та функцій, які описують стан кожного з елементів. Для цього пропонується підхід, детально викладений у (Соломицький, 2020), який полягає у визначенні апріорно невідомої залежності між вхідними та вихідними змінними на основі комплексного застосування теорії планування експерименту, експертного опитування та методу групового урахування аргументів (МГУА) (Ивахненко, 1982).

Для подальшого оцінювання воєнно-політичних процесів, які відбуваються в досліджуваній системі в часі, пропонується побудувати відповідну систему диференціальних рівнянь. З цією метою використаємо положення теорії диференціальних рівнянь на графах (Копась, 2018) та (Курбатова, 2020).

З огляду на те, що вже маємо орієнтований граф, то можемо зв'язати властивості рішення системи рівнянь з геометричними властивостями графа. Відповідно до (Копась, 2018) важливі властивості рішень визначаються тільки геометрією графа та не залежать від вигляду функцій якими описується стан його вершин. Задача дослідження воєнно-політичних процесів за наведеним вище підходом наближена до типової постановки задачі побудови систем диференціальних рівнянь на мережах, пов'язаної з вивченням гідромереж, у скалярній постановці.

Для безпосередньої побудови диференціальних рівнянь, які будуть описувати поведінку елементів графа в часі, використаємо формальне правило для запису системи диференціальних рівнянь (Копась, 2018). При цьому як імовірності станів буде розглядатися безпосередньо стан вершини (елемента) системи, а як інтенсивність переходу – ступінь впливу вершин однієї на іншу. Тобто у лівій частині буде знаходитися похідна *i*-го елементу, а в правій – сума добутків станів, з яких виходять зв'язки в цей елемент, на ступені впливу відповідних зв'язків, мінус сумарна ступінь впливу всіх зв'язків, які виходять з цього елементу помножена на значення цього стану.

Формалізована таким чином когнітивна модель дозволяє проводити розрахунки значень відповідних показників, які характеризують стан елементів системи та системи у цілому, що дає змогу отримати вихідні статистичні дані для певного періоду часу – часові ряди. Вони піддаються стандартній обробці (коригування, декомпозиція, перевірка на аномальність і нестаціонарність) та приведенню до єдиного вигляду (Юрченко, 2018).

Отримані часові ряди є вихідними даними безпосередньо для побудови прогнозу. Однак, для прогнозування необхідно визначити його принципову можливість, тобто визначити наявність певного тренду. Для такого передпрогнозного аналізу доцільно використовувати статистику Херста – "нормований розмах", якій дозволяє встановити факт присутності тренду в часовому ряду.

На відміну від існуючих підходів, пропонується розробляти одразу два типи прогнозу, які відрізняються за проблемно-цільовим критерієм (мета розроблення прогнозу):

– пошуковий (дослідницький) – визначення можливих станів системи (явища) в майбутньому;

– нормативний – визначення шляхів і термінів досягнення можливих станів системи (явища), прийнятих як мета.

Розроблення пошукового прогнозу здійснюється за допомогою МГУА. Однак слід зауважити, що в рамках цього прогнозування можуть розроблятися декілька підтипів пошукових прогнозів: оперативний (експрес); ієрархічний (для відповідної кількості рівнів).

Для оперативного прогнозування будується прогноз часового ряду рівнів ВПО, отриманих за допомогою створеної раніше моделі. Він зазвичай має невисоку точність, але дозволяє робити попередній аналіз щодо тенденцій розвитку ВПО та готувати відповідні рекомендації.

Ієрархічний прогноз будується відповідно до ієрархії розробленої моделі послідовно від нижніх рівнів, коли прогнозуються змінення кожного з показників, а вже на основі отриманих даних розраховуються показники вищих рівнів, тобто послідовно розраховується ланцюг "показник-група показників-зріз-держава-ВПО":

$$VPO = f(X, Y, Z, t),$$

де X, Y, Z – показники, які характеризують стан держави (її внесок у стан ВПО) та, у загальному випадку, є функціями від показників нижчого рівня, наприклад: $X = f(\{X\}, \{Y\}, \{Z\}, t)$ – залежність стану держави X від станів зрізів $\{X\}, \{Y\}, \{Z\}$ та часу;

t – час.

Такий прогноз має більш високу точність, ніж експрес, та дозволяє визначати критичні показники й розробляти більш обґрунтовані рекомендації щодо протидії можливим загрозам.

Нормативне прогнозування, як згадувалося вище, має визначити, яких значень мають набути відповідні показники, з тих, що впливають на стан ВПО, для того, щоб стан ВПО в регіоні досягнув потрібної величини ($VPO^{\text{потр}}$). Тобто:

$$VPO = f(X, Y, Z, t) \geq VPO^{\text{потр}},$$

за умови, що показники нижчих рівнів будуть не менші за мінімально припустимі, а обсяги ресурсів або не перевищують виділені, або мінімальні.

Для задачі, що розглядається, як алгоритму пошукової оптимізації пропонується використовувати QUEST процедуру пошуку (OptQuest, 2023).

Вона не обов'язково гарантує досягнення точного оптимуму, але знаходить близькі до оптимальних рішення й при цьому забезпечує швидку пошукову збіжність алгоритму. Ця процедура використовує результати пошуку для "самонавчання", що дозволяє виконувати інтелектуальний пошук наступного набору альтернатив. Якщо альтернатива в її просторі пошуку не відповідає визначеним користувачем обмеженням, вона автоматично виключається, і досліджуються інші варіанти, які з більшою ймовірністю задовольняють вимогам. У процедурі оптимізації використовуються вхідні дані моделі поведінки для оцінки вхідних даних моделі. Процедура оптимізації виконує спеціальний "немонотонний пошук", коли в результаті послідовно створюваних вхідних даних утворюються різні оцінки, не всі з яких – убік поліпшення, але які згодом забезпечують високоефективний шлях до найкращих рішень.

Результати оптимізації слугують підґрунтям для прийняття рішення щодо вжиття заходів для забезпечення потрібного стану ВПО. Вони визначають, які саме показники та на якому рівні доцільно мати для забезпечення досягнення поставленої мети.

Для розроблення рекомендацій щодо забезпечення потрібного стану ВПО необхідно здійснити аналіз динаміки відповідних воєнно-політичних процесів, значення яких були спрогнозовані. Тобто абсолютні рівні моментальних або інтервальних часових рядів, а також рівні середніх величин необхідно перетворити на відносні величини (Юрченко, 2018).

Пропонується здійснювати подібний аналіз за такими характеристиками динаміки часового ряду: абсолютний приріст; коефіцієнт зростання; коефіцієнт приросту; темп зростання; темп приросту; тощо.

Крім цього пропонується визначити множину критичних показників шляхом порівняння числових значень показників на кожному з рівнів, що досліджуються, з граничними значеннями цих характеристик. Вибір конкретних граничних значень показників доцільно залишити за експертами або особою, що приймає рішення, виходячи з поставлених перед ними цілей щодо наступного розвитку країни, і системи критеріїв, якими вони керуються.

Тобто:

$$g_h \leq g_h^{\text{гр}} \begin{cases} \text{так}, g_h \in G^{\text{крит}}; \\ \text{ні}, g_h \notin G^{\text{крит}}, \end{cases}$$

де g_h – значення будь-якого -го показника;
$g_h^{\text{гр}}$ – прийняте граничне значення h-го показника;
$G^{\text{крит}}$ – множина критичних показників.

За результатами проведеного пошукового та нормативного прогнозування ВПО в регіоні, групах країн, внутрішніх ситуацій в окремих країнах, а також аналізу характеристик динаміки часового ряду приймаються рішення щодо необхідних заходів для забезпечення воєнної безпеки держави.

Висновки (Conclusion)

Запропонований когнітивно-динамічний підхід дозволяє розв'язати задачу оцінювання та прогнозування воєнно-політичної обстановки.

Новизна підходу полягає у:

– використанні нового підходу до когнітивного моделювання складних воєнно-політичних процесів, що дозволяє будувати ієрархічні моделі, де використовуються функціональні зв'язки замість знако-вагових;

– вперше запропонованому підході до визначення впливу показників (факторів) один на одного, який враховує весь можливий спектр таких впливів;

– комплексному використанні теорії планування експериментів та МГУА для побудови функцій, які описують апріорно невідомі залежності між значеннями параметрів системи та результатами її функціонування;

– комплексному застосуванні систем диференціальних рівнянь, які будуються з використанням теорії графів і системної динаміки, та функціоналів для опису перебігу воєнно-політичних процесів у часі;

– розробленні комплексу прогнозів: пошукового експрес-прогнозу, пошукового ієрархічного прогнозу та нормативного прогнозу, з наступним аналізом характеристик динаміки отриманих часових рядів та визначенням критичних показників.

Напрямами подальших досліджень може бути розроблення, на основі отриманих даних, рекомендацій щодо порядку моделювання воєнно-політичних процесів.

Рекомендації (Recommendations)

Матеріали статті можуть бути використані під час підготовки пропозицій щодо формування і реалізації воєнної політики України. Стаття також може бути корисна для фахівців інформаційно-аналітичних служб, науковців і аналітиків, які причетні до вироблення і обґрунтування державних рішень у воєнно-політичній сфері, для викладацького складу і слухачів вищих воєнно-навчальних закладів.

Використані джерела

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The Main Provisions of the Cognitive-Dynamic Approach to Forecasting the Military-Political Situation in the Region

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Abstract. The relevance of the study is due to the need to assess and forecast the military-political situation in order to respond in a timely manner to its possible changes.

The article reveals the main provisions of the cognitive-dynamic approach to forecasting the

military-political situation in the region. It is based on the complex application of cognitive modeling, system dynamics, experiment design theory, the method of group consideration of arguments and methods of time series analysis. It implements a new approach to cognitive modeling of complex military-political processes, which makes it possible to build hierarchical models with functional connections instead of sign-weight ones. The proposed approach makes it possible to take into account during modeling the maximum number of significant relationships between indicators (factors), as well as connections between spheres (slices) that describe the functioning of the elements of the system under study, while for the first time the procedure for determining the influence of indicators (factors) on each other is proposed, which takes into account the entire possible range of such influences, including indirect and auto-influences, as well as the possible time of delay in the implementation of the counteraction strategy. which more accurately reflects the real processes when the system's reaction to excitation cannot be instantaneous.

The basis of the approach is the complex use of the theory of experimental design and the method of group consideration of arguments for the construction of functions that describe a priori unknown dependencies between the values of the parameters of the constructed cognitive model of the system of military-political relations and the results of its functioning, as well as systems of differential equations, which are built using graph theory and system dynamics.

With the help of the cognitive-dynamic approach, complexes of forecasts can be developed: exploratory express and hierarchical, as well as normative forecast with subsequent calculation and analysis of the characteristics of the dynamics of the obtained time series for the development of measures to ensure the required level of military security of the state.

Keywords: cognitive-dynamic approach, military-political situation, forecasting, time series.

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Ontology of the Military Component of the Economic Security System of Ukraine

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Abstract. Given the changes in the resolution of global problems and conflicts, as well as the current geopolitical landscape, it is imperative for state leaders to reassess the importance of developing long-term economic sectors as components of the state's economic security. This is due to the shift from non-military means of resolving conflicts between countries to reliance on military measures. The temporary occupation of part of the territory of Ukraine and the resulting armed conflict necessitates a review and clarification of the military-economic component as an element of the state's economic security.

The article provides an analysis of different views on the components of the state's economic security. Having studied the use of mathematical methods in determining the level of economic security in Ukraine, the authors analyse the chronological changes in the results and identify differences in experts' opinions on its components. According to the current needs, the authors

determine the weight of each component in the aggregate, thus highlighting the military-economic aspect as the most important element of economic security in the legislation. In order to substantiate the importance of the military component in the system of economic security of the state, the authors propose to compare the coefficients of variation (a relative indicator characterising the variability of a feature), correlation (a measure of the relationship between two variables) and stability of the relationship.

By applying these coefficients, it became possible to determine the weight of individual elements in their aggregate, based on the nature of their impact on fluctuations in the level of economic stability in Ukraine, as outlined by the current methodologies used to calculate it. This method makes it possible to strengthen the identification of problems arising at the stages of medium- and long-term planning of priority sectors of the economy, while considering the relevance of the components of the economic security of the State.

Keywords: military security, economic security, weighting coefficient, stability of communication.

Introduction

The first attempts to develop a well-structured framework for calculating economic security in Ukraine date back to twenty years ago. Over the course of these two decades, a number of publications have been produced on the topic, most notably: Economic Security of Ukraine in the Context of Globalization and the Development of Crisis Processes in the World Economy, a publication containing methodological guidelines included in the list of scientific projects of the National Security and Defense Council of Ukraine for 2001-2008 (Methodological guidelines for calculating the level of economic security of Ukraine (2003) and methodology for calculating the level of economic security of Ukraine (2007)). These publications outline the basic principles of assessing the level of economic security, identify patterns and trends in the factors affecting it, and analyze the state of its various components. Drawing on a solid theoretical background and a significant amount of collected information, the researchers behind these publications selected the most applicable metrics, categorized them by individual components, developed a methodology for calculating both actual and threshold values, and conducted comprehensive annual assessments of Ukraine's economic security in recent years.

The Ministry for Development of Economy and Trade (On the The Ministry for Development of Economy and Trade (2013)) and the State Statistics Service of Ukraine have started to develop a comprehensive system for assessing the level of the economic stability of the country and its regions. Although the 2007 Methodology, also known as Order No. 60, had its merits, such as setting thresholds and using a formalized mathematical method to determine weighting coefficients, it also had its limitations. One of the drawbacks was the inability to compare integral indicators and thresholds on a single scale to assess the state of economic equilibrium. This data is crucial for the development of remedial measures. Determined to tackle these issues, the National Institute for Strategic Studies (NISS) has provided an analytical note that addresses the shortcomings of these methods (On Improving the Methodology of Integrated Assessment of the Level of Economic Security of Ukraine. Analytical Note. (2013)).

In 2013, the Ministry for Development of Economy and Trade of Ukraine declared the previous Methodology invalid and replaced it with new non-binding Methodological Recommendations under Order No. 1277 (On Approval of Methodological Recommendations for Calculating the Level of Economic Security of Ukraine (2013)). In December 2014, the National Institute for Strategic Studies proposed an improved methodology for assessing the level of economic security of Ukraine. This new and improved methodology envisaged the use of a multiplicative integral index, methods for

normalizing indicators, justification of thresholds, and weighting coefficients (On Improving the Methodology for Integral Assessment of the Level of Economic Security, 2014).

Voloshchuk (2017) tried to improve Order No. 60 using different scientific and methodological approaches to analyze the economic situation in Ukraine. The researcher noted that both national (On Approval of the Methodology for Calculating Integral Regional Indices of Economic Development (2003)) and foreign scholars often use advanced mathematical tools such as fuzzy set theory, linguistic variables, intersecting plane methods, discriminant analysis, and odd set theory to establish weighting coefficients for individual components of economic security. Two methods were proposed to improve the scientific and methodological approaches to determining the weighting coefficients of individual components of the State Budget expenditures.

One of the advantages of these methods is that they rely on weighting coefficients rather than calculated values, as well as macroeconomic and financial indicators that reflect the current state of the economy. One of the aforementioned methods involves analyzing the breakdown of the state budget expenditures, while the other - analyzing the breakdown of gross value added. This analysis allowed to identify the integral components of Ukraine's economic security. Ukrainian academics, like Dovhenko (2022), Karpenko (2023), and Podmazko (2023) also devoted a lot of attention to studying the distinction between the components of military and economic security and exploring the development of the economy in the face of modern challenges. At the same time, Semenenko and Abramova (2021-2022) emphasized the importance of not only delineating military and economic security but also defining its internal and external components.

In his research, a Ukrainian scholar Shevchuk (2023) strives to develop the theoretical framework, create methodological approaches, and provide science-based practical recommendations for improving the economic security of Ukraine. Another Ukrainian academic Pikhotskyi (2022) examined the major trends and existing methodological approaches used to assess the economic security of the state. Rudyk (2020) explored the process used to model the assessment of the state's economic security level. The assessment of regional economic security levels was extensively studied by Monteiro (2020) and Kodratenko (2023).

Methodological Framework

One of the most important roles of the government is to ensure Ukraine's economic security, as it is a cornerstone of national security. However, at present Ukraine is faced with a dilemma, as the country has to not only follow the highly prioritized strategic path of integrating into the European economy but also simultaneously defend its territories and the rights and freedoms of its citizens (Constitution of Ukraine (2006)). The military component, which is an important part of any country's national security, plays a significant role in ensuring internal economic integration, preserving the domestic market, and maintaining territorial integrity. Given the need for sufficient funding, protection from external and internal threats, and the use of military force (armed forces), a new concept emerges - the military-economic security of the state.

At the same time, it is important to recognize that the European economy is still a battleground for competing national interests. Hence, there is value in creating a coherent and customized system and methodology for measuring the economic security of the state, just as there is value in creating a framework for assessing the impact that the changes in individual components have on the overall level of the state's economic security. The aforementioned approach, among other things, can help curb the potential negative effects of providing expedited external access to the national economy, increase the competitiveness of the national economy, protect local manufacturers, and contribute to more effective cooperation with international financial and economic institutions.

The National Institute for Strategic Studies has also offered calculated weighting coefficients for the elements of the integrated index of economic security. These coefficients were separated by both changes in the structure of the index and changes in the significance of each element.

Nevertheless, despite extensive scientific research dedicated to determining the level of economic security, experts have failed to reach a consensus.

Findings

There are several methods used around the world to comprehensively define the components of economic security. In broad terms, these methods can be divided into two categories: quantitative and qualitative. In Ukraine, defining the elements and indicators that make up the military economic component of the state's economic security system would ensure a more holistic assessment of the country's development and economic stability. Furthermore, this process would be instrumental in identifying the most effective measures to be taken to ensure the required level of economic security (According to Table 1) and simultaneously counter destructive external and internal influences.

In 2023 the Central Research and Development Institute of the Armed Forces of Ukraine invited 54 industry experts to conduct a survey to determine the importance of the economic security components in the period from 2011 till 2023. The results of this survey are shown in Table 1.

Table 1. Components of Ukraine's economic security (as defined by methods for calculating the level of state's economic security)

Order No. 114	**Order No. 60**	**National Institute for Strategic Studies**	**Order No. 1277**	**National Institute for Strategic Studies**	**Central Research and Development Institute of the Armed Forces of Ukraine**
-	Macroeconomic	Macroeconomic	Macroeconomic	-	Macroeconomic
Investment	Investment	Investment	-	-	Investment
Innovation	-	Innovation	-	Innovation	Innovation
Financial	Financial	Financial	Financial	Financial	Financial
-	Foreign economic activity	Foreign economic activity	Foreign economic activity	Foreign economic activity	Foreign economic activity
Social	Social	Social	Social	Social	Social
-	Food	Food	Food	Food	Food
Demographic	Demographic	Demographic	Demographic	-	Demographic
Energy	Energy	Energy	Energy	Energy	Energy
-	Manufacturing	-	Manufacturing	Manufacturing	Manufacturing
-	-	-	-	Transport	-
-	Science and technology	-	-		Science and technology
Foreign trade	-	-	-	-	-
-	-	-	Investment and Innovation	-	-
-	-	-	-	-	Military economic

Source: developed by the authors with due regard for: the Methodology for Calculating Integral Regional Indices of Economic Development. Order of the State Statistics Committee of Ukraine No.114 (2003); Methodology for Calculating the Level of Economic Security of Ukraine. Order of the Ministry of Economy of Ukraine No.60 (2007); Methodology of Integrated Assessment of the Level of Economic Security of Ukraine. National Institute for Strategic Studies (2013); Methodological Recommendations for Calculating the Level of Economic Security of Ukraine. Order No.1277 (2003).

The Ministry for Development of Economy and Trade of Ukraine is the main government agency in charge of the state policy on economy and trade. It was established in 2011 as the successor to the Ministry of Economy of Ukraine. It can be argued that both Order No.60 and Order No.1277

were developed by the same organization, albeit post-reorganization. However, it is important to underline that unlike Order No.60, Order No.1277 has an advisory nature. Consequently, as of today, there is no established methodology to effectively determine the level of economic security in Ukraine, nor is there a standardized system to define its components or a clear list of parameters and their respective thresholds. For instance, comparison of the identified weighting coefficients of different economic security components for 2007, 2013, and 2014 shows that the significance of the components varied year to year. This variability may also be contingent on the state's adherence to its strategic course and, therefore, additional funding.

Table 2. Weighting coefficients of the Ukraine's economic security components (as defined by methods for calculating the level of state's economic security)

No.	Components of Ukraine's Economic Security	Order No. 60	Order No. 1277	National Institute for Strategic Studies	Central Research and Development Institute of the Armed Forces of Ukraine
1	Demographic	0.0836	0.0913*	0.1412**	0.1123**
2	Energy	0.1324**	0.1148	0.1380**	0.1043
3	Food	0.1108	0.1007*	0.1374	0.1022
4	Social	0.0808*	0.1013	0.1341	0.0877*
5	Innovation	-	-	0.1337	0.0865*
6	Foreign economic activity	0.0901	0.1095	0.1273	0.1054
7	Financial	0.1127	0.1294**	0.0898	0.0998
8	Investment	0.0939	-	0.0572*	0.0972
9	Macroeconomic	0.1005	0.1224**	0.0409*	0.1009
10	Manufacturing	0.0769*	0.1218	-	0.1187
11	Science and technology	0.1183**	-	-	0.1101
12	Investment and Innovation	-	0.1089	-	-
13	Military economic	-	0.1089	-	0.1215**

Source: developed by the authors with due regard for: the Methodology for Calculating Integral Regional Indices of Economic Development. Order of the State Statistics Committee of Ukraine No.114 (2003); Methodology for Calculating the Level of Economic Security of Ukraine. Order of the Ministry of Economy of Ukraine No.60 (2007); Methodology of Integrated Assessment of the Level of Economic Security of Ukraine. National Institute for Strategic Studies (2013); Methodological Recommendations for Calculating the Level of Economic Security of Ukraine. Order No.1277 (2003).

Notes: * – the worst values; ** – the best values.

In light of recent events, the authors suggest that it may be worthwhile to explore the possibility of decoupling military and economic security components of Ukraine's economic security. This idea has garnered the support of such esteemed scholars as Pomazko (2023), Kodratenko (2023), and Dovhenko (2022). Comparing the results of various calculations, such as the strength of association (K_n), (calculated based on the findings of Schmidt, 2020), the correlation

coefficient ($r\,y\,x_{n}$) (calculated based on the findings of Gujarati, 2007), and the coefficient of variation (kV_n) (calculated based on the findings of Tolbatov, 2003).

the researchers were able to estimate the non-dimensional coefficient of variation (kV_n) to determine the consistency of changes in the economic security components compared to their average value (1). If it is greater than 30%, this indicates a significant discrepancy between the calculated value and the average.

$$kV_n = \frac{\sigma_n}{\overline{X_n}} * 100\,\%, \tag{1}$$

where, σ_n is the range of sample variance; $\overline{X_n}$ is the weighted arithmetic mean of the sample; *n* is the quantitative parameter of observations.

The correlation coefficient (2) was used to measure the impact that the changes in different economic security components had on its overall level. The correlation coefficient (ryx_{n}) was applied to measure the extend of the impact that the changes in different economic security components (X_{n}) had on its overall level (Y). The sample variance can be calculated by examining the quantitative parameter of observations, designated n, in combination with the weighted arithmetic mean of the entire population. Correlation dependence of more than 70% was believed to indicate a strong impact.

$$r\,y\,x_{n} = \frac{\sum d_{X_{n}}\, d_Y}{\sqrt{\sum d_Y^2 \sum d_{X_{n}}^{2}}}, \tag{2}$$

where $d_{X_{n}}^{2}$ is the standard deviation for X_{n}; d_Y^2 is the standard deviation for Y.

Using the strength of association coefficient (K_{n}) it was possible to determine both the strength of the association and the nature of the impact (direct/inverse) the changes X_{n} had on Y. The association is considered strong if the obtained result is higher than 0.7 and is calculated using the formula:

$$K_{n} = 1 - \frac{\sum \left| d_Y - b_{n}\, d_{X_{n}} \right|}{\sum d_Y}, \tag{3}$$

where b_{n} are the parameters of equations of individual factor variables; d_Y is the magnitude of deviations in the coefficients representing the comparison of empirical values of the effective feature; $d_{X_{n}}$ is the magnitude of deviations in the coefficients representing the comparison of empirical values of the factorial features.

Having carried out multiple calculations following the guidelines of Order No.60, the researchers were able to identify the strongest association (K_{n}) between the changes in the level of the economic security (Y) and changes in the levels of its constituent elements, such as manufacturing and social security (Table 3). At the same time, the researchers also found that changes to demographic and science and technology components had the lowest overall impact on the level of

the economic security. The calculations of the correlation coefficient ($r\,y\,x_n$) confirmed the significant extend of the mutual impact the aforementioned X_n have on the changes in Y. In contrast, the results obtained using the kV_n coefficient indicate the inconsistency in the annual changes of X_n relative to Y, which may indicate the unpredictable development of the selected parameters for economic security components, etc. Calculations carried out by the researchers at the National Institute for Strategic Studies indicate the strongest association (K_n) between the changes in the level of the economic security (Y) and changes in the levels of its constituent elements, such as energy and financial security (Table 3). At the same time, the researchers at the National Institute for Strategic Studies also found that changes to manufacturing and social security components had the lowest overall impact on the level of the economic security. The calculations of the correlation coefficient ($r\,y\,x_n$) and kV_n confirmed the significant extend of the mutual impact the aforementioned X_n have on the changes in Y.

Table 3. Results from calculating the coefficients: of the strength of association (K_n), correlation coefficient ($r\,y\,x_n$), and coefficient of variation (kV)

Components of Ukraine's Economic Security	kV_n		ryx_n		K_n	
	Order No. 60 (1997–2007), in %	**Central Research and Development Institute of the Armed Forces of Ukraine (2011– 2023), in %**	**Order No. 60 (1997–2007)**	**Central Research and Development Institute of the Armed Forces of Ukraine (2011–2023)**	**Order No. 60 (1997–2007)**	**Central Research and Development Institute of the Armed Forces of Ukraine (2011–2023)**
Demographic	6,92**	4.09	0.8579*	0.7494	0.4882*	0.2932
Energy	9.78	3.58**	0.9122	0.7560	0.4953*	0.2988
Food	22.44	3.98	0.9528	0.7494	0.7251	0.2715
Social	24.92	4.34*	0.9926**	0.5377*	0.8894**	0.1032*
Innovation	-	4.17*	-	0.6512	-	0.2733
Foreign economic activity	40.99*	4.17	0.9194	0.2794*	0.6453	-0.1088*
Financial	19.70	3.77**	0.9812	0.8879**	0.8014	0.5155**
Investment	43.85*	3.82	0.9815	0.7022	0.8153	0.2688
Macroeconomic	18.53	3.95	0.9777	0.7373	0.7912	0.2805
Manufacturing	19.57	-	0.9889**	-	0.8778**	-
Science and technology	3.66**	-	0.9096*	-	0.4418*	-
Military economic	-	3.58**	0.9096*	0.7560**	0.4418*	0.2985**

Source: calculated by the authors.
Notes: * – the worst values; ** – the best values.

This means that over different time periods, even despite using the same methodology for calculations (Table 3), researchers noticed variations in the significance of different economic security components. Therefore, the annual revision of the weighting coefficients for different

economic security components serves more of an educational than a practical purpose. Consequently, the authors believe that it would be advisable to draft a piece of legislation, like the Concept (Strategy) for the Development of Ukraine's Economic Security or military-economic security, setting out the hierarchical order for the economic security components prioritized for a given period of time according to the strategic agenda of the state. In addition, it is necessary to adopt a unified approach to determining the potential (medium- and long-term) and actual levels of the state's economic security and military economic security in the nearest future.

Discussions

While studying various research papers, publications, and guidelines on assessing the economic and military security of the state, researchers discovered an inconsistent and insufficient methodological approach to determining the necessary indicators of the state's military economic security, its level and availability of resources. This flaw in the methodology causes several issues, for example, failure to take into account the correlation between the level of military economic security of the state and projected resource capabilities in long-term and medium-term defense planning. Furthermore, as noted by Gomes (2023) and Bapuji (2023), there is a lack of a methodology for assessing the economic component of the state's military security based on the evaluation of available resources, and there is also a gap in the methodology when it comes to evaluating the levels of various allocated resources based on the assessment of relevant components (Karantounias (2023)). In the end, all of this renders it impossible to justify the effective adjustment of the economic component of military security and indicators of resource allocation (Getmanets (2023)). Given the current environment of ongoing reforms in the Armed Forces of Ukraine and limited financial resources, there is a need for research to determine the long-term trajectory for the development of the Armed Forces of Ukraine. This debate is extremely relevant today, as there are many conflicting opinions on how to best assess the correlation between the level of military security of a state and its resource availability. Despite the myriad of points of view, there is no definitive and consistent approach to addressing this issue.

Conclusions

Unfortunately, at present, there is no legislative framework that could regulate the notion of a unified system of elements comprising Ukraine's economic and military economic security or define an unambiguous mathematical approach to be applied when calculating the level of said economic security. Recently the Ministry for Development of Economy and Trade of Ukraine has issued legally non-binding guidelines for calculating the level of the state's economic security, thus, in light of recent events, one cannot definitively state that it is unlikely that the military economic security component will be added to the definition of Ukraine's economic security. The weighting coefficients for different economic security components were calculated by the Ministry for Development of Economy and Trade of Ukraine, the National Institute for Strategic Studies for 2007, 2013, and 2014, as well as by the Central Research and Development Institute of the Armed Forces of Ukraine for 2023 assign priority to different components in terms of how much they can influence the overall level of Ukraine's economic security.

Having carried out extensive analysis relying on the statistical data from the Ministry for Development of Economy and Trade of Ukraine, the results of expert assessment from the National Institute for Strategic Studies, and using the strength of association and correlation coefficients, the researchers were able to not only study the highest and lowest impact that the changes in specific components had on the overall level of the economic security but also look at the permanence of these results taking into account the coefficients of variation. The results of the calculations show a discrepancy between the extent of the impact that changes to certain components have on the overall level of economic security in the annual assessment and for a separate period, even if the same

methodology is used. Thus, the authors believe that their approach might be useful for drafting concepts (strategies) for the development of Ukraine's economic security or military-economic security that would also set out the hierarchical order for the economic security components prioritized for a given period of time according to the strategic agenda of the state, current financial capabilities, etc.

Further research should focus on developing recommendations for the application of the proposed methodology in the existing system of medium- and long-term defense planning.

Recommendations

The findings presented in this paper will be of interest to researchers analyzing the economic security components, as well as ministries dealing with the issues of medium- and long-term planning and allocation of financial resources to the sectors of the Ukrainian economy.

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A methodical approach to the distribution of tasks of the Armed Forces and other military formations of Ukraine during the development of the code on the defense of Ukraine

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Abstract. The accuracy of the article is due to the need to streamline the distribution of defense tasks of Ukraine and responsibility for their implementation between the Armed Forces of Ukraine and other military formations to ensure the planning of defense measures. In this regard, the article is aimed at revealing the organization of the distribution of tasks between the Armed Forces and the other military formations, which are involved in the organization and implementation of the defense of Ukraine. Today, there is no clear mechanism for delineating responsibility for the defense of the state between the entities that organize and carry it out. Based on this, the justification of such a mechanism is an important scientific and practical task that needs to be solved. The leading approach to solving this problematic issue is to use the results of the analysis of the legal framework of the state defense to build trees of goals and objectives that determine the achievement of the goal of defense. On the basis of this tree, the main Law is determined and on its basis to propose changes in other legislative acts. This is allows to comprehensively consider ways to improve the regulatory framework in a certain problematic issue. The article presents the results of the analysis of the regulatory and legislative framework of defense, reveals their inconsistencies with the Constitution of Ukraine and the main Law, proposes and justifies measures to amend some laws and by-laws on the organization of defense of Ukraine. The materials of the article are of practical importance for specialists who are responsible for improving normative legal acts regarding the organization of defense of Ukraine.

Keywords: Defense of Ukraine, national security of Ukraine, military security of Ukraine, purpose, tasks of defense, distribution of tasks, responsibility for the implementation of tasks.

Introduction

The results of the study of the legislation in the field of defense of Ukraine indicate the presence of repetitions, contradictions and inconsistencies in the provisions regarding the distribution of defense tasks of Ukraine and responsibility for their implementation between the Armed Forces and

the other military formations. Elimination of these inconsistencies in the legislation on the defense sector is an important task today and needs to be addressed.

A situation has arisen where, contrary to the requirements of Article 17 of the Constitution of Ukraine, where the defense of Ukraine, the protection of its sovereignty, territorial integrity and inviolability are entrusted to the Armed Forces of Ukraine (AF of Ukraine), some other military formations (OMF) of the security and defense sector of Ukraine (SDS) have exactly the same tasks, which, on the one hand, complicates the organization of state defense, on the other hand, blurs responsibility for the final result of such activities. Based on this, solving such a problem in the context of resource constraints is relevant today.

The imperfection of Ukrainian legislation in the field of defense is identified in the Strategic Defense Bulletin of Ukraine (SDB) as one of the problems of the functioning of the defense forces during the implementation of defense reform (President of Ukraine, 2021). This concerns the uncertainty of the governing body responsible for the state of defense capability, the duplication of defense tasks by individual components of the OMF, the Constitution of Ukraine (Constitution of Ukraine 1996) entrusted to the Armed Forces of Ukraine. The development of the Defence Code of Ukraine (the Code) is the basis for eliminating repetitions, contradictions and inconsistencies in defence legislation.

Today, in some legislative acts (Law of Ukraine 2018), (Law of Ukraine 2020), (Law of Ukraine 1992) and other laws regulating the activities of the OMF of Ukraine, there is a coexistence of inherited outdated norms and new provisions with existing and previously adopted regulations, which are the result of long-term (2014 – 2022) amendments to the laws governing the management of the defense sector. Thus, the task of developing the Code determines the scientific and practical orientation of the article.

Methodological Framework

The aim of the article is to get acquainted with the view on the distribution of tasks of the Armed Forces of Ukraine, other military formations of Ukraine in the field of defense during the preparation of the provisions of the Defense Code of Ukraine.

Since at the present stage there is no Law of Ukraine, which is the basis for the task of distributing defense tasks, it is proposed to distribute tasks on the basis of the requirements of the Constitution of Ukraine, the Law of Ukraine "On Defense of Ukraine", the Defense Plan of Ukraine, the appointment of the Armed Forces and OMF of Ukraine (Law of Ukraine 2003), the Law of Ukraine 2014), (Law of Ukraine 1992-1), (Law of Ukraine 2015), the Joint Operational Concept, a list of typical tasks that achieve the strategic goals of the state in the settlement of interstate contradictions.

In the opinion of the authors of the article, the task of filling the draft Code with the necessary information on the distribution of state defense tasks is achieved by the consistent implementation of a number of measures shown in Fig. 1.

Fig. Figure 1 shows a possible logical sequence of determining (adjusting) the list and content of measures that would be expedient for specialists to perform to solve the problems of streamlining the requirements of the laws of Ukraine regarding the tasks of state defense.

The results of the analysis of the legislative framework for the defense of Ukraine indicate that the main reasons for the imperfection laid down by the latest amendments are non-compliance with the requirements of the Constitution of Ukraine of 1996, the Law of Ukraine On Defense of Ukraine of 2020 regarding responsibility for the state of defense capability of the state (Law of Ukraine (1991)) and the formation of new approaches to the organization of state defense based on the principles and rules of NATO member states. In the first and second cases, many components of the OMF of Ukraine became responsible for defense, protection of sovereignty, territorial integrity and

inviolability of the state, in the third case, the transition to NATO principles and standards led to the development of new approaches to the organization of defense of Ukraine.

This state of affairs requires a clear definition of the meaning and content of the terms "defense of Ukraine", "management of the defense sector", to clarify the responsibility for the defense of Ukraine: its organization, implementation and provision of the necessary (defense) resources.
Without taking into account the results of coordination and consolidation of the content of the definitions of these basic provisions, the work will be incomplete, which will require another revision in the future.

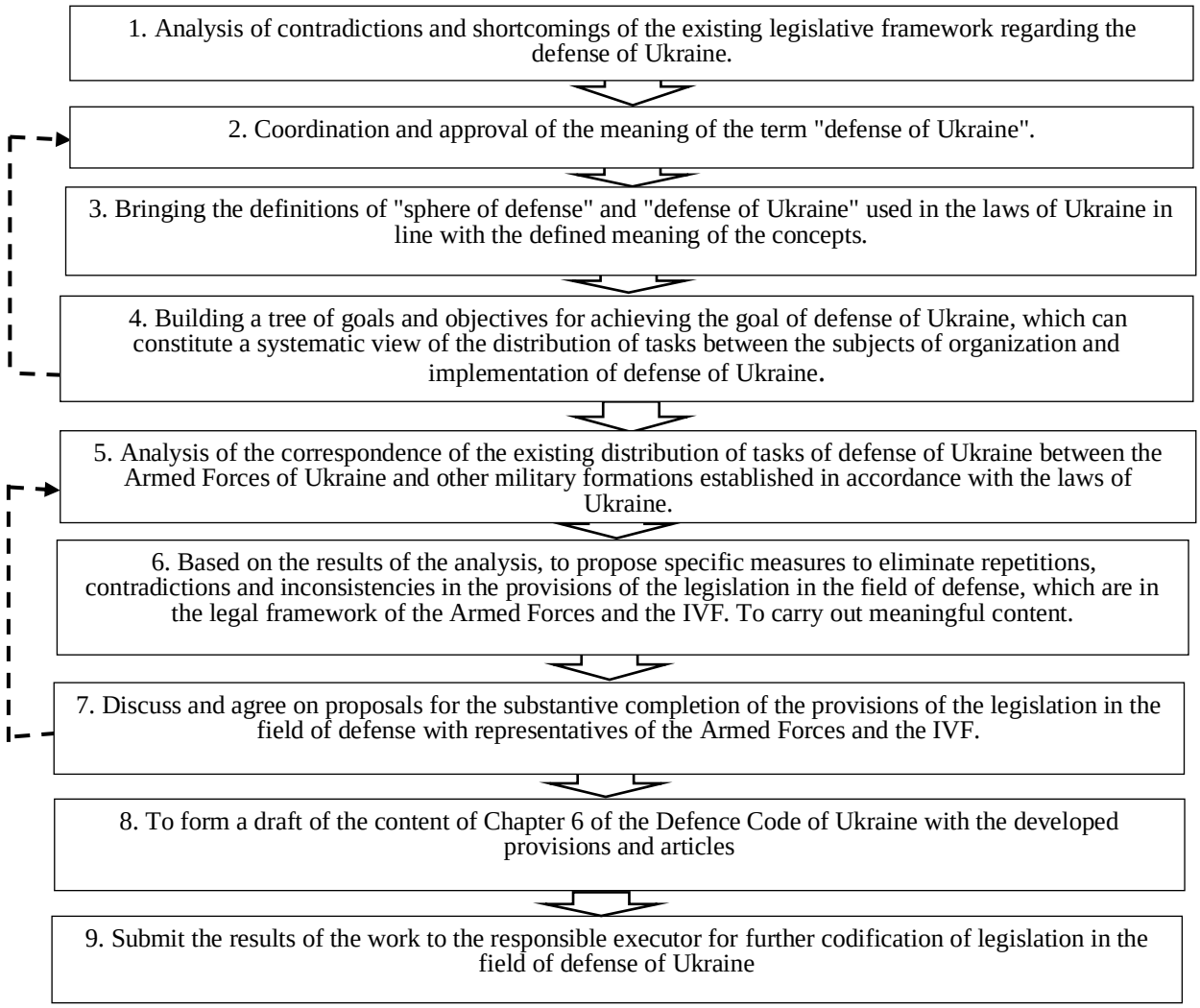


Figure 1. Schematic representation of the sequence of solving problems to eliminate repetitions, contradictions and inconsistencies in the provisions of legislation in the field of defense

Since the purpose of the work is achieved through the consistent implementation of interdependent measures, it is expedient to focus the content of the draft Code in the part related to the distribution of state defense tasks on a deeper analysis of the shortcomings and contradictions of the legislative framework of defense of Ukraine.

The content of the draft Code should be based on the results of work on the implementation of the idea (plan) of the implementation of new approaches to the organization of defense of Ukraine, definitions of their content should be proposed, especially with regard to the consistency of definitions of such concepts as "defense capability of the state", "defense sphere", clarification of "defense

planning", etc. These concepts require a revision of a significant number of concepts that are derived from and depend on them (Fig. 2).

Fig. Figure 2 shows the content and sequence of the task related to the content of the draft Code regarding the distribution of tasks, powers and responsibilities for the defense of Ukraine. For further work, it is advisable:

to build a tree of goals and objectives for achieving the goal of defense of Ukraine according to the requirements of a new approach, which can constitute a systematic view of the distribution of tasks between the subjects of organization and implementation of defense of Ukraine;

to bring the definitions of "defense sector" and "defense of Ukraine" used in the laws of Ukraine in line with the defined meaning of the proposed concepts, in accordance with the requirements of new approaches;

analysis of the correspondence of the existing distribution of tasks of defense of Ukraine between the Armed Forces of Ukraine and other military formations established in accordance with the laws of Ukraine;

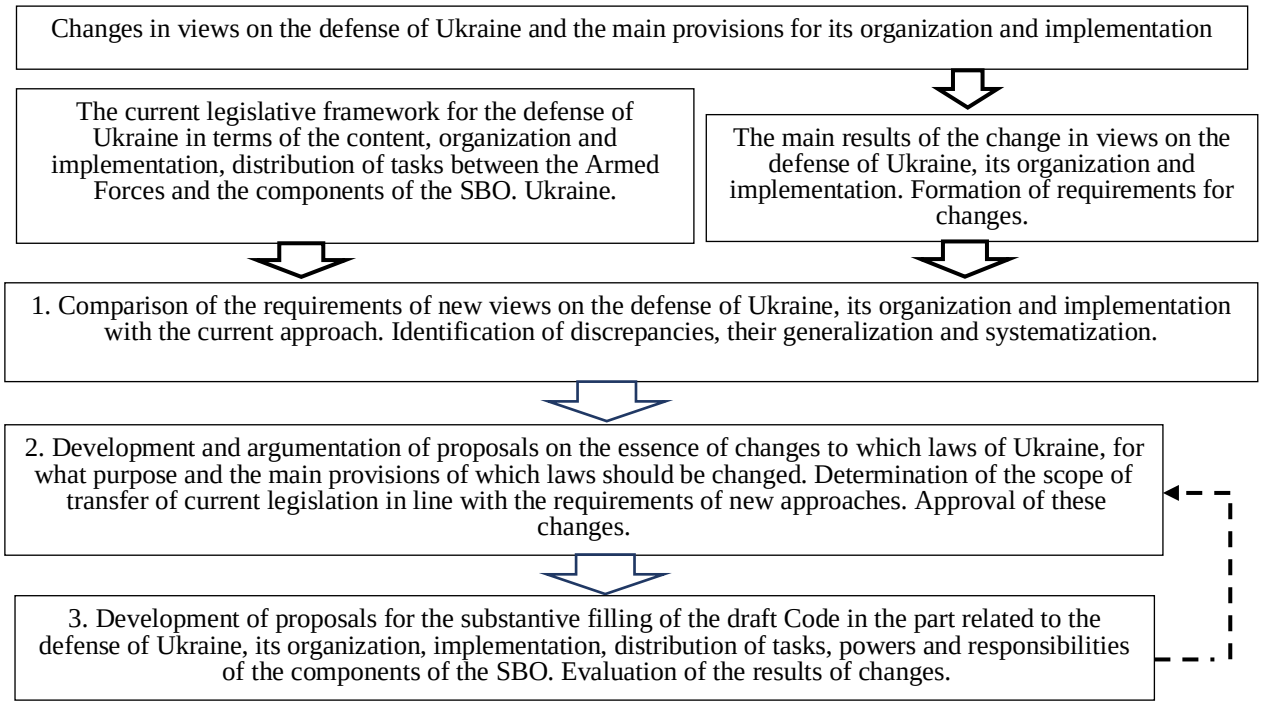


Figure 2. Schematic representation of the sequence and content of the solution of measures to eliminate repetitions, contradictions and inconsistencies in the provisions of the legislation in the field of defense

discuss and agree on proposals for the substantive completion of the provisions of the legislation in the field of defense with representatives of the Armed Forces and the OMF;

to formulate a draft of the substantive content of the Defence Code of Ukraine regarding the distribution of defence tasks with the developed provisions and articles.

Feedback during discussion and coordination involves scientific and professional discussions on the proposed measures, since in accordance with the tasks set, each chapter is developed separately, without agreeing on the main provisions and analyzing what and who is not satisfied with the current legislation in the field of defense (except for what is provided in the methodological recommendations).

The determination of specific laws of Ukraine depends on the consideration of agreed and approved changes in views on the defense of Ukraine, its organization and implementation during the development and argumentation of proposals. The difference between the proposals for amendments to the basic provisions on the defense of Ukraine and the existing provisions determines the scope of improvement of the legislative framework, the transfer of current legislation in line with the requirements of new approaches.

The issue of using the basic Law of Ukraine, the requirements of which should be taken as a basis for the formation of the Code, turned out to be not an easy one: the Law of Ukraine "On Defense of Ukraine" (Law of Ukraine 2020) or the Law of Ukraine "On National Security of Ukraine" (Law of Ukraine 2018). The first Law of Ukraine is more in line with the requirements of the Constitution of Ukraine, the second is of a later year of development, which includes many differences from the first, but more at the same time, the SDS contains a matrix for the distribution of tasks according to scenarios for the use of components of the security and defense sector in crisis management. The situation shows that, first of all, changes should be made in the basic Law of Ukraine "On Defense of Ukraine". The current approach to the organization of defense is shown in Fig. 3.

The figure shows the enshrined provision that the defense of the state is considered in peacetime and in the event of armed aggression or armed conflict. But defense capability is considered only in the event of armed aggression or armed conflict. At the same time, it is well known that the defense capability of a state is a category not only in wartime, but more in peacetime, since the conditions for the ability to defend are formed mainly in peacetime (Law of Ukraine 2020).

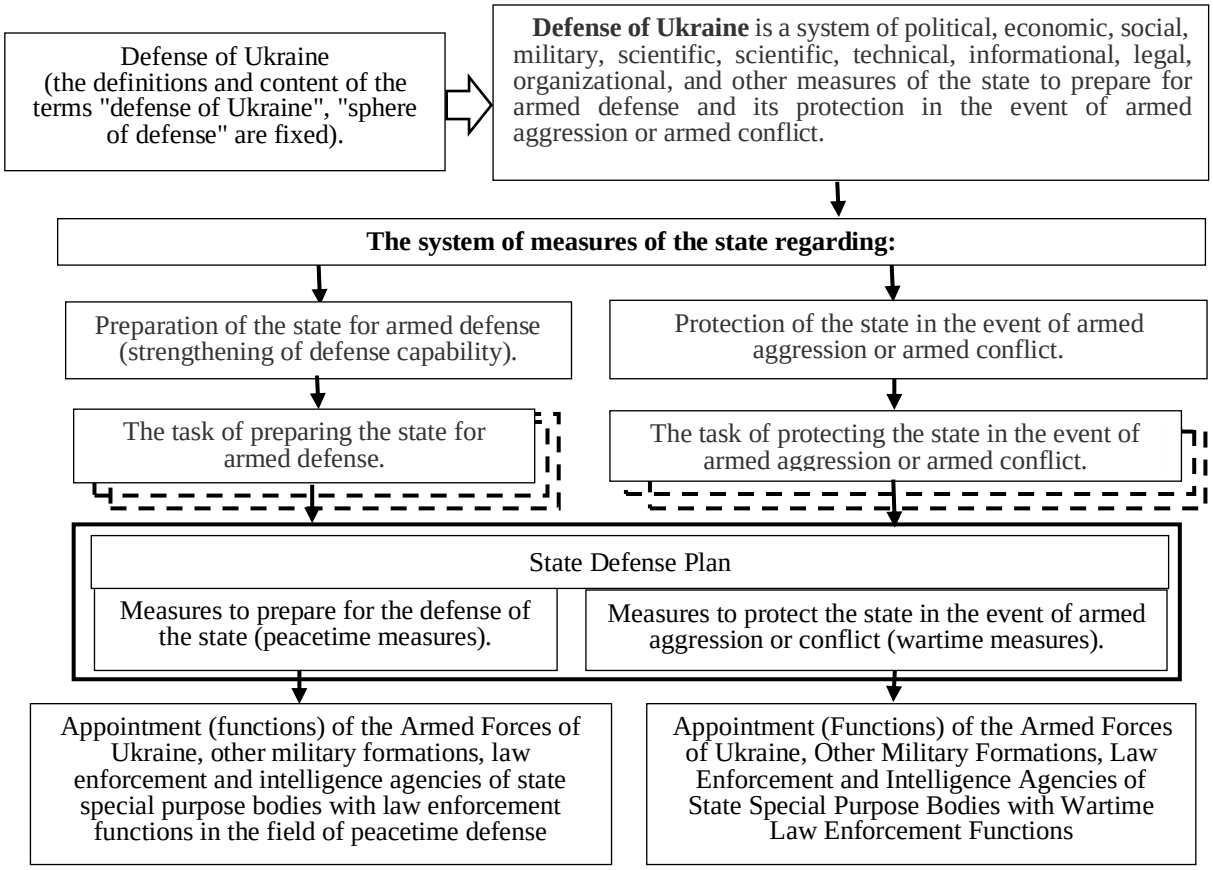


Figure 3. Schematic representation of the dependence of peacetime and wartime tasks on the main provisions of the organization and implementation of defense of the current legislative framework

Non-compliance with the requirements of the laws of Ukraine (Law of Ukraine 2020), (Law of Ukraine 2011), (Law of Ukraine 2011-1) over the past 12 years has not yielded results regarding the readiness of the State for armed defense. For these reasons, among the system of measures to prepare for the armed defense of the state in peacetime and in the event of armed aggression or armed conflict, the issues of identifying, constructing and maintaining Ukraine's defense capability is not fully envisaged. The powers of the Cabinet of Ministers of Ukraine are defined by the law (Law of Ukraine 2020) in this matter in fragments, which only partially affect the content of defense capability, or do not at all interpret the attitude to the organization of the production of weapons and military equipment (establishes the sale and disposal of weapons, military equipment, other property of the Armed Forces of Ukraine and other military formations and law enforcement agencies, as well as the disposal of scrap metal generated in them).

It should be borne in mind that a serious impetus for making changes in the foundations of the organization and implementation of Ukraine's defense is the experience gained by Ukraine in the course of the anti-terrorist operation and repelling the full-scale aggression of the Russian Federation against Ukraine. This primarily concerns the establishment of the limits of powers and responsibilities of the components of the OMF regarding the organization and implementation of the defense of Ukraine, the implementation and responsibility for the appointment and role of the Cabinet of Ministers of Ukraine in meeting the needs of defense.

Such a provision practically excludes the most important part of the activities of the Cabinet of Ministers of Ukraine, which is defined by the Law of Ukraine "On the Cabinet of Ministers of Ukraine" - the management of issues related to the creation and maintenance of the necessary level of defense capability of the state (Law of Ukraine 2011).

The relationship between the definition of the content of Ukraine's defense and the tasks of the subjects should ensure the achievement of the defense goal through advance training in peacetime, and the implementation of the results of training in wartime (in the event of armed aggression or armed conflict).

The emergence of the concepts of "special period", "legal regime of martial law", "state of emergency", "crisis situation of a military nature" in other laws of Ukraine affect the definition of the main provisions of Ukraine's defense, the definition of peacetime and wartime defense tasks, taking into account new approaches.

Results and Discussions

In order to distribute tasks between the Armed Forces of Ukraine and other military formations, law enforcement and intelligence agencies, state special purpose bodies with law enforcement functions in the field of defense, it is necessary to have appropriate documents that would allow to:

- to determine the share of participation of military formations, law enforcement and intelligence agencies of state special purpose bodies with law enforcement functions in the field of defense in solving the tasks of defense of Ukraine in peacetime and wartime;
- On the basis of the share of participation, to determine the tasks of peacetime and wartime, which are solved by military formations, law enforcement and intelligence agencies of state special purpose bodies with law enforcement functions in the field of defense.

It should be borne in mind that the laws of Ukraine contain, as a rule, principles and mechanisms for the formation of tasks that do not change often, and strategic goals, defense priorities are variable and are derived from the general goals of Ukraine's development and the military-political situation. The list of typical tasks also refers to permanent tasks, is the basis for the formation of the Joint Operational Concept (JOC), which is determined for the appropriate planning period to achieve strategic goals in the security and operational environment.

The above-mentioned indicates that the current legislation does not fully ensure the rational distribution of state defense tasks between the Armed Forces and the OMF in the course of forming

the content of the draft Code. This is also complicated by Ukraine's transition to the principles and rules used by NATO member states.

The laws of Ukraine, which are the content of the Code of Laws on Defense of Ukraine, in our opinion, should determine the purpose of state defense management bodies, the Armed Forces and the OMF, determine their powers and responsibilities, be a mechanism for forming a tool for performing the tasks of preparing and implementing the defense of Ukraine in peacetime, threatening period, wartime and post-war period.

At the same time, it is expedient to determine the specific tasks of the defense of the Armed Forces and the OMF of Ukraine for the selected planning period, which are derived from the requirements of the Joint Operational Concept to achieve the strategic goals of the state in the security and operational environment, defense priorities of the state, the Defense Plan of Ukraine (Fig. 4).

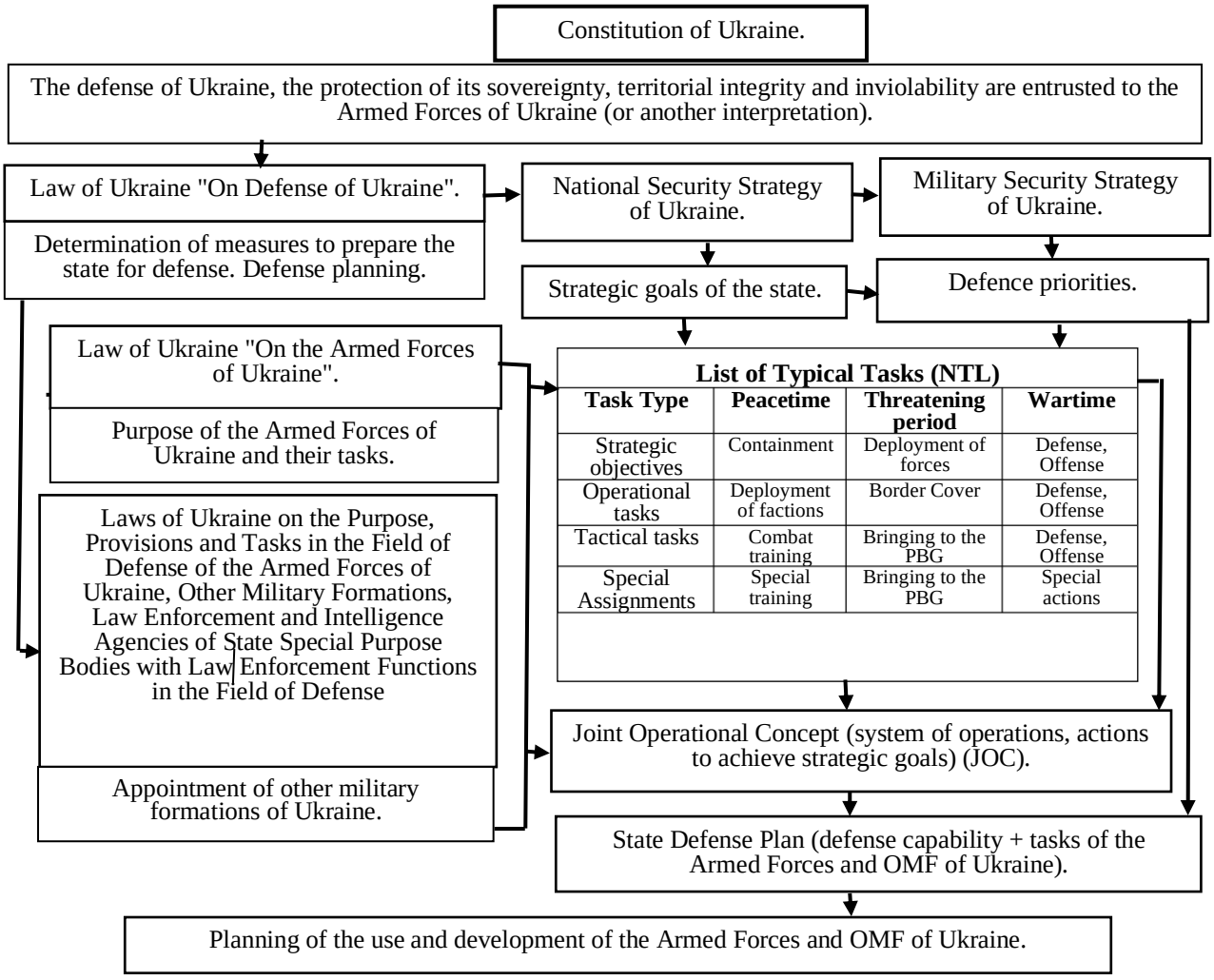


Figure 4. Schematic representation of further detailing of defense tasks in the laws of Ukraine in the process of defense planning

The figure shows that the tasks of defense in the laws of Ukraine are detailed in the process of defense planning and planning of the strategic use of the Armed Forces and OMF in:

strategic goals of the state;

defence priorities;

the Joint Operational Concept;

list of typical tasks (national list of tasks).

The main idea of the Defense Code, in our opinion, should be based on the discussed and approved plan for the defense of Ukraine under various possible scenarios for the development of the military-political and military-strategic situation.

Conclusions

The article shows the authors' view on the preparation of provisions of the Defence Code of Ukraine on the distribution of tasks of the Armed Forces and the OMF in the field of defence. It is based on the discussed and approved plan for the defense of Ukraine under various possible scenarios for the development of the military-political and military-strategic situation.

The Code of Laws on Defense of Ukraine can determine the purpose of state defense management bodies, the Armed Forces and the OMF of Ukraine, determine their powers and responsibilities, be a mechanism for the formation of a tool for performing the tasks of training and implementation of the defense of Ukraine in peacetime, threatening period, in wartime and in the post-war period.

It is proposed to determine the specific tasks of the defense of the Armed Forces and the OMF of Ukraine for the selected planning period, which are derived from the requirements of the JOC to achieve the strategic goals of the state in the security and operational environment, defense priorities of the state, the Defense Plan of Ukraine.

Recommendations

In the future, it is expedient to focus on determining the content of the components of the state's defense capability, defining the tasks of its formation and maintenance at a certain level, consolidating the tool for distributing defense tasks between the state defense management bodies, especially with regard to the coordination of the powers of the National Guard of Ukraine (Law of Ukraine 2014) and the Territorial Defense Forces, the Armed Forces (Law of Ukraine 1991) and the OMF, their powers and responsibilities.

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Improvement of the informatively computational task of determining the ratio of forces and means of the parties in terms of predicting the loss of combat potential of forces in an operation

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Abstract. The article highlights the views on improving the informatively computational task of determining the ratio of forces and means of the parties from the complex of mathematical models and informatively computational task in terms of predicting the loss of combat potential of troops in an operation. It should be noted that during the planning of an operation, as a rule, the effectiveness of the use of forces and means of the opposing parties is assessed, and the main indicators are the projected losses of forces and means of both parties in the operation. That is, the timeliness, reliability and efficiency of obtaining the results of forecasting the losses of forces and means of the parties depend on the development of the plan and, as a result, on the success of the operation. Therefore, the question of the need to automate the process of determining the projected losses of the combat potential of the parties arises, and this is the reason for the relevance of the article.

In this regard, it is proposed to improve the informatively computational task "Ratio" by using analytical expressions characterizing the dependence of losses of combat potential of forces on the initial ratio of the parties. These expressions are based on the processing of statistical data obtained as a result of a numerical experiment on simulation of a military operations. The dependence of the values of the final ratio, the losses of the combat potential of the parties on the initial ratio for different levels of Task Forces was presented in the form of histograms. Based on the analysis of the histograms, hypotheses about the type of functions of dependence of the values of the final ratio, the loss of combat potential of the parties on the initial ratio with the relevant parameters were made. Based on the results of the regression analysis in MathCAD's environment, the corresponding parameters of the functions were obtained. The parameters of the functions are determined for different levels of Task Forces and conditions of readiness of the position of the defending party. Then the determination coefficients was carried out by comparing statistical data (obtained from the results of simulation of combat operations using the informatively computational task "UA") and theoretical data (obtained using the defined dependencies). The values of the coefficients of determination are within acceptable limits, which allows us to conclude that the defined dependencies (formulas) should be used to predict the loss of combat potential of forces during an operation. An example of the application of the proposed analytical dependencies for certain conditions of the level of Task Forces and the degree of readiness of defensive positions is considered. The values of the

final ratio, losses of combat potential of the parties calculated by the proposed formulas differ by 2-3% from the same values obtained as a result of simulation, which allows to use them in the informatively computational task "Ratio" during operational calculations. Thus, the proposed approach makes it possible to automate the calculation process, which significantly increases the efficiency of obtaining results, and allows eliminating subjective errors of the operational staff and, accordingly, increasing the validity of decisions made by the commander. The materials are of practical value for the work of C2 in planning and conducting operations.
Promising areas for further research are the improvement of this informatively computational task in terms of automating the formulation of a conclusion on the possibility of achieving the purpose of the operation.

Keywords: combat potential, simulation of combat operations, projected losses, ratio of forces and means of the parties, regression analysis.

Introduction

The operation under study (combat actions) can be quantitatively characterised by a number of performance indicators, each of which reflects its specific characteristics. Among these indicators, the most important in the theory of the formation and use of armed forces was and is the category of the ratio of forces to means. The ratio of forces and means is an objective indicator of the combat power of the parties, which makes it possible to determine the degree of superiority of one side over the other. Correct calculation of the ratio of forces and means and their assessment contribute to making an informed decision on timely creation and maintenance of the necessary advantage in the selected areas. In this field of research, methods of assessing the ratio of forces belonging to the traditional forms of armed struggle (operations and combat actions) have been and are being used (Romanchenko, 2008). The ratio is determined by comparing the quantitative and qualitative characteristics of units, brigades, task forces, weapon systems of one's own troops and those of the enemy (Military Encyclopedic Dictionary, 1984). It is calculated on a strategic, operational and tactical scale over the entire battlefield, in the main and secondary directions. This assessment is used both to determine the forces and means necessary for an operation (battle) during planning, and to assess the situation at any stage of the operation in order to predict further operations and respond in time to changes in the situation (General Tactics. Division (Regiment) in Offensive, 1986).

The purpose of the article is to describe an approach to improving the informatively computational task "Ratio" in terms of predicting the loss of combat potential of forces in an operation depending on the initial ratio of forces and means of the parties, the degree of engineering equipment of the positions of the defending party, and the level of the grouping.

It should be noted that the existing methods of calculating the ratio of forces are based on an assessment of the combat capabilities of the opposing parties (Katsalap, 2013), which are summed up by the combat capabilities of their weapon systems and military equipment, and the losses of the combat capabilities of the attacking and defending parties are determined from tables that show the dependence of the amount of losses on the initial ratio of the parties (Straychnyi, 2012). However, these tables can be used to predict losses within a limited range of the ratio of forces and means of the parties. Another drawback of these tables is the assumption made during the numerical experiment (simulation of military operations) using the informatively computational task "UA" that in case of critical losses of combat potential (30% for the attacking and 40% for the defending side), the troops of the parties stop fighting, which does not correspond to the experience of military conflicts in the world during XX-XXI centuries. In addition, predicting losses in such a "manual" way by selecting values from tables significantly reduces the efficiency of obtaining the results. Subjective errors on the part of the operational staff of military command and control bodies in determining the projected losses of the combat potential of the parties and analyzing the data obtained

cannot be ruled out, especially when the values of the initial ratio go beyond the range given in the tables. Therefore, automating the process of determining the projected losses of the combat potential of the parties is an important and urgent issue.

Materials and Methods

The research materials are the values of losses of combat capabilities of the attacking and defending sides, which are determined by the following initial data (Methodology for determining the combat capabilities of mechanized (tank) units, 2000, 2004):

the initial ratio of parties;

the degree of the defending party's fortifications (hasty defense, deliberate defense);

level of Task Forces (Joint TF (operational level), TF (tactical), brigade (regiment)).

The method of regression analysis is used in the research. This is a statistical method of research the relationship between two variables, the purpose of which is to determine how changes in one or more independent variables are related to changes in the dependent variable (Frost, 2020). Regression analysis is used to solve a number of problems, including predicting future values of the dependent variable (Draper, 2007). Therefore, this method was chosen to determine the predicted amount of losses of their own and enemy troops in the operation, based on the initial ratio of forces and means of the opposing parties.

The tool chosen for the necessary calculations was the universal mathematical package MathCAD, which is designed to perform engineering and scientific calculations (Herhager, 2000).

Results and Discussions

It should be emphasized that in a number of works, in particular (Combat capabilities of troops in defense, 1977) (Combat capabilities of troops in offensive, 1977), (General tactics. Defense of the Division (Regiment), 1985), (General Tactics. Offensive of a Division (Regiment), 1986) generally abandoned the determination of the projected losses of the parties depending on the value of the ratio. The approach implemented in these sources provides only for the values of the ratio necessary to achieve the objective of the operation, depending on the type of battle (operation), the degree of engineering equipment of the defending side. That is, the question of the cost of achieving the goal of the operation is excluded.

Pavlovsky in 2014 and in 2015 analyzed the analytical dependence of troop losses on the initial ratio of forces and means of the parties. However, they focused not on the loss of combat potential, but on the calculation of losses of certain types of weapon systems and military equipment.

Zahorka (2020) presents a methodology that allows determining the projected losses of forces of one of the parties in an operation (battle) given the losses of forces of the other party, taking into account the initial ratio of forces of the parties. The methodology provides a reasonable mathematical apparatus, but a detailed analysis reveals some inconsistencies. There is no consideration of such an important factor as the degree of the defending party's fortification. According to the benchmark example given in the source, with a ratio of 1 : 1 and critical losses of the attacking party of 40 percent, the losses of the defending party are also 40 percent. With a ratio of 1 : 1.14 (in favor of the attackers) and critical losses of the attacking party of 40 %, the losses of the defending party are 53 %, which contradicts tactical (operational) standards, analyzes of real operations, and simulation results.

Today, the task of calculating the ratio of forces and means of the parties can be partially solved by using such the informatively computational systems as SLAVUTYCH, DZVIN, and TMSS. However, none of them allows for automatic calculations of the projected amount of losses of their troops and the enemy in the operation, based on the initial ratio of forces and means, although these calculations are necessary when planning an operation at the stage of assessing the situation and during the operation to assess the situation at any stage of the operation.

Using the informatively computational systems "UA" (simulation of the actions of our troops and the enemy's troops), we calculated the losses of combat potential of our troops and the enemy during the offensive and defense, as well as at different initial ratios of the parties and the degree of preparedness of the defense. The actions of different types of military forces, such as Joint Task Forces, Task Forces, and brigade were simulated. Based on the results obtained, the relevant tables of dependencies of combat potential losses on the initial ratio of forces and means of the parties, the degree of the positions' fortification of the defending party, and the level of the TF were compiled.

It should be noted that when simulating the actions of the parties in an operation using the informatively computational systems UA, certain restrictions were adopted, such as: calculations were stopped when the losses of the defending party reached 40% or the offensive party reached 30%. This restriction was justified as follows. When the party conducting the offensive suffers losses of 30% or more, it becomes limitedly combat-ready and will be forced to abandon its further conduct. In turn, when the defending side suffers losses of 40% or more, it becomes incapacitated and will be forced to abandon its positions. Although these assumptions are reasonable, they significantly limit the range of loss forecasting. In some cases, it is necessary to forecast the losses of the parties to the transaction beyond these limitations.

In our opinion, the least costly, analyzing the above software products, will be the improvement of the informatively computational systems "Ratio" (from the complex of mathematical models and the informatively computational systems "TMSS") in terms of predicting the loss of combat potential of troops in an operation.

To automate this process, it is proposed to apply the following analytical expressions that characterize the dependence of losses of combat potential of troops on the initial ratio of the parties. These expressions are based on the processing of statistical data obtained as a result of a numerical experiment (simulation of combat operations) using the informatively computational systems "UA" from the complex of mathematical models. This the informatively computational systems was used to determine the value of the projected losses of combat potential at different ratios of the parties for different types of military formations (JTF, TF, brigade) at different degrees of defense readiness. At the same time, the indicators of critical losses were not included in the informatively computational systems "UA".

Table 1 shows the results of the combat simulation for the JTF (deliberate defense).

Table 1. Results of the JTF simulation (deliberate defense)

Parties ratio (defense: offense)	at the beginning of engagement, $\alpha_{поч.}$	1 : 1,5 1,5	1 : 1,6 1,6	1 : 1,7 1,7	1 : 1,8 1,8	1 : 1,9 1,9	1 : 2,0 2,0	1 : 2,1 2,1	1 : 2,2 2,2	1 : 2,3 2,3
	at the end of of hostilities, $\alpha_{кін}$	1 : 0,94 0,94	1 : 1,06 1,06	1 : 1,23 1,23	1 : 1,42 1,42	1 : 1,69 1,69	1 : 1,87 1,87	1 : 2,08 2,08	1 : 2,77 2,77	1 : 3,03 3,03
Loss of combat potential	Defense, β_O	15,13	17,61	21,14	25,11	28,5	32,31	34,31	41,16	43,5
	Offensive, β_H	46,63	45,48	43,32	39,2	38,3	36,37	35,06	26,23	24,01

Notes: Indicators $\alpha_{поч}$ and $\alpha_{кін}$ characterize how many times the attacking party outnumbers the defending party at the beginning and end of engagement, respectively.

Graphically, in the form of histograms, the dependencies $\alpha_{кін}$ $(\alpha_{поч})$, β_O $(\alpha_{поч})$ and β_H $(\alpha_{поч})$ for the TF (deliberate defense) are shown in Figure 1.

Similar tables and histograms were compiled for the JTF, TF, and brigade for different types of operations (defense, offense) under hasty and deliberate defense conditions. After analyzing them, we hypothesized that the dependencies $\alpha_{кін}$ $(\alpha_{поч})$ and β_O $(\alpha_{поч})$ can be represented as a function of the type $f(x) = b \cdot x^c$, and the dependency β_H $(\alpha_{поч})$ can be represented as a function of the type $f(x) = d - b \cdot x^c$, where *b*, *c* and *d* are certain constants (parameters of functions).

Then the following dependencies were obtained for regression analysis in MathCad:

$$\alpha_{кін} = A \cdot \alpha_{поч}, \quad (1)$$

$$\beta_O = C \cdot \alpha_{поч}^{\ D}, \quad (2)$$

$$\beta_H = 100 - C \cdot \alpha_{поч}^{\ D}, \quad (3)$$

where *A*, *B*, C, and *D* are the parameters of the functions.

The values of the function parameters for different military formations and the types of operations they conduct are given in Tables 2 and 3.

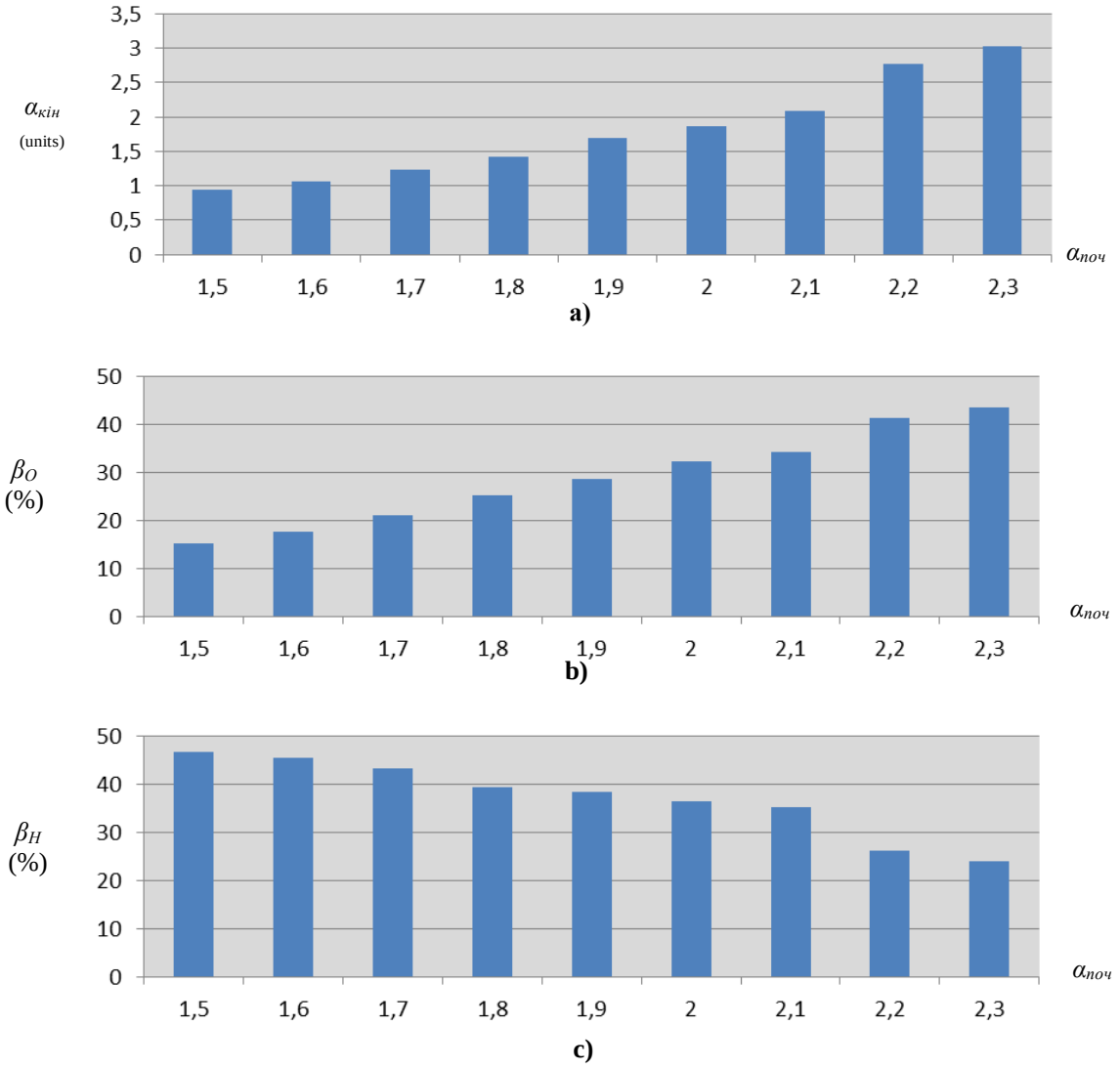


Figure 1. Histograms of dependencies: a) $\alpha_{кін}$ $(\alpha_{поч})$; b) β_O $(\alpha_{поч})$; c) β_H $(\alpha)_{поч}$

Table 2. Parameter values of the function $\alpha_{кін} = f(\alpha)_{поч}$

Military formation	Defense readiness (for the defending party)	Function parameters		The coefficient of determination R^2
		A	*B*	
Brigade	deliberate	0,149	3,398	0,994
	hasty	0,397	2,757	0,997
TF	deliberate	0,251	2,974	0,988
	hasty	0,496	2,549	0,994
JTF	deliberate	0,345	2,744	0,992
	hasty	0,534	2,637	0,998

Table 3. Parameter values of the functions $\beta_O = f(\alpha_{поч})$ and $\beta_H = f(\alpha)_{поч}$

Military formation	Type of operations	Defense readiness (for the defending party)	Function parameters		The coefficient of determination R^2
			C	*D*	
Brigade	defense	deliberate	4,4	2,547	0,986
		hasty	16,5	1,378	0,984
	offensive	on a deliberate defense	27,2	1,061	0,989
		on hasty defense	51,0	0,549	0,997
TF	defense	deliberate	5,8	2,439	0,996
		hasty	14,8	1,639	0,994
	offensive	on a deliberate defense	36,5	0,85	0,992
		on hasty defense	54,7	0,458	0,999
JTF	defense	deliberate	9,7	1,879	0,969
		hasty	20,8	1,33	0,999
	offensive	on a deliberate defense	49,2	0,523	0,998
		on hasty defense	54,7	0,51	0,999

Let's consider an example of applying the proposed analytical dependencies.

Suppose, you need to determine the final ratio $\alpha_{кін}$, the losses of the defending side β_O, and the losses of the attacking side β_H, under the following conditions: the level of the unit is TF, the defense is deliberate, the initial ratio $\alpha_{поч}$ is 1 : 1.7.

Solution. According to the given conditions, we determine the parameters of the functions: A=0.251; B=2.974; C_O =5.8; D_O =2.439; C_H =36.5; D_H =0.85.

According to the formula (1), $\alpha_{кін} = 0.251\text{-}1.7^{2,974} = 1.22$ (1.23 according to the simulation results).

According to the formula (2), $\beta_O = 5.8\text{-}1.7^{2,439} = 21.16$ (21.14 according to the simulation results).

According to the formula (3), $\beta_H = 100\text{-}36.5\text{-}1.7^{0,85} = 42.7$ (43.3 according to the simulation results).

The example shows that the values of $\alpha_{кін}$, β_O, β_H, calculated by formulas (1-3), differ from the same values obtained in the simulation by 2-3 %. To verify this, the use of task forces was simulated using the informatively computational systems "UA" with ratios outside the range indicated in the tables (Sluchayniy, 2012). The values of $\alpha_{кін}$, β_O, β_H, calculated using formulas (1-3), differ from the modeling results by no more than 3 %.

Conclusion

Thus, an element of improvement in the proposed approach to determining the projected losses of the parties is the transition from tabulated values to analytical expressions, where independent variables are calculated by regression analysis based on the results of simulation. This makes it

possible to automate the calculation process, which significantly increases the efficiency of the overall assessment, which is especially important in conditions of limited time for operational planning and decision refinement in the forces mission command in the course of military operations. The result of solving the information and calculation problem - the overall balance of forces of the parties is indicative, but in general it allows to increase the validity of predicting possible outcomes of military operations.

Promising areas for further research are the improvement of the said informatively computational systems "Ratio" (from the complex of mathematical models and informatively computational systems "TMSS") in terms of automating the formulation of a conclusion on the possibility of achieving the goal of the operation as a whole.

Recommendations

The materials of the article are recommended for use by the staff elements of military HQ at the tactical, operational, and tactical levels and for developers of mathematical models and informatively computational tasks for operational planning.

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Evaluation of the effectiveness of the protection of troops from unmanned aerial vehicles by the forces and means of engineering support

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Abstract. The relevance of the study is due to the high level of troop losses from enemy unmanned aerial vehicles during hostilities and the need to increase the level of their protection by engineering support forces and means, by implementing a set of engineering measures to fortify military facilities and camouflage them with service camouflage kits. In this regard, this article is aimed at identifying the factors that in modern conditions most affect the effectiveness of the engineering protection of military facilities and taking these factors into account when developing a methodical approach to evaluating the effectiveness of the protection of troops from unmanned aerial vehicles by the forces and means of engineering support , the use of which will make it possible to obtain more correct evaluation results and, based on them, to develop effective practical recommendations for improving the protection of troops from unmanned aerial vehicles during hostilities. To solve this problem, the method of mathematical modeling was used, which allows describing the complex process of engineering protection of military facilities in the language of mathematics and obtaining results for the further development of the above recommendations. The article presents a structural and logical diagram of a methodological approach to assessing the effectiveness of troop protection against unmanned aerial vehicles by engineering support forces and means, describes the stages of assessment, basic initial data, partial and generalized performance indicators, criteria and conditions for assessment. The materials of the article are of practical value for command-and-control bodies that, when planning the use of troops, perform calculations to determine the required amount of engineering measures to increase the survivability of troops during hostilities and reduce their losses from unmanned aerial vehicles.

Keywords: unmanned aerial vehicles, engineering support, military facilities.

Introduction

The analysis of the Russian-Ukrainian war shows that the enemy is increasingly using unmanned aerial vehicles (UAVs) to defeat our troops to reduce their combat capability and gain an advantage on the battlefield (Zaluzhnyi, Moisiuk, Shaptala, 2022). Since the beginning of the full-scale invasion of Ukraine by Russian troops, the Armed Forces of Ukraine (hereinafter - the AFU) have gained some experience in protecting their facilities from UAVs, by hiding them in field fortifications and camouflaging them with service camouflage kits (Office of the President of Ukraine, 2022). However, the losses of our troops from enemy UAVs during hostilities are still high, especially in areas where troops are stationed for a long time and where the enemy conducts targeted UAV strikes (Zaluzhnyi, Moisiuk, Shaptala, 2022). This is a problem that directly affects the survivability of our troops during hostilities and the fulfilment of their combat missions. To solve this problem, it is necessary to develop recommendations for increasing the protection of troops from UAVs by engineering support forces and means, by sheltering their facilities in field fortifications

and camouflaging them with service camouflage kits. This task requires, first, the development of a methodological approach to assessing the effectiveness of troop protection against UAVs by engineering support forces and means, which will be used to develop the above recommendations.

Methodological Framework

The analysis of modern armed conflicts shows that the warring parties widely use UAVs to destroy enemy targets. The greatest success in protecting troops from UAVs has been achieved by the armies of the United States, Turkey, France, and Israel, whose troops have been directly involved in hostilities in the Middle East and Africa (Tkachenko and Danik 2002). The armies of these countries, along with traditional measures to protect troops from UAVs by air defence systems, effectively use support forces and means, in particular, electronic warfare forces and means to suppress the electronic reconnaissance and guidance systems of the ground and airborne components of UAVs with radio interference, engineering support forces and means to carry out engineering measures for fortification equipment (hereinafter - FE) and engineering measures for camouflage, both individual troops and areas of their concentration, as well as chemical, biological, radiation and nuclear protection forces and means to conceal troops' objects by means of aerosol camouflage. Engineering support forces and means have gained particular importance in the implementation of measures to protect troops from UAVs, but the practice of their use shows that they imperfectly combine existing methods and techniques of engineering protection, which significantly reduces their effectiveness (Romanchenko, Zahorka, Butenko, Deinega, 2011). The experience gained in the engineering protection of troops from UAVs in the Russian-Ukrainian war suggests that by implementing measures to protect troops from the effects of military operations and camouflaging troops with service camouflage kits, the effectiveness of protecting troops from UAVs can increase by 1.5-2 times (Voloshchenko, Kushnirenko, Chernykh, 2020), (Kotsiuruba, Datsenko, Dachkovsky, Cherevko, Androshchuk, Tsybizov, Kryvtsun, 2021).

Results and Discussions

Since the beginning of the full-scale invasion of Ukraine by Russian troops, partial tasks have been solved to protect military facilities from UAVs and to develop a comprehensive methodological apparatus for a comprehensive assessment of the effectiveness of the protection measures that were being implemented at that time. Methodological recommendations on this issue were developed by specialized research units of research institutions of the Ministry of Defence of Ukraine and the Armed Forces of Ukraine. These recommendations set out the general principles and approaches to assessing the effectiveness of troop protection measures against UAVs, considering the peculiarities of troop damage in modern operations (combat actions), identify the main patterns of emergence and development of positive and negative impact factors, and analyse the state of the main components of the system of comprehensive troop protection created in Ukraine and the Armed Forces of Ukraine. Tkachenko and Danik (2002) describe the methodological apparatus for assessing the effectiveness of measures to protect troops from UAVs by air defence and electronic warfare forces and means. Voloshchenko, Kushnirenko, Chernykh (2020) and Kotsiuruba, Datsenko et al. (2021) provide methods for calculating the stability of the coating of field fortifications to protect troops from hinged fire. However, currently, the sources of information known to the author do not contain a methodological apparatus (method, methodological approach) for assessing the effectiveness of protecting troops from UAVs by engineering support forces and means. In developing a methodological approach to assessing the effectiveness of troop protection against UAVs by engineering support forces and means, certain provisions of probability theory (Wentzel, 1972), engineering support modelling methods (Yurkov, 1990), as well as a methodology for assessing the survivability of point military objects in the event of targeted attack and a comprehensive methodology for assessing the effectiveness of camouflage measures to conceal and imitate military objects (Yurkov, 1990) were used. As a criterion for assessing the

effectiveness of troop protection against UAVs by engineering support forces and means, the average degree of troop protection against UAVs ($k_{ІП}^{зах.В}$) was chosen, which is achieved by engineering support forces and means by performing the required amount of engineering work on the FE of military objects and their masking with time sheets camouflage kits. The adopted performance indicator, its thresholds and conditions for evaluation are shown in Figure 1.

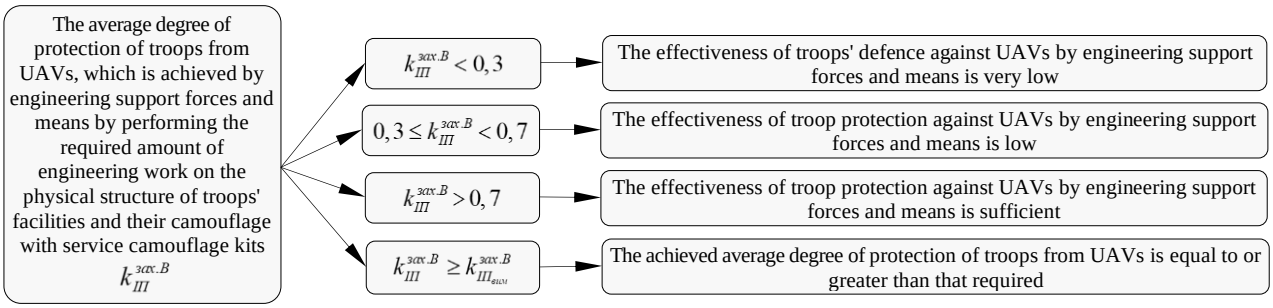


Figure 1. The adopted performance indicator, its thresholds and conditions for assessing the effectiveness of troop protection against UAVs by engineering support forces and means (option)

The structural and logical diagram of the methodological approach is shown in Figure 2.

According to Fig. 2, the effectiveness of protecting troops from UAVs by engineering support forces and means is carried out in the following stages.

At stage 1, the initial data is generated.

At stage 2, indicators, criteria, and conditions are selected to assess the effectiveness of troop protection against UAVs by engineering support forces and means.

At stage 3, the selected indicators are calculated and the effectiveness of troop protection against UAVs by engineering support forces and means is assessed.

For this purpose, in 3.1, the number of troop objects that will be FE by forces and means of engineering support for the time determined by the commander (commander) is determined, *units*:

$$N_{ФО}^{ОВ} = M_{ФО_{ОВ}}^{ІП} \cdot (1 - \beta_{зм}) \cdot T^{ФО} \cdot k_{ФО}^{ум}, \quad (1)$$

where $M_{ФО_{ОВ}}^{ІП}$ is the capabilities of engineering support forces and means for the FE of military facilities, *units/hour* (Ivan Cherniakhovskyi National Defence University of Ukraine, 2015); $\beta_{зм} = 0,3...0,4$ is the norms of irrecoverable losses of engineering equipment for the FE (Order of the Armed Forces of Ukraine, 2023); $T^{ФО}$ is the time determined by the commander (commander) for the FE of military facilities, *hour*; $k_{ФО}^{ум}$ is the average coefficient of FE conditions (Tables 1-3) (Ivan Cherniakhovskyi National Defence University of Ukraine, 2015).

Table 1: Coefficient of soils and methods of their development, $k_{гр}$

Methods of soil development	Soil			
	Lightweight	**Medium**	**Solid**	**Rocky**
Manually and by means of mechanization	1,1-1,2	1,0	0,6-0,7	0,2-0,3
Manually and with explosives	0,7			0,3-0,55
Manually, by means of mechanization and explosives	0,75			0,55
By means of mechanization and explosives	0,8			0,7

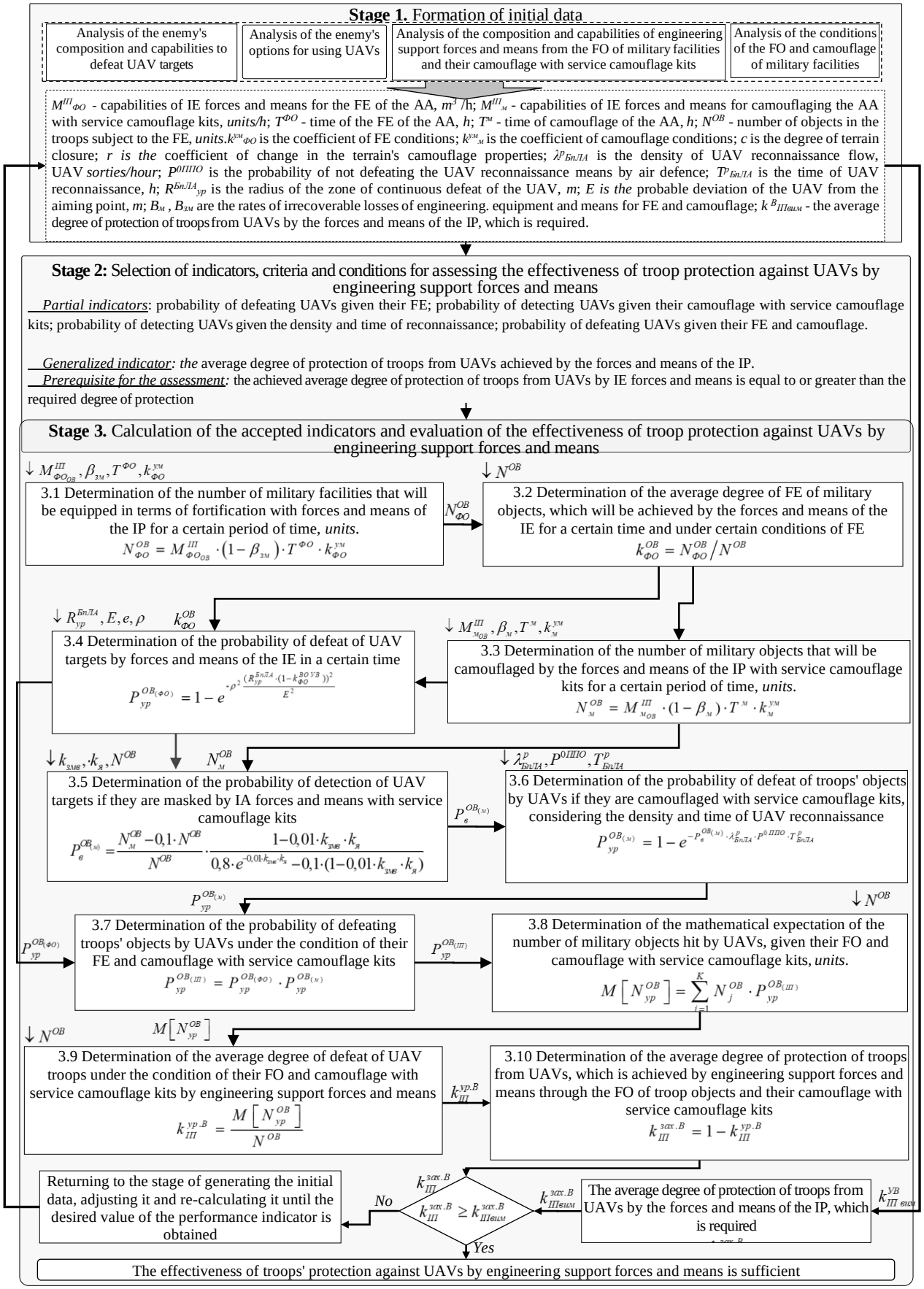


Figure 2. Flowchart of the methodological approach to assessing the effectiveness of troop protection against UAVs by engineering support forces and means

Table 2: Time of day coefficient, k_o

Time of day		
Day	**Evening (morning)**	**Night**
1	0,85	0,7

Table 3: Air temperature coefficient in the contaminated area, k_t

Air temperature, $^{\circ}C$	**- 20**	**- 10**	**0**	**+10**	**+ 20**	**+ 30**
k_t	0,8	0,75	0,7	0,6	0,5	0,1

Section 3.2 determines the average degree of FO of troop objects that will be achieved by engineering support forces and means within the time specified by the commander (commander):

$$k_{ФО}^{OB} = N_{ФО}^{OB} / N^{OB}, \quad (2)$$

where $N_{ФО}^{OB}$ is the number of troops' objects that will be FE by forces and means of engineering support within the time specified by the commander (commander), *units*; N^{OB} is the total number of troops' objects for FE, *units*.

In 3.3, the number of troop objects to be camouflaged by engineering support forces and means with service camouflage kits within the time specified by the commander (commander) is determined, *units*:

$$N_{м}^{OB} = M_{м_{OB}}^{ІП} \cdot (1-\beta_{м}) \cdot T^{м} \cdot k_{м}^{ум}, \quad (3)$$

where $M_{м_{OB}}^{ІП}$ - capabilities of engineering support forces and means for camouflage with service camouflage kits, *units/hour* (Ivan Cherniakhovskyi National Defence University of Ukraine, 2015); $\beta_{м} = 0,1...0,3$ - norms of irrecoverable losses of service camouflage kits (Order of the Armed Forces of Ukraine, 2023); $T^{м}$ - time determined by the commander (commander) for camouflaging troops, *hours*; $k_{ФО}^{ум}$ - average coefficient of conditions for camouflaging troops with service camouflage kits (Tables 2-4) (Ivan Cherniakhovskyi National Defence University of Ukraine, 2015).

Table 4. Terrain camouflage coefficient by months of the year and type of forest plantations, $k_л$

Forest type	**Values by month of the year**											
	1	2	3	4	5	6	7	8	9	10	11	12
Coniferous	1	1	1	1	1	1	1	1	1	1	1	1
Deciduous	0,5	0,5	0,6	0,8	0,9	1	1	1	0,9	0,8	0,5	0,5
Mixed	0,75	0,75	0,8	0,9	0,95	1	1	1	0,95	0,9	0,75	0,75

Experience has shown that the radius of the UAV's area of destruction decreases significantly with the growth of the average degree of military objectives FE (Fig. 3).

That is why the mathematical dependence used in (Methodology for assessing the survivability of point military objects under targeted attack, 1990) to determine the probability of defeating military objects in the event of a targeted attack is supplemented by the indicator $k_{ФО}^{OB}$ (2), the growth of which reduces the radius of total destruction of UAVs and, accordingly, the probability of defeating these military objects in the event of their FE:

$$P_{ур}^{OB_{(ФО)}} = 1 - e^{-\rho^2 \frac{(R_{ур}^{БпЛА} \cdot (1-k_{ФО}^{ВО УВ}))^2}{E^2}}, \quad (4)$$

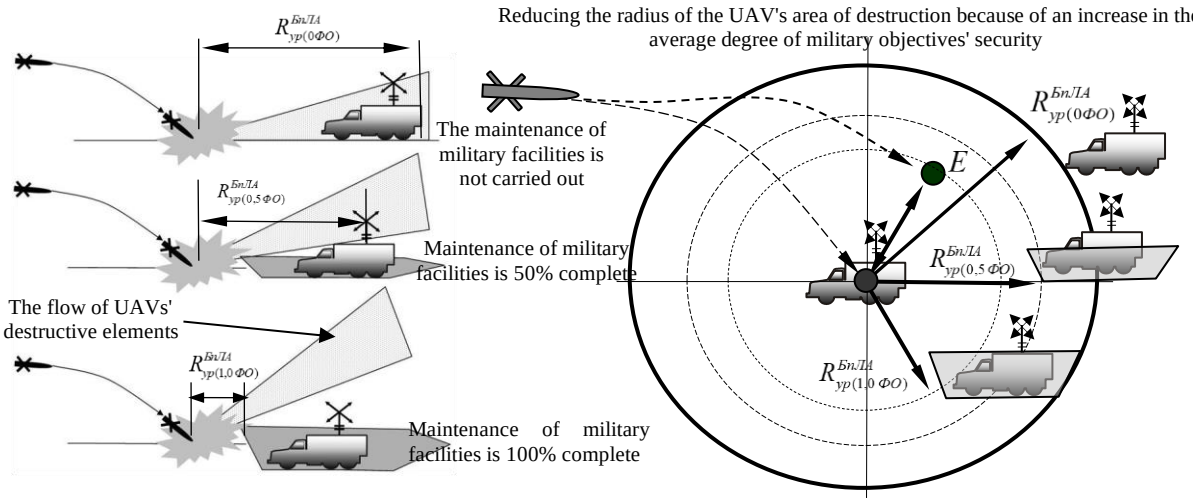


Figure 3. Reducing the radius of the UAV's area of destruction with the growth of the average degree of military objectives FE

where $k_{ФО}^{OB}$ is the average degree of FE of military objects achieved by the forces and means of engineering support; $R_{ур}^{БпЛА}$ is the radius of the UAV's zone of continuous defeat (Technical Report (Shahed-131). Kyiv. 2022.), m; E - probable deviation of the UAV from the aiming point (Technical Report (Shahed-131). Kyiv. 2022), m; $\rho = 0,477$ - Laplace's coefficient.

In 3.5, by analogy with (Comprehensive Methodology, 1993), the probability of detection of troop objects by UAVs is determined if they are camouflaged by engineering support forces and means with service camouflage kits. To obtain more correct results, the mathematical dependence used in (Comprehensive Methodology, 1993) to determine the probability of detection of troop objects by enemy intelligence means is supplemented by the quality coefficients of service camouflage kits $k_{я}$ and changes in the camouflage properties of the terrain $k_{змв}$, which directly depend on the category of camouflage kits, terrain, its forestation, type of forest and vegetation cover, as well as the season, time of day, nature of fog and frequency of cloudy days in the area of military operations:

$$P_{в}^{OB_{(м)}} = \frac{N_{м}^{OB} - 0,1 \cdot N^{OB}}{N^{OB}} \cdot \frac{1 - 0,01 \cdot k_{змв} \cdot k_{я}}{0,8 \cdot e^{-0,01 \cdot k_{змв} \cdot k_{я}} - 0,1 \cdot (1 - 0,01 \cdot k_{змв} \cdot k_{я})}, \quad (5)$$

where $N_{м}^{OB}$ is the number of military objects camouflaged by service camouflage kits, *units*; N^{OB} is the total number of objects in the military that are subject to camouflage, *units*; $k_{я}$ is the quality factor of service camouflage kits (determined by an expert survey); $k_{змв}$ is the average coefficient of change in the camouflage properties of the terrain (Table 5) (Ivan Cherniakhovskyi National Defence University of Ukraine, 2015).

In 3.6, according to the Comprehensive Methodology for Evaluating the Effectiveness of Camouflage Measures for Concealment and Imitation of Military Objects, 1993, the probability of UAVs hitting military objectives is determined if they are camouflaged with service camouflage kits, as well as considering the density of the UAV reconnaissance flow and the probability of not hitting UAVs by air defence systems:

$$P_{ур}^{OB_{(м)}} = 1 - e^{-P_{в}^{OB_{(м)}} \cdot \lambda_{БпЛА}^{р} \cdot P^{0\,ППО} \cdot T_{БпЛА}^{р}}, \quad (6)$$

Table 5. Coefficients of change in the camouflage properties of the terrain, $k_1...k_7$

№ n/a	Name of the coefficients	Meaning.
1.	Terrain coefficient, k_1 (mountainous, rugged, flat)	0,4; 0,7; 1,0
2.	Forest cover, k_2 (small, medium, large)	0,5; 0,8; 1,0
3.	Time of year coefficient, k_3 (winter – spring, summer – fall)	0,75; 1,0
4.	Forest type and vegetation cover factor, k_4 (deciduous, coniferous)	0,5; 1,0
5.	Time of day factor, k_5 (evening – night, morning – day)	0,75; 1,0
6.	Fog Character Coefficient, k_6 (thick, liquid)	0,6; 1,0
7.	Coefficient of the number of cloudy days k_7 (small, large)	0,85; 1,0

where $P_{в}^{ВОУВ_{(м)}}$ is the probability of detecting the objects of the UAV troops if they are camouflaged with service camouflage kits; $\lambda_{БпЛА}^{р}$ is the density of the UAV reconnaissance flow, UAV *sorties/hour*; $P^{0ППО}$ is the probability of not being hit by air defence systems; $T_{БпЛА}^{р}$ is the time of UAV reconnaissance, *hour*.

Section 3.7 determines the probability of defeating troops' objects by UAVs, if they are equipped with FE and camouflage with service camouflage kits:

$$P_{ур}^{ОВ_{(ІП)}} = P_{ур}^{ОВ_{(ФО)}} \cdot P_{ур}^{ОВ_{(м)}}. \quad (7)$$

In 3.8, we calculate the mathematical expectation of the number of military objects that will be hit by UAVs, if they are equipped with FE and camouflage with service camouflage kits, *units*:

$$M\left[N_{ур}^{ОВ}\right] = \sum_{j=1}^{K} N_{j}^{ОВ} \cdot P_{ур}^{ОВ_{(ІП)}}, \quad j = \overline{1,K}. \quad (8)$$

In 3.9, the average degree of defeat of troops by UAVs is determined, provided that the engineering support forces and means carry out a set of engineering measures to protect the physical environment of military facilities and camouflage them with service camouflage kits:

$$k_{ІП}^{ур.В} = \frac{M\left[N_{ур}^{ОВ}\right]}{N^{ОВ}}. \quad (9)$$

Section 3.10 defines the average degree of protection of troops from enemy UAVs, which is achieved by engineering support forces and means by performing the required amount of engineering measures to protect the physical environment of troop objects and their camouflage with service camouflage kits:

$$k_{ІП}^{зах.В} = 1 - k_{ІП}^{ур.В}. \quad (10)$$

The resulting value $k_{ІП}^{зах.В}$ is compared with the value required by $k_{ІП_{вим}}^{зах.В}$. If the accepted condition $k_{ІП}^{зах.В} \geq k_{ІП_{вим}}^{зах.В}$ is met, it is considered that the effectiveness of protecting troops from UAVs by engineering support forces and means is sufficient. If this condition is not met, the algorithm of the proposed methodological approach provides for a return to the stage of generating the initial data, adjusting them by the number of means for FE, camouflage or the time of execution of these

measures, and repeating the calculations until the desired value of the accepted performance indicator is reached.

Conclusion

The peculiarities of the proposed methodological approach are the consideration of the most important indicators for the protection of troops from UAVs, the values of which numerically characterize the main parameters of the combat use of UAVs, as well as the most influential on the effectiveness of engineering protection conditions for the implementation of measures for the protection of troops and camouflage with service camouflage kits (Kotsiuruba, Datsenko, Dachkovsky, Tkach, Holda, Holda, Klontsak, Mykhailova, 2021), (Kosenko, Voloshchenko, Kushnirenko, 2022), (Voloshchenko, Kovbasa, 2020), (Sukhodolia, 2016). Considering these indicators and parameters allows us to obtain more correct assessment results and, on their basis, develop more effective practical recommendations for improving the protection of troops from UAVs by engineering support forces and means. The author believes that his approach to assessing the effectiveness of troop protection against UAVs by engineering support forces and means can be useful for improving the existing methodological apparatus for assessing the effectiveness of troop protection in modern operations (combat operations), as well as for assessing the effectiveness of the use of engineering units designed to increase the survivability of troops. Further research in this area will be aimed at developing a comprehensive methodology for assessing the effectiveness of troop protection against UAVs by engineering support forces and means.

Recommendations

The materials of the article are of practical value for management bodies that, when planning the use of troops, perform calculations to determine the required amount of engineering protection measures to increase the survivability of troops during hostilities and reduce their losses from UAVs.

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An approach to evaluating opposing parties over time based on the analytical solution of a system of nonlinear differential equations using the method of average dynamics

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Abstract The relevance of this research stems from the need for a critical analysis of a rapidly developing military conflict (as an integral part of military security). It can be described by the nonlinear Lanchester equations. This critical analysis focuses on two aspects. The first aspect allows to establish a formula-driven relationship of the initial force ratio with predetermined criterion values. This relationship takes the form of a biquadratic equation. The second aspect concerns the critical assessment of the time required to achieve the ultimate objective of one of the parties in a conflict, where the original system is reduced to a single nonlinear first-order differential equation that can be solved for the time parameter using tabular integration. The aim of the article is to develop an approach for calculating the initial ratio of firepower available to the warring parties, as well as the predicted duration of hostilities that would produce an acceptable extent of losses for one of the parties while achieving the final predefined firepower ratio. Conventional approaches based on the dynamic averaging method, allow to calculate the required initial ratios of forces and assets of the warring parties using models describing conflicts of a certain intensity based on linear differential equations with a constant destructive effect under predefined (acceptable) loss thresholds. At the same time, the use of mathematical models based on systems of nonlinear differential equations to describe combat operations allows to account for the intensity of the destructive effect, which, as is common for modern military conflicts, changes over time. Nowadays, systems of these equations are usually solved using numerical methods, which is a rather laborious task. The article presents an approach based on the analytical solution of a system of nonlinear differential equations using the dynamic averaging method, which takes into account the intensity of the destructive effect, which changes in the course of hostilities. Such an approach makes it possible to quickly calculate the parameters that can be used in operation (combat) planning (in particular, when justifying the required force composition and duration of an operation). The suggested method allows to calculate the initial ratio of firepower available to the warring parties, as well as the predicted duration of hostilities that would produce an acceptable extent of losses for one of the parties while achieving the final predefined firepower ratio. The feasibility of this approach is confirmed by a computational example.

Keywords: analytical analysis, mathematical model, dynamics, combat operations, conflict, correlation.

Introduction

Applied research in the field of conflict between warring parties is quite multifaceted and concerns a wide range of interdependent processes that require extensive calculations. The analytical calculations are based on methods of mathematical analysis (differential and integral calculus) with the subsequent transition into the field of optimal control theory (Kotliarov, 2020), primarily in the part that concerns the choice made by one of the warring parties regarding the best (necessary) process parameters or their optimal ratios, for example, the force ration throughout the entire duration of the conflict. When assessing this parameter, the most important task is to determine the appropriate initial ratio of firepower available to the warring parties, as well as the predicted duration of hostilities that would produce an acceptable extent of losses for one of the parties while achieving the final predefined firepower ratio. The article is presented in a manner that provides a quantitative assessment of all these variables in relation to conflicts of varying intensity (the least studied in the specialized literature).

It is worth noting that the existing methods for calculating the force ratio are mainly based on assessing the combat capabilities of the warring parties, which are calculated by summing up their combat potentials (Leontiev, 2009), (Zahorka, 2020). Then the assumed initial force ratio of the warring parties is determined by taking into account the value of the combat sustainability factor.

A similar approach was considered by Leontiev (2009), and Mozharoskyi (2019) when describing the method of static modeling used to determine the combat potential of troops (forces). However, as for the value of the combat sustainability coefficient, it is usually determined based on the lessons learned from wars and military conflicts and it can have a fairly wide variation margin. Moreover, given static problem is somewhat incomplete in terms of the time-based analytical interrelation between the required initial force ratio and the final required values of the relevant indicators at the end of hostilities.

The dynamic averaging method can help address this issue. By applying this method to models describing conflicts of varying intensity based on linear differential equations with a constant destructive effect, researchers obtained the corresponding mathematical dependences (Venttsel, 1964), (Zahorko, 2020), (Romanchenko, 2020).

At the same time, analysis of lessons learned from deterring Russian armed aggression against Ukraine (Tom Cooper, 2022), (Zaluzhnyi, 2023), shows that the intensity of the destructive effect exerted by both parties can change in the conditions of prolonged hostilities if one or both parties lack forces and assets for a rapid offensive (offensive operation along Kherson axis) or rapidly evolving hostilities (offensive operation along Kharkiv axis). Mathematical models based on systems of nonlinear differential equations are better suited to take into account the rapidly changing combat environment. At present, systems of such equations are usually solved using numerical methods, which is a rather laborious task that requires a long time, special equipment, software, and large amounts of input data.

The aim of the article is to develop an approach for calculating the initial ratio of firepower available to the warring parties, as well as the predicted duration of hostilities that would produce an acceptable extent of losses for one of the parties while achieving the final predefined firepower ratio.

Methodological Framework

First of all, let's formalize the problem to be solved.

Let's say there are two warring parties - A and B.

The following values are given: for A party – the initial amount of firepower $A(0)$ and the average intensity of the actual destructive effect α; for B party – the average intensity of the actual

destructive effect β.

Moreover, the following restrictions are set at the start $t = T$ of the operation (onset of hostilities):

$$\begin{cases} K(t) = K(T)_{необх}; \\ R(t) = R(T)_{доп}, \end{cases} \quad (1)$$

where $K(T)_{необх}$ is the final firepower ratio to be achieved by the parties;

$R(T)_{доп}$ – the acceptable level of firepower losses for the *B* party.

To solve the problem, it is necessary to determine the required initial ratio of firepower of the warring parties $K(0)_{необх}$ the projected duration of the operation *T*, which satisfies the conditions (1).

At the same time, the dynamic changes in the number of firepower assets available to the warring parties can be described by a system of nonlinear differential equations that takes into account the intensity of the destructive effect, which changes in the course of hostilities. According to (Venttsel, 1964), (Mashkin. 2019), and (Romanchenko, 2022) it is recorded as:

$$\begin{cases} \frac{dA(t)}{dt} = -f_B(t)B(t); \\ \frac{dB(t)}{dt} = -f_A(t)A(t), \end{cases} \quad (2)$$

where $A(t), B(t)$ is the number of firepower assets of the forces of the warring parties;

$\frac{dA(t)}{dt}, \frac{dB(t)}{dt}$ – the dynamics of changes in the number of firepower assets available to the warring parties over time;

$f_A(t), f_B(t)$ is the intensity of the destructive effect of the firepower assets available to the warring parties (non-linear values). According to (Romanchenko, 2022) $f_A(t) = \alpha \frac{A(t)}{B(t)}$, $f_B(t) = \beta \frac{B(t)}{A(t)}$;

t is the current duration of the operation (hostilities).

The proposed approach envisages two stages of calculations.

Stage one involves calculating the required initial ratio of firepower $K(0)_{необх}$.

Let's introduce some metrics that are typically used to assess warring parties into this problem. These metrics include, first of all, the ratio between the number of firepower assets available to the warring parties:

$$K(t) = \frac{A(t)}{B(t)},$$

which is important to assess both at the initial stage of the operation (hostilities) and at the final stage at the given point in time $t = T$. Let's document these relationships as follows:

$$K(0)=\frac{A(0)}{B(0)};\qquad K(T)=\frac{A(T)}{B(T)}, \tag{3}$$

where $K(0)$ is the initial ratio of firepower assets of the warring parties at *t=0;*

$K(T)$ is the ratio of firepower assets of the warring parties at the time $t=T$.

Let's introduce a metric:

$$R(T)=\frac{B(0)-B(T)}{B(0)}, \tag{4}$$

that characterizes the relative losses of party *B* at a given time $t=T$.

Dividing the first equation of the system (2) by the second, the result is as follows:

$$\frac{dA(t)}{dB(t)}=\frac{\beta}{\alpha}\frac{B^3(t)}{A^3(t)}. \tag{5}$$

From there, integration gives us:

$$A^4(t)=\frac{\beta}{\alpha}B^4(t)+C, \tag{6}$$

where *C* is an arbitrary integrating constant.

Formula (6) is true for any given moment in time and thus, in general, establishes an analytical relationship between the number of firepower assets of the warring parties. In that case, for the beginning of the operation (hostilities), this formula (6) can be written as follows:

$$A^4(0)=\frac{\beta}{\alpha}B^4(0)+C, \tag{7}$$

and for the $t=T$ point in time:

$$A^4(T)=\frac{\beta}{\alpha}B^4(T)+C. \tag{8}$$

Eliminating from the functions (7), (8) the integration constant *C* and taking into account the relations (3), (4), one gets the general function for $K(0)$:

$$K(0)=\sqrt[4]{K^4(T)(1-R(T))^4+\frac{\beta}{\alpha}(1-(1-R(T))^4)}. \tag{9}$$

By replacing in (9) the parameters $K(T)$ and $R(T)$ with their required values $K(T)_{необх}$ and $R(T)_{доп}$, one gets a formula for determining the required initial ratio of firepower assets of the warring parties under the given constraints (1):

$$K(0)_{необх} = \sqrt[4]{K^4(T)_{необх}(1-R(T)_{доп})^4 + \frac{\beta}{\alpha}(1-(1-R(T)_{доп})^4)}. \quad (10)$$

The second stage allows to calculate the projected duration of the operation (hostilities) under the same constraints (1).

Taking into account equations (3), (4), let us find the value of the integration constant from equation (8):

$$C = K^4(T)B^4(0)(1-R(T))^4 - \frac{\beta}{\alpha}B^4(0)(1-R(T))^4. \quad (11)$$

From (6), taking into account (11), one obtains:

$$A^2(t) = \sqrt{\frac{\beta}{\alpha}}\sqrt{B^4(t) + \frac{\alpha}{\beta}K^4(T)B^4(0)(1-R(T))^4 - B^4(0)(1-R(T))^4}. \quad (12)$$

For convenience, let's introduce a designation:

$$D = \frac{\alpha}{\beta}K^4(T)B^4(0)(1-R(T))^4 - B^4(0)(1-R(T))^4. \quad (13)$$

Substitute (12), taking into account (13), into the second equation of system (2). Then the result is:

$$\frac{dB(t)}{dt} = -\frac{\sqrt{\alpha\beta}}{B(t)}\sqrt{B^4(t)+D}, \quad (14)$$

from there

$$dt = -\frac{B(t)dB(t)}{\sqrt{\alpha\beta}\sqrt{B^4(t)+D}}. \quad (15)$$

Integrating expression (15), one obtains the following result:

$$t = -\frac{1}{2\sqrt{\alpha\beta}}\ln\left|B^2(t) + \sqrt{B^4(t)+D}\right| + C_1. \quad (16)$$

In function (16), the integration constant C_1 is determined from the initial conditions ($t=0$):

$$C_1 = \frac{1}{2\sqrt{\alpha\beta}}\ln\left|B^2(0) + \sqrt{B^4(0)+D}\right|. \quad (17)$$

Then for t, the formula (16) is written as follows:

$$t = \frac{1}{2\sqrt{\alpha\beta}} \ln \left| \frac{B^2(0) + \sqrt{B^4(0) + D}}{B^2(t) + \sqrt{B^4(t) + D}} \right|. \quad (18)$$

Taking into consideration equation (3),the required initial number of firepower assets $B(0)_{необх}$ for party *B* given a known initial value $A(0)$ for party *A* and the calculated value of $K(0)_{необх}$ is calculated using the following formula:

$$B(0)_{необх} = \frac{A(0)}{K(0)_{необх}}. \quad (19)$$

At the $t = T$ point in time equation (4) can be used to obtain the estimated number of firepower assets for party *B*:

$$B(T)_{розр} = B(0)_{необх}(1 - R(T)_{доп}). \quad (20)$$

Then, taking into account equation (18), the obtained values for $B(0)_{необх}$ and $B(T)_{розр}$, one can obtain the projected duration of the operation (hostilities) under the given constraints (1):

$$T = \frac{1}{2\sqrt{\alpha\beta}} \ln \left| \frac{B^2(0)_{необх} + \sqrt{B^4(0)_{необх} + D^*}}{B^2(T)_{розр} + \sqrt{B^4(T)_{розр} + D^*}} \right|. \quad (21)$$

where $D^* = \frac{\alpha}{\beta} K^4(T)_{необх} B^4(0)_{необх}(1 - R(T)_{доп})^4 - B^4(0)_{необх}(1 - R(T)_{доп})^4$.

It is important to highlight that the entire algorithm for critical system analysis (2) can be extrapolated to other instances of armed conflict, including small tactical-level operations.

Findings

Thus, the derivation of formulas (10) and (21) achieves the goal of the article.

To confirm the accuracy of the obtained equations (10) and (21), let us compare the results of their calculation with the results of the numerical integration of system (2).

Let's select the following set of initial data for the calculation. Known initial number of firepower assets *A(0)* = 2270 *standard units* for party *A* at the intensity of the actual destructive effect $\alpha = 0{,}01$ *умов.од./доба* and $\beta = 0{,}03$ *умов.од./доба*, for the $t = T$ point in time, the required ratio of the number of firepower assets of the parties is specified $K(T)_{необх} = 1$ as well as the acceptable magnitude of relative losses $R(T)_{доп} = 0{,}33$ for party *B*.

For a hypothetical operation (hostilities) between the warring parties *A* and *B*, one has to calculate:

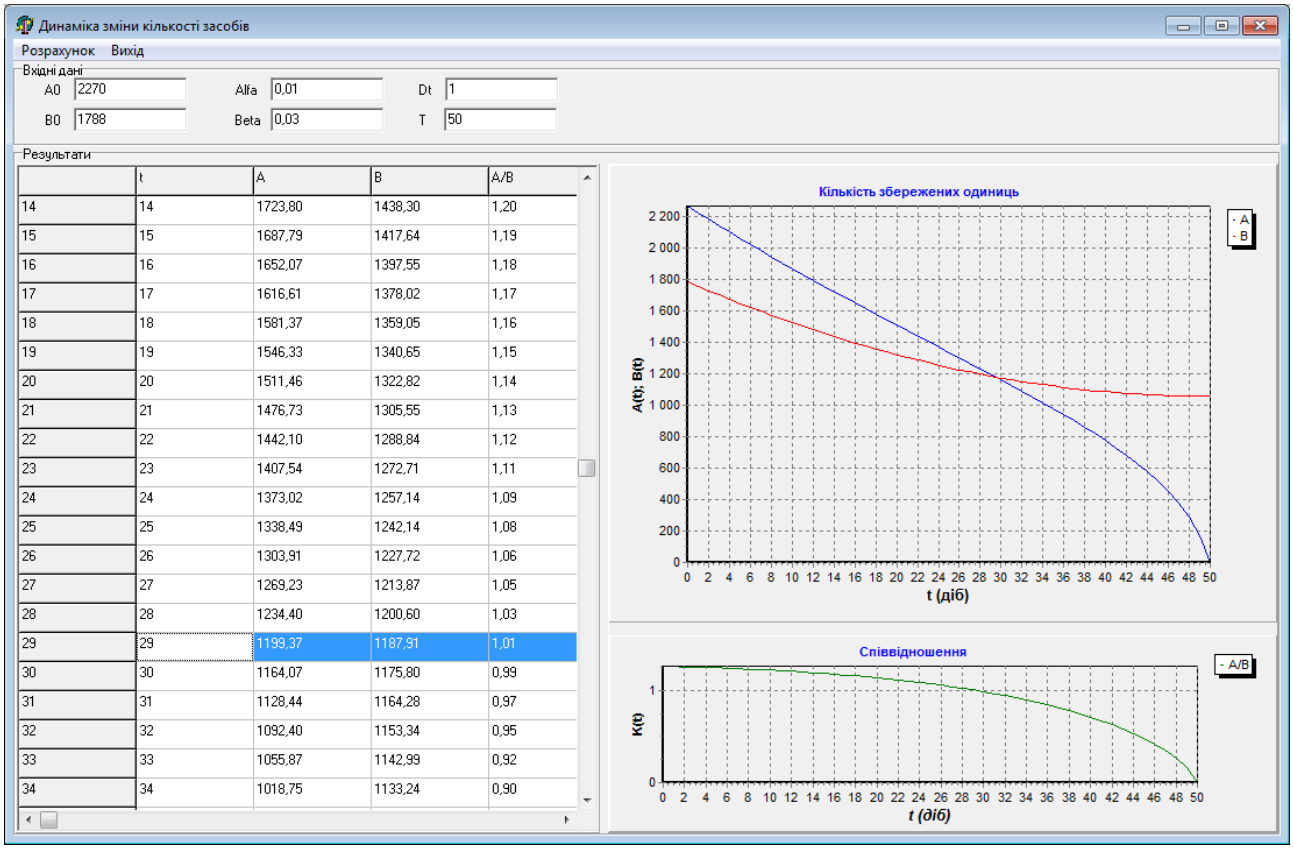
first, such an initial ratio of the number of firepower assets that will eventually yield the predetermined ratio $K(T)_{необх} = 1$, while meeting the condition of acceptable relative losses $R(T)_{доп} = 0{,}33$ for party *B;*

second, the projected duration of the operation (hostilities) T under the given constraints.

By plugging into equation (10) the values for $K(T)_{необх}$ and $R(T)_{доп}$, one gets the required

initial ratio of firepower assets of the warring parties $K(0)_{необх} \approx 1{,}3$. Using the obtained value $K(0)_{необх}$ in (19) to calculate the value of $B(0)_{необх} = 1788$ *умов.од.* that satisfies the given constraints (1). The projected duration of the operation (hostilities) is calculated using the formula (21) and amounts to $T \approx 29$ *діб*. For this purpose, the following values were used (21): $B(T)_{розр} = 1198$ *умов.од.*, calculations based on the formula (20), taking into account $B(0)_{необх} = 1788$ *умов.од.*, $R(T)_{доп} = 0{,}33$.

After numerical integration of the system (2) at *A(0)* = 2270 *standard units, B(0)* = 1788 *standard units* and the above given α, β (Figure. 1) for the duration of operation (hostilities) $T \approx 29$ *діб*, one gets $K(T)_{необх} \approx 1$ and $R(T)_{доп} \approx 0{,}33$. This result coincides with the values of the abovementioned analytical calculations, which indicates the validity of the estimates obtained using equations (10) and (21), which are the basis of the proposed approach.



	t	A	B	A/B
14	14	1723,80	1438,30	1,20
15	15	1687,79	1417,64	1,19
16	16	1652,07	1397,55	1,18
17	17	1616,61	1378,02	1,17
18	18	1581,37	1359,05	1,16
19	19	1546,33	1340,65	1,15
20	20	1511,46	1322,82	1,14
21	21	1476,73	1305,55	1,13
22	22	1442,10	1288,84	1,12
23	23	1407,54	1272,71	1,11
24	24	1373,02	1257,14	1,09
25	25	1338,49	1242,14	1,08
26	26	1303,91	1227,72	1,06
27	27	1269,23	1213,87	1,05
28	28	1234,40	1200,60	1,03
29	29	1199,37	1187,91	1,01
30	30	1164,07	1175,80	0,99
31	31	1128,44	1164,28	0,97
32	32	1092,40	1153,34	0,95
33	33	1055,87	1142,99	0,92
34	34	1018,75	1133,24	0,90

Figure 1. Numerical integration results

When performing calculations based on the abovementioned approach, one must bear in mind that describing the actions of the warring parties using systems of differential equations is to some extent a simplified interpretation of reality. Regardless, even in this case it is possible to calculate approximate values for different parameters of the operation (hostilities) that can used for planning purposes, particularly when justifying the required force composition and duration of the operation

Discussions

Dynamic averaging method is one of the tools used to study different dynamic processes taking place during a conflict (Venttsel, 1964), (Hrabchak, Mashkin, 2019), (Fursenko, 2020). It is centered

around the model of bilateral actions taken by parties, which is described by a system of differential equations. For systems of linear differential equations with a constant destructive effect, mathematical dependencies are obtained to determine the required initial ratio of firepower assets of the warring parties and the projected duration of combat operations under the predefined (acceptable) extend of losses (Venttsel, 1964), (Zahorko, 2020), (Romanchenko, 2020).

At the same time, the issue has been partially addressed for systems of nonlinear differential equations that more fully describe the nature of military conflict between the parties. In particular, researchers were able to obtain formulas describing dependencies only for the equations representing a prolonged operation (hostilities) with a slow decrease of available forces and assets over time (Kotliarov, 2020).

For systems that describe operations (hostilities) in a fast-paced environment, (Romanchenko, 2020) in his research emphasizes the importance of determining analytical dependencies that establish the relationship between the initial ratio of forces and assets of the warring party and the projected duration of hostilities between them that would produce an acceptable extent of losses for one of the parties while achieving the final predefined firepower ratio. However, no equations were derived describing these relationships. It is important to quickly calculate the aforementioned parameters that can be used in operation (combat) planning (in particular, when justifying the required force composition and duration of an operation (hostilities)).

Conclusions

The article further explores the field of critical analysis for Lanchester's nonlinear differential equations in the form of systems (2) used to describe fast-paced conflicts. In mathematical terms, such a conflict is described by a nonlinear model, where the right-hand sides of the differential equations are chosen to be a combination of the product of the current values of the combat power of the warring parties, which reflects the dynamic nature of the process to the fullest extent possible. Thus, the article proposes a double-pronged approach to critical analysis. The first aspect allows to establish a formula-driven relationship of the initial force ratio with predetermined criterion values. This relationship takes form of a biquadratic equation.

The second aspect concerns the critical assessment of the time required to achieve the ultimate objective of one of the parties in a conflict, where the original system is reduced to a single nonlinear first-order differential equation that can be solved for the time parameter using tabular integration.

For the first time, this approach is based on the analytical solution of the system of nonlinear differential equations with the dynamic averaging method, taking into account the possible changes in the intensity of the destructive effect delivered by forces and assets over the course of the hostilities, which is typical for modern armed conflicts.

Recommendations

Unlike the existing approaches, the proposed approach allows to perform calculations quickly without reducing their accuracy using the obtained formula-based dependencies. The practical applicability of this approach is demonstrated by the relevant computational example.

Further research should focus on developing recommendations on the application of this approach during operation planning and its integration into various sets of mathematical models.

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Mathematical model of the analytical solution of a nonlinear system of differential equations for calculating the increase in efficiency indicators during the build-up of military efforts

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Abstract. To assess the degree of fulfillment of certain tasks by troops (forces), certain numerical characteristics are used – performance indicators. They are a quantitative measure of the performance of combat missions and are obtained as a result of the use of various methods of operation research. One of the indicators is the growth rates during the build-up of efforts. The procedure for calculating the increment of performance indicators, taking into account the non-linear nature of the process, is unambiguously uncertain. For a linear class of systems, the problem of analytical solution is solved completely, which makes it possible to calculate performance indicators with the subsequent determination of estimated values of their positive growth. For nonlinear systems there is no such completeness of the results, but for a certain class of them it is possible to find an analytical solution. The objectives of the study are formulated as follows. It is necessary to find such a dependence that would relate the number of parties in one analytical expression, taking into account non-linear nature of the process.

The methodical approach is based on the derivation of the analytic relation, which is the general integral of nonlinear systems of differential equations of means. With the help of this relation (where the functional relationship between the indicators of the number of opposing sides is established), the original system is reduced to one nonlinear differential equation of the first order (for the time indicator), which has an analytical solution by means of table integrals. Obtaining two algebraic equations is key to determining the increase in performance indicators, which significantly increases the efficiency of calculations compared to numerical methods.

Keywords: nonlinear and systems, dynamics of averages, analytical relations, algebraic and equation, performance indicators.

Introduction

To assess the degree of performance of combat missions by troops, certain numerical characteristics and indicators of effectiveness are used. They are a quantitative measure of the performance of combat missions and are obtained as a result of the use of various methods of

operation research during the analysis of complex systems (military formations) or processes. The investigated operation (combat operations) can be quantitatively characterized by a certain set of performance indicators, each of which reproduces its specific feature. Among these indicators, one of the most important is the indicator of losses of the group, which should not exceed the specified value depending on the nature of hostilities (operation). Here, from the point of view of assessment, the most interesting case is the case when it is necessary to additionally calculate the change in this indicator in terms of reducing losses over a certain time.

Under such conditions, it is expedient to use the method of dynamics of averages in a nonlinear formulation, which establishes an analytical relationship between the given parameters. A positive effect (reduction of the loss rate and time of task completion) is achieved by increasing efforts (one task is performed by more than one unit) while other conditions remain unchanged.

It should be noted that the analytical solution of this problem is quite relevant in the applied field of research of nonlinear systems of differential equations, especially in the case of their nonlinearity.

Methodological Framework

Among the large arsenal of mathematical models in the applied field of confrontation between the parties, a special place is occupied by Lanchester's analytical models.

The study of such models, which was initiated in the works of their author, was further developed in the form of a generalized Lanchester model:

$$\frac{dA(t)}{dt} = P - aB(t) - cA(t) - kA(t)B(t);$$

$$\frac{dB(t)}{dt} = Q - bA(t) - gB(t) - lB(t)A(t),$$

where is the number of units of groups of parties (or their number); $A(t)$, $B(t)$

$\frac{dA(t)}{dt}$, $\frac{dB(t)}{dt}$ is the dynamics of changes in the number of units of the parties over time;

a, b – the intensity of the effective damaging effect of each unit of the parties, respectively (in the general case of the function of quantities); $A(t)$, $B(t)$

P, Q – the speed of recovery of losses due to the introduction of reserves;

C, G, K, L are non-negative parameters.

An analysis of the generalized Lanchester model at $k=l=0$ was carried out in (Morse and Kimbell, 1956; Chuev 1970; Saati, 1977). For $k\neq0$, $l\neq0$, but at $c=g=0$, it was continued in a monograph (Wentzel, 1968), as well as in a number of other works, for example (Diener, 1970).

The next stage in the development of the method of dynamics of averages in the form of Lanchester equations was the further detailing of the process of counteraction for different types of means with an increase (in terms of the number of these means) of the order of the system of differential equations, which significantly complicated its study. To reduce the dimensionality of the problem in (Pliuta 1989) and in a number of other works (Brezgin, Buravlev, 2011), an approach using the coefficients of proportionality of different types of means was proposed. As a result, the original multidimensional system was transformed into a system of differential equations. Thus, the study of the system of differential equations has not lost its significance to this day.

Results and Discussions

Presentation of the essence of the methodical approach to determining the analytical solution

of the nonlinear system of differential equations of the method of dynamics of averages with the subsequent calculation of the increase in efficiency indicators.

In general, the initial nonlinear system of the method of means dynamics is represented in the form:

$$\begin{aligned}\frac{dm_A}{dt} &= -f_B(\lambda_B)\cdot m_B;\\ \frac{dm_B}{dt} &= -f_A(\lambda_A)\cdot m_A,\end{aligned} \tag{1}$$

where functions are approximated by dependencies of the form: $f_A(\lambda_A)$, $f_B(\lambda_B)$

$$\begin{aligned}f_A(\lambda_A) &= \lambda_A\left(\frac{m_B}{N_B}\right)^q;\\ f_B(\lambda_B) &= \lambda_B\left(\frac{m_A}{N_A}\right)^q.\end{aligned} \tag{2}$$

The objectives of the study are formulated as follows. It is necessary to find such a dependence that would relate the number of sides in one analytical expression, taking into account the nonlinear form of the system (1). To do this, as in the previous case, we will use the methods of finding the general integrals of the system of differential equations. Then writing the equations in the form (1), where $q = 1$ allows you to find one of these integrals. Indeed, performing the necessary mathematical calculations, we get:

$$m_A = \frac{\lambda_B N_B}{\lambda_A N_A} m_B + C, \tag{3}$$

where the constant integration C is defined by the expression:

$$C = \frac{N_A^2\lambda_A - N_B^2\lambda_B}{\lambda_A N_A}. \tag{4}$$

Let us substitute (3) taking into account (4) in the original equation (1) and we get:

$$\frac{dm_B}{dt} = -\frac{\lambda_B}{N_A} m_B^2 - \left(\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A}\right) m_B. \tag{5}$$

Let's rewrite (5) as follows:

$$dt = \frac{dm}{-\frac{\lambda_B}{N_A} m_B^2 - \left(\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A}\right) m_B}, \tag{6}$$

where the right part is represented by the form of a tabular integral (Bronstein, Semendyaev, 1986).

Then, integrating the expression (6), we get the dependency:

$$t = \frac{1}{-\frac{\lambda_A N_A}{N_B} + \frac{\lambda_B N_B}{N_A}} \ln \frac{m_B}{-\frac{\lambda_B}{N_A} m_B - (\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A})} + C_1. \quad (7)$$

Depending on (7), the constant integration of_{C1} is determined from the initial conditions. Finally, for t, the expression (7) is written as:

$$t = \frac{N_A N_B}{\lambda_B N_B^2 - \lambda_A N_A^2} \ln \frac{m_B(-\frac{\lambda_B}{N_A} N_B - \frac{\lambda_A N_A^2 - \lambda_B N_B^2}{N_A N_B})}{N_B(-\frac{\lambda_B}{N_A} m_B - \frac{\lambda_A N_A^2 - \lambda_B N_B^2}{N_A N_B})}. \quad (8)$$

Let's combine (3) and (4) and write:

$$m_A = \frac{\lambda_B N_B}{\lambda_A N_A} m_B + \frac{N_A^2 \lambda_A - N_B^2 \lambda_B}{\lambda_A N_A}. \quad (9)$$

Equations (8) and (9) are a solutionof the nonlinear system (1) and are further used to determine the increase in performance indicators during the increase in efforts.

We will also show another way to solve the system (6), by $q=1$. Then equation (5) is rewritten as:

$$\dot{m}_B + (\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A}) m_B = \frac{-\lambda_B}{N_A} m_B^2. \quad (10)$$

The form of notation (10) corresponds to the Bernoulli equation (Bronstein, Semendyaev, 1986) (Dwight, 1977), which has its own solution algorithm. Here, by special substitution of variables, equation (10) is reduced to a linear differential equation:

$$\dot{z} + az = b, \quad (11)$$

which is easy to integrate.

Further, by reverse substitution of variables, the solution of the original system (10) is found:

$$m_B = \frac{N_B(\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A})}{\frac{\lambda_A N_A}{N_B} e^{(\frac{\lambda_A N_A}{N_B} - \frac{\lambda_B N_B}{N_A})t} - \frac{\lambda_B N_B}{N_A}}, \quad (12)$$

from which time *t* is determined. Oheld expression coincides with (8) taking into account the analytic transformation of this expression. With a similar approach, the value of m_A is calculated.

Now let's find an increase in performance indicators. Suppose that at the final stage of hostilities (t 1) the value *of* m B has reached the value of m B (t 1) (the parameter at which side B refuses to conduct further hostilities). Then the value *of* $m_A(t_1)$ is uniquely found from expression (9).

Suppose that side A has increased the number of its units *by n* times, while the parameters of side B have remained unchanged. With this in mind, let us set ourselves the goal of determining the reduced time of hostilities (t 2), as well as reducing the value of the relative losses of side *A* at time t_2, assuming that $m_B(t_1) = m_B(t_2)$.

In this case, expressions (13) and (14) are written as:

$$m_A(t_2) = \frac{\lambda_B N_B}{\lambda_A n N_A} m_B(t_1(t_2)) + \frac{(nN_A)^2 - N_B\lambda_B}{\lambda_A n N_A}; \tag{13}$$

$$t_2 = \frac{nN_A N_B}{\lambda_B N_B^2 - \lambda_A n^2 N_A^2} \ln \frac{m_B(t_1(t_2))(-\frac{\lambda_B}{N_A} N_B - \frac{\lambda_A n^2 N_A^2 - \lambda_B N_B^2}{nN_A N_B})}{N_B(-\frac{\lambda_B}{nN_A} m_B(t_1(t_2)) - \frac{\lambda_A n^2 N_A^2 - \lambda_B N_B^2}{nN_A N_B})}. \tag{14}$$

Then the time of hostilities will be reduced by the amount of:

$$\Delta t = t_1 - t_2,$$

and the relative loss of side *A* is reduced by the amount of:

$$\Delta B_A = \frac{N_A - m_A(t_1)}{N_A} - \frac{nN_A - m_A(t_2)}{nN_A}.$$

Thus, the desired effect will be achieved in a shorter period of time and with fewer losses.

The solution of system (1) by *q=2* looks somewhat more complicated. Here it is advisable to use the Bernoulli (Saati) method. Then the equation for m_B is written as:

$$m_B = -\frac{\lambda_A N_A}{N_B^{2+R}} m_B^{2+R}, (R = \frac{\lambda_B N_B^2}{\lambda_A N_A^2}),$$

and its solution will be determined by the expression:

$$m_B = \sqrt[-1-R]{(-1-R)(-\frac{\lambda_A N_A}{N_B^{2+R}})t + N_B^{-1-R}}.$$

Here, the calculation of the increase in performance indicators is similar to the case where *q = 1*.

The basis for choosing a model in the form of (1) was the calculation of its parameters according to the following algorithm. Initially, system (1) was matched with the transient process, which is shown in Fig. 1.

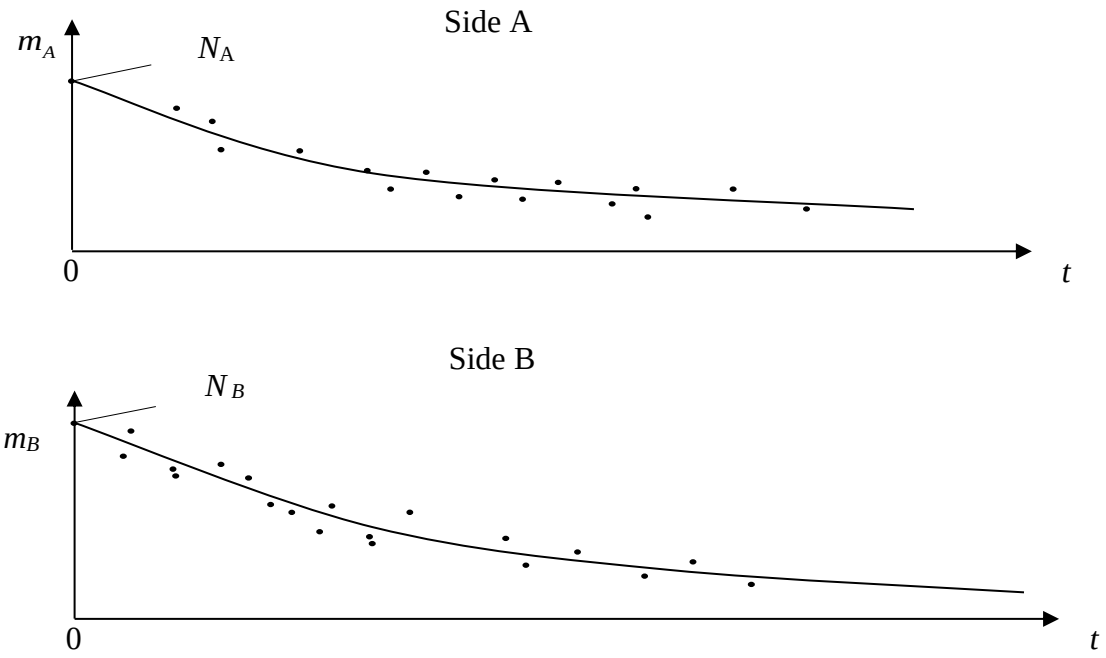


Figure 1. Calculation of model parameters

Fig. 1 dots indicate the values that were obtained by different variants of simulation modeling. Subsequently, for each dependency, a regression polynomial was formed in the form of a dependence:

$$m_{A(B)} = a_0^{A(B)} + a_1^{A(B)} t + a_2^{A(B)} t^2 + a_3^{A(B)} t^3 + \dots \; . \qquad (15)$$

To determine the parameters of this polynomial, the method of least squares was used. Then, by differentiating the dependencies (1, 2), the left-hand sides of the equations (1) were determined. At the end of the whole process, the coefficients and . As a criterion of truth, those values of independent variables were taken, in which over the entire time interval of identification of the deviation of the calculated (pd time of differentiation of equations ($1 \lambda_A \lambda_B$)) values of the corresponding values (found by polynomial dependence) did not exceed the integral error. $m_{A(B)\,розр}$ $m_{A(B)}$ $\Delta_{A,B\,зад}$

A number of works (Romanchenko, Kotlyarov) are devoted to the issues of determining analytical dependencies for performance indicators on the basis of the method of dynamics of averages in a linear formulation, where the solution of equations is carried out on the basis of general analytical approaches to the study of the system of differential equations (Bronstein, 1986, Wentzel, 1972, Dwight, 1977).

For example, in the work (Romanchenko, Kotlyarov, Pavlyuk, 2018), thisplace is occupied by the model of conducting bilateral combat operations of groups in the confrontation of the parties on the basis of linear differential equations of the dynamics of means. In general, they are written in the form of:

$$\begin{aligned} \frac{dm_A}{dt} &= -m_B\lambda_B; \\ \frac{dm_B}{dt} &= -m_A\lambda_A, \end{aligned} \tag{16}$$

where is the number of combat-ready units of the parties' groups; m_A, m_B

$\lambda_A = const$, $\lambda_B = const$ – fire performance of the parties;

$\frac{dm_A}{dt}$, $\frac{dm_B}{dt}$ – the dynamics of changes in the number of combat-ready units of the parties over time.

The solution of the system (16) allows you to establish analytical dependencies. For this purpose, methods of finding the general integrals of the system of differential equations are used. In this case, writing the equations in the form (16) allows you to find one of these integrals. Indeed, performing the necessary mathematical calculations, we get:

$$m_A^2 = \frac{\lambda_B}{\lambda_A} m_B^2 + C, \tag{17}$$

where *C is* an arbitrary integration constant.

Expression (17) is valid for any point in time and, thus, in a general way, establishes an analytical relationship between the numbers of groups, which is especially important when calculating such an indicator of efficiency as the balance of forces of the parties.

As for the constant integration of C, it is unchanged both for the initial balance of forces of the parties and for the numbers of the parties at the end of the operation. This is used in the future. Based on the requirements of regulatory documents, through the values and under the known, such a ratio of forces of the parties at the end of the operation is set, which satisfies us. Then the value of *C* is m_A^k m_B^k λ_A λ_B easily found from equation (17).

Now let's write down this equation for the initial values of the number of sides and in the form: $m_A^н$ $m_B^н$

$$m_A^н = \sqrt{\frac{\lambda_B}{\lambda_A}(m_B^н)^2 + C}. \tag{18}$$

Thus, taking into account the previously found value of C, given the initial composition of the grouping of one of the parties (for example) it is possible to find, according to expression (18), the initial number of the $m_B^н$ other side. It should be emphasized that in this case, the initial balance of forces $\frac{m_A^н}{m_B^н}$ ($m_B^н$ – set, $m_A^н$, – determined) will ensure the achievement of the goal of the operation according to the previously set criterion of the balance of forces at the time of its $m_A^н$ $\frac{m_A^н}{m_B^н}$ $m_B^н$ $m_A^н$

$\frac{m_A^к}{m_B^к}$ completion.

In the considered methodical approach, only the issue of determining the necessary time for conducting an operation (combat operations) according to the selected criterion remains unresolved.

In the paper (Romanchenko, Kotlyarov, Shapoval, 2008) the following algorithm for solving this problem is proposed. First, the system (16) is solved for a given value and a value of . Then the following time dependencies are obtained: m_B^H m_A^H

$$2\sqrt{\lambda_A}m_A = (f_A(\lambda_A, m_A^H) - f_B(\lambda_B, m_B^H)) \cdot e^{\sqrt{\lambda_A\lambda_B}t} + (f_A(\lambda_A, m_A^H) + f_B(\lambda_B, m_B^H)) \cdot e^{-\sqrt{\lambda_A\lambda_B}t};$$
$$2\sqrt{\lambda_B}m_B = -(f_A(\lambda_A^{/}, m_A^H) - f_B(\lambda_B, m_B^H)) \cdot e^{\sqrt{\lambda_A\lambda_B}t} + (f_A(\lambda_A, m_A^H) + f_B(\lambda_B, m_B^H)) \cdot e^{-\sqrt{\lambda_A\lambda_B}t}. \quad (19)$$

Further, in expression (19), the right and left parts of the equations are summed up, after which the value of the time parameter *t* is determined from the obtained dependence in the form:

$$t = \frac{1}{\sqrt{\lambda_A\lambda_B}} \ln \frac{f_A(\lambda_A, m_A^H) + f_B(\lambda_B, m_B^H)}{m_A\sqrt{\lambda_A} + m_B\sqrt{\lambda_B}}. \quad (20)$$

According to the known, by substituting in ($m_{A,B}^H$, $\lambda_{A,B}$ 20) instead of the values of their values that satisfy the goals of achieving the operation, the duration of hostilities t is also determined m_A *i* m_B $m_{A,B}^K$. Note that for linear systems, the problem of analytical solution is solved completely. This makes it possible to calculate other performance indicators with the subsequent determination of the estimated values of their positive growth.

As for nonlinear systems, there is no such completeness of results in this field of research, but for a certain class of them it is possible to obtain an analytical solution.

Conclusions

The proposed methodical approach is based on the derivation of the analytical relation, which is the general integral of the nonlinear systems of differential equations of the dynamics of the means. With the help of this analytic expression (where the functional relationship between the indicators of the number of opposing sides is established), the original system is reduced to one nonlinear differential equation of the first order (for the time indicator), which has an analytic solution by means of tabular integration or by solving the Bernoulli equation. Obtaining two algebraic equations is key to determining the increase in performance indicators.

A further direction of research can be considered a numerical interpretation of the use of this approach to determine the increase in performance indicators in specific operations (combat operations).

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Mathematical model and algorithm for evaluating the effectiveness of the on-board weapon control radar stations in the conditions of obstacles and countering them in air combat

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Abstract. The development and practical implementation of new methods of active counteraction to enemy interference stations in air combat necessitate considering their impact on the overall efficiency of airborne radar weapons control stations, which requires improving existing mathematical models for describing their functioning in conditions of interference and simultaneous active counteraction. In the article, the author describes an improved mathematical model for assessing the effectiveness of airborne radar weapons control stations in air combat to ensure the survivability of a fighter aircraft and its reliable performance of a combat mission. The analysis of modern airborne radar systems and active interference stations as objects of mathematical modelling, methods of active counteraction to enemy airborne interference stations and existing mathematical models of the functioning of airborne radar weapons control stations is carried out. The initial data on the mathematical modelling of the functioning of airborne radar weapons control stations in conditions of interference with simultaneous counteraction to enemy interference stations are formed and the selected air combat situation is presented, which is subject to mathematical description. Indicators and criteria characterizing the effectiveness of the functioning of airborne weapons control radar stations have been selected, the main of which is the limitation on the range of their use depending on the method of counteraction used. Preliminary calculations have been made regarding the use of these methods of active counteraction. Considering the peculiarities of using methods of counteracting enemy stations, it is proposed to divide the cycle of air combat between aircraft into 5 stages depending on the distance between them. An algorithm for justifying the choice of methods of countering enemy interference stations, considering the range between aircraft for continuous target tracking, is developed and the probability of target tracking is determined, considering the use of various combinations of countermeasures. For a qualitative and complete assessment of the effectiveness of the functioning of airborne radar weapons control stations, it is proposed to use fuzzy sets and game theory, which are used to build a mathematical model for assessing the effectiveness of airborne radar weapons control stations in terms of countering enemy interference stations, which

was used to develop an algorithm and select the most effective combination of countermeasures.

Keywords: efficiency of functioning, weapon control, mathematical modelling, interference station.

Introduction

The experience of local wars and conflicts shows that aircraft without electronic warfare equipment have very low survivability. The use of active interference stations for individual protection (AISIP) on aircraft brings the probability of not hitting an aircraft in an air battle to 45-75%, and the integrated use of electronic warfare (EW) equipment can bring this probability to 80-95%. Thus, due to the importance of the tasks performed by onboard electronic warfare equipment and their effectiveness, the issue of electronic countermeasures to electronic warfare equipment itself - the so-called counter-radio-electronic countermeasures (CREM) - has recently been increasingly studied.

Today, there are several ways to counteract AISIP systems, the use of which is random. However, the analysis of their use shows that most methods of active counteraction have different conditions of use, which are associated with changes in the operation of onboard weapon control radars (WCRs), which imposes restrictions on their range of use.

The development and practical implementation of new methods of active counteraction to enemy interference stations in air combat necessitate considering their impact on the overall efficiency of the WCRs functioning, which in turn necessitates the improvement of existing mathematical models for describing the functioning of WCRs in conditions of interference and simultaneous active counteraction to them.

Therefore, for the further development of electronic countermeasures against enemy interference stations, it is necessary to improve mathematical models for assessing the effectiveness of the WCRs both in conditions of interference and simultaneous countermeasures to form a clearly defined algorithm for applying the developed and practically implemented countermeasures. Given the above, the purpose of the article is to develop an improved mathematical model for assessing the effectiveness of the WCRs in air combat.

Methodological Framework

Recent studies and publications on the subject under consideration (Androsov and Kutakhov, 1996), (Semenenko, 2015), (Semenenko, Vodchyts, Dobrovolskyi, 2011), (Vasilevich, 1989), (Semenenko, Kablukov, Mironenko, Dobrovolskyi, 2019), (Perunov, Matsukevych, Vasilev, 2010), (Semenenko, Kablukov, Chernega, 2019), (Semenenko, Sorokin, Dobrovolskyi, Kablukov, 2019), (Vasilevich, 2000) show that the vast majority of mathematical models describing the processes of interaction between EW and radar means are designed to assess the effectiveness of the functioning of the WCRs in conditions of interference without active counteraction to them (Androsov and Kutakhov, 1996), (Semenenko, 2015), (Semenenko, Vodchyts, Dobrovolsky, 2011).

Special cases are models that allow to assess the effectiveness of the use of certain passive means of protection of WCRs against certain types of interference (Vasilevich, 1989), (Semenenko, Kablukov, Mironenko, Dobrovolsky, 2019), (Perunov, Matsukevich, Vasilev, 2010).

The works (Semenenko, Kablukov, Chernega, 2019), (Semenenko, Sorokin, Dobrovolskyi, Kablukov, 2019) are devoted only to methods of active counteraction to CREM, which have different conditions of their application and are associated with changes in the operation of WCRs, which imposes restrictions on their range of use.

In (Vasilevich, 2000), the author notes that the process of confrontation in air combat between WCRs and AISIP occurs under conditions of stochastic uncertainty of the interference situation due to the lack of complete information about the conduct of CREM, the characteristics of enemy AISIP,

unknown conditions of air combat, and the lack of practical assessments of radar interference protection during CREM at certain stages of combat.

In the process of confrontation in the air battle between the WCRs and the AISIP, there are a number of software engineering methods for estimating software costs (Kirsanov, Sahun, 2014), (Potrap, Krivonozhko, 2022), (Andon, Ignatenko, Sinitsyn, Slabospytska, 2016), (Official website of the Center for Systems and Software Engineering at the University of Southern California, 2022), (Information technology - Software measurement - Functional size measurement - Part 1: Definition of concepts ISO, 2022), (Koregin, Chick, 2020).

The authors propose a classification of such methods, according to which they are divided into empirical and analytical. Empirical methods are based on empirical statements, principles, and assumptions formed based on targeted research, observation of software development projects, and measurements of its individual quantitative characteristics related to cost. Analytical methods are based on the use of analytical expressions, analytical models that describe the dependence of quantitative characteristics of software and the cost of its development According to the classification proposed by the authors, empirical methods are classified as follows:

the method of expert evaluation, in which the software cost is estimated by an individual specialist (expert) or a group of experts with relevant experience and data on previous similar projects, the capabilities of development companies, scientific achievements and scope of application in relation to software, the use of several methods of cost calculation;

analogies method, which involves comparing with similar projects in the field of developing software for the process of confrontation in air combat of the WCRs and the AISIP defence system; the result is an adjusted value that is estimated taking into account quantitative and qualitative differences;

Parkinson's estimation, a method based on Parkinson's law - the amount of work increases to the extent necessary to take the time allocated for its completion. According to this law, the effort spent on work is distributed evenly over the time allocated to the project. The criterion for estimating the cost of software for the air combat process of the WCRs and the AISIP air defence system is human resources;

The Price-to-win method is based on the principle that the client is always right. The essence of the method is that regardless of the estimated real costs of project development, the cost of the software depends on the customer's budget, not on the functional characteristics of the software for the air combat process of the WCRs and the AISIP air defence system being developed.

To conduct a comparative analysis of methodological approaches, we have chosen a procedure consisting of the following stages (Surmin, 2006), (Gusak, Kirsanov, Ostrovsky, 2021):

defining the purpose of the comparative analysis;

selection of methodological approaches for comparative analysis;

studying methodological approaches, collecting the necessary information about their advantages and disadvantages, and the differences between them;

defining criteria (indicators) for comparative analysis;

conducting a comparative analysis based on certain criteria (indicators);

formulation of conclusions (recommendations) based on the results of the comparative analysis.

The purpose of the comparative analysis of methodological approaches to estimating software development costs is to develop recommendations for choosing a methodological approach that can be used to justify the costs of software development for the needs of the Armed Forces of Ukraine.

The fourth stage of the methodological approach involves substantiating the procedure for implementing the process of managing C4ISR troops in an air combat confrontation between WCRs and the AISIP air defence systems (Husak, Kirsanov, Ostrovsky, 2021).

At this stage, we consider the peculiarities of building and functioning of the C4ISR type from the cybernetic point of view, namely, regarding:

Ensuring the focus (clear implementation of a specific goal) of management;

use of cause-and-effect and feedback relationships between elements (automated control systems and their complexes);

considering the impact on the elements of the external environment (enemy actions, physical and geographical conditions of the area of operation), which leads to the stochastic nature of the process of commanding troops;

the exchange of information between elements as a prerequisite for its functioning and integrity;

the dynamic nature of the management process carried out in (constant change of state over time in accordance with the intensity of the flow of information that comes out at each stage of the troop management cycle).

To achieve compatibility of the structures of the Armed Forces of Ukraine with the relevant structures of NATO member states, in June this year, the NATO Secretary General signed the updated NATO-Ukraine Partnership Goals 2021 (NATO UNCLASSIFIED, 2021). The goal of G 1000 is the need to train and evaluate units of the Armed Forces of Ukraine that may be assigned to participate in multinational operations, including NATO-led operations, in accordance with NATO concepts, doctrines, standards and procedures.

Thus, a comparative analysis of approaches to assessing the command-and-control bodies (CCB) of the Armed Forces of Ukraine and the NATO Joint Forces is an urgent scientific task.

The analysis of recent studies and publications shows that there are several approaches to assessing the CCB of the Armed Forces of Ukraine and the NATO Allied Forces, as set out in the methods, instructions, guidelines, doctrines, manuals, and standards of the NATO Allied Forces (Handbook “Operational capabilities concept evaluation and feedback (OCC E&F) program”, 2020), (Allied Command Operations Forces Standards Volume VII, 2020). At the same time, each of the approaches to assessing CCB has its own significant differences.

However, there are no studies and publications on assessing the level of compliance of the Ukrainian Armed Forces' guiding documents with the NATO Allied Forces’ guiding documents, on assessing the CCB, or the results of a comparative analysis of the approaches to assessing the CCB of the Ukrainian Armed Forces and the NATO Allied Forces.

On this topic (Komarov, 2019), (Pat. 109226, Komarov, Tkachenko, Galushka, 2016) shows that most of the literature covers statistical methods of analysis and diagnosis of aircraft, but when considering these issues, no attention is paid to cases of aircraft reliability.

Almost no attention is paid to the use of methods and approaches to controlling the frequency of natural oscillations when choosing a method of aircraft restoration, as well as to methods for determining the safety margin of combat aircraft based on the analysis of dynamic characteristics.

Results and Discussions

The structural and logical scheme of the application of the improved mathematical model for evaluating the efficiency of the WCRs consists of five stages.

At the first stage, the initial data on modelling the functioning of the WCRs in conditions of interference and countering enemy AISIP were formed. An air combat situation subject to mathematical description was chosen (Fig. 1), as well as four methods of CREM used to counteract enemy interference stations, namely:

Methods 1 and 2 – “Counteracting the enemy’s active interference station by changing the polarization of the signal at the reception of the WCRs”;

Method 3 – “Counteracting the enemy's active interference station by changing the power of the irradiating signal of the WCRs”;

Method 4 – “Counteracting the enemy's active interference station by disrupting the irradiation regularity”.

At the second stage, we selected indicators and criteria (Table 1) that characterize the efficiency of the WCRs functioning, considering which we made preliminary calculations.

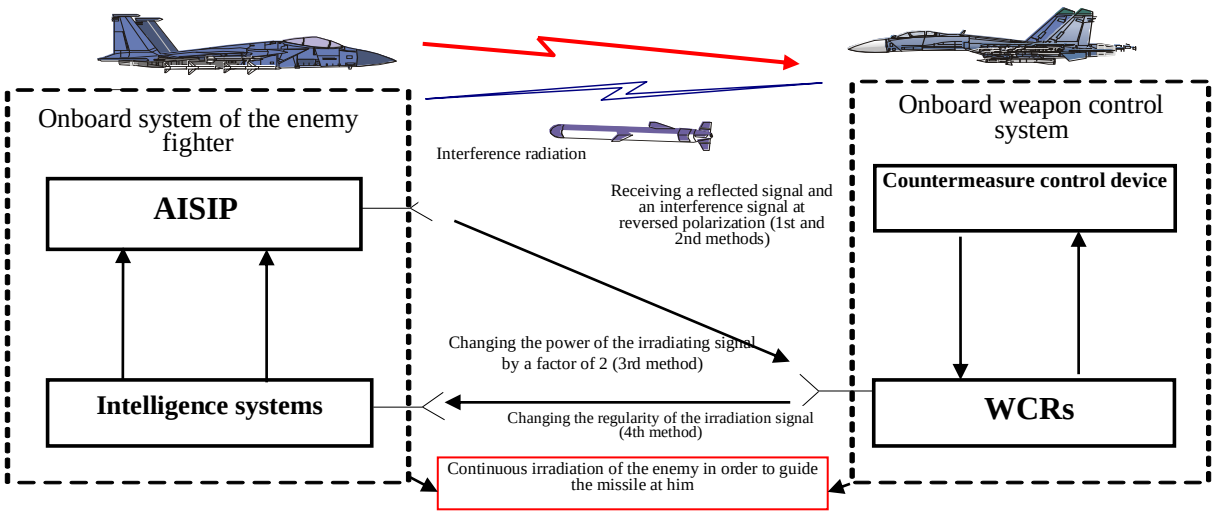


Figure 1. Air combat situation

Table 1: Performance indicators of WCRs in conditions of interference

Indicators and criteria	Without considering the enemy's countermeasures	Considering the enemy's counteraction to the AISIP
Target detection range	$D_{\max} = \sqrt[4]{\frac{N_c G_c G_n \sigma_ц \lambda^2}{64 \pi^3 N_{c\,вх}}}$,	$D = \sqrt[4]{\frac{N_c G_c \lambda^2 G_n \sigma_ц}{64 \pi^3 N_{c\,вх}} \cdot \cos^2 \Delta\beta}$
Range of application of the continuous direction-finding mode	$D_{РБП} = \beta \cdot D_{\max}$, $\beta = f\begin{pmatrix} W_{XT} = 0{,}5\left[1-\Phi(q_0)\right], \\ W_{ПВ} = \left[1+\Phi(q-q_0)\right] \end{pmatrix}$	does not change
Signal-to-noise ratio at the input of the ultrasonic radar receiver	$\frac{N_{c\,вх}}{N_{n\,вх}} = \frac{N_{c\,вх} G}{\left(N_{n\,вх} + N_ш\right) G^k}$	$\frac{N_{c\,вх}}{N_{n\,вх}} = \frac{N_{c\,вх} \cdot G + N_n \cdot G \sin^2 \Delta\beta}{\left(N_{n\,вх} + N_ш\right) \cdot G^k \cos^2 \Delta\beta}$
The power of the useful signal at the input of the receiver of the ultrasonic radar	$N_{c\,вх} = \frac{N_c G_c}{4\pi D^2} \frac{\sigma_ц}{4\pi D^2} \frac{\lambda^2 G_n}{4\pi}$	$N_{c\,вх} = \frac{N_c G_c}{4\pi D^2} \cdot \frac{\lambda^2 G_n}{4\pi} \cdot \frac{\sigma_ц}{4\pi D^2} \cdot \cos \Delta\beta \pm$ $\pm \frac{N_n G_c}{4\pi D^2} \cdot \frac{\lambda^2 G_n}{4\pi} \cdot \frac{\Delta f_{прм}}{\Delta F_n} \cdot \alpha \cdot \sin \Delta\beta$
Radar suppression coefficient	$\frac{N_n G_n}{N_c G_c} \frac{\Delta f_{ПРМ} 4\pi \alpha F_c(\theta_ц, \beta_ц)}{\Delta F} \cdot D^2 \geq K_n$	$K_n \geq \frac{N_{n\,вх} G^k \cos \Delta\beta}{N_{c\,вх} G \cos \Delta\beta + \alpha N_{n\,вх} G \sin \Delta\beta}$
Probabilities of target tracking	$P_{зриву} = 1 - \prod_{i=1}^{4}(1-P_i)$;	$P'_{зриву} = 1 - \prod_{i=1}^{4}\left(1-k_i^{пр} P_i\right)$
	$P_{супр} = 1 - P_{зриву}$ - is chosen as a criterion for the efficiency of radar operation	

where N_c ($N_{c\,вх}$) is the power of the transmitter signal and the signal at the antenna input; G_c (G_n) is the maximum gain of the WCRs and the AISIP antennas; λ *is the* operating wavelength; $\sigma_ц$ is the effective scattering plane of the target; $\Delta\beta$ *is the* angle of change of the polarization plane; W_B is the detection probability; W_{XT} is the false alarm probability; $\Delta f_{прм}$ is the radar receiver bandwidth; ΔF_n is the emission band of the interfering signal; F_c ($\theta_ц$,$\beta_ц$) is the normalized radiation pattern of the antenna by the radar power; α is a coefficient that takes into account the polarization mismatch between the antenna of the WCRs and the AISIP to be suppressed; K_n is the suppression coefficient; $P_{зриву}$ is the probability of disruption; $P_{супр}$ is the probability of target tracking; $k_i^{пр}$ is the countermeasure effectiveness coefficient.

Source: developed by the author based on (Semenenko, Vodchyts, Dobrovolsky, 2011), (Semenenko, Kablukov, Myronenko, Dobrovolsky, 2019), (Semenenko, Kablukov, Chernega, 2019), (Semenenko, Sorokin, Dobrovolsky, Kablukov, 2019).

Limitations on the use of the selected methods of active counteraction were calculated, the main criterion for limitation being the range of their use depending on the method of CREM used.

The calculations show that when using the 1st and 4th methods, the maximum range is reduced by 4%; when using the 2nd or 3rd methods, by 16%; and when using all four methods, by 20%.

The criterion for the effectiveness of radar operation in conditions of interference and simultaneous counteraction to them is the probability of tracking the target (Table 1).

To improve the efficiency of the functioning of airborne radars, it is necessary to revise the sequence of air combat, considering the peculiarities of the use of methods of electronic countermeasures against enemy interference stations. Therefore, it is proposed to divide the air combat cycle between aircraft into 5 stages depending on the range (Fig. 2).

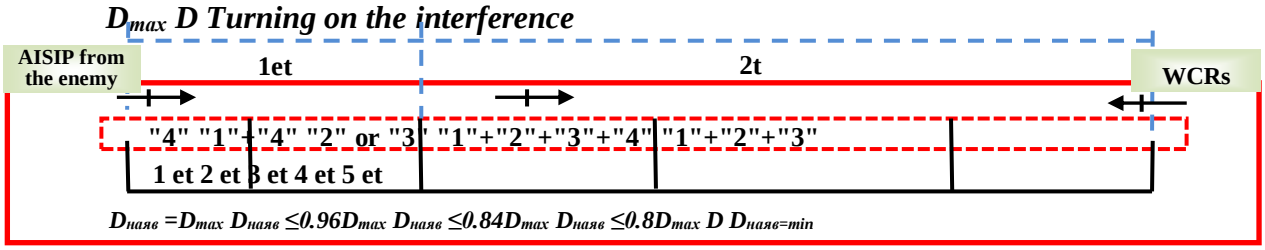


Figure 2. Stages of air combat

Next, an algorithm was developed to justify the choice of methods for countering enemy interference stations for continuous target tracking, considering the range between aircraft. The probabilities of tracking the target are also determined, considering the use of various combinations of countermeasures and the corresponding countermeasure coefficients (Fig. 3).

The developed algorithm improves the existing approach to the functioning of the onboard WCRs in terms of the probability of tracking the target in the conditions of application of the proposed methods of counteracting enemy interference stations and considering the limitations of their use.

For a qualitative and complete assessment of the effectiveness of the WCRs, it is proposed to use fuzzy sets and game theory. The use of fuzzy scales is caused by the lack of clear assessments of the effectiveness of the use of various types of interference and ways to counter them, as well as the natural uncertainty of air combat [9]. In an air battle, there are situations in which possible strategies for the use of enemy AISIP are known, but it is not known which of the known strategies is currently in place, that is, data on the types of fighter aircraft and countermeasures installed on these aircraft, as well as options for their use, may be known, but it is not known at this time what types of interference it is currently creating, whether the AISIP is turned on at all and further options for continuing the battle.

Figure 4 shows a mathematical model for assessing the effectiveness of the WCRs in air combat, which was used to develop the algorithm and select the most effective combination of countermeasures. In our opinion, it is advisable to present the mathematical model for assessing the effectiveness of the operation of the WCRs in the conditions of interference and simultaneous counteraction to the AISIP in the form of a fuzzy matrix game, which is the most adequate to describe such a situation with regard to the WCRs of a fighter aircraft and the enemy's AISIP in the conditions of their active counteraction. The proposed mathematical model makes it possible to assess the effectiveness of the WCRs in the conditions of interference and simultaneous counteraction to them and has the form of an effectiveness matrix $|a_{ij}|$, where the elements of the matrix are a_{ij} - fuzzy estimates of the effectiveness of the WCRs, namely, indicators of the probability of tracking the target for each of its decisions to apply countermeasures A_i and each state of the environment B_j regarding the emission of interference by the AISIP.

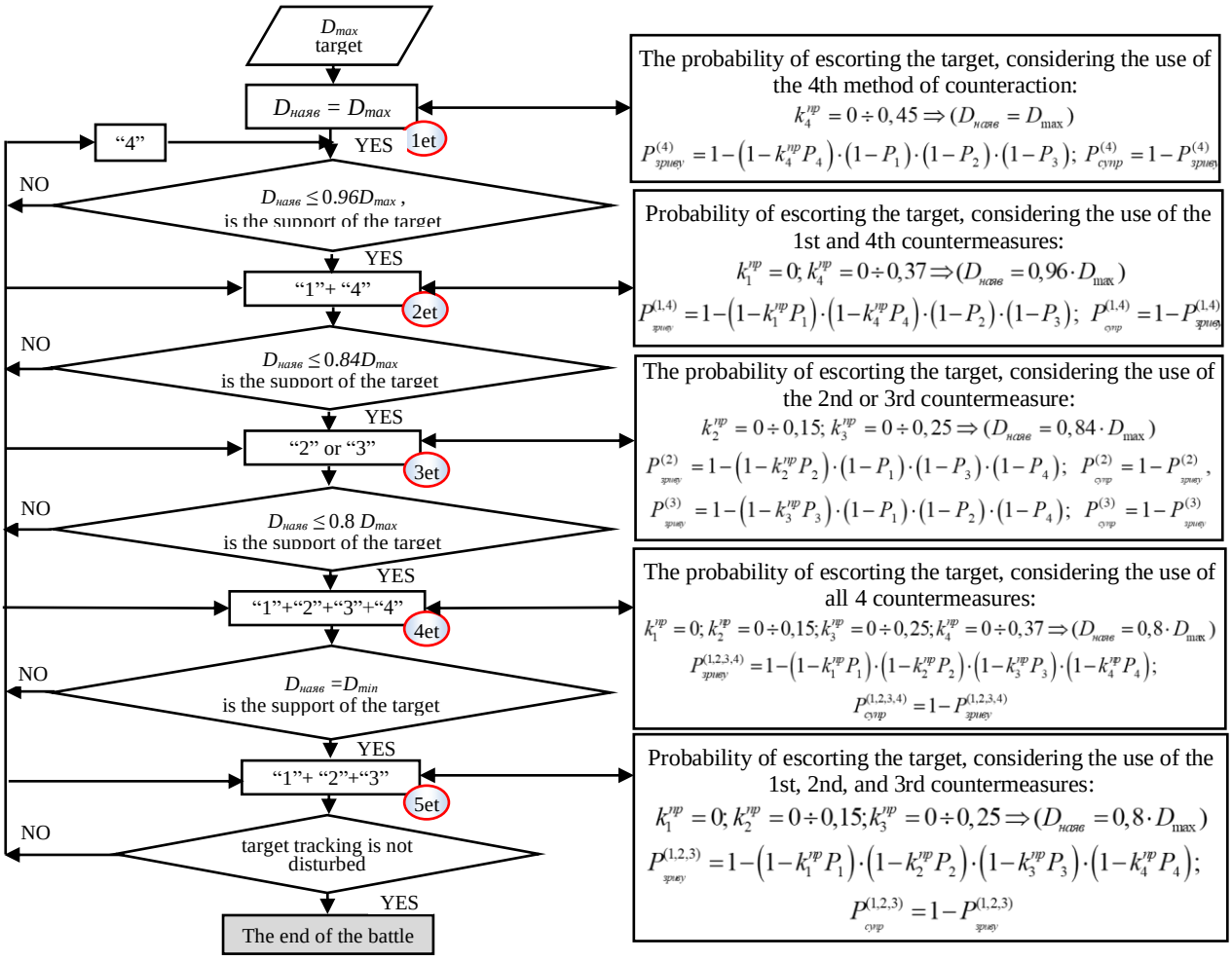


Figure 3. Algorithm for justifying the choice of countermeasures

$$A = \left\| a_{ij} \right\| = \begin{matrix} & B_1 & B_2 \\ A_1 & a_{11} & a_{12} \\ A_2 & a_{21} & a_{22} \end{matrix} = \begin{vmatrix} \{0,65;0,7;0,75;0,8\} & \{0,15;0,2;0,25;0,3\} \\ \{0,05;0,1;0,15;0,2\} & \{0,8;0,85;0,9;0,95\} \end{vmatrix}$$

solution by the approximate (iterative) method

$$S_A \approx \left|\frac{15}{30};\frac{15}{30}\right|,\quad p_1 = \frac{m^*_i}{n_\Sigma} = 0,5;\quad p_2 = \frac{m^*_i}{n_\Sigma} = 0,5,\ S_B \approx \left|\frac{11}{30};\frac{19}{30}\right|,\quad q_1 = \frac{n^*_i}{n_\Sigma} = 0,37;\quad q_2 = \frac{n^*_i}{n_\Sigma} = 0,63.$$

$$\nu_A = \frac{\alpha+\beta}{2} \approx \frac{\alpha \sum_{\min} + \beta \sum_{\max}}{2 \cdot k} \approx \{0,42;0,47;0,52;0,57\}$$

Figure 4. Mathematical model for assessing the efficiency of radar operation

The proposed mathematical model makes it possible to assess the effectiveness of the WCRs in the conditions of interference and simultaneous counteraction to them and has the form of an effectiveness matrix $|a_{ij}|$, where the elements of the matrix are a_{ij} - fuzzy estimates of the effectiveness of the WCRs, namely, indicators of the probability of tracking the target for each of its decisions to apply countermeasures A_i and each state of the environment B_j regarding the emission of interference

by the AISIP.

The results of solving the matrix game at each stage of the proposed algorithm are estimates of the effectiveness of the WCRs at certain stages of air combat under different conditions of its use - both in conditions of interference and in conditions of simultaneous counteraction to them. The overall assessment under different conditions of the air combat environment is calculated using the full probability formula. Formula (1) calculates the assessment of the effectiveness of the WCRs in conditions of interference without counteraction of the enemy's air defence system, and formula (2) - considering the counteraction.

$$E_{супр}^{\text{без КРЕП}} = \sum_{i=1}^{2} P_{супр.i} \cdot P(П_i) = P_{супр.1}(a_{12}) \cdot P(П_1) + P_{супр.2}(a_{21}) \cdot P(П_2) \ , \qquad (1)$$

$$E_{супр}^{\text{КРЕП}} = \sum_{j=1}^{2} P_j \cdot P(П_j) = P_{супр.1}(a_{11}) \cdot P(П_1) + P_{супр.2}(a_{22}) \cdot P(П_2) . \qquad (2)$$

where $P_{1,2}$ - the state of the I&C system (on and off)

Conclusion

Thus, the improved mathematical model for assessing the effectiveness of the WCRs allows for its reasonable description in conditions of interference and simultaneous active counteraction to enemy interference stations, which, according to preliminary calculations, will increase the effectiveness of the WCRs by 14-33 percent, as well as consider the uncertainty of the situation during air combat. The developed algorithm improves the existing approach to the functioning of the WCRs in terms of the probability of tracking the target in the conditions of using an effective combination of the proposed methods of counteracting interference stations.

Recommendations

Further research should be aimed at improving the method of mathematical modelling of the functioning of the WCRs in the conditions of active counteraction to enemy interference stations, as well as providing recommendations for the implementation of an improved mathematical model during the modernization of fighters of the Air Force of Ukraine, considering various types of interference and the emergence of new ways of counteraction.

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An approach to assessing the impact of radio interference on the means of radio technical and artillery radar reconnaissance in operations (combat actions) of troops (forces)

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Abstract. The article discusses one of the approaches to taking into account the influence of radio interference during radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces). An assessment of opportunities has been carried out and directions for the practical implementation of these issues have been determined. The relevance of the topic is due to the need to improve (develop) tools for calculating (modeling) operations (combat operations), taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance. It is established that to date, taking into account the conduct of radio and artillery radar reconnaissance by means of radio interference during the simulation of operations (combat operations) occupies an important place in the practical activities of headquarters at all levels (strategic, operational and tactical) when playing out options (plans) at the stages of preparation and planning of the use of the Armed Forces (Semenenko, Kirsanov, Mashkin, Pravdyvets, Petrozhalko, 2022). The analysis showed the lack of a unified approach to mathematical modeling of operations (combat operations), taking into account the capabilities of radio engineering and artillery radar reconnaissance in the conditions of radio interference in general. And the issues of assessing such an impact on the course and results of operations (combat operations) of troops (forces) do not have a practical content (contribution) at the stages of playing out options (plans). In addition, some of the existing mathematical models allow for typical calculations for specific types samples of weapons (means) for radio engineering purposes (support) or specific tasks for electronic warfare and reconnaissance support with the participation of existing means and complexes, which significantly limits the research (accounting) of both individual means and the system as a whole, in order to form requirements for promising samples. The aim of the article is to

consider the approach to taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces). Assessment of opportunities and determination of directions for practical implementation of these issues. The article discusses the solution of the issues of modular integration of mathematical calculations (expressions) of the radio-electronic situation (radio intelligence, radio communication, radio interference) into the simulation mathematical model of operations (combat operations), the exclusion of logical incidents of the iterative approach in simulation models and the sequence of calculations in the interaction of modules. The practical results of the implementation of these issues on the basis of the mathematical model of the operation (combat operations) are presented, the analysis of the possibilities and significance of such implementation as an element of improvement. It is also found that the obtained result clarifies the model time of the operation (combat operations) of the grouping of troops (forces), which makes it possible to analyze in detail the contribution of each module in stages, details the simulation of the operation (combat operations), increases the reliability of the modeling results, allows to assess the impact of radio interference during radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both by partial indicators (range reconnaissance, probability of detection, secrecy, survivability, etc.), and in terms of effectiveness for the entire grouping of troops (losses of the parties, combat potential, depth of the offensive).

Keywords: mathematical model, radio interference, electronic intelligence, artillery radar reconnaissance.

Introduction

An overview of the work of military authorities, especially during the war in Ukraine, formulated acute problems in making calculations and taking into account the impact of radio interference on certain variants of operation (combat operations) scenarios. In particular, during the planning and practical conduct of electronic intelligence, artillery radar reconnaissance, proposals are developed, as a rule, based on experience, sometimes even on intuition, and in some cases, approximate express calculations are carried out (Semenenko, Marko, Chernyshova, Koverga, Pekuliak, 2021). In addition, the issues of taking into account radio interference to such means both on their own side and on the side of the enemy are taken into account conditionally at the level of generalized coefficients.

Currently, the preparation and planning of operations (combat operations) in the Armed Forces is limited to the use of a mathematical model of the operation (combat operations), other calculation tasks (programs) at the level of calculating the ratio of the sides and further forecasting of possible losses, respectively. However, the issue of calculating support, especially radio engineering, and even in conditions of active radio interference, is advisory in nature, and the correct assessment of such an impact in terms of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.) is difficult. Therefore, taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance in the simulation of operations (combat operations) occupies an important place in the practical activities of headquarters when playing out options (plans) at the stages of preparation and planning of the use of the armed forces (Korniychuk, 2020), (Theses of reports, 2018), (Pushkov, 2021).

Analysis (Semenenko, Pavlovskyi, Solomitsky, Zvarych, Skurinevska, 2020), (Sova, Shyshatskyi, Ostapchuk, Trotsko, Pylypchuk, 2022), (Semenenko , Mashkin, Onofriichuk, Paiuk, Cherevatyi, 2021) indicates the lack of a unified approach to the mathematical modeling of operations (combat operations) taking into account the capabilities of radio engineering and artillery radar reconnaissance in the face of radio interference in general. The issues of assessing such an impact on the course and results of operations (combat operations) of troops (forces) according to the indicators

of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.) do not have a practical content (contribution) at the stages of playing out options (plans). Most of the sources describe the rules, approaches, methods, practical options for the implementation and application of a particular direction, with appropriate recommendations, for example, the calculation of electronic warfare zones, reconnaissance zones, artillery and electronic reconnaissance capabilities, etc. Other publications describe in detail the calculation of the ratios of the opposing sides, the simulation of combat operations (operations) without taking into account the calculations of the capabilities and results of the work of radio engineering and artillery radar reconnaissance in conditions of radio interference, or such consideration is carried out at the level of separate, veryclose (conditional) coefficients (Semenenko, Khomchak, Kirsanov, Dobrovolskyi, Shyhyda, 2021), (Butvin, Mashkin, Sobolev, Open'ko, Maslenko, 2022), (Semenenko, Mashkin, Onofriichuk, Paiuk, Cherevatyi, 2021).

Thus, the conditions of modern armed struggle (confrontation) are characterized by the widespread use of new radio-technical weapons (Romanchenko, Zagorka, Butenko, Deyneha, 2019) and difficult conditions of the radio-electronic situation (radio intelligence, radio communications, radio interference), and the rational application and further assessment of such actions require appropriate calculations. At the same time, due to the lack of a unified approach to the mathematical modeling of operations (combat operations). Taking into account the capabilities of electronic and artillery reconnaissance in the conditions of radio interference at the level of mathematical (simulation) models, the quality of justification of decisions on plans (plans) of the Armed Forces headquarters of all levels (strategic, operational and tactical) may decrease.

Thus, consideration of the issues of taking into account the impact of radio interference on the means of radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces) is relevant and necessary and requires tools for calculations (modeling) of improvement (development).

Methodological Framework

The use of analytical modeling methods in existing mathematical models makes it possible to carry out typical calculations for specific types of weapons (means) for radio technical purposes (support) or specific tasks for electronic warfare and reconnaissance support with the participation of existing means and complexes (Ermak, 2019). However, the use of such research methods does not make it possible to form (specify) requirements for further improvement of such means (complexes, systems) or options for their use on the battlefield (in operation).

In general, in the study of the issue of approaches to taking into account the impact of radio interference during radio engineering and artillery radar reconnaissance in the mathematical model of the operation (combat operations) of troops (forces), the methods of the theory of simulation modeling were also used - during calculations (mathematical modeling) of operations (combat operations) of troops (forces) taking into account the relevant electronic situation and methods of operations research - in the formalization of the assessment of impact calculations radio interference during radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators and in terms of effectiveness for the entire grouping of troops (forces) (losses of the parties, combat potential, depth of the offensive, etc.).

Results and Discussions

The peculiarity of the armed struggle today is the use of a number of high-tech new radio equipment for both reconnaissance and electronic warfare. Neglect of the capabilities of the latter in the calculations or their conditional declaration leads to the disclosure to the enemy of their positions, places of redeployment, loss of communication, incorrect assessment of the situation, losses of

military equipment and manpower. The use of unmanned aerial vehicles for electronic reconnaissance, jamming, and fire strikes are everyday occurrences in modern warfare and international conflicts, and the development of new models for creating radio interference is one of the first points in the development (rearmament) programs of modern armed forces.

Thus, the issue of special calculations during the planning and conduct of radio engineering and artillery radar reconnaissance in conditions of active radio interference is very acute for the headquarters of the armed forces. In addition, their solution requires a significant number of calculations of the radio-electronic situation in a certain operational zone (battlefield) (Menshakov, 2008), (Movchan, Brazhnikova, Bogucharsky, 2018).

An accessible and sufficient way to solve this problem is the modular integration of mathematical expressions of calculations of the radio-electronic situation (radio intelligence, radio communications, radio interference) into the simulation mathematical model of operations (combat operations) (Osinovy, Subach, Bykov, Kolchygin, 2018). A successful combination of mathematical expressions in the general process of modeling (simulation) of an operation (battle) will allow only half to satisfy all aspects of planning and conducting radio engineering and artillery radar reconnaissance in conditions of active radio interference. As a result, the issues of excluding logical incidents of the iterative approach in simulation models (Military Standard 01.101.003, 2008), (Tyapkin, Fomin, Garin, 2011) will remain open. A separate point is the sequence of calculations and the interaction of modules. Such problematic issues are related, first of all, to the different effects of electronic warfare on objects of destruction (suppression), the degree of suppression of which depends on the interaction of the latter with other targets, as evidenced by the general formulas for suppression of receivers of radar systems of artillery reconnaissance (formula 1) and means of passive electronic intelligence (formula 2) (Romanchenko, Zagorka, Butenko, Deyneha, 2019):

$$D\ radar\ min = \sqrt[4]{\frac{P_{radar} \cdot G_{radar} \cdot \sigma_n \cdot K_n \cdot \Delta f_n \cdot D_n^2}{P_{nn} \cdot G_{nn} \cdot 4\pi \cdot \Delta F_{np} \cdot \nu_n}}\ , \quad (1)$$

where $D_{\text{radar min}}$ is the minimum range of artillery radar reconnaissance during electronic warfare, D_n is the range from the radar station to electronic warfare, P_{radar} is the radar power, P_{nn} is the power of the radio jammer, G_{nn} and G_{radar} – the gain of the antennas of the radio jammer in the direction of the radar receiver and the receiving antenna in the direction of the radar transmitter, respectively, σ_n is the effective scattering surface of the target, ΔF_{np} and $f\Delta_n$ are the bandwidth of the receiver and the jammer, respectively, is the polarization coefficient. ν_n

$$D_n = D_p \sqrt{\frac{P_{nn} \cdot G_{nn} \cdot G_{np}(\beta) \cdot \Delta F \cdot \nu_n}{P_{nc} \cdot G_{nc} \cdot G_{np} \cdot \Delta f \cdot K_n}}\ , \quad (2)$$

where D_n is the jamming range of the signals intelligence stations, D_p is the passive signal reconnaissance range of the target, P_{nc} is the power of the target radio signal transmitter, G_{nc} is the gain of the antenna of the radio signal transmitter in the direction of the radio receiver , $G_{np}(\beta)$ is the gain of the radio receiver antenna in the direction of the radio interference transmitter, G_{np} is the gain of the radio receiver antenna in the direction of the target radio signal transmitter, K_n *is* the suppression factor.

Also, in addition to the basic conditions for modeling radio interference for the mentioned systems (complexes), where each object is simultaneously subjected to different influences and calculated for each whole separately, it is also necessary to take into account the orientation of antenna systems in space (2), as well as to carry out such analysis (correction) of work at each iteration in a dynamically changing environment (Semenenko, Baranov, Shyhyda, Remez, Momot,2023).

One of the approaches to the implementation of taking into account the impact of radio interference during the implementation of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) is presented in Figure 1 in the form of a flowchart.

The main feature of this implementation is the parallel integration of mathematical calculations for the implementation of reconnaissance of radio engineering (blocks 2, 4, 6, 8), artillery radar (blocks 3, 5, 7, 9) and the impact of radio interference (block 1) at the stage of selection of reconnaissance targets for further development of a decision to defeat (block 11) of these targets (solving target distribution problems) in the mathematical model of operations (combat operations). An important functional block of the stage of selection of reconnaissance targets is taking into account the capabilities of radio communication facilities (block 10), again, in conditions of radio interference (block 1).

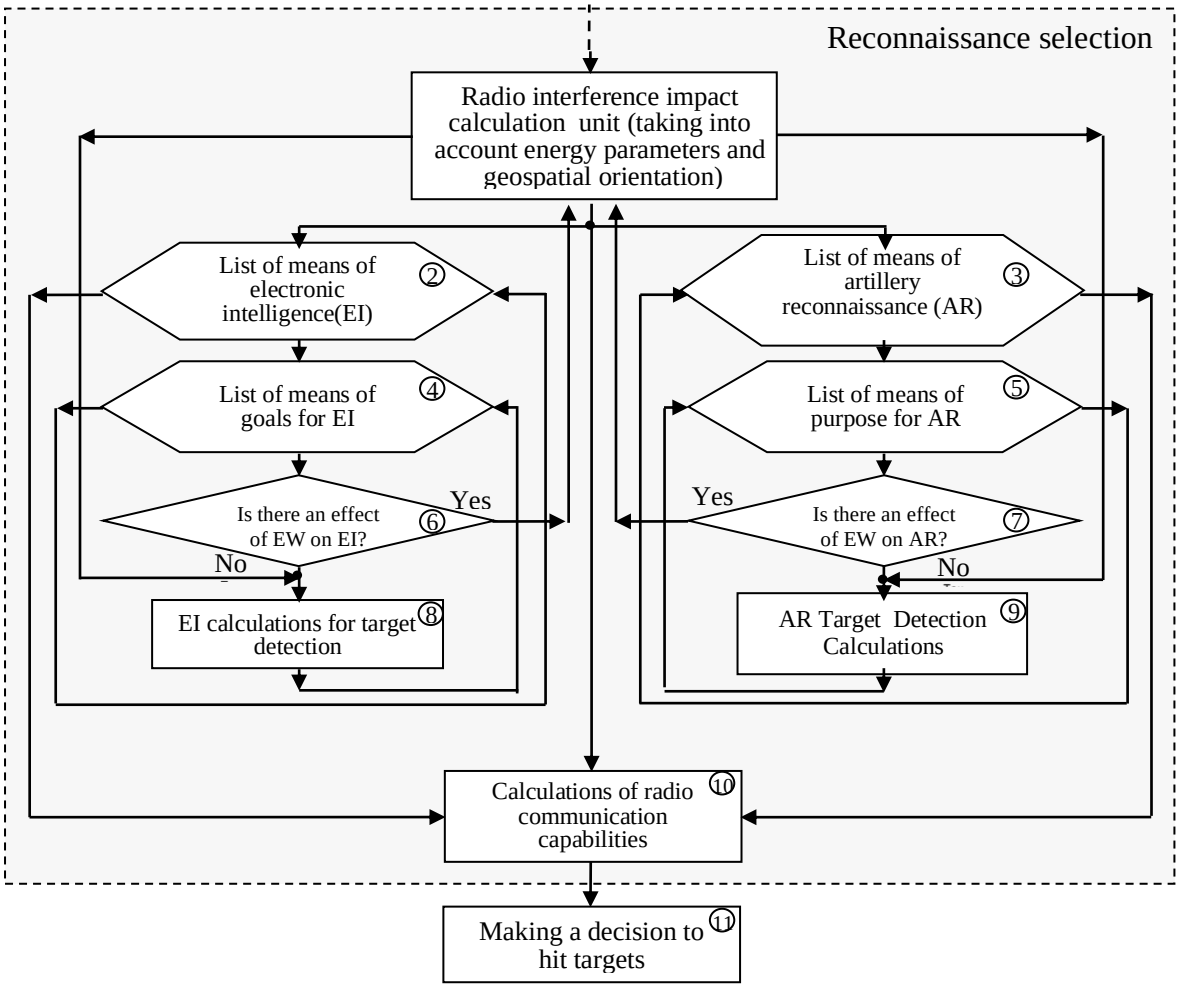


Figure 1. Block diagram of taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance based on a mathematical model of operations (combat operations)

The flowchart presented in Figure 1 allows to take into account all the above-mentioned features to avoid logical errors when choosing reconnaissance objects for further modeling of operations (combat operations), to calculate a single electronic situation (radio intelligence, radio communication, radio interference) and to minimize the number of iterative returns and

recalculations. In addition, the proposed flowchart makes it possible to distinguish (separate) the work of different types of reconnaissance and electronic warfare for step-by-step (separate) variants of modeling (research).

The main advantage of the issue under consideration is the combination of reasonable mathematical calculations of radio engineering and artillery radar reconnaissance in the conditions of radio interference, which excludes coefficient (approximate) approaches of their logical iterative differentiation for the formation of a single radio-electronic space (radio intelligence, radio communication, radio interference), as well as data on explored objects for a mathematical model of operations (combat operations). This approach also makes it possible to evaluate the results of modeling (impact) of the mentioned radio equipment by indicators of the effectiveness of the grouping of troops (losses of the parties, combat potential, depth of the offensive, etc.).

The practical result of the work of the flowchart shown in Figure 1 on solving the issue of taking into account the impact of radio interference on the means of radio engineering and artillery reconnaissance in the mathematical model of operations (combat operations) of troops (forces) is presented in Figure 2.

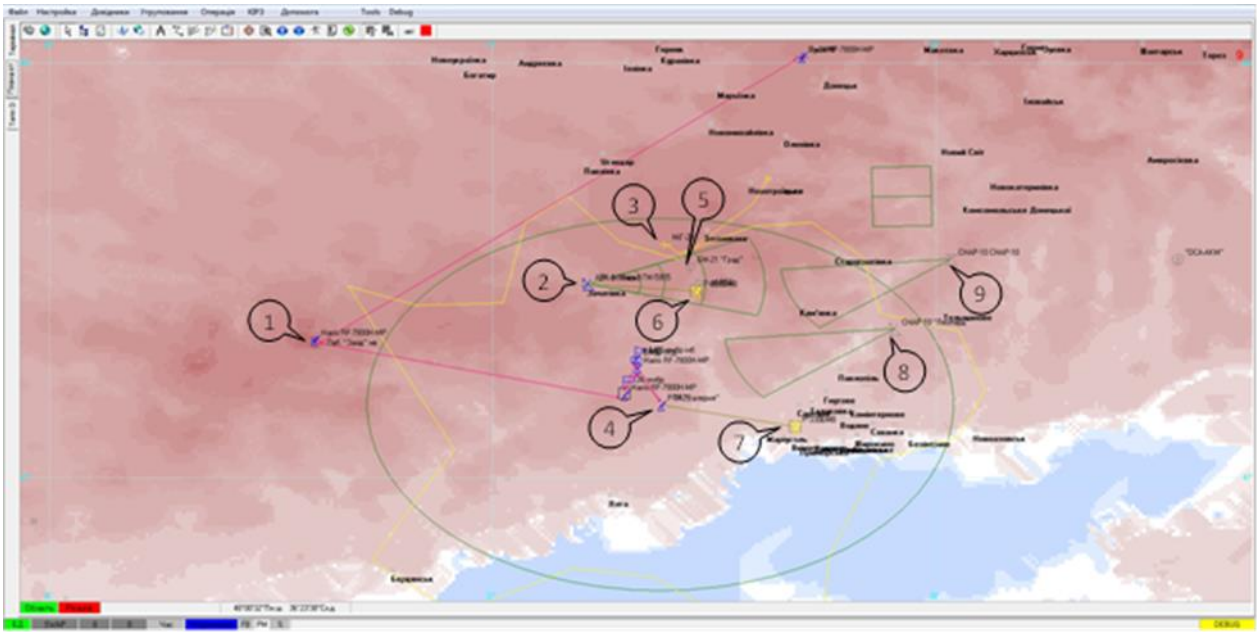


Figure 2. Taking into account the influence of radio interference on the means of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations)

Figure 2 shows that the artillery reconnaissance station (mark 2) is under the influence of electronic warfare (mark 6), which makes it impossible to reconnoiter the multiple launch rocket system (mark 5). In addition, the passive signals intelligence station (mark 4) has a circular area of responsibility, but is under the influence of electronic warfare (mark 7), which makes it impossible to detect the enemy's radar station (mark 8). It should be noted that at the same time, active electronic warfare (marks 6, 7) and an aircraft with an active reconnaissance radar station (mark 3) are detected under these simulation conditions. Also, data on the enemy's reconnaissance objects, provided that they are not suppressed, are transmitted via the displayed communication channels to the command post (mark 1), after which the reconnaissance objects are highlighted in the color of the enemy and fall into the array of targets for destruction (destruction).

Such an analysis of the radio-electronic situation, the state of reconnaissance of enemy objects is repeated at each step of the simulation. This makes it possible to detail the simulation of the operation (combat operations), to increase the reliability of the simulation results, to evaluate the calculation of the impact of radio interference during the conduct of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators (reconnaissance range, detection probability, secrecy, survivability, etc.) and in terms of effectiveness for the entire grouping of troops (forces) (losses of the parties, combat potential, depth of the offensive, etc.). In addition, such a practical implementation will enable the headquarters at all levels to fully conduct and, most importantly, take into account the considered components at all phases of preparation and planning of the operation (combat operations) (Tyapkin, Fomin, Garin, 2011). Also, the obtained result clarifies the model time of the operation (combat operations) of the grouping of troops (forces), which allows for a detailed analysis of the contribution of each module in stages.

Conclusions

Thus, the article considers an approach to taking into account the calculations of the impact of radio interference on the means of electronic and artillery reconnaissance in the mathematical model of operations (combat operations) of troops (forces), which will improve the quality of decision-making in the headquarters of the Armed Forces of all levels (strategic, operational and tactical). The solution of these issues allows to detail the simulation of the operation (combat operations), increase the reliability of the simulation results and increase the accuracy of the simulation model operations (combat operations), as well as to assess the impact of radio interference during the implementation of radio engineering and artillery radar reconnaissance on the basis of a mathematical model of operations (combat operations) both in terms of partial indicators and in terms of effectiveness for the entire grouping of troops (forces).

Preliminary analysis of the obtained results of mathematical modeling confirms the efficiency and feasibility of the considered issues regarding the impact of radio interference on the means of radio engineering and artillery radar reconnaissance. The implementation of a unified approach to the mathematical modeling of operations (combat operations) using the parallel integration of mathematical calculations will make it possible to eliminate significant differences in the ways of formalizing the solution of individual problems used in well-known specialized methods and models, and to integrate them.

Prospect for further research is the development of mathematical modeling of operations (combat operations) of troops (forces) taking into account the issues under consideration, which will provide reasonable recommendations to the headquarters and military command and control bodies.

Recommendations

The development of mathematical modeling of operations (combat operations) of troops (forces), taking into account the calculations of the impact of electronic warfare during radio and artillery reconnaissance in the mathematical model of the operation (combat operations) of troops (forces), as a prospect for further research, will provide reasonable recommendations to the headquarters and military command and control bodies regarding the consideration of a full range of intelligence support data in the conditions of radio interference during planning and conduct operations (combat operations) of groups of troops. In addition, it will make it possible to study the use of both individual tools and the system as a whole in order to form requirements for promising samples.

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Justification of measures to improve the efficiency of engineering support for the use of troops (forces)

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Abstract. The relevance of the study is due to the need to increase the efficiency of engineering support for the use of troops (forces) of the Armed Forces of Ukraine in the modern armed conflict due to the high level of their losses in personnel, weapons and equipment, in particular on the enemy's minefields and from its firepower. In connection with the armed aggression of the Russian Federation against Ukraine, the question. The increase in the effectiveness of engineering support was further exacerbated by the massive use of mine weapons by the enemy and the rapid increase in these losses of our troops along the entire front line. The analysis of the use of our troops (forces) in the ongoing war showed the existence of a number of problematic issues of engineering support, which significantly reduce its effectiveness and lead to unjustifiably high levels of losses of troops (forces) in all types of combat. To eliminate these issues, it is considered expedient to determine the factors that most affect the efficiency of engineering support and determine the main measures to increase it to the appropriate level. The results of the study allowed to conclude that the main measures to improve the efficiency of engineering support the use of troops (forces) of the Armed Forces of Ukraine in the modern armed conflict is: improvement of the existing regulatory framework for engineering support of the Armed Forces of Ukraine, in particular to determine the required number of engineering units and subdivisions; improvement of organizational and staff structures of engineering units and subdivisions, as well as improvement of the existing management system of engineering support of the Armed Forces of Ukraine regarding the place of its command and control bodies in the general system of command and control bodies of the Armed Forces of Ukraine. The materials of the article are of practical value for the command-and-control bodies, which in modern operations (combat operations) of troops solve complex problems of early engineering preparation of the territory of the state for war and direct engineering support for the use of troops (forces).

Keywords: engineering support, efficiency, armed conflict.

Introduction

In connection with the armed aggression of the Russian Federation against Ukraine, the issue of the effectiveness of the use, provision and support of the Armed Forces of Ukraine, in particular engineering support, is considered an urgent issue of national security and defense of Ukraine (Zaluzhnyi, 2023). Analysis of the Anti-Terrorist Operation (hereinafter – ATO), the Joint Forces Operation (hereinafter referred to as JFO) and the Russian-Ukrainian war showed the important role of engineering support for the use of troops (forces) in achieving their success in combat operations. However, this analysis also showed that there are currently problems and questions engineering support, which significantly reduces its effectiveness and leads to unjustifiably high losses of our troops during hostilities along the entire front line (Calculation of the effectiveness of the use of engineering units in the ATO, 2015), (Analysis of the losses of the Armed Forces in the ATO from explosions on engineering barriers and recommendations for their reduction, 2018),

(Zaluzhnyi, Moisiuk, Shaptala, 2023). Experience shows that the main issue in a number of problematic issues of engineering support is the issue of the discrepancy between the capabilities of the existing composition of engineering units and subdivisions and the amount of engineering during the course that they need to perform in order to maintain mobility of their troops (forces), increasing their survivability and safety of use, as well as in order to limit the mobility of the enemy's forces and means (Voloschenko, 2016), (Order of the Chief of the General Staff – Commander-in-Chief of the Armed Forces of Ukraine, 2019), (Voloschenko, Chernykh, 2022), (Voloschenko, Kovalsky, 2023). To eliminate this problematic issue, it is considered necessary to determine the factors that most affect the effectiveness of engineering support for the use of troops (forces) and, taking them into account, to develop appropriate recommendations for raising it to the appropriate level (Voloshchenko, 2016).

Methodological Framework

The analysis of the organization of engineering support for the use of troops (forces) of the Armed Forces of Ukraine in recent operations and during the Russian-Ukrainian war shows that the main factors of negative impact on the effectiveness of engineering support are the combined nature of the use of troops (forces) during hostilities, as well as the relentless growth and the unprecedented use of minefields and engineering ammunition by the enemy to inflict losses on our troops (forces) (Matsko, 2020), (Kiziak, 2013), (Voloschenko, 2016). In modern conditions, in order to reduce the influence of these factors, it is considered expedient to expand the boundaries of research on problematic issues of engineering support in the following areas (Fig. 1).

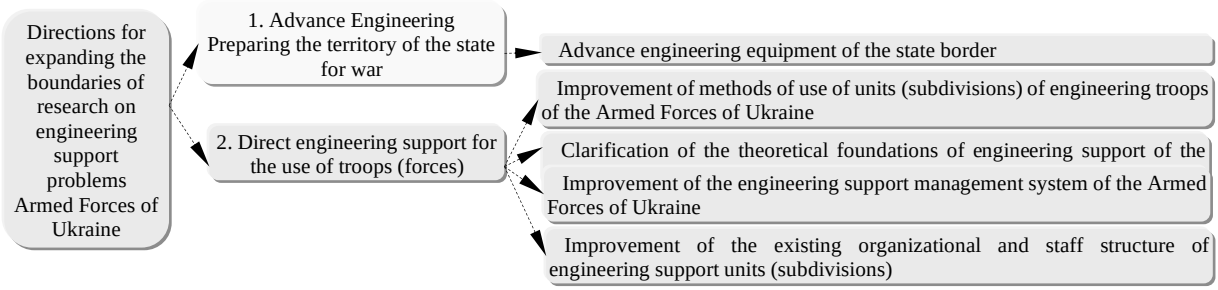


Figure 1. Possible directions to expand the boundaries of research on the most problematic issues of engineering support of the Armed Forces of Ukraine (option)

Results and Discussions

Let's take a closer look at the most important of these areas.

1. Advance engineering preparation of the territory of the state for war.

The need for early engineering preparation of the state's territory for war in the interests of increasing its defense capability is currently in no doubt (Voloschenko, 2016), (Zaluzhnyi, Moisiuk, Shaptala, 2022). However, in terms of scale, nature and scope of work, this preparation should be a clear answer at the moment It doesn't. The Armed Forces of Ukraine believe that the engineering preparation of the territory of the state for war should be carried out according to a single plan along the entire line of the state border to a depth of 150- 200 km (Doctrine of Engineering Support for the Use of Troops (Forces), 2020). The basis of this training should be engineering measures, which should be carried out in order to establish a system of field fortifications of troops (forces), preparation of a network of rockade and frontal roads, as well as the arrangement of a system of engineering barriers, which should be carried out by the engineering troops of the Armed Forces of Ukraine. Adherents of the other view, taking into account the large resource component of these measures, strongly reject such an approach and propose to act on the principle of "reasonable sufficiency", the

need for which is motivated by significant savings in resources (Peredrii, Khazanovich, Voloschenko, 2017). Taking into account the arguments of the parties, an expedient option is to determine the most problematic sections of the state border of Ukraine and the implementation of engineering measures in these areas by engineering units and subdivisions of the Armed Forces of Ukraine in cooperation with enterprises of the local economy in accordance with the plans for the mobilization deployment of troops and operational equipment of the territory of Ukraine.

2. Improvement of existing methods of use of units (subdivisions) of engineering troops of the Armed Forces of Ukraine in the modern armed conflict.

The need to improve the existing methods of using units (subdivisions) of the engineering troops of the Armed Forces of Ukraine in the current armed conflict is due to the experience gained in combat operations of our troops, primarily in the Russian-Ukrainian war (Moisyuk, Shaptala, 2022). In addition to the existing methods, in the author's opinion, it is necessary to consider the following options for the use of engineering units and subdivisions as military units and subdivisions that perform combat missions on a par with combined arms (Voloschenko, 2016) (Fig. 2).

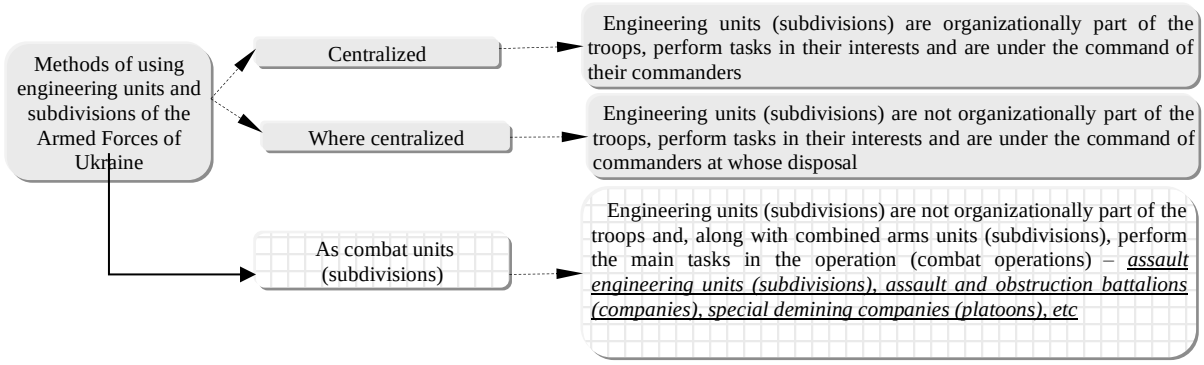


Figure 2. Methods of using engineering units and subdivisions of the Armed Forces of Ukraine in the modern armed conflict, which are proposed
(option)

3. Clarification of the theoretical foundations of engineering support of the Armed Forces of Ukraine.

Clarification of the theoretical foundations of engineering support of the Armed Forces of Ukraine (National Defense University of Ukraine named after Ivan Chernyakhovskyi, 2015) primarily concerns the definition of engineering support as one of the types of support for the use of troops (forces) and the need to determine groups of its measures or individual measures for comprehensive implementation in order to support mobility of its troops (forces), increasing their survivability and safety of use in operations (combat operations), as well as in order to limit the mobility of the enemy's forces and means. The variant of grouping in the course of engineering support of the Armed Forces of Ukraine, as proposed, is shown in Figure 3.

Analysis of information sources on the need to increase the effectiveness of engineering support for the use of troops (forces) in modern wars and armed conflicts (Matsko, 2020), (Kiziak, 2013), (Voloschenko, 2014), (Peredrii, Khazanovych, Voloschenko, 2017) indicates that the recommendations developed in this area are consideredin a scattered and unsystematic manner. Taking into account the above, the main measures to increase the effectiveness of engineering support for the use of troops (forces) of the Armed Forces of Ukraine in the modern armed conflict should be considered as those shown in Figure4.

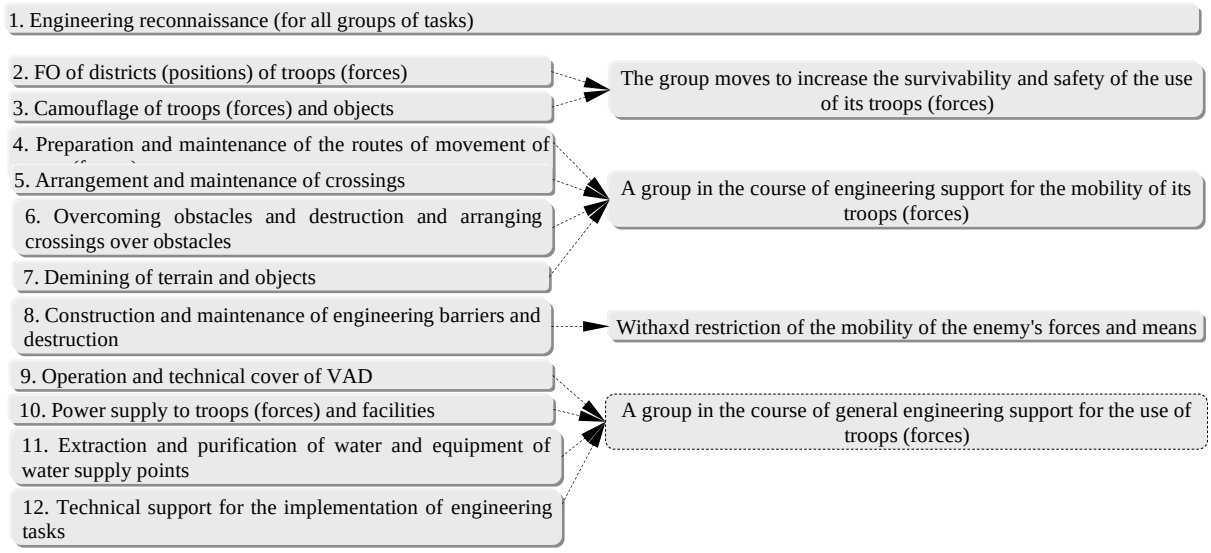


Figure 3. Grouping in the course of engineering support of the Armed Forces of Ukraine, which is proposed (option)

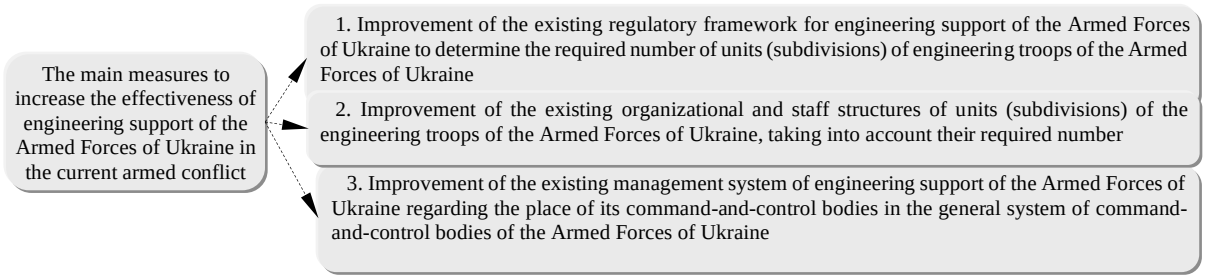


Figure 4. The main measures to increase the efficiency of engineering support for the use of troops (forces) of the Armed Forces of Ukraine in the modern armed conflict (option)

In the author's opinion, the most important measure in this list is the improvement of the existing regulatory framework for engineering support of the Armed Forces of Ukraine, in particular, regarding the determination of the required number of engineering units and subdivisions of the Armed Forces of Ukraine. And the importance of this issue is due to the lack of provisions in the current governing documents of the Armed Forces of Ukraine, how they determine the necessary the ratio of the total number of these units and subdivisions to the total number of troops (forces) that they support in engineering terms in the operation (combat operations) (Voloschenko, 2016). As an example, Figure5 shows a diagram that clearly demonstrates the existing ratio of the number of engineering units and subdivisions in the ground forces of the armed forces of the countries of the world and the Armed Forces of Ukraine to the total number of troops (forces) supported by them.

Figure 5 shows that the average number of engineering units and subdivisions is 5.5% of the total number of troops (forces). Taking into account this value, the number of engineering units and subdivisions of the Armed Forces of Ukraine should be approximately within 6%. As an example, the total number of engineering units of a separate mechanized brigade (SMB) of the Armed Forces of Ukraine is 3.5% of the total number of this brigade, which is 1% less than the total number of engineering units of a separate motorized rifle brigade of the Russian Federation (Table 1).

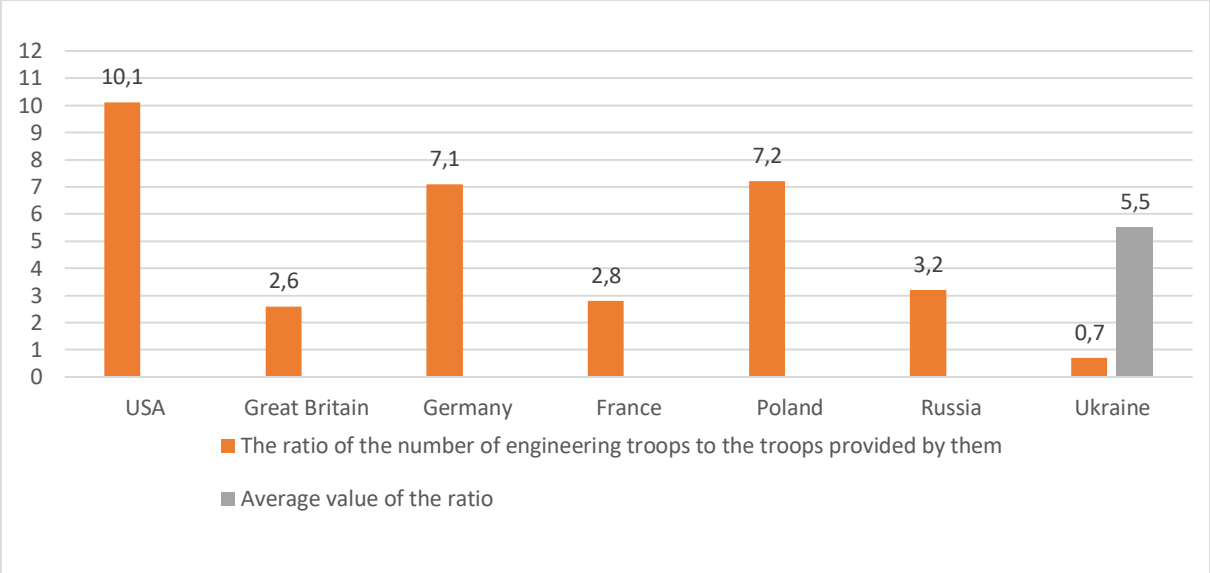


Figure 5. The existing ratio of the number of engineering units and subdivisions in the ground forces of the armed forces of the countries of the world and the Armed Forces of Ukraine to the total number of troops (forces) supported by them

Table 1. Comparative table of the number of engineering units of the *Separate Mechanized Brigade* of the Armed Forces of Ukraine and the *Motorized Rifle Brigade* of the Russian Federation

Motorized Rifle Brigade **(BMP) of the Russian Armed Forces**	***Mechanized Brigade*** **(on BMP) of the Armed Forces of Ukraine**
The number of *motorized rifle brigades* is 5885 people. Number of engineering units *Motorized Rifle Brigade* (5 engineering companies) – 276 people. 4,6 %	The number of *mechanized brigades* is 5044 people. Number of engineering units *Giz Mechanized Brigade* (2 engineering companies) – 179 people. 3,5 %

Thus, to achieve the average indicator (6%), the number of engineering units in a separate mechanized brigade, a separate tank brigade and a separate motorized infantry brigade of the Armed Forces of Ukraine should be increased by at least 2%, because of which this number will increase in: a separate motorized infantry brigade for 101 people. and will be 277 people; a separate motorized infantry brigade for 120 people. and will be 296 people; a separate tank brigade for 55 people. and will be 231 people. Such an increase in the number of engineering units will further form a separate mechanized brigade, a separate motorized infantry brigade and a separate tank brigade of the Armed Forces of Ukraine at least two engineering companies and instead of the engineering support group 2 company personnel of 179 people. have in these brigades an engineering and engineer battalion of 5 company personnel of approximately 250-300 people.

As part of this battalion, it is recommended to have: an engineering and engineer company as part of an engineering and engineer platoon and platoons of disfigurement and controlled mining; engineering and technical company consisting of 2 engineering and technical platoons and platoon of control room equipment; engineering and road company as part of a platoon of mechanized bridges and engineering and road platoon; engineering-positional company consisting of 3 engineering-positional platoons and a pontoon company consisting of 2 pontoon platoons and a coastal platoon. The proposed organizational structure of engineering units of a separate mechanized brigade, a separate motorized infantry brigade and a separate tank brigade of the Armed Forces of Ukraine will increase the overall level of their engineering support activities for these brigades approximately in 2,5 times, which will cover the whole range of engineering support measures and timely implement

them in order to increase mobility, survivability and safety of the use of units of these brigades, as well as effectively limit the mobility of enemy forces and means in their area of responsibility (Voloshchenko, 2023).

Conclusions

The carried out research allowed to conclude that the main measures to increase the efficiency of engineering support of the Armed Forces of Ukraine in the current armed conflict are: improvement of the existing regulatory framework for engineering support of the Armed Forces of Ukraine on the required number of engineering units and subdivisions of the Armed Forces of Ukraine; improvement of the existing organizational and staff structures of engineering units and subdivisions of the Armed Forces of Ukraine, taking into account their required number, as well as improvement of the existing system of management of engineering support of the Armed Forces of Ukraine on the issues of determining the place of engineering support management bodies in the general management system of the Armed Forces of Ukraine.

Recommendations

The materials of the article are of practical value for the governing bodies, which, when planning the use of troops (forces), solve the problem of early engineering preparation of the territory of the state for war and direct engineering support for the use of troops (forces) in operations (combat operations).

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Modelling the performance of repair and restoration bodies in combat conditions

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Abstract. Today, when the Russian Federation has launched a full-scale war against Ukraine, the most important and urgent task of maintaining equipment in a combat-ready state is to find ways to improve the efficiency of the system of its maintenance and repair, i.e., the productive work of repair and restoration bodies in a combat situation. The success of the armed forces on the battlefield will depend on the effective work of the repair and maintenance bodies.

The purpose of this study is to model the production activity of repair and restoration bodies taking into account combat operations. The study was conducted on the example of the self-propelled gun of the Buk-M1 anti-aircraft missile system.

To solve this problem, the method of analytical modeling with the use of probability theory is used, which allows a comprehensive consideration of all approaches to solving this issue.

The article discusses the reasons why military equipment can fail. This is due to limited technical reliability, due to fire from the enemy during hostilities, or due to the combined effect of both of these factors. The article provides a variant of finding the number of equipment that is out of service due to each of these reasons. The author considers how the achieved value of the average uptime of a self-propelled gun will affect the nature of its damage, how the value of time between failures will change, taking into account losses (failures) as a result of limited technical reliability, compared to the value of relative losses due to enemy fire. It is proved that with an increase in the average operating time before the failure of a self-propelled gun, the number of vehicles that are disabled due to limited technical reliability alone will decrease. The correlation between the number of vehicles that failed due to limited technical reliability and the number of self-propelled guns that failed due to enemy fire is proposed. The values of the probability of failure-free operation and the probability of equipment failure for both of these cases are estimated. Knowing the expected value of the repair fund, it is possible to model the performance of repair and restoration bodies taking into account the combat situation. Taking into account the ratio between the number of equipment that failed due to limited technical reliability and the number of equipment that failed due to combat damage allows to increase the efficiency of the system of restoration of self-propelled guns damaged in combat operations, improve the planning of production activities of repair and restoration bodies, i.e., increase the overall combat capability of a military formation, for example, in the process of repelling an air attack on troops (objects).

The materials of the article are of practical value for predicting the work of repair and restoration bodies in the conditions of hostilities.

Keywords: modeling, technical reliability, combat situation, probability of failure.

Introduction

In peacetime, the failure of weapons and military equipment in the Armed Forces of any state

is largely due to the length of time it has been in service, as the samples experience deterioration in the technical condition of elements and materials due to their aging and wear. In wartime, damage to equipment in a combat situation is added. Before the war began, the Armed Forces of Ukraine were equipped with almost all types of weapons and military equipment, but more than 60% of the equipment had been in service for more than 15 years. Military equipment can fail for various reasons: due to limited technical reliability, due to enemy fire during combat operations, or due to the combined effect of both factors. This study was conducted on the example of the Buk-M1 self-propelled rocket launcher (SRL). An analysis of the current technical condition of the SRL showed that there are quite frequent failures due to limited technical reliability. The task of the relevant repair and restoration bodies will be to timely restore the technical readiness of disabled SRLs, and this task will be more difficult to solve in relation to equipment that has failed because of enemy fire, and therefore repair and restoration bodies will be mainly engaged in the restoration of these SRLs. Therefore, the most important and urgent task in today's warfare environment to maintain equipment in a combat-ready state is to find ways to improve the efficiency of its maintenance and repair system, i.e., the productive work of repair and restoration bodies in combat conditions.

The issues of improving the system of maintenance and repair of weapons and equipment are reflected in numerous literatures of both theoretical and applied nature. Startsev V. V. et al. (2022) discusses methods for assessing the effectiveness of the restoration of ground-based samples of the Air Force of Ukraine both as part of a group of troops and in military units and individual units. The authors in (Openko P. V. et al., 2021) use the methodology for assessing the possibility of eliminating combat damage and restoring the suitability of weapons and equipment to calculate the effectiveness of the restoration of anti-aircraft missile system combat assets. The authors in (Doska O. M. et al., 2020) determine the performance indicators for the restoration of anti-aircraft missile weapons. Modelling can play a crucial role in improving production activities and supporting combat operations of repair and restoration bodies. By using mathematical and computational models to simulate various scenarios, it becomes possible to identify potential bottlenecks, optimize workflows, and allocate resources more efficiently, according to scientists (Mair J. et al., 2023) and authors in (National Defense Authorization Act for Fiscal Year, 2023).

Materials and Methods

During wartime, maintenance and repair organizations face several unique challenges that can significantly impact their ability to support military operations. These challenges may include limited resources, time constraints, and unpredictable operating conditions. In order to effectively solve these problems, it is important to understand the specific needs and requirements of repair and recovery agencies during combat operations. This will help to identify opportunities to improve operations and support combat operations.

Efficient production activities are crucial to sustainment of combat operations, as they allow repair and restoration authorities to repair damage quickly and effectively of equipment and infrastructure caused by the conflict. To achieve this efficiency, it is necessary to optimize production processes and workflows, minimize downtime and ensure efficient resource allocation. This requires a deep understanding of the specific challenges and requirements faced by repair and maintenance organizations during hostilities, as well as the ability to quickly adapt to changing circumstances.

Modelling plays an important role in improving production activities and supporting the combat operations of repair and restoration agencies. By using mathematical and computational models to simulate various scenarios, it becomes possible to identify potential bottlenecks, optimize workflows, and allocate resources more efficiently. This can help maintenance and repair facilities make more informed decisions about resource allocation and prioritization, ultimately leading to more efficient and effective operations. In addition, by incorporating data from previous combat situations, models

can be refined and improved over time, leading to even greater efficiency and effectiveness in supporting military operations.

Modelling the production activities of repair and restoration facilities can help ensure that they have the necessary resources to fulfil their tasks. By considering factors such as the number of weapons and equipment in need of repair, the types of equipment required, and the availability of spare parts, a model can be developed that accurately predicts resource demand. This, in turn, can help ensure that the right equipment and supplies are available when needed, minimizing delays and downtime.

Another important aspect of modelling production activities in repair and restoration organizations is maximizing efficiency. By developing models that consider combat experience, repairs and remanufacturing can be conducted in a way that minimizes downtime and maximizes the quality of work. This can include developing models that consider factors such as the types of repairs required, the availability of skilled personnel, and the types of equipment needed. In this way, maintenance and repair facilities can ensure that they are operating at maximum capacity even in the most critical situations, which is exactly what happens in a combat environment.

In addition to minimizing downtime and maximizing efficiency, modelling production activities in the maintenance and repair facility can also help minimize delays in critical situations. By using mathematical and computational models to simulate different scenarios, it becomes possible to identify potential bottlenecks, optimize work processes and allocate resources more efficiently. This may include developing models that consider factors such as the types of equipment needed, the availability of spare parts, and the time required to complete repairs. In this way, repair and restoration authorities can ensure that they are able to respond quickly and effectively to critical situations while minimizing the impact on the fighting.

Military equipment can fail for various reasons: due to limited technical reliability, due to enemy fire during combat operations, or due to the combined effect of both factors. The probability of a complete group of incompatible events will be calculated as follows (O. Wentzel, 2006):

$$P(t) = P(t)_1 + P(t)_2 + P(t)_3 + P(t)_4, \quad (1)$$

where $P(t)_1$ is the state of the equipment sample, taking into account only the technical component;

$P(t)_2$ - the state of the equipment sample, taking into account only the enemy's fire impact;

$P(t)_3$ is the state of the equipment under the combined influence of both of these factors;

$P(t)_4$ - the state of the sample equipment if no factors affect it.

In turn, we can write down that

$$P(t)_1 = P(t)_H \cdot (1 - P(t)_\beta), \quad (2)$$

$$P(t)_2 = P(t)_\beta \cdot (1 - P(t)_H), \quad (3)$$

$$P(t)_3 = P(t)_H \cdot P(t)_\beta, \quad (4)$$

$$P(t)_4 = (1 - P(t)_H) \cdot (1 - P(t)_\beta), \quad (5)$$

where $P(t)_H$ is the probability of IED failure due to only limited technical reliability;

$P(t)_\beta$ - the probability of IED failure due to only enemy fire

Substituting expressions (2)-(5) into (1), we obtain:

$$P(t) = P(t)_H \cdot (1 - P(t)_\beta) + P(t)_\beta \cdot (1 - P(t)_H) + P(t)_H \cdot P(t)_\beta + (1 - P(t)_H) \cdot (1 - P(t)_\beta) =$$
$$= P(t)_H - P(t)_H \cdot P(t)_\beta + P(t)_\beta - P(t)_\beta \cdot P(t)_H + P(t)_H \cdot P(t)_\beta + 1 - P(t)_\beta - P(t)_H +$$
$$+ P(t)_H \cdot P(t)_\beta = 1$$

Thus, the result indicates that all IED states have been considered, since the probability of a complete group of incompatible events is equal to one.

Next, we need to investigate how the state of the SRL will change when the factors act in different combinations. If we exclude the state of the equipment sample when no factors affect it, the probability of SRL failure can be written down according to the probability addition theorem:

$$P^0(t) = P(t)_1 + P(t)_2 + P(t)_3, \quad (6)$$

Substituting expressions (2)-(4) into (6), we obtain:

$$\begin{aligned} P^0(t) &= P(t)_H \cdot (1 - P(t)_\beta) + P(t)_\beta \cdot (1 - P(t)_H) + P(t)_H \cdot P(t)_\beta = \\ &= P(t)_H - P(t)_H \cdot P(t)_\beta + P(t)_\beta - P(t)_H \cdot P(t)_\beta + P(t)_H \cdot P(t)_\beta = \\ &= P(t)_H + P(t)_\beta - P(t)_H \cdot P(t)_\beta \end{aligned} \quad (7)$$

It is advisable to model the reliability of an SRL without taking into account the conditions of the combat situation using the Weibull-Gnedenko distribution, which allows for a more correct account of the aging and wear of its components [13]:

$$P(t)_H = e^{-\theta \cdot t^\alpha}, \quad (8)$$

where *t is the* time of continuous operation of the SRL (h);

θ - is the Weibull distribution parameter, which in this case determines the intensity λ ($\lambda = \frac{1}{T}$, 1/h) of SRL failures due to limited technical reliability;

T - is the value of the average operating time before SRL failure, taking into account all factors affecting its condition (hours);

α - is a parameter that considers the aging and wear and tear of SRLs during operation in the military.

The probability of an SRL failure due to enemy fire, for example, with an exponential distribution of a random variable of uptime, will be:

$$P(t)_\beta = e^{-\varepsilon \cdot t}, \quad (9)$$

where ε is the generalized (inferred) value of the relative hourly combat losses of equipment because of enemy fire.

Substituting (8) and (9) into (7), we obtain an expression for calculating the probability of SRL failure during its continuous operation, considering both factors:

$$P^0(t) = e^{-(\theta \cdot t^{\alpha-1} + \varepsilon) \cdot t} = e^{-\left(\frac{1}{T} \cdot t^{\alpha-1} + \varepsilon\right) \cdot t} \geq P_{ПОТР}, \quad (10)$$

where $P_{ПОТР}$ is the required (desired) value of the probability of SRL failure, considering both limited technical reliability and enemy fire.

If the value of ε is known, it is possible to determine the number of ΔN_β disabled SRLs only due to enemy fire during the time of continuous operation of the equipment for future planning of the work of repair and restoration bodies. This number can be determined as follows:

$$\Delta N_\beta = Q_\beta \cdot (1 - Q_H) \cdot N_0, \quad (11)$$

where N_0 is the number of SRLs in the unit before the start of hostilities;

Q_H - the probability of SRL failure due to limited technical reliability;

Q_β - the probability of failure of weapons and military equipment due to the influence of the enemy alone.

At the same time, SRLs can fail during hostilities due to limited technical reliability. In this case, the number of equipment that failed during the time of continuous operation only for this reason is determined as follows:

$$\Delta N_H = Q_H \cdot (1 - Q_\beta) \cdot N_0, \quad (12)$$

A certain number of IEDs $\Delta N_{H\beta}$ can be disabled both due to limited technical reliability and simultaneously because of fire impact on them by the enemy:

$$\Delta N_{H\beta} = Q_H \cdot Q_\beta \cdot N_0. \quad (13)$$

The issue of modelling the production activity of repair and restoration bodies becomes important. In this case, it is necessary to determine to what extent this performance can be predicted depending on the nature of SRL damage. Or, in other words, how will the achieved value of the average SRL uptime affect the maintenance of the SRL in a technically ready condition, how will the value of *T* change, taking into account losses (failures) as a result of limited technical reliability, compared to the value of relative losses due to enemy fire.

Suppose that when planning the value of the time *T* before SRL failure, it is assumed that the value of ΔN_H should be σ times less than the value of ΔN_β, that is, that the following ratio (according to $\varepsilon \neq 0$) is fulfilled:

$$\frac{\Delta N_H}{\Delta N_\beta} = \frac{Q_H \cdot (1 - Q_\beta)}{Q_\beta \cdot (1 - Q_H)} = \frac{\left(1 - e^{-\frac{1}{T} \cdot t^\alpha}\right) \cdot e^{-\varepsilon \cdot t}}{\left(1 - e^{-\varepsilon \cdot t}\right) \cdot e^{-\frac{1}{T} \cdot t^\alpha}} = \frac{1 - e^{-\frac{1}{T} \cdot t^\alpha}}{1 - e^{-\varepsilon \cdot t}} \cdot e^{-\left(\varepsilon - \frac{1}{T} \cdot t^{\alpha - 1}\right) \cdot t} = \frac{e^{-\left(\varepsilon - \frac{1}{T} \cdot t^{\alpha - 1}\right) \cdot t} - e^{-\varepsilon \cdot t}}{1 - e^{-\varepsilon \cdot t}} \leq \sigma, \quad (14)$$

from

$$e^{-\left(\varepsilon - \frac{1}{T} \cdot t^{\alpha - 1}\right) \cdot t} \leq e^{-\varepsilon \cdot t} + \sigma \cdot (1 - e^{-\varepsilon \cdot t}), \quad (15)$$

By logarithmizing this expression, we obtain the value of the time *T* before the SRL fails under the given conditions of use of the equipment during continuous operation at $\sigma > 0$:

$$T \geq \frac{t^\alpha}{\varepsilon \cdot t + \ln\left[e^{-\varepsilon \cdot t} + \sigma \cdot \left(1 - e^{-\varepsilon \cdot t}\right)\right]}, \quad (16)$$

It is at this value of *T that* the condition $\frac{\Delta N_H}{\Delta N_\beta} \leq \sigma$ will be fulfilled.

Results and Discussions

The calculation of the operating time before SRL failure is shown in Table 1.

Table 1 shows that, for example, fire damage will predominate at $\sigma = 0{,}2$. Therefore, the repair teams must be prepared to eliminate failures due to enemy fire.

As we can see, with an increase in $P_{ПОТР}$ for any value of σ , *the required value of T* increases, which is natural. With a decrease in σ , i.e., with a decrease in ΔN_H for any value of $P_{ПОТР}$, the required value of *T* should increase, which is also expected. The calculations show that the value of the SRL repair fund due to enemy fire is 1.6 times higher than the value of the SRL repair fund formed as a result of the limited technical reliability of equipment.

Researchers of the National Defense Academy of Ukraine in their works, namely (Khazanovych O. I., 2004) and (Polyakov A. P., 2004), consider the role and place of the maintenance and repair system in the system of technical support of troops from different perspectives, analyse the peculiarities of its functioning.

Table 1. Time between failures for a given ratio σ , required (desired) value of the probability of failure and continuous operation time

Possible meanings for σ	Possible values $P_{ПОТР}$				
	0,6	0,7	0,8	0,9	0,95
1	33 $(\ )\varepsilon = 0{,}0450$	49 $(\ )\varepsilon = 0{,}0325$	81 $(\ )\varepsilon = 0{,}0211$	95 $(\ )\varepsilon = 0{,}0010$	186 $(\ )\varepsilon = 0$
0,5	45 $(\ )\varepsilon = 0{,}0597$	68 $(\ )\varepsilon = 0{,}0435$	116 $(\ )\varepsilon = 0{,}0282$	264 $(\ )\varepsilon = 0{,}0137$	362 $(\ )\varepsilon = 0{,}0050$
0,45	47 $(\ )\varepsilon = 0{,}0619$	73 $(\ )\varepsilon = 0{,}0451$	125 $(\ )\varepsilon = 0{,}0293$	280 $(\ )\varepsilon = 0{,}0142$	469 (481) $(\ )\varepsilon = 0{,}0062$
0,4	50 $(\ )\varepsilon = 0{,}0643$	77 $(\ )\varepsilon = 0{,}0468$	134 $(\ )\varepsilon = 0{,}0303$	307 $(\ )\varepsilon = 0{,}0147$	643 $(\ )\varepsilon = 0{,}0073$
0,3	59 $(\ )\varepsilon = 0{,}0700$	93 $(\ )\varepsilon = 0{,}0509$	161 $(\ )\varepsilon = 0{,}0328$	381 $(\ )\varepsilon = 0{,}0159$	744 $(\ )\varepsilon = 0{,}0077$
0,2	76 $(\ )\varepsilon = 0{,}0771$	122 $(\ )\varepsilon = 0{,}0558$	221 $(\ )\varepsilon = 0{,}0359$	952 $(\ )\varepsilon = 0{,}0190$	1082 $(\ )\varepsilon = 0{,}0085$

The option of determining the number of spare parts required to compensate for combat damage to weapons and military equipment in repair bodies of different levels is provided in (Maltsev V. A. et al., 2015). The problem of the procedure for restoration, repair, modernization, increase of the installed resource and extension of the service life (storage) of weapons, military and special equipment is addressed in the Resolution of the Cabinet of Ministers of Ukraine (2018). The authors (V. Shuienkin et al., 2010) consider the problems of logistics support of troops in combat conditions. Scientists (M. A. Tkachuk et al., 2018) consider mathematical models when changing the state of elements of combat vehicles and technological systems for their manufacture; (H. S. Zalevskyi et al., 2019) propose a methodology for assessing the effectiveness of logistics support tasks of military units of the Air Force of the Armed Forces of Ukraine in an armed conflict.

However, these papers rather indirectly deal with the calculation of the repair fund, considering the combat situation.

Conclusion

Thus, knowing the expected value of the repair fund, it is possible to model the production activities of repair and restoration bodies considering the combat situation. Taking into account the ratio between the number of equipment that has failed due to limited technical reliability and the number of equipment that has failed due to combat damage makes it possible to choose the value of the average operating time before equipment failure, which makes it possible to increase the efficiency of the system for restoring SRLs damaged in combat, to improve the planning of production activities of the repair and restoration bodies used for this purpose, that is, to increase the overall combat capability of a military formation, for example, in the process of warfare. Given the value of σ , it is possible to calculate the required time to failure.

The subject of further research may be the consideration of other factors that affect the productivity of repair and restoration bodies. This may include personnel training, the financial component, and the use of impersonal repair in the military.

Recommendations

The materials of the article are of practical value for predicting the work of repair and restoration bodies in combat conditions for specialists of the Command of the Logistics Forces of the Armed Forces of Ukraine.

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The data transfer protocols analysis in the perspective scientific (scientific and technical) information exchange automated system in the Armed Forces of Ukraine

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Abstract. The relevance of the study is due to the need to define effective data transfer protocols that ensure high quality of service and security of automated information exchange systems in the Armed Forces of Ukraine and their components.

In this regard, the article is aimed at revealing the protocols of the transport level of the TCP/IP and OSI network models - User Datagram Protocol, User Datagram Protocol Lite, Transmission Control Protocol, Multipath Transmission Control Protocol, Stream Control Transmission Protocol, Datagram Congestion Control Protocol, Reliable User Datagram Protocol from the perspective of their application point of view in the automated systems of scientific (scientific and technical) information exchange in the Armed Forces of Ukraine.

The leading approaches to the study of this problem are the use of informational and logical analysis methods, which allow a comprehensive consideration of network models by means of comparison.

About 15 characteristics has been considered, in particular: transmission reliability, overload control, multithreading. Taking into account the requirements and features of the promising automated system of scientific (scientific and technical) information exchange in the Armed Forces of Ukraine, it was proposed to use certain technological combinations with higher-level protocols to achieve optimal data protection. As a result of the analysis, it was established that, in accordance with the functions of the automated exchange of scientific (scientific and technical) information system, it is more expedient to use the Stream Control Transmission Protocol.

The materials of the article are of a theoretical value for conducting further scientific research on the problem raised, as well as practical value for the improvement of military information systems, in accordance with the standards of the North Atlantic Alliance and today's challenges in cyberspace.

Keywords: data exchange, information technologies, network technologies, military-scientific automated systems.

Introduction

Automated systems of a scientific and technical information exchange in the Armed Forces of Ukraine (AF of Ukraine) are important for ensuring national security and defense. However, their development and functioning require the use of appropriate data transmission protocols that ensure the security of information exchange and the reliability of data transmission without loss of speed.

One of the problems that needs attention in this area is the lack of standards and a unified system of data transmission protocols in the scientific and technical information exchange systems in the Armed Forces of Ukraine. This leads to interaction of different systems difficulties, that can reduce the speed of data transmission, increase the risks of information leakage and compromise the confidentiality of data.

In addition, there is a problem of compliance of existing data transfer protocols with modern requirements for information protection, in particular for counter-cyber-attacks and cyber espionage protection. Due to insufficient security and efficiency of such protocols, significant threats to national security and defense may arise, therefore their analysis with the possibility of further improvement and optimization is an urgent scientific and practical task.

Methodological Framework

The exchange of scientific (scientific and technical) information automated systems (ESIAS) are specialized information systems used for the exchange of scientific data, articles, studies, technical information, etc. between scientific institutions, scientists, researchers and other interested parties.

These systems enable the efficient exchange of scientific information by creating a centralized repository where scientific publications and data can be stored, searched and accessed. Some ESIASs also provide opportunities for interaction between users, such as forums for discussing research or the ability to comment on articles.

The main functions of the scientific information exchange automated systems are:

– information storage and retrieval;
– information classification and processing;
– scientific materials publication and review;
– interaction and cooperation;
– information monitoring;
– scientific productivity assessment.

Considering the advanced scientific (scientific and technical) information exchange automated system in the Armed Forces of Ukraine and its main specifics - application in the military environment, it is necessary to highlight a number of basic necessary functions:

– privacy and security;
– integration with other military systems.

Based on the last two functions, it can be stated that the data transfer protocols in the prospective automated system of the scientific (scientific and technical) information exchange in the Armed Forces of Ukraine must meet the following requirements:

– reliability;

– security;
– standardization;
– multithreading;
– data flow control;
– resistance to failures;
– support of operating systems used in the Armed Forces of Ukraine.

Results

Let`s consider the protocols of the transport layer (Table 1). The computer networks` transport layer is a conceptual division of methods in the multi-level protocol architecture of the TCP/IP (Transmission Control Protocol/Internet Protocol) and OSI (The Open Systems Interconnection model) models. Protocols provide end-to-end communication services for applications at this layer (Papastergiou, 2017).

User Datagram Protocol (UDP) is one of the protocols in the TCP/IP stack. It differs from the TCP protocol in that it works without establishing a connection. UDP is one of the simplest protocols of the transport layer of the OSI model, which exchanges messages (datagrams) without acknowledgment and delivery guarantee. When using the UDP protocol, the responsibility for error handling and data retransmission is assigned to the protocol layer above. But despite all the shortcomings, the UDP protocol is efficient for servers sending small responses to a large number of clients.

UDP Lite (light UDP) is a connectionless protocol that belongs to the transport layer of the OSI model and is similar to UDP. Unlike UDP, in which a packet is either completely checksum protected or the packet is not protected at all, UDP Lite allows the possibility of partial checksums that cover only part of the datagram, thus allowing the delivery of partially corrupted packets. This was created for multimedia protocols where receiving packets with a partially corrupted payload is considered a more feasible option than not receiving the packet at all.

Transmission Control Protocol (TCP) together with the IP protocol is the core protocol of the Internet, that gave the name of the TCP/IP model. The protocol is designed to manage data transmission in computer networks, works at the transport level of the OSI model.

Unlike another common transport layer protocol, UDP, TCP ensures reliable delivery of data from the sending host to the receiving host by establishing a logical connection between the hosts. Thus, TCP belongs to the class of protocols with an established connection.

TCP receives data streams from protocols of the upper layers of the OSI model, the initial source of which are application layer protocols such as Hyper Text Transfer Protocol (HTTP), File Transfer Protocol (FTP), and others. Each upper layer protocol has its own designated TCP port.

TCP divides a particular data stream into chunks and adds a header with a sequence number to each chunk. Data portions obtained in this way are traditionally called TCP segments. Each segment is then encapsulated into an IP packet and transmitted over the IP protocol to the receiving host.

After receiving the IP packet, the receiving host checks the correctness of the received data in the TCP segment by the checksum calculation method and makes sure that the previous data segments were also successfully received. The receiving host then sends a request to the sending host for a new or retransmitted chunk of data, which is also an acknowledgment that all segments with sequence numbers less than the number of the new request have been successfully received.

In turn, TCP segments are de encapsulated from IP packets, placed in the correct order, and TCP headers are removed from them. The resulting data stream is forwarded to the higher-level protocol from which the data was originally received on the sending host side.

Multipath TCP (MPTCP) is the work of the Internet Engineering Group's (IEG) Multipath TCP Working Group, which aims to allow Transmission Control Protocol (TCP) connections to use multiple paths to maximize throughput and increase redundancy.

Table 1. Comparison of transport layer protocols

Characteristic	Protocols						
	UDP	UDP-Lite	TCP	Multipath TCP	SCTP	DCCP	RUDP
Packet header size	8 bytes	8 bytes	20–60 bytes	50–90 bytes	12 bytes	12 or 16 bytes	14+ bytes
Typical costs of data packages	8 bytes	8 bytes	20 bytes	? bytes	44-48+ bytes	12 or 16 bytes	14 bytes
Object package transport. equal	Datagram	Datagram	Segment	Segment	Datagram	Datagram	Datagram
Connection oriented	No	No	So	So	So	So	So
Reliable transportation	No	No	So	So	So	No	So
Keeping message boundaries	So	So	No	No	So	So	So
Delivery	Disorganized	Disorganized	Organized	Organized	Ordered / Unordered	Disorganized	Disorganized
Checksum	Yes No	So	So	So	So	So	Yes No
Checksum size	16 bits	16 bits	16 bits	16 bits	32 bits	16 bits	16 bits
Partial checksum	No	So	No	No	No	So	No
Block maximum transmission path	No	No	So	So	So	So	?
Flow control	No	No	So	So	So	No	So
Congestion control	No	No	So	So	So	So	?
Explicit overload notification.	No	No	So	So	So	So	?
Multithreading	No	No	No	No	So	No	No
Multihoming	No	No	No	So	So	No	No
Stratification / Nagle's algorithm	No	No	So	So	So	No	?

Source: developed by the authors based on open data sources.

In January 2013, the IEG published the Multipath specification as an experimental standard in RFC 6824. In March 2020, it was superseded by the Multipath TCP v1 specification in RFC 8684.

The redundancy offered by Multipath TCP provides inverse multiplexing of resources and thus increases TCP's bandwidth to the sum of all available channels at the connection layer, instead of using one as required by standard TCP. MPTCP is backward compatible with standard TCP.

Stream Control Transmission Protocol (SCTP) is a transport layer protocol in computer networks created in 2000 by the IEG. RFC 3286 provides a technical introduction to it.

Like any other transport layer data transfer protocol, SCTP works similarly to TCP or UDP. TCP and UDP work so differently that it is incorrect to draw an analogy between the two. The whole analogy is that SCTP, TCP and UDP belong to the same layer of the OSI model. But in fact, SCTP has a wide range of innovations in its arsenal, such as multithreading, protection against SYN-flood, as well as synchronous connection between two hosts on two or more independent physical channels (multi-homing).

Datagram Congestion Control Protocol (DCCP) is a transport layer network protocol developed by the IEG. Adopted as a standard in March 2006, it provides mechanisms to monitor network congestion, avoiding the need for application layer mechanisms. This protocol does not guarantee the delivery of information in the desired order.

DCCP is very effective for applications in which data arriving out of time becomes useless. For example: streaming media, online games and Internet telephony. The main feature of these applications is that old messages become useless very quickly, so it is better to receive a new message than to try to forward an old one. But at the moment, most such applications independently implement congestion monitoring, and TCP or UDP are used as transmission protocols.

Reliable Data Protocol (RDP) is designed to ensure reliable data transmission between packet-oriented applications. It was originally designed for applications that implement remote data loading and troubleshooting, but it can be used in other applications that require reliable transmission of messages. There are two versions of RDP, described in the RFC 908 and RFC 1151 specifications, respectively.

Reliable User Datagram Protocol (RUDP) is based on the RDP protocol for transmitting telephone signals over IP networks. This protocol is not standardized and has no official specification.

RDP and RUDP protocols are used in cases where UDP cannot be used due to its unreliability, and the use of TCP causes too high complexity of the data transfer process.

From the point of view of reliability, the following protocols can be considered as providing reliable transport: TCP, Multipath TCP, SCTP, RUDP.

The organization of reliable transport in these protocols has some common features, but also differs depending on the specific protocol (Kurose, 2017).

TCP:

– uses the ACK (Acknowledgment) confirmation mechanism, where the recipient returns a receipt (confirmation) about the successful receipt of each packet;

– provides detection and recovery of lost packets by retransmitting lost packets;

– uses flow control mechanisms, such as a transmission window (Window), to regulate the speed of data transmission from the sender to the receiver.

Multipath TCP (MPTCP):

– distributes traffic between different paths using flow control and load balancing mechanisms;

– has mechanisms to detect and manage packet loss that take into account the distributed nature of a multipath network;

– provides the possibility of dynamic switching between paths in case of changing network conditions.

SCTP:

– uses mechanisms of associations (Association), channels and streams to organize data transmission;

– has mechanisms for detection and recovery of lost packets, including retransmission algorithms and duplicate detection algorithms;

– supports flow control at the channel and thread level.

RUDP:

– contains mechanisms for detecting and restoring lost packets, similar to TCP, but with less complexity;

– may have flow control mechanisms, although the specific implementation may vary depending on the library or software used.

The RUDP protocol does not meet the requirements of standardization.

Consider the protocols TCP, MPTCP, SCTP from the point of view of security.

The TCP protocol has a number of vulnerabilities to modern types of attacks. The shortcomings of the protocol are revealed in successful theoretical and practical attacks, in which an attacker can gain access to transmitted data, impersonate another party, or bring the system to a non-working state. Examples of these attacks are TCP Hijacking and TCP Reset.

Despite a number of obvious advantages of Multipath TCP over its predecessor, this protocol creates new problems. From a network security perspective, multipath routing causes cross-fragmentation of data, making firewalls and malware scanners ineffective when they only see traffic from one path. Additionally, SSL decryption will become ineffective due to end-to-end encryption protocols.

SCTP was designed with some features to improve security, such as a "4-way handshake" (vs. "three-way handshake" in TCP) to prevent SYN-flood attacks, and a large cookie to verify association authenticity. Reliability was one of the key aspects of SCTP security design. Multi-homing allows the association to remain open even if some routes and interfaces in use become unavailable. This makes it possible to achieve resilience during short-term outages to support telecommunications services, even in the event of serious network anomalies. There is protection against DDoS attacks. Encryption is not part of the original SCTP design.

Although SCTP has some security methods, it does not have the same level of support and ecosystem for security as TCP. But it should be noted that, unlike TCP, there are no well-known facts of successful attacks on infrastructures using the SCTP data transfer protocol. It is also worth noting that when using the Transport Layer Security (TLS) protocol in connection with SCTP, a sufficiently high level of information security during transmission can be achieved.

Having examined the SCTP protocol for compliance with other requirements for data transmission protocols in a prospective automated system of scientific (scientific and technical) information exchange in the Armed Forces of Ukraine, namely: multithreading, control of data flows, resistance to failures, support of operating systems used in the Armed Forces of Ukraine , it can be argued that the Stream Control Transmission Protocol fully complies with them (RFC4960, 2015; Seggelmann, 2012).

Discussions

Analyzing the latest publications in the field of research on data transmission protocols of transport and other levels of network models (Kostiuk, 2021; Ivanchuk, 2020; Malokhvii, 2022; Zhikharev, 2022; Svitlichnyi, 2018; Chaudhari, 2018; Kravchenko, 2020; Moskvin, 2022), it is possibly come to the following conclusions:

– in general, only the most frequently used protocols are considered, some of them are outdated and vulnerable to modern attacks;

– the analysis is carried out on the basis of one of the parameters of the protocols, the characteristics are not considered in the complex and the disadvantages and advantages of each protocol are not taken into account, in accordance with the task;

– research is based on consideration of protocols of higher levels of network models;

– insufficient information on the use of the latest technologies in the field of ensuring the functioning of educational and scientific systems;

– scientists of the russian federation are considering the use of more modern data transmission technologies in their automated systems (including military ones) as opposed to outdated domestic systems.

Thus, due to the insufficient number of studies in the field of using data transmission protocols in automated information exchange systems, it is not possible to give a thorough answer about the rationality of using this or that tool in certain systems. The need for modern and secure methods of information exchange necessitates the analysis of this field, with the definition and explanation of the role of protocols that can be used for data transmission in a prospective automated system of exchange of scientific (scientific and technical) information in the Armed Forces of Ukraine.

Conclusion

The transport layer ensures the reliability of information communication between two end nodes, and the TCP/IP protocol stack provides transport services to application processes. The transport services of these protocols have differences.

Among the analyzed protocols, the SCTP protocol stands out for its scalability, reliability, security support and other functions. This makes it a better option for modern networks and applications, especially in situations where seamless transmission of information is important.

Thus, in accordance with the above functions of the given system, the use of the SCTP protocol is more appropriate for the exchange of scientific (scientific and technical) information.

The perspective of further research is seen in the analysis of the expediency of using the latest data transfer protocols Tachyon, FASP and determining their compatibility with other existing data transfer protocols for their use in an automated system of exchange of scientific (scientific and technical) information.

Recommendations

The results of the above material may be useful to researchers involved in the description and creation of automated systems for military purposes.

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A variant of building an optimal plan for the target's distribution to forces and means of mechanized (tank) troops in an operation's simulation model (combat operations)

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Abstract. The relevance of the problem under study is confirmed by numerous analyses of the experience of modern military conflicts in general and the Russian-Ukrainian war in particular, which state that the most significant role in the operations of task forces remains assigned to units of mechanized (tank) troops, and therefore to their forces and means. This demonstrates the urgency of conducting comprehensive studies of the regularities of the processes that take place during the use of forces and means of mechanized (tank) troops. An important condition for achieving the objectives of an operation (general battle) is the optimal (best possible) distribution of forces and means to perform tasks to destroy the enemy. In this regard, this article is aimed at building an optimal plan for the target distribution to forces and means of mechanized (tank) troops in an operations simulation model. The leading method of operations research used to solve optimization problems is the linear programming method. This method allows a comprehensive consideration of the peculiarities of building an optimal plan for the target distribution to forces and means of mechanized (tank) troops. The article analyses the factors influencing the distribution of forces and means of mechanized (tank) troops, ranks typical targets for fire destruction by forces and means of mechanized (tank) troops by the indicator of importance (danger), develops a variant of building an optimal plan for the target's distribution for mechanized (tank) troops, and on its basis formulates a generalized algorithm for simulation the decision-making process and assignment of fire tasks in a simulation model of an operation (combat) of troops (forces). The materials of the article have theoretical value for further research on the problem, as well as practical value for improving the methods that are directly used in military headquarters when planning joint fire against the enemy.

Keywords: research of operations, mathematical simulation, distribution of forces and means, optimal plan, fire control of mechanized (tank) troops.

Introduction

High maneuverability and rapidity, richness and variety of weapons, and specificity of their use characterize modern combined arms combat. At the same time, the specificity of deployment is determined by the characteristics of weapons and the current tactical situation.

The main weapon systems of mechanized (tank) units are infantry fighting vehicles (IFVs), armored personnel carriers (APCs), and tanks, which in turn have different types of weapons (e.g., BMP-3 is equipped with a 100 mm smoothbore gun, 30 mm automatic gun, anti-tank missile system (ATMS) and machine guns). Different types of these weapons are designed to destroy different types of enemy targets that will be in the area of operations of mechanized (tank) units.

The diversity of both weapons and targets, along with changes in the tactical situation, require an optimal distribution of existing weapon systems (means) to effectively destroy the most important and dangerous enemy targets. The solution to this problem requires taking into account the importance and threat of the objects to friendly forces, as well as their characteristics that are important for choosing a certain type of weapon to defeat them with maximum efficiency.

In addition, in the course of the Russian-Ukrainian war, units of mechanized (tank) forces received from the allies weapon systems and military equipment of various production and tactical and technical characteristics (for example Javelin, NLAW, etc. ATGMs; IFV Bradley; Leopard tanks of various modifications). The study of the issue of targeting these fire systems that are not inherent in the domestic defence industry is necessary for the adequacy of the results of simulation of the operation (combat) as a whole, which determines the relevance and urgency of researching on the chosen topic.

Predicting the course and results of the actions of mechanized (tank) units and assessing the impact of the latter on the overall combined arms battle is a rather complex task. To solve it, simulation is usually used as a sufficient and affordable method of conducting the necessary research. At the same time, the accuracy of the results obtained largely depends on the completeness and correctness of taking into account the main factors (features) of all stages of a general combat.

Mathematical simulation of the process of fire control of forces and means of mechanized (tank) troops and their targeting is key in the simulation model of an operation (combat) (Romanchenko, 2017). This process is conducted to maximize their firepower in the context of the rapidity of a combined arms battle. It can be represented by constructing a specific targeting plan that must meet the requirement of optimality (be the best possible). The most appropriate method for solving problems of allocating certain forces and means (resources) is the method of linear programming, which is sufficiently covered, for example, in the literature on operations research (Wentzel, 1972), (Abchuk, 1979).

This and similar methods are aimed at building an optimal plan that meets the conditions of the task and meets the goal and can be used as a basis. At the same time, such methods do not fully take into account certain features of a general battle, namely the relatively low level of automation of the fire control process (Yudin, 1961). Under such conditions, the influence of subjective factors (in particular, the level of training of the respective commanders, tank, and IFV crews, their ability to correctly assess the level of threat of the target, etc.) imposes several restrictions that must be taken into account in simulation models. Otherwise, the simulation results will reflect only the results of solving an optimization problem, which does not always correctly reproduce the real processes of fire control in combat.

Materials and Methods

In general terms, the task of fire C2, decision-making, and assignment of fire missions for mechanized (tank) units, and as a result, the building of an optimal plan for the target's distribution to forces and means of mechanized (tank) troops can be formulated as follows (Milgram, 1968).

Suppose that there are m groups of different types of means (mechanized (tank) units) of their troops, each consisting of N units of weapons and must carry out fire damage to n detected objects of enemy military equipment. The objects of destruction (targets) are characterized by the coefficients of importance and danger p_j and vulnerability of the *j-th* object using the *i-th* group - w_{ij}.

Mathematically, the set of importance and hazard indicators can be described by a matrix of $n \in N$ classes of elements of the "vector" of means by $m \in N$ classes of elements of the "vector" of goals:

$$\|P\| = [p_{ij}], \tag{1}$$

where p_{ij} - is the value of the indicator of importance and danger j-class of objects of military equipment (weapons) of the enemy for $i$the -th class of means of the mechanized (tank) forces of the grouping of their troops, $i = 1, \dots, n, j = 1, \dots, m$.

Accordingly, a set of indicators of vulnerability of enemy military equipment:

$$\|W\| = [w_{ij}], \tag{2}$$

where w_{ij} - is the value of the vulnerability indicator j-class of enemy military equipment (weapons) for $i$the -th class of the mechanized (tank) forces of the grouping of their troops, $i = 1, \dots, n$, $j = 1, \dots, m$.

The allocation of assets to targets is characterized by the matrix $A = \|x_{ij}\|$, where x_{ij} is the number of assets of *the i-th* group assigned to the *j-th target*.

It is necessary to allocate means to targets in such a way that the mathematical expectation of the number of targets hit M_{max} taking into account their importance and danger is maximized (Danzig, 1966):

$$M_{max} = \sum_{j=1}^{n} p_j \left[1 - \prod_{i=1}^{m} (1 - w_{ij})^{x_{ij}}\right], \tag{3}$$

where. n - is the number of detected fire damaged objects (enemy vehicles);
m - the number of groups of destruction means (units of their troops);
p_j - is the importance and danger coefficient of the *j-th* object;
w_{ij} - vulnerability of the *j-th* object by means of the *i-th* group;
x_{ij} - is the number of means of *the i-th* group assigned to the *j-th* object of fire destruction

under the following conditions:

$$\begin{cases} \sum_{j=1}^{n} x_{ij} = N_i, i = 1,2 \dots, m; \\ x_{ij} \geq 0, i = 1,2, \dots, m, j = 1,2, \dots, n. \end{cases} \tag{4}$$

Results and Discussions

In general, the issue of studying the optimization of the distribution of various forces and means, as well as military resources, has been open for quite some time. For example, I. Kulinich (2020) proposed an approach to optimizing the allocation of air defense forces and means, and O. Poluiko (2016) put forward his version of the optimal allocation of air forces brigade's forces and means to specified targets in a massive strike for consideration by the academic community. In addition: V. Chuiev (2016) proposed models for calculating the results of combat operations of several task forces; B. Butvin (2019) published his vision of using modified equations of dynamics of averages for operational forecasting of the course and results of combat operations;

V. Nazarenko (2014) formulated a methodology for assessing methods of combat; O. Semenenko (2023) developed a mathematical model for solving a multi-criteria problem of choosing rational forms and methods of deployment of forces; O. Poluiko (2016) proposed an approach to the optimal allocation of forces and means of an air forces brigade; O. Drol (2020) put forward a methodology for determining the optimal number and type of weapon systems of mobile tactical task forces to effectively deter the enemy; S. Teliukov (2023) proposed an author's methodology for optimizing the composition of forces and means of the force protection observation post. Quite informative and useful are the works of V. Shvaliuchynskyi (2013) on optimizing the allocation of flight resources and B. Demianchuk (2023) on optimizing the volume of additional material reserves and combat equipment of transport logistics units. O. Zahorka (2023), O. Morozov (2015), B. Popkov (2013), and many others, also addressed other equally important tasks of optimizing processes in the military sphere. However, insufficient attention has been paid to the study of the problems of building optimal plans for the target's distribution to forces and means of mechanized (tank) troops in simulation models of operations (combat), and with the level of detail to a single unit of military equipment (weapons).

The above formulation of the problem of fire C2, decision-making, and assignment of fire missions to mechanized (tank) units can be solved by constructing an optimal plan for the distribution of firepower to the objects described above. Thus, we consider this problem as a transport problem of linear programming.

A universal method for solving linear programming problems is the simplex method, which is based on multiple recalculations of the system of constraint equations of the main linear programming problem concerning new free and base variables. However, the solution of such linear programming problems as transport problems can be obtained by simpler methods (Lysenko, 2017).

Since the number of detected objects (enemy military equipment) whose fire damage must be assigned to vehicles (units of your troops) is unknown in advance, we get a special case of the transport problem, namely the problem of assignment with an incorrect balance.

The solution to the problem of target distribution is based on the so-called Hungarian method (algorithm) of linear programming, the final result of which is an optimal plan matrix, in the subject area of the task of controlling the fire of mechanized (tank) units allows to fully achieve the condition of maximum mathematical expectation of the number of targets hit and to distribute firearms to targets, taking into account their importance and danger.

The number of steps $k$required to solve problem (3) by the Hungarian linear programming method is equal to the total amount of funds to be distributed:

$$k = \sum_{i=1}^{m} N_{i.} \tag{5}$$

The procedure for calculating the importance (threat) and vulnerability coefficients of targets should be noted separately. The concepts of "important" and "dangerous" targets are somewhat different, for example, the command post of an enemy battalion is an important target, and the position of a mortar battery that is firing on the positions of a mechanized (tank) unit is a dangerous target. Therefore, the task is to prioritize the targets to be destroyed. Indirectly, the priority of defeating the detected objects is determined in the work of O. Wentzel (1972), so, in our opinion, it is quite possible to build a priority series of the importance of targets using a single coefficient p_j. In other words, in any case, first of all, mechanized (tank) units will open fire at the most dangerous targets (anti-tank missile systems, tanks, IFVs, and APCs), then at the positions of command posts and command and control vehicles, and only then at the positions of enemy artillery, anti-aircraft missile units, etc.

The probability of defeating the *j-th* object by a weapon of *the i-th* group can be considered as the product of the dependent variables (Alekseev, 1989):

$$q_{ij} = v_i w_{ij}, \quad (6)$$

where v_i - is a coefficient that takes into account the level of training of the unit's personnel;
w_{ij} - vulnerability of the *j-th* object using the *i-th* group.

The coefficient v_i takes into account the level of training of personnel in the use of the *i-th munition*. Since the level of training of personnel is generally a random variable, several assumptions can be made.

The time factor in the context of the rapidity of combat is quite important and must be unconditionally taken into account in the simulation model. In addition, the level of training of personnel can be determined by the time standards for performing certain exercises using the *i-th munition, i.e., the* coefficient v_i is a function of time. Assuming a normal law of distribution of the time spent by personnel to perform a certain exercise using the *i-th munition*, its distribution function $F_i(t)$ on the interval $t_1 \div t_2$ will have the form shown in Fig. 1. The boundary values of this interval correspond to the standard values for performing control exercises using different munitions against typical targets (e.g, t_1 - corresponds to the normative time for an "excellent" score, t_2 - "satisfactory").

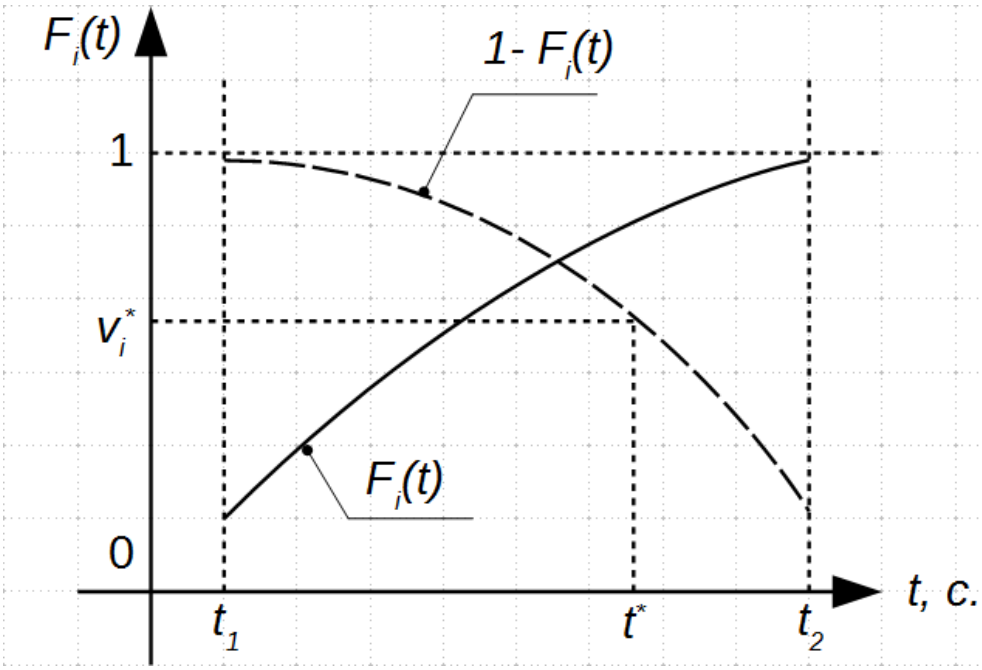


Figure 1. Distribution function $F_i(t)$

Since the level of training of personnel is usually unknown in advance, a certain value of the coefficient v_i is selected using a random variable t uniformly distributed over the interval $t_1 \div t_2$and the function $\left(1 - F\middle|\ \middle|i(t)\right)$ (Fig. 1). This approach will to some extent allow to take into account the influence of the subjective factor in calculating the results of actions of mechanized (tank) units.

As a result of the research on this topic, an algorithm for simulating the actions of units (parts) of mechanized (tank) troops was developed, which is carried out step by step and whose core is the proposed option for building an optimal plan for the targeting of forces and means of this type of troops (Fig. 2).

Building an optimal plan for the target distribution to forces and means of mechanized (tank) troops is a key procedure (structural element) of the proposed algorithm. The optimal targeting plan is built at each simulation step of the operation (combat operations), taking into account the importance and danger of the targets for fire damage available at a particular simulation step.

The proposed variant of building an optimal targeting plan is complex and, unlike the approaches proposed by O. Sobolev (2010) and V. Stebletskyi (2010), takes into account the level of training of personnel.

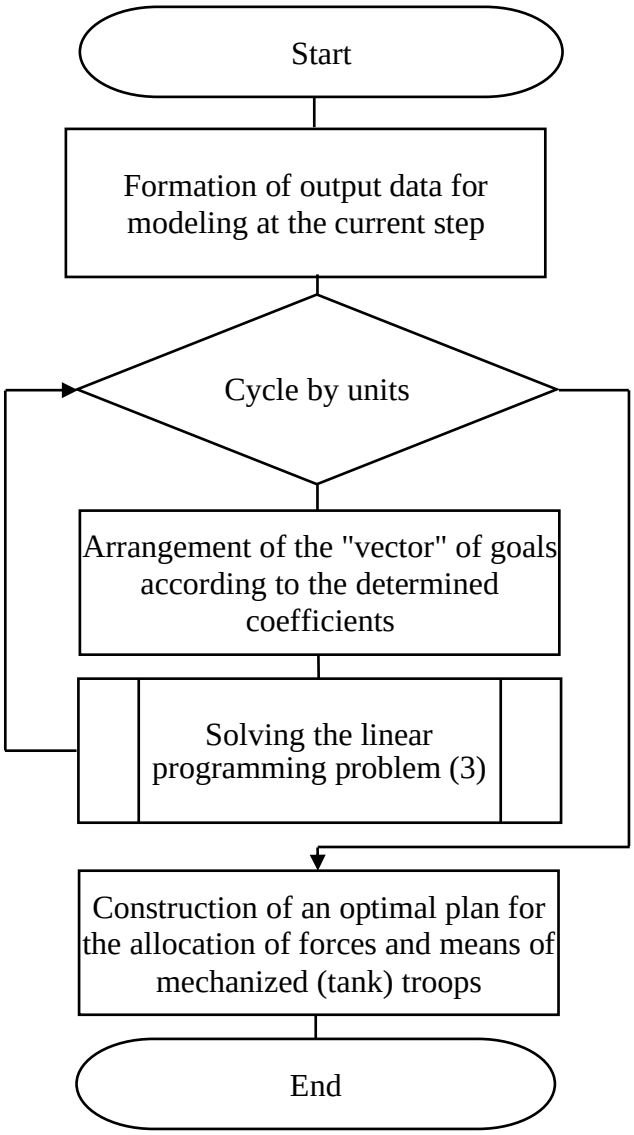


Figure 2. Flowchart of the algorithm for decision-making and assignment of fire tasks to mechanized (tank) units

Direct targeting is carried out during the operation of the "optimization problem solving" block of the algorithm and is carried out for each element of the set of means. Thanks to the previous steps of the algorithm, it can be argued that the set of objectives and the set of means include the objectives identified as the most important and dangerous in the given situation and the means whose effectiveness in the relevant class of objectives is the highest.

Conclusion

The proposed author's variant of building an optimal plan for the target distribution to forces and means of mechanized (tank) troops in the simulation model allows for taking into account the peculiarities of the fire C2 process, decision-making, and tasking of mechanized (tank) units. In addition, its use will make it possible to take into account the influence of the subjective factor and the actions of the respective commanders under conditions of a sufficiently low degree of automation of such a process. By taking into account the influence of the coefficients of importance and danger of enemy targets during the fire C2 of the forces and means of mechanized (tank) troops on the course and results of the operation (combat operations), a preliminary assessment of the simulation results showed an increase in their accuracy and reliability in terms of key performance indicators. The main academic novelty is the method of assigning targets to mechanized (tank) units by solving a transport (optimization) problem using the Hungarian linear programming method. As a direction for further research, it is proposed to consider improving the mathematical model of actions of mechanized (tank) units by taking into account additional partial indicators, such as the terrain of the area of operation (combat), the role of the unit in the plan of the senior commander, the place in the combat order, mathematical simulation of intelligence at the tactical level, etc.

Recommendations

The materials presented in this article may be useful for specialists (researchers and teaching staff) in the field of mathematical simulation of complex military systems, as well as for higher education students (cadets, students, trainees, and associate students) studying these issues.

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